ACT-R 7.30^{+} Reference Manual

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Includes material adapted from the ACT-R 4.0 manual by Christian Lebiere, documentation on the perceptual motor components by Mike Byrne and the Introduction is a shortened version of the ACT-R description written by Raluca Budiu for the ACT-R web site.

Notice

The purpose of this document is to describe the current software. It does not generally describe the differences from prior versions, but in places where such changes are significant some additional information may be provided.

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Preface

This document is a work in progress. It started as the reference manual for ACT-R 7 and has been updated to reflect the software for versions 7.x (where x > 5). All of the information has been updated and should accurately reflect the operation of the new software, but there are some features of the new system (as well as the older ones) which are not yet documented. The hope is that although it is not yet complete, this working version will be of some use to ACT-R modelers.

Introduction

ACT-R is a cognitive architecture: a theory about how human cognition works. Its constructs reflect assumptions about human cognition which are based on numerous facts derived from psychology experiments. It is a hybrid cognitive architecture – it has both symbolic and subsymbolic components. Its symbolic structure is a production system and its subsymbolic structure is represented by a set of massively parallel processes that can be summarized by a number of mathematical equations. The subsymbolic equations control many of the symbolic processes, and are also responsible for most learning processes in ACT-R.

Using ACT-R, researchers can create models that incorporate ACT-R's view of cognition and their own assumptions about a particular task. These assumptions can be tested by comparing the results of the model performing the task with the results of people doing the same task. By "results" we mean the traditional measures of cognitive psychology: time to perform the task, accuracy in the task, and, (more recently) neurological data such as those obtained from fMRI.

One important feature of ACT-R that distinguishes it from other theories in the field is that it allows researchers to collect quantitative measures that can be directly compared with the quantitative measures obtained from human participants.

ACT-R has been used successfully to create models in domains such as learning and memory, problem solving and decision making, language and communication, perception and attention, cognitive development, and individual differences.

Beside its applications in cognitive psychology, ACT-R has also been used in other fields including:

- human-computer interaction to produce user models that can assess different computer interfaces
- education (cognitive tutoring systems) to "guess" the difficulties that students may have and provide focused help
- computer-generated forces to provide cognitive agents that inhabit training environments
- neuropsychology, to interpret fMRI data.

For more detailed information, please refer to the description of the ACT-R theory in the paper "An Integrated Theory of the Mind" (2004) which is available from the ACT-R web site at: http://act-r.psy.cmu.edu/papers/403/IntegratedTheory.pdf, or to the book “How Can the Human Mind Occur in the Physical Universe?”.

Document Overview

This manual is a guide and reference for the ACT-R 7.26 (and newer) software implementation. It is not meant to be a tutorial or a textbook on the ACT-R theory or a "how to" on writing models using ACT-R. The ACT-R Tutorial, which accompanies the software, is designed to introduce the theory and techniques for modeling with ACT-R. This document is intended to be a compliment to the tutorial, and it describes the components of the implementation, how they are connected, the commands available to the user, and some recommended practices for use.

This manual is a reference for the ACT-R 7.26 (and newer) implementations only. It does not describe mechanisms from older implementations nor does it thoroughly discuss how commands may differ from similar commands in previous versions.

General Software Description

The ACT-R software is written in ANSI Common Lisp. To use the remote capabilities of the software will also require Quicklisp to load the following additional libraries: :bordeaux-threads, :usocket, and :cl-json, but it can be loaded in a Lisp only mode which does not require Quicklisp. It was implemented and tested using Allegro Common Lisp by Franz Inc. http://www.franz.com/ and Clozure CL http://www.clozure.com/clozurecl.html. The remote capable version has also been tested with LispWorks by LispWorks Ltd http://www.lispworks.com and SBCL http://sbcl.sourceforge.net/. Although the necessary Quicklisp libraries are also available for ABCL http://common-lisp.net/project/armedbear/, there appears to be some problem with the socket implementation which prevents it from working. However, ABCL will work in the Lisp only mode as will Embeddable Common-Lisp https://common-lisp.net/project/ecl/. If you have problems loading or running ACT-R in any Lisp please contact Dan Bothell (db30@andrew.cmu.edu) with the details. We also make the ACT-R system available as a standalone application for those that do not have or do not want to install Lisp software. The standalone versions include a command line only version of Clozure CL or SBCL (for Apple silicon processor machines) and thus are as complete a system as one has when using the ACT-R source code, but it may not be as easy to use as a Lisp which has a nice IDE or which is used through an interface like SLIME, SLIMV, or with the Inferior Lisp mode of Emacs. The software is also available bundled into a Docker container that includes SBCL as the Lisp running ACT-R and a Jupyter Notebook server along with pages that provide the Python commands for running all of the tasks in the tutorial.

It is not necessary for one to be a Lisp programmer to be able to use ACT-R. However, because ACT-R is running in Lisp and the ACT-R model files are written using Lisp syntax, some familiarity with basic Lisp constructs can be helpful. An introduction to Lisp is beyond the scope of this document, but there are many introductory Lisp books available as well as many online resources. Two online resources where you can find additional information about Lisp are The Association of Lisp Users and CLiki, the Common Lisp wiki.

In versions of ACT-R prior to 7.6, the only means of interacting with ACT-R was through the Lisp read-eval-print loop (a command line interface) and a set of GUI tools called the ACT-R Environment (which is described in its own manual). While those are still available, this version of the software also contains an RPC (remote procedure call) system which allows one to interact with the software from external systems as well. The controller for that RPC system will be referred to as the dispatcher. Not all of the commands are currently available through that remote interface (which is described in detail in a separate document), but those that are will be noted in this manual.

Also, included with the ACT-R tutorial materials is a Python module (in the Python usage of the term module – not the ACT-R usage) which provides access to all of the ACT-R commands necessary for running the tutorial's experiments and interacting with ACT-R from an interactive Python session. Information on using that interface are included in the tutorial.

Licensing

The ACT-R software is provided under the LGPL license version 2.1, which can be found in the docs directory of the distribution.

Case sensitivity

Generally the names of items in ACT-R are not case-sensitive. However, the one exception to that is that the names of commands accessed through the RPC interface are case sensitive, but the names of ACT-R elements passed to those commands through the RPC interface are still case insensitive. In addition to that, names provided through the RPC may not necessarily be returned in the same case as provided. The ACT-R software typically upcases names, but that is not guaranteed and no assumptions should be made about the case of names for ACT-R elements.

When using the ACT-R source code one should only use an ANSI compliant case insensitive Lisp system. A Lisp like the "modern mode" version available with ACL may result in problems when trying to use ACT-R and a warning will be displayed if the software is loaded into such a system to indicate that problems could occur.

Functions vs. Macros

When working from Lisp many of the ACT-R user commands are implemented as macros which do not evaluate their arguments. This makes it generally easier to work with the ACT-R software without having to worry as much about Lisp syntax, but does mean that if one wants to use ACT-R commands programmatically, more effort is required to either explicitly evaluate the macro command with its arguments or to use a corresponding ACT-R function. Most of the macro based ACT-R commands also have a corresponding function which will have the same name, but with a –fct appended to it e.g. add-dm and add-dm-fct. The functions occasionally require a slightly different specification of the parameters relative to the macro, for example requiring that a list of items be provided instead of just specifying an arbitrary number of items. A command's description and examples will indicate any such differences.

Compatibility issues

There are a few minor issues with particular Lisp versions that require some patches in the ACT-R code. Those changes are described here because it may affect other Lisp code which one writes in those Lisps while using ACT-R.

Two such issues occur with SBCL. The first is that the internal SBCL code already defines a function called reset. To fix that the ACT-R code just shadows the reset function. The other patch for SBCL occurs for the Windows version of the directory function because it does not handle wildcard characters in the same way as other Lisps (or even other OS versions of SBCL). Again, to address this the default function is shadowed with one in the ACT-R code which handles things as needed.

There is one such issue with CLisp because it has a function named execute defined internally. The fix for that is to shadow the internal function with the one defined in ACT-R.

Notations in the Documentation

Commands

This document will use the term command to refer to the operators that are provided for using ACT-R as well as those that are created by users either in Lisp or made available remotely through the dispatcher. The commands described in this document will typically be functions, macros, or methods written in Lisp, but many are also available from outside of Lisp through the dispatcher. If a command has a remote version available that will be noted in the description along with any differences that may occur when used remotely.

Signals

A subset of the commands available through the dispatcher do not perform any actions and only exist for monitoring purposes. Those commands are referred to as signals. There are many signals generated by the software, and they are used to indicate a variety of things both for the underlying software and for the operation of the running cognitive models. The signals will be described along with the other commands in the appropriate sections.

Command Syntax

When describing a command's syntax the following conventions will be used:

- items appearing in **bold** are to be entered verbatim
- items appearing in *italics* take user-supplied values
- items enclosed in **{**curly braces**}** are optional
- items enclosed in [square brackets] represent possible options each separated by a |
- (parentheses) denote that the enclosed items are to be in a list
- * indicates that any number of items may be supplied including zero
- + indicates that one or more items may be supplied
- -> indicates that calling the command on the left of the "arrow" will return the item to the right of the "arrow"
- **::=** indicates that the item on the left of that symbol is of the form given by the expression on the right

These additional indicators will be used when describing the syntax of commands available through the remote interface and in the documentation strings provided with commands available through the dispatcher.

- <angle brackets> denote an options list for providing optional named parameters to a command and the available parameter names and values are indicated between the angle brackets separated by ,
- 'single quotes' around one or more parameters indicate that those parameters use the additional string encoding noted below
- /slashes/ bracketing an item in a documentation string mean the value between the brackets must be provided explicitly (like a bold entry in this document)

Generalized Boolean

In the description of some commands it will describe a parameter or return value as a "generalized boolean". What that means is that the value is used to represent a truth value – either true/successful or false/failure. If the value is the symbol **nil** (or the remote equivalent as described below) then it represents false. All other values represent true. When a generalized boolean is returned by one of the commands, one should not make any assumptions about the returned value for the true case. Sometimes the true value may look like it provides additional information, but if that is not specified in the command's description then it is not guaranteed to hold for all cases or across updates to the command.

Command Identifier

In the description of some commands it will describe a parameter or return value as a "command identifier" or "command id". That means the value represents a command which can be called. That can be provided either as a string which names a command made available through the dispatcher or a symbol naming a function in Lisp. Additionally, if one is using the software in the Lisp only mode then it can also be a Lisp function object (typically indicated with the #' syntax or returned from the lambda function). Lisp function objects are not allowed as command identifiers in the normal system because they cannot be transmitted through the remote interface.

Name

When working with ACT-R the items in the system are typically accessed by a name instead of directly accessing the underlying representation. The names of ACT-R items are represented as symbols in Lisp because that typically does not require using any additional syntax to specify one when working with the Lisp interface. However, because symbols are not a native type in other languages, names must be specified using strings when accessing ACT-R items remotely. The names of ACT-R items are not case-sensitive. When a command description indicates that a name is required that must be either a Lisp symbol or a string, and in most cases when calling a command directly in Lisp a symbol must be used instead of a string.

Remote commands

When a command is available for use through the RPC interface the name of the command to access it and any differences in the parameters for using it through the RPC interface will be described. One general issue to note is that many of the items provided through the RPC interface will be in strings since Lisp symbols are not a valid data format for the communication protocol (nor in most other languages from which the RPC will likely be accessed). That is true for values that are being passed into ACT-R commands as well as any values that they return. When the strings refer to the names of ACT-R constructs (chunks, productions, modules, etc) they are not case sensitive and no assumptions should be made about the case of any result e.g. just because the Lisp being used is upcasing symbol names does not guarantee that all strings of names returned through the RPC interface will be upper case.

Embedded Strings

For some commands in Lisp either a symbol or a string could be provided and that distinction would be important (for example in a slot value of a chunk). In those cases a special syntax is required for the strings sent through the RPC interface to distinguish a string containing a name from a value which should be treated as just a string. The special syntax for that is to mark the item which should be a string instead of a name with an additional bracketing of single quotes inside the string e.g. "chunk1" would represent the symbol chunk1 but "'chunk1'" would represent the string "chunk1". If a command requires this addition syntax for differentiating names (symbols) from strings it will be noted, otherwise the assumption is that all strings will be converted to symbols coming into ACT-R commands and symbols will be converted to strings when returned from ACT-R commands that are sent through the remote interface.

Transmission Protocol

The underlying format for the data sent through the remote interface is JSON. When dealing with the Lisp symbols **t** or **nil** as return values from ACT-R commands, they will be converted to the JSON values of **true** and **null** respectively. When truth values are passed into an ACT-R command through the RPC it will convert the JSON value of **true** to the Lisp symbol **t** and both the JSON values **false** and **null** will be converted to the Lisp symbol **nil**.

Examples

When examples are provided for the commands they are shown as if they have been evaluated at a Lisp prompt. The prompt that is shown prior to the command indicates additional information about the example. There are three types of prompts that are used in the examples:

- A prompt with just the character '>' indicates that it is an individual example – independent of those preceding or following it.
- A prompt with a number followed by '>', for example "2>" means that the example is part of a sequence of calls which were evaluated and the result depends on the preceding examples. For any given sequence of calls in an example the numbering will start at 1 and increase by 1 with each new example in the sequence.
- A prompt with the letter E preceding the '>', like this "E>", indicates that this is an example which is either incorrect or was evaluated in a context where the call results in an error or warning. This is done to show examples of the warnings and errors that can occur.

ACT-R Software Distribution

There are two primary means of acquiring the ACT-R software. The first is from the ACT-R web site http://act-r.psy.cmu.edu. The software page of the web site has the most recently released version of ACT-R available as either a .zip of the source files or built into a standalone application for Linux, Mac OS, or Windows. The released versions have been tested against the reference models and the output of the models should be consistent with respect to what is printed in the tutorial. New releases are made when there are significant updates or patches and typically happen two or three times a year. The other method for acquiring the software is via version control software called Subversion. More information on Subversion can be found at http://subversion.apache.org/. The ACT-R archive is located at <svn://act-r.psy.cmu.edu/actr7.x>. The Subversion archive contains the most up to date version of ACT-R, and often contains minor changes or bug fixes not yet available in a released version. Note however that the minor changes made to the sources available through Subversion are not all tested thoroughly against the tutorial models and there may be discrepancies with respect to the tutorial or other documentation until the next released version.

It is also possible to get a Docker container with ACT-R and supporting applications in it from Docker Hub by pulling the db30/act-r-container or going to https://hub.docker.com/r/db30/act-r-container. No software other than Docker is needed to run that version. This version of the software is still a work in progress but should be fully functional. It may also lag slightly behind the most recent release from the website.

Distribution Contents

The ACT-R distribution consists of: the Lisp source code files which implement ACT-R, the ACT-R Environment application along with its corresponding Tcl/Tk source code files, the ACT-R Tutorial unit texts and models, documentation for the software and tools, examples showing some advanced capabilities not covered in the tutorial, and some extensions of the system which are not included by default. All of the files are distributed in a single directory, called actr7.x, which contains four files and several subdirectories. The files are load-act-r.lisp which is the file that should be loaded to load the main ACT-R software (see Loading and Running the ACT-R System), load-single-threaded-act-r.lisp which loads a special "Lisp only" version of the software (see Single-threaded mode), recompile-act-r.lisp which can be used to force the software to be recompiled if one makes changes to any of the source code (see Recompiling), and a file called readme.txt which contains some information about the distributed files. Here is a listing of the subdirectories along with a general description of their purpose and some of their specific contents.

Subdirectories

commands

This directory contains the Lisp code for user commands for some of the central modules. One feature of this directory is that any file with a .lisp extension placed into this folder will be compiled and loaded with the rest of the system.

core-modules

This directory contains the Lisp code that defines the modules which instantiate the main ACT-R system described in the theory. They are assumed to always be available, but are not absolutely required. The core modules are Procedural, Declarative, Goal, Vision, Auditory, Motor, Speech, and Imaginal and are all described in this manual.

dev-tools

This directory contains subdirectories with the scripts that are used to build the distribution bundles as well as the standalone applications. It is not intended for users and is only included in the subversion repository – not in the distributed software releases.

devices

This directory previously contained subdirectories where one could provide the implementation of devices for ACT-R which can interact with particular Lisps' GUI components. The overall notion of a device for ACT-R has changed as of ACT-R 7.6 to better support remote interactions, and thus the current version only contains a generic virtual system for models to use. [However, the Lisp specific implementations from prior versions of ACT-R may be updated and included in the future.] The details on creating and using devices is described later in this manual and there is also an additional manual with documentation on using the virtual GUI components implemented with the provided device called the AGI (ACT-R GUI Interface).

docs

This directory contains the documentation files for ACT-R. They include details on using the system, as well as documents describing particular features. Most are either Microsoft Word documents (.doc

files) or PDFs depending on how the files were acquired (the Subversion repository holds the .docs but they are converted to .pdf for the releases found on the website). Here are descriptions of some of the files found there:

- AGI
  - The manual for the AGI tools.
- compilation.xls
  - An Excel Spreadsheet that is used to define the operation of the production compilation mechanism for different buffer styles.
- EnvironmentManual
  - A manual for the GUI tools provided by the ACT-R Environment application.
- LGPL.txt
  - The Lesser Gnu Public License text. That is the license under which the ACT-R software is distributed.
- QuickStart.txt
  - A text file with instructions on how to load ACT-R and start the ACT-R Environment.
- reference-manual
  - This document.
- remote
  - A document which describes the underlying details of the remote interface.
- Task_Interfacing
  - A document indicating some issues to be aware of when building and working with devices in ACT-R which connect to real GUI items or external systems.

In the subversion repository (but not the released versions) there is also a subdirectory called notes which contains some files with historical documentation on utility learning and production compilation as well as some files that contain information which is useful for development purposes (not generally applicable to users).

environment

The environment directory contains all of the files necessary for using the ACT-R Environment. There are several items in this directory: Lisp files that provide the internal support for the tools, the Environment applications for Linux, Mac OS X, and Windows, and a gui directory that contains the Tcl/Tk files used by the Environment application.

examples

Several Lisp files and directories which contain examples of using more advanced components of the software like multiple models, visual tracking, creating new visual features, making remote connections in various languages (currently C, Lisp, Java, MATLAB, Node.js, Python, R, and Tcl/tk examples available), and adding new modules (both locally in Lisp and remotely from Python).

extras

The extras directory contains additional modules and other files that have been contributed to the distribution, but which are not part of the default ACT-R system and are not loaded by default. Each addition is included in its own subdirectory and directions for using the extension should be found within the files themselves or the documentation which accompanies them. For most of the extras there is a command which can be added to a model file to load the file(s) necessary to use that extra automatically described in the loading extra components section.

framework

The framework directory contains the Lisp files that define the software framework upon which the ACT-R system is based. The software framework is a basic discrete event simulation system that was designed to implement ACT-R, but is not itself a part of the ACT-R theory.

modules

The modules directory contains Lisp files which implement additional modules which are loaded into the default ACT-R system. As with the commands directory, any files with a .lisp name placed into this directory will be loaded automatically when ACT-R is loaded.

other-files

This directory contains Lisp files that add additional tools for ACT-R. Like the commands and modules directories, any file with a .lisp extension placed into this directory will be automatically loaded with the system.

support

The support directory contains Lisp files that may be needed for certain Lisp implementations, by certain modules of the system, or for particular extensions or tools. These files are loaded when required by other files. Files with a .lisp name placed here can be compiled and loaded when needed using the require-compiled command.

test-models

This directory contains tasks and models from the ACT-R tutorial (in both Lisp and Python), other model and task files, and files of the expected output for the tests. These are used for regression testing the software and this directory is only available via subversion.

tools

The tools directory contains Lisp files that define additional functions and tools for ACT-R. Like the commands and modules directories, all files with a .lisp name placed into this folder will be automatically loaded.

tutorial

The tutorial directory contains several subdirectories. There are directories for each of the units in the tutorial, and also directories for implementations of the experiments used in the tutorial for different languages (currently Lisp and Python). Each unit consists of a text on a particular aspect of ACT-R, one or more demonstration models, a partial model which provides a starting point for an assignment, a text describing the code that implements the tasks for the models in that unit, and in some units there is an additional text with more details on using the ACT-R software and how to debug models along with a broken model to work through the debugging process.

user-loads

The user-loads directory contains no files in the distribution. It is provided as a place for users to add files which will be loaded automatically after ACT-R has finished loading and initializing. All of the files in the user-loads directory with a .lisp name will be compiled and loaded in order based on the file names sorted using the Lisp string< function. Because this occurs after the system has been initialized it is safe to put a model file into this directory.

Loading and Running the ACT-R System

To start ACT-R from source code all one needs to do is load the load-act-r.lisp file into a Lisp which also has Quicklisp installed. That will load all of the necessary files for ACT-R. The file should only be loaded into a given Lisp session once.

The files are compiled before loading and that may generate some warnings from the compiler. Those warnings can usually be safely ignored. The files are only compiled the first time you load ACT-R. The compiled files are saved with the source files and on subsequent loadings there is no need to recompile everything. Thus, on all loadings after the first one, it should load faster and produce fewer warnings, but there may be times when you need to have files compiled again and that is described in the section below.

Single-threaded mode

If one does not need to use the remote connection ability and is not accessing ACT-R commands from other threads in Lisp then the load-single-threaded-act-r.lisp file may be used instead. When that file is loaded Quicklisp is not necessary and the system generally runs faster without the need to support the remote interface.

If you want to use the Quicklisp libraries :bordeaux-threads, :cl-json, or :usocket, but do not need the remote connection ability in ACT-R then those can be loaded before or after loading the load-single-threaded-act-r.lisp file. The single-threaded ACT-R code creates "dummy" versions of the packages corresponding to those libraries which it used when compiling the ACT-R code. If any of those quicklisp libraries are being used with the single-threaded ACT-R and any of the ACT-R extras are also needed, then those extras must be loaded through require-extra instead of loading it directly so that the appropriate packages are used.

One difference between the single-threaded mode and the normal version of ACT-R is that the history tools in single-threaded mode will not encode the data as JSON strings. Instead the raw Lisp data will be recorded and returned.

ACT-R version details

Once the loading of the ACT-R code is complete, you will see a print out describing the current version of ACT-R that has been loaded. That is indicated by the line that starts with Software followed by a version description. That will take one of two general forms:

```
####################################
ACT-R 7 Version Information:
Software              : 7.6.1-<internal>
```

or

```
####################################
ACT-R 7 Version Information:
Software              : 7.6.1-<2496:2018-01-11>
```

The first number, 7 in this case, indicates the current version of the ACT-R cognitive architecture. That will be followed by one or two digits (separated by periods) indicating the specific version of the software that implements ACT-R, and then a hyphen and a tag in angle brackets which describes where that code came from. If the tag says "internal" that means that it was not a released version of the software and it was likely checked out from the subversion repository. For an official release of the software the tag will indicate which specific repository revision it contains followed by a colon and then the date on which the release occurred (the above example indicating that it is repository revision 2496 and was released on January 11th, 2018). If it is a standalone version there will be an additional letter after after the revision number indicating the OS for which it was built.

The digits representing the software version will be updated when a significant change (not minor maintenance or bug fixes) to the software occurs. A significant change which does not affect the operation of existing models (which would usually be an addition of a new capability or extension of an existing one) will result in an increment of the second version number or setting the second version number to 1 if it doesn't currently have one. A change which may affect the operation of existing models will cause the first version number to be incremented.

That means models written for version 7.A.B should run the same in any version 7.A.C where C is greater than or equal to B (where B is considered to be 0 if it does not exist) i.e. within a given major version (the A) models can be expected to run the same in any version after the one in which they were initially created but not necessarily those before because those prior versions may be lacking in some new feature or capability. Whereas a model written for major version A is not guaranteed to run the same in any different major version – it might still work the same but that is not guaranteed.

In a later section there are additional details on how one can test the current version information if needed, and it also describes a command which can be placed into a model file to warn users if the version of ACT-R being used may not be compatible with the version for which the model was written.

Component and Module versions

After the ACT-R version has been printed there will be a listing of all the components and modules that are currently defined in the software along with their versions and brief descriptions. That will look like this:

```
================================================
Components
------------------------------------------------
AGI             : 5.0        Manager for the AGI windows
...
================================================
Modules
------------------------------------------------
AUDICON-HISTORY       : 3.0        Module to record audicon changes.
...
```

The version information for a module is not as structured as the overall ACT-R version, but generally a change in the major version number for a module indicates a significant change that likely affects the compatibility with existing models/code (and would trigger a corresponding change in the ACT-R version). Whereas a minor version number change can occur for many reasons, but typically does not affect the existing functionality of the module.

The module details will be followed by a line that looks like this:

```
######### Loading of ACT-R 7 is complete #########
```

At that point, all of the ACT-R code has been loaded and if there are no user provided files to be loaded the software is ready to use.

User Load files

If there are any files in the user-loads directory then there will be at least two additional lines displayed. The first will be:

```
######### Loading user files #########
```

That will be followed by any information displayed while the files in that directory are compiled and loaded. After all of those files have been loaded this will then be displayed:

```
######### User files loaded #########
```

The software is then ready to use.

Lisp Compiler Optimizations

Normally, when ACT-R compiles its files it uses the current optimization settings of the Lisp. However, if **:actr-fast** is on the features list when load-act-r.lisp is loaded it will apply these settings before compiling the ACT-R sources:

```
(proclaim '(optimize (speed 3) (safety 1) (space 0) (debug 0))))
```

and those settings will remain after the loading is finished. With those settings ACT-R should run faster, but how much faster will vary from Lisp to Lisp. If the ACT-R source files were compiled without the switch then setting the switch and recompiling them will be required to see the improved performance.

Logical Host

As part of loading ACT-R a logical host of “ACT-R” is defined which maps to the directory where the load-act-r.lisp file is located. That logical host is available for use by the user, and it can be useful when working with the tutorial to load the tutorial models. Here is an example which will load the count model from unit1 (assuming that one has not moved the tutorial files):

```
> (load "ACT-R:tutorial;unit1;count.lisp")
; Loading C:\Users\db30\Desktop\actr7\tutorial\unit1\count.lisp
T
```

Note however that some Lisps will not allow a logical pathname to be passed to commands like load and one will have to translate that into a physical pathname using translate-logical-pathname:

```
> (load (translate-logical-pathname "ACT-R:tutorial;unit1;count.lisp"))
; Loading C:\Users\db30\Desktop\actr7\tutorial\unit1\count.lisp
T
```

To avoid having to explicitly translate the pathname, there is a function provided which performs those two steps, and two additional functions which will optionally compile a file as well which can also be used remotely.

actr-load

Syntax:

actr-load *pathname* -> [load-return-value | **nil**]

Arguments and Values:

pathname ::= a string or pathname indicating the location of a file to load
load-return-value ::= a generalized boolean returned from calling the load command

Description:

The actr-load function takes one parameter which is the pathname to a file to be loaded. It will first use the Lisp function translate-logical-pathname to create a physical pathname to the file and if that file exists it will be loaded and return the result of the load function call.

If the file does not exist then a warning is printed and **nil** returned.

Examples:

```
> (actr-load "ACT-R:tutorial;unit1;count.lisp")
T

E> (actr-load "ACT-R:tutorial;unit12;no-file.lisp")
#|Warning: File #P"C:\\actr7.x\\tutorial\\unit12\\no-file.lisp" does not exist.|#
NIL
```

load-act-r-model/load-act-r-code

Syntax:

load-act-r-model *pathname* {*compile*} -> [**t** | **nil**]
load-act-r-code *pathname* {*compile*} -> [**t** | **nil**]

Remote command names:

load-act-r-model
load-act-r-code

Arguments and Values:

pathname ::= a string or pathname indicating the location of a file to load
compile ::= a generalized boolean indicating whether to compile the file before loading

Description:

The load-act-r-model and load-act-r-code commands take one required parameter which is the pathname to a file to be loaded. They use the Lisp function translate-logical-pathname to create a physical pathname to the file. If such a file exists and the optional parameter is not provided or is **nil** then they will attempt to load that file. If the optional parameter is provided as a non-**nil** value then that file will be compiled and the resulting compiled file will attempt to be loaded. While loading and compiling the file these commands will capture all of the output which is generated and that output will be output to the ACT-R warning trace when complete under a line which says "Non-ACT-R messages during load of *pathname*:". These commands also trap any errors which occur during the compiling and loading and will terminate if an error occurs and output the details of the error to the warning trace.

If the file is successfully compiled and loaded then a value of **t** is returned otherwise they return **nil**.

Only one instance of each of these commands can be operating at a time as a safety measure since they are available through the remote interface. If a second call is made to one of them before a current call completes (regardless of the origin of that ongoing call) it will report an error and return **nil**.

Examples:

NOTE: The tutorial unit task implementation files like demo2.lisp or demo2.py include a call to load-act-r-model to load the corresponding model file for the task. The last error output shown indicates a result of T because the warning was generated by the call to load-act-r-code that is in the provided file (the model file could not be loaded with load-act-r-model) but the demo2.lisp file itself was successfully loaded.

```
> (load-act-r-code "ACT-R:tutorial;lisp;demo2.lisp")
#|Warning: Non-ACT-R messages during load of "ACT-R:tutorial;unit2;demo2-model.lisp":
; Loading C:\Users\db30\Desktop\actr7.x\tutorial\unit2\demo2-model.lisp

 |#
#|Warning: Non-ACT-R messages during load of "ACT-R:tutorial;lisp;demo2.lisp":
; Loading C:\Users\db30\Desktop\actr7.x\tutorial\lisp\demo2.lisp

 |#
T

> (load-act-r-code "ACT-R:tutorial;lisp;demo2.lisp" t)
#|Warning: Non-ACT-R messages during load of "ACT-R:tutorial;unit2;demo2-model.lisp":
; Loading C:\Users\db30\Desktop\actr7.x\tutorial\unit2\demo2-model.lisp

 |#
#|Warning: Non-ACT-R messages during load of "ACT-R:tutorial;lisp;demo2.lisp":
;;; Compiling file C:\Users\db30\Desktop\actr7.x\tutorial\lisp\demo2.lisp
;;; Writing fasl file C:\Users\db30\Desktop\actr7.x\tutorial\lisp\demo2.fasl
;;; Fasl write complete
; Fast loading C:\Users\db30\Desktop\actr7.x\tutorial\lisp\demo2.fasl

 |#
T

E> (load-act-r-model "ACT-R:tutorial;unit12;no-file.lisp")
#|Warning: Error "Error #<SIMPLE-ERROR File \"ACT-R:tutorial;unit12;no-file.lisp\" which
translates to #P\"C:\\\\Users\\\\db30\\\\Desktop\\\\actr7.x\\\\tutorial\\\\unit12\\\\no-
file.lisp\" does not exist.> occurred while trying to evaluate command \"load-act-r-
```

```
model\" with parameters (\"ACT-R:tutorial;unit12;no-file.lisp\" NIL)" while attempting to
evaluate the form ("load-act-r-model" "ACT-R:tutorial;unit12;no-file.lisp" NIL) |#
NIL

E> (load-act-r-model "ACT-R:tutorial;lisp;demo2.lisp")
#|Warning: Error "Load-act-r-model currently loading a model" while attempting to evaluate
the form ("load-act-r-model" "ACT-R:tutorial;unit2;demo2-model.lisp" NIL) |#
#|Warning: Non-ACT-R messages during load of "ACT-R:tutorial;lisp;demo2.lisp":
; Loading C:\Users\db30\Desktop\actr7.x\tutorial\lisp\demo2.lisp

 |#
T
```

Load order

For those considering adding extensions or just having files loaded automatically, the files and directories are loaded in the following order:

- framework directory files in a predefined order
- core-modules directory files in a predefined order
- all .lisp files from the commands directory in no particular order
- the virtual device files
- any Lisp specific device files
- all .lisp files from the modules directory in no particular order
- all .lisp files from the tools directory in no particular order
    - the ACT-R Environment files are loaded as part of this step
- all .lisp files from the other-files directory in no particular order
- all .lisp files from the user-loads directory in order with the file names sorted using the Lisp string< function.

Recompiling

If one of the source files in the distribution changes (the date on the .lisp file is newer than the date on the compiled version of that file) then it will automatically be recompiled the next time it is loaded. However, there may be times when you need to force all of the ACT-R files to be recompiled. For instance, if you upgrade or change your Lisp system you will likely need to recompile everything. Also, if you get an update to your current set of ACT-R files it is often best to force a recompile the next time you load it because there may be some interdependencies that will require more than just the updated file to be recompiled.

To force ACT-R to recompile all of its files you can add the :actr-recompile switch to the features list which can be done with this call before loading the load-act-r.lisp file:

```
(push :actr-recompile *features*)
```

Alternatively, you can load the recompile-act-r.lisp file which will add that feature and then load the main ACT-R load file.

If you change which load file is used relative to the version that was loaded previously (from load-act-r.lisp to load-single-threaded-act-r.lisp or vice-versa) then it will also automatically recompile all of the files.

There is also a feature switch called :dont-compile-actr which will prevent the loader from compiling any of the files and instead just load the existing compiled files. This overrides the :actr-recompile switch. This is likely not useful for users of the system, but can be helpful when testing or upgrading the ACT-R software itself.

Packaging

By default, the ACT-R files are loaded into which ever package is current at the time they are loaded i.e. there are no package specifications. However, there are two features which can be set that will change the package into which ACT-R is loaded. If the ACT-R files have been compiled previously, then it will be necessary to also force the recompiling of the sources when changing the package into which they are loaded. Note that these options may not work properly in all Lisps since there may be differences in how other default packages are defined – please contact Dan if you have any problems or questions with using the packaged ACT-R code.

Clean

The first option is to add the :clean-actr switch to the features list before loading. That will force the files to be loaded into the :cl-user package in most Lisps (the only exception is that in ACL with the IDE it will load them into the :cg-user package).

Packaged

The other option is to add the :packaged-actr switch to the features list. That will create a new package called :act-r when the load-act-r.lisp file is loaded and the ACT-R code will be loaded into that package. Nothing is exported from that package by the ACT-R code.

Requiring files

Files placed into the support directory of the distribution can be compiled and loaded when needed by using an ACT-R extension of the Lisp require function.

require-compiled

Syntax:

require-compiled *lisp-module-name* {*pathname*} -> [load-return-value | **nil**]

Arguments and Values:

lisp-module-name ::= a string containing the name of a Lisp module (the value provided in the file)
pathname ::= a string or pathname indicating the location of a .lisp file which provides the module
load-return-value ::= a generalized boolean returned from calling the load command

Description:

The require-compiled function has one required parameter and one optional parameter. The required parameter is the Lisp module name string as would be passed to the require function (note this is not the same as an ACT-R module name). The optional parameter is the pathname to the file to be loaded. If the pathname is not provided, then it will try to load the file with the module name given (converted to all lowercase characters) and a .lisp type from the ACT-R support directory. In the ACT-R source code files, only those in the support directory use the provide function to specify a module name for use in requiring.

The reason for using require-compiled compared to just loading the file directly is that require-compiled will only compile and load the file if it has not been loaded previously, the previously compiled version was from a different ACT-R mode, or the mode under which the previous version was compiled is unknown. That way one can specify that a particular support file is necessary in multiple files and only the first one will actually compile and load it. The differences between this and the Lisp require function is that this will guarantee that the file is compiled instead of just being loaded and the optional pathname for this function must be a single pathname instead of a list of pathname designators.

If the file is compiled and loaded the return value will be the one returned by that load. If it does not need to be compiled and loaded it will return **nil**.

To go along with the intended use of this command there is another logical host created when ACT-R is loaded called “ACT-R-support” which refers to the support directory of the current ACT-R source code tree.

Examples:

```
1> (require-compiled "TIME-FUNCTIONS")
;;; Compiling file C:\Users\db30\actr7.x\support\time-functions.lisp
;;; Writing fasl file C:\Users\db30\actr7.x\support\time-functions.fasl
;;; Fasl write complete
; Fast loading C:\Users\db30\actr7.x\support\time-functions.fasl
T
2> (require-compiled "TIME-FUNCTIONS")
NIL

> (require-compiled "CENTRAL-PARAMETERS" "ACT-R-support:central-parameters")
NIL
```

Overall Software Design

The ACT-R software is composed of three major subsystems. From the perspective of the user, they operate together to implement "ACT-R", but it is important to note that not everything in the software is a representation of elements of the ACT-R cognitive architecture.

The first subsystem is a discrete event simulation system which controls the timing and coordination of operations within ACT-R. It was designed to provide all of the support necessary to implement the current ACT-R theory, but is not itself a part of the theory. It defines the abstractions and tools which underlie the operations of the system, namely a meta-process, a model, a module, a component, a buffer, a chunk and a parameter. Some of those items are elements of the theory of ACT-R, for example buffers and chunks, but their specific implementation in the software is not prescribed by the theory.

The next subsytem is the RPC server which provides the remote interface for the system to interact with other software (typically referred to as the dispatcher). This is not a component of the ACT-R cognitive architecture and is purely a construct for the software implementation. As part of providing the external interface, the dispatcher is also used to coordinate the output of the system in a way that makes it available remotely. Many of the commands described in this manual are available remotely through the dispatcher. When that is the case, the remote name and any additional details needed will be described with the command. However, this document does not describe the operation of the underlying RPC system itself. That information is found in the document called remote in the docs directory.

The last subsystem is the set of modules that instantiate the theory of ACT-R. These modules contain the components that are used to model human cognition as described in the paper "Integrated Theory of the Mind" and the book "How Can the Human Mind Occur in the Physical Universe?". The actions and timing profiles generated by these modules when a model is run are the actual predictions of the theory. Anything else, for instance the actual time it takes the software to run the simulation, is not based on the theory. Those distinctions can be important so that the modeler appropriately differentiates what is a psychological claim of a model and what is just a consequence of the current software implementation.

Model files

Generally, when working with ACT-R one will generate text files that contain the description of a model which will be loaded into the ACT-R system. This is not the only way to develop models in ACT-R, but is by far the most typical usage.

An ACT-R model file is a text file of Lisp source code. It can be generated in any text editor. Because it will be loaded into Lisp it must be syntactically correct Lisp code. Thus, it can be useful to use an editor that helps with that. The editors built into the GUI based Lisp systems (like CCL on a

Mac, LispWorks, or ACL with its IDE) are good choices if using such a Lisp, but if not, an editor like Emacs which has automatic Lisp indenting and parentheses matching can also help.

A typical model file will have the following structure:

```
(clear-all)

{supporting Lisp code}

(define-model model-name
   (sgp {parameter value}*)
   {chunk-type definitions}
   {initial chunks are defined}
   {productions are specified}
   {any additional model set-up commands}
   {additional model parameter settings}
)
```

The ACT-R commands shown above and the model components referenced (chunk-types, chunks, and productions) will be described in detail in later sections of this document, but for now here is a basic description of what the components of the model file do (information on creating and using models is covered in the ACT-R tutorial).

- **(clear-all)**
  The clear-all command completely resets ACT-R's state to a clean slate. This does not have to be the first thing in the file, but it should occur before defining any models.

- *{supporting Lisp code}*
  Since the model file will be loaded into ACT-R (which is running in Lisp) it can be convenient to also create the experiment/task for the model in Lisp along with the actual ACT-R model, and sometimes one may also want to extend or modify the operation of the ACT-R system by providing support functions for things like generating similarity values dynamically.

- **(define-model** *model-name*
  The define-model command is used to specify exactly what constitutes the components of the model and to give it a name for reference. Everything between the name specified for the model and the closing parenthesis of this command are considered the model's initial configuration. The commands are processed sequentially from left to right (which would be top down if spread over multiple lines as shown above).

- ***(sgp** {parameter value}***)***
  The sgp command is used to set parameters that control the general operation of the system. This is typically the first command in the model's definition so that all of the conditions are properly set before anything else occurs.

- *{chunk-type definitions}*
  Descriptions are given for declaring the configuration of slots that will be used in the chunks in the model.

- *{initial chunks are defined}*

The initial chunks for the model are created and typically placed into the model's declarative memory.

- *{productions are specified}*
  The productions that control how the model will act are usually specified after the chunk-types and chunks have been defined.

- *{any additional model set-up commands}*
  Any other commands necessary to configure components of the model or modules are specified.

- *{additional model parameter settings}*
  Parameters for chunks and productions specified above are set.

- **)**
  The define-model call is ended with a closing parenthesis.

ACT-R Output

The output of ACT-R is coordinated through signals. All of the ACT-R output commands result in the generation of a signal with the corresponding output in a string. There are four output signals which can be monitored through the dispatcher for displaying the various types of ACT-R output. By default, all of the output signal strings are sent to *standard-output* for display in Lisp. That output can be disabled and enabled using commands described below. The commands for generating output are described in a later section.

Commands & Signals

general-trace

Signal:

general-trace output-string

Arguments and Values:

output-string ::= a string containing output from an ACT-R output command

Description:

The general-trace signal is used to provide ACT-R output which is not dependent upon there being a current model.

model-trace

Signal:

model-trace output-string

Arguments and Values:

output-string ::= a string containing output from an ACT-R output command

Description:

The model-trace signal is used to provide ACT-R output from a model. That output is controlled by the :v parameter in the printing module for that model.

command-trace

Signal:

command-trace output-string

Arguments and Values:

output-string ::= a string containing output from an ACT-R output command

Description:

The command-trace signal is used to provide ACT-R output from a model. That output is controlled by the :cmdt parameter in the printing module for that model.

warning-trace

Signal:

warning-trace output-string

Arguments and Values:

output-string ::= a string containing output from an ACT-R output command

Description:

The warning-trace signal is used to provide ACT-R output which indicates a warning or error has occurred. Some warnings can be suppressed through the :model-warnings parameter in the printing module for a model.

echo-act-r-output

Syntax:

echo-act-r-output -> name

Arguments and Values:

name ::= a string containing the name of the command which is used to monitor the output signals

Description:

The echo-act-r-output command is used to route all of the output generated by ACT-R to *standard-output* in Lisp. When it is called, first it removes any existing output signal monitors which were previously created by echo-act-r-output. Then it generates a new name for a command to use to print output to the current *standard-output*. That new command is then set to monitor all four of the output signals: model-trace, command-trace, warning-trace, and general-trace. It returns the name of the command which it created.

This command is called during the loading of ACT-R which means that all of the output is displayed by default.

Examples:

```
> (echo-act-r-output)
"G2354"
```

turn-off-act-r-output

Syntax:

turn-off-act-r-output -> [**t**, **nil**]

Arguments and Values:

none

Description:

The turn-off-act-r-output command is used to stop printing the output from ACT-R to *standard-output* in Lisp as enabled by echo-act-r-output. When it is called, it removes any output signal monitors which were previously created by echo-act-r-output. If there were output signal monitors then it returns **t** otherwise it returns **nil**.

Examples:

```
1> (turn-off-act-r-output)
T

2> (turn-off-act-r-output)
NIL
```

suppress-act-r-output

Syntax:

suppress-act-r-output *form** -> result

Arguments and Values:

form ::= a Lisp form to be evaluated
result ::= the return value from the last form evaluated

Description:

The suppress-act-r-output command can be used to temporarily disable the outputting of information through echo-act-r-output. It is a macro which can be wrapped around any number of Lisp forms to evaluate. While those forms are being evaluated any output which is created is not sent to *standard-output* by the echo-act-r-output monitoring commands, but those monitoring commands (if there are any) are not removed. It returns the return value from the last form evaluated. This does not affect any other commands which may be monitoring the output signals.

This is generally more efficient than turning off the output and then echoing it again for short blocks of code since the removal and addition of monitors is costly. However, for large blocks of code it

may be more efficient to turn it off and then echo again since the monitoring function is still active during suppressed output and will be called even though it is not printing to *standard-output*.

Examples:

```
1> (echo-act-r-output)
"G2360"

2> (act-r-output "This")
This
NIL

3> (suppress-act-r-output
     (act-r-output "That"))
NIL

> (act-r-output "Other")
Other
NIL
```

Software Operation

The next several sections are going to discuss the operation and data structures of the underlying software. Although some of these are used to represent components of the ACT-R cognitive architecture, like chunks, the specific implementation and operations of these items are not a part of the cognitive architecture itself. For example, while the architecture says that declarative knowledge is represented in chunks which contain slots and values, it does not say how those chunks are represented nor what specific operators should be available to work with them.

Meta-process

The operation of the discrete event simulation system is controlled by a mechanism called the meta-process. The meta-process maintains the schedule of events, the simulation clock, the available models, and executes the events at the appropriate times when it is run. Currently, with this version of ACT-R, there is only one meta-process which is defined automatically when the software starts and it is not possible to create any others. [Note: some prior versions of ACT-R allowed for the creation of more than one meta-process and you may still see references to the "current meta-process" in this documentation. The single meta-process in this version of ACT-R will always be the current meta-process.]

The operation of the scheduling and running will be discussed in following sections. Here we will describe the high-level commands applicable to the meta-process.

Commands & Signals

clear-all

Syntax:

clear-all -> nil

Arguments and Values:

none

Description:

Clear-all restores ACT-R to its initial state:

- It generates the clear-all-start signal.
- It removes all currently defined models and their associated modules.
- It removes all events from the event queue and the waiting queue.
- It removes all event hooks which have been created.
- It sets the current simulation time to 0.
- It restores the default real time clock.
- It initializes all components which have been added.

In addition, the current binding of the Lisp variable *load-truename* is recorded for use by the reload command.

The typically usage of clear-all is to place it at the top of a model file to ensure that when the model is defined it starts with a clean system and that the reload command can be used.

Clear-all cannot be used while the meta-process is actively running, and doing so will result in the generation of a Lisp error which provides details on how to resolve that issue under the typical situations where it can occur.

Examples:

```
> (clear-all)
NIL
```

clear-all-start

Signal:

clear-all-start

Arguments and Values:

none

Description:

The clear-all-start signal is generated whenever the clear-all command starts to initialize the system, and there are no parameters associated with the signal.

reset

Syntax:

reset -> [**t** | **nil**]

Remote command name:

reset

Arguments and Values:

none

Description:

The reset command is used to clear the event queue and restore the current set of models and modules to their initial states (unlike clear-all which removes all of the models and modules).

- It generates a reset-start signal.
- It removes all events from the event queue and the waiting queue.
- It sets the current simulation time to 0.
- It resets all components, modules, and models.

The details of what happens when a model, module, and component are reset are described in the corresponding sections.

Reset cannot be used while the model is running and trying to do so will result in a warning being output to indicate that. If the reset completes successfully then it will return **t** otherwise it will return **nil**.

Examples:

```
> (reset)
T

E> (reset)
#|Warning: Top-level-lock unavailable. Reset cannot be used. |#
NIL
```

reset-start

Signal:

reset-start

Arguments and Values:

none

Description:

The reset-start signal is generated whenever the reset command starts to reset the system, and there are no parameters associated with the signal.

reload

Syntax:

reload {*compile?*} -> [load-return-value | **:none**]

Remote command name:

reload

Arguments and Values:

compile? ::= a generalized boolean indicating whether or not to compile the file
load-return-value ::= a generalized boolean returned from calling the load command

Description:

The reload command calls the Lisp load command to load the file recorded during the last call to the clear-all command. It is provided as a shortcut for loading a model file that has been edited. If the compile? parameter is specified with a true value and that file has a type of "lisp" it will be compiled before loading. If the compile? parameter is specified as true but the recorded file is not of type "lisp" then it is not compiled, a warning is printed, and the file is just loaded.

If there is no file recorded by clear-all then no file is loaded and the keyword **:none** is returned. Reload cannot be used while the system is running. If there are any errors generated during the reloading of the model they will be automatically handled and the error messages printed as warnings. There may be additional information printed in warnings even for a successful load because all output to Lisp *standard-output* and *standard-error* during the load will be captured and printed in warnings.

If the reload completes successfully it will return a true value, otherwise it will return **nil**.

Examples:

```
> (reload)
T

> (reload)
#|Warning: Non-ACT-R messages during load of #P"C:demo-model.lisp":

; Loading C:demo-model.lisp

 |#
T

> (reload t)
#|Warning: To use the compile option the pathname must have type lisp. |#
; Loading C:\model.txt
T

E> (reload)
#|Warning: No model file recorded to reload. |#
:NONE
```

mp-time

Syntax:

mp-time -> current-time

Remote command name:

mp-time

Arguments and Values:

current-time ::= a number representing the current simulation time in seconds

Description:

Mp-time returns the current time of the meta-process in seconds.

This is generally used for two purposes, either debugging a model or collecting response time data from a model.

Examples:

```
> (mp-time)
0.3
```

mp-time-ms

Syntax:

mp-time-ms -> current-time

Remote command name:

mp-time-ms

Arguments and Values:

current-time ::= a number representing the current simulation time in milliseconds

Description:

Mp-time-ms returns the current time of the meta-process like mp-time. The difference is that mp-time-ms returns the time as an integer count of milliseconds.

Examples:

```
> (mp-time-ms)
300
```

mp-print-versions

Syntax:

mp-print-versions -> **nil**

Remote command name:

mp-print-versions

Arguments and Values:

none

Description:

Mp-print-versions outputs using the general-trace the specific version number of the ACT-R software with a tag indicating whether the code is an official release or an internal version checked out of the source repository followed by the name, version number, and documentation string of each of the components and modules which is currently defined in the system. It always returns **nil**.

Examples:

```
> (mp-print-versions)
ACT-R 7 Version Information:
Software              : 7.6.2-<internal>
================================================
Components
------------------------------------------------
AGI              : 5.0        Manager for the AGI windows
CHUNK-SPEC       : 3.0        Maintains a table of chunk-specs for remote use
HISTORY-RECORDER: 1.0         Maintain the tables of defined history recorders and state ...
KEYBOARD-TABLE   : 2.0        Record the keyboards used for each model.
MOUSE-TABLE      : 2.0        Record the mouse devices that are used.
NAMING           : 2.0        Provides new symbol generation for the system.
TRACE-HISTORY    : 1.0        Component for recording trace information
================================================
Modules
------------------------------------------------
AUDICON-HISTORY       : 3.0        Module to record audicon changes.
AUDIO                 : 5.1        A module which gives the model an auditory attentional ...
BOLD                  : 4.0        A module to produce BOLD response predictions from ...
BUFFER-HISTORY        : 2.0        Module to record buffer change history.
BUFFER-PARAMS         : 1.0        Module to hold and control the buffer parameters
BUFFER-TRACE          : 3.0        A module that provides a buffer based history mechanism.
CENTRAL-PARAMETERS    : 1.2        a module that maintains parameters used by other modules
DECLARATIVE           : 5.1        The declarative memory module stores chunks from the ...
DEVICE                : 4.0        The device interface for a model
GOAL                  : 2.1        The goal module creates new goals for the goal buffer
HISTORY-RECORDER      : 2.0a1      Module to support the saving and accessing of ...
IMAGINAL              : 4.0        The imaginal module provides a goal style buffer with ...
MOTOR                 : 4.0        Module to provide a model with virtual hands
NAMING-MODULE         : 2.0        Provides safe and repeatable new name generation for ...
PRINTING-MODULE       : 1.3        Coordinates output of the model.
PROCEDURAL            : 5.0        The procedural module handles production definition ...
PRODUCTION-COMPILATION: 2.0        A module that assists the primary procedural module ...
PRODUCTION-HISTORY    : 2.0        Module to record production history for display in ...
RANDOM-MODULE         : 1.0        Provide a good and consistent source of pseudorandom ...
RETRIEVAL-HISTORY     : 2.0        Module to record retrieval history data.
SPEECH                : 5.1        A module to provide a model with the ability to speak
STEPPER               : 1.0        Store the model specific information for the ...
TEMPORAL              : 2.1        The temporal module is used to estimate short time ...
UTILITY               : 4.0        A module that computes production utilities
VISICON-HISTORY       : 3.0        Module to record visicon changes.
VISION                : 6.0        A module to provide a model with a visual attention system
NIL
```

Events

As indicated in the description of the meta-process, the simulation system for ACT-R is implemented using discrete events. The system runs by executing a sequence of events each occurring at a specific simulated time. Effectively, every action of the model is performed by an event in the system, and the model's trace when it runs is a printing of those events as they occur.

Each event consists of the time at which it should occur, an indication of which, if any, module created the event, and an action to perform. There are some additional details and capabilities of events (like the ability to have them wait for some other action to occur instead of having a pre-specified time) and those will be described in the section on creating events. This section will only describe the commands for inspecting the events which exist in the current meta-process.

Commands

mp-show-queue

Syntax:

mp-show-queue {*indicate-traced*} -> event-count

Remote command name:

mp-show-queue

Arguments and Values:

indicate-traced ::= a generalized boolean indicating whether to mark events that will occur in the trace
event-count ::= a number indicating how many items are in the event queue

Description:

Mp-show-queue outputs a line of text that says "Events in the queue:" followed by all of the events that are on the event queue in the order that they will be executed using the general-trace output signal. If the indicate-traced value is provided and is non-**nil** then the character "*" will be displayed before the events which will be displayed in the trace with the current parameter settings for the associated model. It returns the number of events in the queue.

This command can be useful for debugging a model as well as when working on creating modules and experiments which generate events.

Examples:

```
> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FREE NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   GOAL                  CLEAR-DELAYED-GOAL
```

```
4

> (mp-show-queue t)
Events in the queue:
      0.000   NONE                  CHECK-FOR-ESC-NIL
*     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FREE NIL
*     0.000   PROCEDURAL            CONFLICT-RESOLUTION
      0.000   GOAL                  CLEAR-DELAYED-GOAL
4
```

mp-queue-text

Syntax:

mp-queue-text {*indicate-traced*} -> events-string

Remote command name:

mp-queue-text

Arguments and Values:

indicate-traced ::= a generalized boolean indicating whether to mark events that will occur in the trace
events-string ::= a string containing the printed event details

Description:

Mp-queue-text generates a string containing the printed form of all of the events that are on the event queue in the order that they will be executed. If the indicate-traced value is provided and is non-**nil** then the character "*" will be included before the events which will be displayed in the trace with the current parameter settings for the associated model. That generated string is returned.

Examples:

```
> (mp-queue-text)
"     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FREE NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   GOAL                  CLEAR-DELAYED-GOAL
"

> (mp-queue-text t)
"      0.000   NONE                  CHECK-FOR-ESC-NIL
*     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FREE NIL
*     0.000   PROCEDURAL            CONFLICT-RESOLUTION
      0.000   GOAL                  CLEAR-DELAYED-GOAL
"
```

mp-queue-count

Syntax:

mp-queue-count -> event-count

Remote command name:

mp-queue-count

Arguments and Values:

event-count ::= a number indicating how many items are in the event queue

Description:

Mp-queue-count returns the number of events which are currently in the queue of the meta-process.

Examples:

```
> (mp-queue-count)
4
```

mp-show-waiting

Syntax:

mp-show-waiting -> event-count

Remote command name:

mp-show-waiting

Arguments and Values:

event-count ::= a number indicating how many items are in the waiting queue

Description:

Mp-show-waiting outputs all of the events that are on the waiting queue of the meta-process to the general-trace along with the description of the condition for which it is waiting to occur to be added to the main event queue. The first element in the waiting description indicates whether it is waiting for any event or a particular module. If it is waiting on a module then the second element indicates which module. The last element of the description indicates whether a maintenance event will satisfy the condition. It returns the number of events that are in the waiting queue.

This command can occasionally be useful for debugging, but is generally more important when working on creating modules and experiments.

Examples:

```
> (mp-show-waiting)
Events waiting to be scheduled:
       NIL   PROCEDURAL            CONFLICT-RESOLUTION Waiting for: (ANY NIL)
1
```

mp-modules-events

Syntax:

mp-modules-events *module-name* -> event-list

Arguments and Values:

module-name ::= the name of a module
event-list ::= a list of event numbers for the events scheduled for the named module

Description:

Mp-modules-events returns a list of all of the events from both the regular and waiting queues of the meta-process which have a module specified that matches the module-name provided. The elements of the list are the actual event structures which should only be accessed with the commands described in the event accessors section.

Examples:

```
> (mp-modules-events 'goal)
(4 3)

> (mp-modules-events 'not-a-module)
NIL
```

Component

A component is a software construct used to build the system that implements the ACT-R theory, but which has no basis in the theory. A component is a data structure which is instantiated once in the software and can provide commands which will be called automatically when clear-all, reset, model definition, and model deletion occur. Currently, the interface for creating and working with components is only an internal mechanisms and is not documented for user use.

Module

Module is an overloaded term in ACT-R (as well as outside of ACT-R). Within ACT-R it has different connotations when talking about the software and the theory. At the software level a module is a part of the system which may be instantiated for each model that is defined. It can serve any number of purposes, for instance there is a printing module, a pseudorandom number generator module, as well as a vision module, a declarative memory module and many others. Each module is essentially an independent structure, and it is the modules which provide the functionality for a model. There are basically no restrictions on what a software module can do and adding new modules is the primary way of extending or modifying the overall system.

From the ACT-R theory perspective a module is a reference to some cognitive faculty which can typically be ascribed to a particular region of the brain. Thus, something like the printing module in the software obviously would not be considered a module of the theory. To further complicate the issue, the implementation of the cognitive modules as software modules is not always one-to-one. For example, the vision system of ACT-R, which is implemented in the software as one module, is probably more appropriately considered as two cognitive modules – one for location information and one for object information. In the other direction, the theory's single procedural module is actually implemented as three modules in the software (one that controls production definition and matching, one to handle the utility computations, and one to implement the production compilation mechanism).

Often the context in which one encounters "module" with respect to ACT-R makes it clear what is being discussed (the software or the theory) so it is not always as confusing as it might seem. For clarity, from this point on in the manual, when it says module, the reference will be to the software modules unless explicitly stated otherwise.

Each of the specific modules of the ACT-R software will be described in its own section of this manual. There will also be sections describing the mechanisms which can be used in a module, like buffers and parameters, as well as how to implement a new module. This section will only include the general commands related to modules.

Commands

all-module-names

Syntax:

all-module-names -> (module-name*)

Remote command name:

all-module-names

Arguments and Values:

module-name ::= the name of a module in the system

Description:

All-module-names returns a list of the names of the currently defined modules in the system in alphabetical order.

Examples:

```
> (all-module-names)
(:AUDICON-HISTORY :AUDIO BOLD BUFFER-HISTORY BUFFER-PARAMS BUFFER-TRACE ...)
```

use-modules

Syntax:

use-modules *module-name** -> **nil**
use-modules-fct (*module-name**) -> **nil**

Arguments and Values:

module-name ::= the name of a module in the system

Description:

The use-modules command allows one to restrict the set of modules that are used in models. It can be called when there are no models defined to specify the set of modules that are needed. It takes any number of module names as parameters. Those modules along with any that are required (see the define-module command for details on how a module can be required) will be the only ones instantiated in the models. Most of the support modules (things like printing, random, and naming, as well as helper modules like utility and production-compilation) are required by default or when their corresponding cognitive module is used. Therefore, it will typically only be the cognitive modules which will be necessary to specify: goal, imaginal, declarative, procedural, temporal, :vision, :motor, :speech, and :audio. However, if one is using additional data processing tools like those for BOLD predictions or history recorders then the corresponding modules would also need to be specified as well when using a restricted set of modules.

If use-modules is not used, then all modules will be available just like before, and clear-all will also return the system to using all modules.

This reason one would use this is to speedup the time it takes to reset and run a model. Models that use few modules and get reset frequently will see the biggest improvement, whereas models that use most of the modules or run for a long time between resetting will see little to no improvement from restricting the set of modules.

Examples:

```
> (use-modules goal imaginal :vision :motor procedural declarative)
NIL

> (use-modules-fct (list 'goal 'procedural :audio))
NIL
```

```
E> (use-modules :bad-name)
#|Warning: :BAD-NAME is not a valid module name in call to use-modules |#
NIL

E> (use-modules procedural)
#|Warning: Use-modules can only be used when there are no models defined. |#
NIL
```

Buffers

Buffers in ACT-R are the interfaces between modules. Each buffer is connected to a specific module and has a unique name by which it is referenced e.g. the goal buffer or the retrieval buffer which are associated with the goal and declarative modules respectively. A buffer is used to relay requests for actions to its module, to query its module about the module's state, to hold one chunk which is visible to all other modules, and it will respond directly to queries about the contents of the buffer itself.

A module will respond to a query through its buffer with a generalized-boolean indicating the result. In response to a request, the module will usually generate one or more events to perform some action(s) and may place a chunk into the buffer to indicate the result of that action. Any module may access or modify the chunk in any buffer at any time, but typically a module will only manipulate its own buffer(s).

The buffer itself responds to five queries all specified with the name buffer and the possible values: empty, full, failure, requested, and unrequested. Each query will return **t** if the condition is true and **nil** if it is false. The first three query values, empty, full, and failure, are determined based on whether there is a chunk in the buffer and whether or not the failure flag for the buffer has been set. Only one of those queries will be true at a time. If the buffer contains a chunk then full will be true. If the failure flag has been set then failure will be true (it is not possible to set the failure flag if there is a chunk in the buffer). If neither of those is true then empty will be true. The other two queries indicate whether the chunk which is in the buffer or the failure flag, if it is set, was the result of a request or not. The determination of whether a chunk or failure flag in the buffer was the result of a request is indicated when calling the command that sets that item (see the Using Buffers section for details). If there is no chunk in the buffer and the failure flag is not set then both of those queries will be false.

An important thing to note is that when a chunk is placed into a buffer the buffer makes a copy of that chunk which it then makes available. Any changes made to the chunk in the buffer only affect the copy that it holds – they do not affect the original chunk from which it was copied. Another thing to note about the chunk which is held in a buffer is that it my not always have a new name i.e. copying a chunk into a buffer may result in a chunk in the buffer with the same name as a chunk previously in the buffer. This is done for efficiency reasons, and will not affect the model as long as all the modules which use the buffer do so appropriately (all the provided modules treat the chunks in buffers appropriately). If one needs a buffer's chunk to always have a unique name when a copy is created, then the buffer-requires-copies command can be used to indicate that.

One of the current research areas with ACT-R is in using the buffers to track the activity of their associated modules and then comparing that activity to data from neruoimaging studies (fMRI, MEG, or EEG) to find correlations between regions of the brain and particular buffer/module activity in ACT-R models. Thus providing a mechanism for mapping cognitive modeling work onto actual brain regions and even being able to make predictions about where activation should show up in future neruoimaging research. Details on how that is done can be found in the Module Activity and Brain Predictions section.

The commands described here provide general information about buffers which is most often needed for modeling in ACT-R. The Using Buffers section describes the commands one can use for more low-level interaction with the buffers which would be necessary for creating a new module.

Commands

buffers

Syntax:

buffers {*sorted*} -> (buffer-name*)

Remote command name:

buffers

Arguments and Values:

sorted ::= a generalized boolean indicating whether to sort the list of names
buffer-name ::= the name of a buffer

Description:

The buffers command will return a list with the names of all the currently defined buffers (it does not require a current model). If the sorted parameter is provided with a non-**nil** value then the list will be in alphabetical order otherwise it will be in no particular order.

Examples:

```
> (buffers)
(RETRIEVAL IMAGINAL MANUAL GOAL IMAGINAL-ACTION VOCAL AURAL PRODUCTION VISUAL-LOCATION
AURAL-LOCATION TEMPORAL VISUAL)

> (buffers t)
(AURAL AURAL-LOCATION GOAL IMAGINAL IMAGINAL-ACTION MANUAL PRODUCTION RETRIEVAL TEMPORAL
VISUAL VISUAL-LOCATION VOCAL)
```

model-buffers

Syntax:

model-buffers {*sorted*} -> (buffer-name*)

Remote command name:

model-buffers

Arguments and Values:

sorted ::= a generalized boolean indicating whether to sort the list of names

buffer-name ::= the name of a buffer which exists in the current model

Description:

The model-buffers command will return a list with the names of all the buffers which are available in the current model. If the sorted parameter is provided with a non-**nil** value then the list will be in alphabetical order otherwise it will be in no particular order. This differs from the buffers command because it is possible that a model does not have an instance of every defined buffer because the use-modules command can restrict the set of modules that a model uses.

Examples:

```
> (model-buffers)
(RETRIEVAL IMAGINAL MANUAL GOAL IMAGINAL-ACTION VOCAL PRODUCTION VISUAL-LOCATION VISUAL)

> (model-buffers t)
(GOAL IMAGINAL IMAGINAL-ACTION MANUAL PRODUCTION RETRIEVAL VISUAL VISUAL-LOCATION VOCAL)

E> (model-buffers)
#|Warning: No current model in call to model-buffers. |#
NIL
```

buffer-chunk

Syntax:

buffer-chunk *buffer-name** -> [((buffer-name {chunk-name})*) | ([chunk-name | **:error**]*) | **nil**]
buffer-chunk-fct (*buffer-name**) -> [((buffer-name {chunk-name})*) | ([chunk-name | **:error**]*) | **nil**]

Remote command name:

buffer-chunk

Arguments and Values:

buffer-name ::= the name of a buffer
chunk-name ::= the name of a chunk

Description:

Generally, the buffer-chunk command prints out the names of buffers along with the chunks those buffers hold in the current model using the command-trace.

If no buffer names are specified, then it prints all the buffers and the chunk name of the chunk in that buffer (or **nil** if the buffer is empty) one per line to the command-trace and returns a list of lists where the first element of each sublist is the name of a buffer and if the buffer holds a chunk there will be a second element in the list containing the name of that chunk.

If specific buffers are provided, then for each of those buffers, in the order provided, it prints the buffer name followed by the name of the chunk in that buffer (or **nil** if the buffer is empty) and if there is a chunk in the buffer that chunk is also printed. In this case it returns a list of the names of

the chunks in the buffers provided in the same order as they were specified in the call. If an invalid buffer name is provided the corresponding value in the return list will be the keyword **:error** and nothing will have been printed.

If there is no current model then a warning is printed and **nil** is returned.

The remote version of the command takes parameters in the same way as the macro buffer-chunk – any number of buffer names.

Examples:

These examples (except for the final error example) were generated after running the addition model in unit 1 of the tutorial like this:

```
1> (actr-load "ACT-R:tutorial;unit1;addition.lisp")
T

2> (run 1)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL SECOND-GOAL NIL
...
     0.550   ------                  Stopped because no events left to process
0.55
77
NIL

> (buffer-chunk)
AURAL: NIL
AURAL-LOCATION: NIL
GOAL: NIL
IMAGINAL: NIL
IMAGINAL-ACTION: NIL
MANUAL: NIL
PRODUCTION: NIL
RETRIEVAL: NIL
TEMPORAL: NIL
VISUAL: NIL
VISUAL-LOCATION: NIL
VOCAL: NIL
((AURAL) (AURAL-LOCATION) (GOAL) (IMAGINAL) (IMAGINAL-ACTION) (MANUAL) (PRODUCTION)
(RETRIEVAL) (TEMPORAL) (VISUAL) ...)

> (buffer-chunk-fct '(retrieval goal))
RETRIEVAL: NIL
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   ARG1  FIVE
   ARG2  TWO
   SUM  SEVEN

(NIL GOAL-CHUNK0)

E> (buffer-chunk-fct '(bad-buffer-name))
(:ERROR)

E> (buffer-chunk retrieval bad-name goal)
RETRIEVAL: NIL
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   ARG1  FIVE
   ARG2  TWO
   SUM  SEVEN
```

```
(NIL :ERROR GOAL-CHUNK0)

E> (buffer-chunk)
#|Warning: buffer-chunk called with no current model. |#
NIL
```

printed-buffer-chunk

Syntax:

printed-buffer-chunk *buffer-name** -> [output-string | **nil**]

Remote command name:

printed-buffer-chunk

Arguments and Values:

buffer-name ::= the name of a buffer
output-string ::= a string containing the output of the corresponding buffer-chunk

Description:

The printed-buffer-chunk command works like the buffer-chunk command except that it does not print the information to the command-trace and instead of returning the list of chunks or buffers and chunks it returns a string containing the output that buffer-chunk would have sent to the command-trace.

Examples:

These examples (except for the final error example) were generated after running the addition model in unit 1 of the tutorial like this:

```
1> (actr-load "ACT-R:tutorial;unit1;addition.lisp")
T

2> (run 1)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL SECOND-GOAL NIL
...
     0.550   ------                  Stopped because no events left to process
0.55
77
NIL

> (printed-buffer-chunk)
"RETRIEVAL: NIL
IMAGINAL: NIL
MANUAL: NIL
GOAL: GOAL-CHUNK0
IMAGINAL-ACTION: NIL
VOCAL: NIL
AURAL: NIL
PRODUCTION: NIL
VISUAL-LOCATION: NIL
AURAL-LOCATION: NIL
TEMPORAL: NIL
```

```
VISUAL: NIL
"
> (printed-buffer-chunk 'retrieval 'goal)
"RETRIEVAL: NIL
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   ARG1  FIVE
   ARG2  TWO
   SUM  SEVEN
"

E> (printed-buffer-chunk 'bad-buffer-name)
""

E> (printed-buffer-chunk)
#|Warning: printed-buffer-chunk called with no current model. |#
NIL
```

buffer-status

Syntax:

buffer-status *buffer-name** -> [([buffer-name | **:error**]*) | **nil**]
buffer-status-fct (*buffer-name**) -> [([buffer-name | **:error**]*) | **nil**]

Remote command name:

buffer-status

Arguments and Values:

buffer-name ::= the name of a buffer

Description:

The buffer-status command prints the current values for the possible queries to which the buffers and their modules respond from the current model using the command-trace. For each buffer specified (or all buffers if none are specified) the buffer name is printed followed by the current result of the buffer's queries and the required module queries, one per line, indicating **t** for a true query and **nil** for a false result. That is followed by any module specific status the module prints (the module specific status is not constrained by the system and could be any type of output). It returns a list of the buffer names of the buffers for which the status was printed.

If specific buffers are provided, and an invalid buffer name is specified, the corresponding value in the return list will be the keyword **:error** and nothing will have been printed.

If there is no current model then a warning is printed and **nil** is returned.

The remote version of the command uses the same syntax as the buffer-status macro.

Examples:

```
> (buffer-status)
RETRIEVAL:
```

```
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
  recently-retrieved nil: NIL
  recently-retrieved t  : NIL
IMAGINAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
MANUAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
  preparation free      : T
  preparation busy      : NIL
  processor free        : T
  processor busy        : NIL
  execution free        : T
  execution busy        : NIL
  last-command          : NONE
...

 (RETRIEVAL IMAGINAL MANUAL VISUAL AURAL PRODUCTION VOCAL ...)

> (buffer-status goal)
GOAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
(GOAL)

> (buffer-status-fct '(retrieval))
RETRIEVAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
  recently-retrieved nil: NIL
  recently-retrieved t  : NIL
(RETRIEVAL)

E> (buffer-status goal non-buffer)
GOAL:
```

```
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
 (GOAL :ERROR)

E> (buffer-status)
#|Warning: buffer-status called with no current model. |#
NIL
```

printed-buffer-status

Syntax:

printed-buffer-status *buffer-name** -> [output-string | **nil**]

Remote command name:

printed-buffer-status

Arguments and Values:

buffer-name ::= the name of a buffer
output-string ::= a string containing the output of the corresponding buffer-chunk

Description:

The printed-buffer-status command works like the buffer-status command except that it does not print the information to the command-trace and instead of returning the list of buffers it returns a string containing the output that buffer-status would have sent to the command-trace.

Examples:

```
> (printed-buffer-status)
"RETRIEVAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
  recently-retrieved nil: NIL
  recently-retrieved t  : NIL
IMAGINAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
```

```
MANUAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
  preparation free      : T
  preparation busy      : NIL
  processor free        : T
  processor busy        : NIL
  execution free        : T
  execution busy        : NIL
  last-command          : NONE
...
"

> (printed-buffer-status 'goal)
"GOAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL"


E> (printed-buffer-status)
#|Warning: printed-buffer-status called with no current model. |#
NIL
```

buffer-requires-copies

Syntax:

buffer-requires-copies *buffer-name* -> [**t** | **nil**]

Remote command name:

buffer-requires-copies

Arguments and Values:

buffer-name ::= the name of a buffer

Description:

The buffer-requires-copies command can be called to ensure that the specified buffer creates a chunk with a new unique name every time it creates a copy of a chunk. This should be called at reset time by a module which requires its buffer to always have unique chunks or in the model definition before productions are defined. If the buffer-name provided is valid then that buffer will generate uniquely named copies and **t** will be returned. Otherwise a warning will be printed and **nil** will be returned.

Note that this would only be necessary for a model if there is additional code with the model that is reading the name of the chunk in a buffer and recording it for use at a later time.

Examples:

```
> (buffer-requires-copies 'goal)
T

> (buffer-requires-copies 'not-a-buffer)
#|Warning: buffer-requires-copies called with an invalid buffer name NOT-A-BUFFER |#
NIL
```

reusable-buffer-p

Syntax:

reusable-buffer-p *buffer-name* -> [**t** | **nil**]

Remote command name:

reusable-buffer-p

Arguments and Values:

buffer-name ::= the name of a buffer

Description:

The reusable-buffer-p command can be called to check whether the specified buffer is creating a chunk with a new unique name every time it creates a copy of a chunk or if it is reusing a chunk with a fixed name for the copies. If the buffer-name provided is valid then it will return **t** if that buffer is reusing a single chunk for copies and **nil** if it generates uniquely named copies. Otherwise a warning will be printed and **nil** will be returned.

Examples:

```
1> (reusable-buffer-p 'goal)
T

2> (buffer-requires-copies 'goal)
T

3> (reusable-buffer-p 'goal)
NIL

> (reusable-buffer-p 'not-a-buffer)
#|Warning: reusable-buffer-p called with an invalid buffer name NOT-A-BUFFER |#
NIL
```

Models

An ACT-R model is one simulated cognitive agent. Theoretically the software can have any number of models defined simultaneously (practically there is of course a limit that will depend on the hardware and Lisp software). All of the defined models will be run at the same time by the meta-process. However, the most common usage of ACT-R is to work with only one model at a time. Most of this manual assumes that one is working with only one model at a time. Information about dealing with more than one model simultaneously is covered in the multiple models section.

A model is referenced by the name specified when it is defined, and that name must be unique among the currently defined models. A model consists of the code specified in its definition, an instance of each module in the system (which is independent of any other model's copy of that module unless a specific module indicates otherwise), and its set of chunks (which are always independent of the chunks of any other model).

A model is created using the define-model command which specifies the model's name and its initial conditions and results in the creation of a new instance of each module for that model to use.

Specifically, when a model is created the following sequence of actions occur:

- A new instance of each module is created for that model
- The default chunk-types and chunks are created
- All of the buffers for that model are set to empty
- The model's modules have their primary reset commands called (in no specific order)
- The parameters of all the model's modules are set to their default values (in no specific order)
- The model's modules have their secondary reset commands called (in no specific order)
- The model's definition code is evaluated in the order given (left to right)
- The model's modules have their tertiary reset commands called (in no specific order)

When a model is reset a similar sequence of actions occurs. The difference is that new module instances are not created and instead any chunks and chunk-types in the model are deleted first.

Regardless of how many models are defined, only one is accessible at any given time. This is referred to as the current model. Only the current model may be manipulated or inspected by ACT-R commands. If there is only one model defined, then it will be the current model. If there is more than one model defined, then it is up to the modeler to specify which is current before executing any commands (see the multiple models section for more details).

Commands

define-model

Syntax:

define-model *model-name {model-code*}* -> [model-name | **nil**]
define-model-fct *model-name* (*{model-code*}*) -> [model-name | **nil**]

Arguments and Values:

model-name ::= a symbol that will be the name of the model
model-code ::= a Lisp expression that will be evaluated when the model is created and when it is reset

Description:

The define-model command creates a new model with the given model-name. Its initial conditions are specified by the model-code provided.

If there is not already a model by that name and there are no errors in evaluation of the model-code forms then the new model is created and model-name is returned.

If the model-name is already the name of a defined model or an error occurs during the evaluation of the model-code then a warning is printed and **nil** is returned.

Examples:

Only basic usage of define-model is shown here – see the tutorial for the definitions of actual cognitive models that perform meaningful tasks.

```
> (define-model-fct 'model-10 (list '(chunk-type start slot)))
MODEL-10

1> (define-model model-1 (chunk-type goal state))
MODEL-1

2E> (define-model-fct 'model-1 nil)
#|Warning: MODEL-1 is already the name of a model in the current meta-process.  Cannot be
redefined. |#
NIL


E> (define-model model-3 (pprint "start") (pprnt "end"))

"start"
#|Warning: Error encountered in model form:
(PPRNT "end")
Invoking the debugger. |#
#|Warning: You must exit the error state to continue. |#
Debug: attempt to call `PPRNT' which is an undefined function.
[condition type: UNDEFINED-FUNCTION]
#|Warning: Model MODEL-3 not defined. |#
NIL
```

delete-model

Syntax:

delete-model *{model-name}* -> [**t** | **nil**]
delete-model-fct *model-name* -> [**t** | **nil**]

Arguments and Values:

model-name ::= the name of a model

Description:

The delete-model command removes the model with the specified model-name. If model-name is not provided the current model is deleted. Deleting a model removes all events generated by that model from the event queues, deletes each of the model's instances of the modules, and removes the model from the set of models currently defined. If a model is successfully deleted then **t** is returned.

If model-name is not the name of a currently defined model or no model-name is given and there is no current model, then a warning is printed and **nil** is returned.

The delete-model command is typically only useful when working with multiple models.

Examples:

```
> (delete-model)
T

> (delete-model-fct 'model)
T

E> (delete-model)
#|Warning: No current model to delete. |#
NIL

E> (delete-model-fct 'model)
#|Warning: No model named MODEL in current meta-process. |#
NIL
```

Chunks & Chunk-types

Chunks are the elements of declarative knowledge in the ACT-R theory and are used to communicate information among modules through the buffers. A chunk consists of a set of named slots each holding a single value. A chunk also has a name which is used to reference it, however, the name is not considered to be a part of the chunk itself from a theoretical standpoint. Previous versions of ACT-R also required each chunk to have a specific chunk-type associated with it that defined the set of slots which it had. As of ACT-R 6.1 chunks are no longer cast into specific types. A chunk may have any combination of slots desired without having to first specify an appropriate type, and a chunk may also now have slots removed as well as added. Chunk-types still exist as a potentially useful tool for modelers, but they are no longer a required component of chunks.

In the ACT-R software, chunks exist at the "model level" and may be created and used by any module or additional code – they do not have to be associated with a model's declarative memory module unlike older versions of ACT-R (those prior to 6.0). In addition to the slots and values of a chunk, in the software each chunk also maintains a set of parameters which contain additional information needed by the modules or the modeler. A modeler may add chunk parameters for recording additional information as needed. See the section on extending chunks for more information on adding and manipulating chunk parameters. Along with the parameters, there are two additional features associated with a chunk in the software. The first indicates whether the slots and values of the chunk can be modified or not. When a chunk is created it is initially able to have its content modified, but the modeler (or a module) may mark a chunk as "immutable" at any point after it has been created. Once a chunk is marked as immutable it cannot be changed back to modifiable. The other feature is whether the chunk has a unique name and is safe to store for later use, or should be copied before storing. This relates to the buffers possibly reusing chunk names for efficiency. If a chunk is marked as not storable then one should create a copy it the contents may be needed later or set the buffer from which it came to always require creating new copies. The final thing to note about chunks is that they should always be referenced by their name and only manipulated through the provided mechanisms – the underlying representation of a chunk in the code is not considered to be part of the ACT-R software's API.

Chunk-types in ACT-R are used as a pre-processing mechanism in the definition of a model. A chunk-type associates a name with a set of slots and optional default values for those slots. That chunk-type name may then be used when creating chunks and specifying productions to indicate the slots which are intended and to include the default slot values from that chunk-type for any slots not specified in the chunk or production. The chunk-type name itself does not get recorded in the model with the chunk or production it is used in – it only serves as a declaration which will be used to provide warnings if the chunk or production does not conform to the chunk-type indicated and to fill in any default slot values from that chunk-type. If a chunk-type does not include default values for its slots then whether it is specified or not in the creation of a chunk or production will not affect the resulting item – it will be the same with or without the chunk-type specification.

When creating chunk-types they may be organized into a hierarchy, with new chunk-types inheriting slots from one or more parent chunk-types. If a chunk-type is created with one or more parent chunk-types then that new type will include all the slots and default values from all of the parent chunk-types along with those specified in the new chunk-type. A default value specified for a slot directly in a chunk-type overrides any default value which would be inherited from a parent type. If multiple parent chunk-types specify a default value for the same slot then unless those default values are all

the same such a chunk-type cannot be created. When specifying a chunk-type in creating a chunk or production a parent type may be specified and use any of the slots specified for the children of that chunk-type, but only the default values for the specific chunk-type named will be applied.

Note on slot contents

The software allows any Lisp data to be specified as the value of a slot. However, not all Lisp data types may be transmitted through the remote interface. Thus, only names, numbers, and strings are recommended for use as the values in slots if one wants to access that content remotely.

Default Chunk-types

There are a few chunk-types created with every model automatically. Those are, chunk, constant-chunks, query-slots, and clear. These are used to create some of the default chunks for the model and may be used freely in creating additional chunks or productions. Many of the provided modules also specify new chunk-types which may be used and those will be indicated with a module's description.

chunk

The chunk-type named chunk has no slots specified for it. Its purpose is to serve as the root of the chunk-type hierarchy i.e. all chunk-types which are created implicitly inherit from the chunk-type named chunk.

constant-chunks

The constant-chunks chunk-type specifies one slot named name.

query-slots

The query-slots chunk-type specifies three slots named state, buffer, and error. Those are the names of the queries which all buffers will respond to and by creating a chunk-type with those slot names one can create chunk-specs which use those slots to perform queries from code.

clear

The clear chunk-type has one slot named clear which has a default value of t. It is provided as a convenient and consistent mechanism for use when creating a module which needs to provide a request which performs some sort of "clearing" of the module.

Default Chunks

There are several chunks created for each model automatically which may be used as needed. All of these default chunks are marked as immutable. There will also be many chunks created by the provided modules and the details of those can be found in the specific module sections.

Chunks named free, busy, error, empty, full, failure, requested, and unrequested are created each with a slot named name that is set to the chunk's name i.e. the chunk named free has one slot called name with the value free.

A chunk named clear is created having one slot named clear with a value of t.

Commands

The commands described here are general chunk and chunk-type actions which can be used for any chunk. Some modules provide additional commands for manipulating or inspecting the chunks that are being used by that module and the details of those commands can be found in the specific module sections.

Chunk-type Commands

chunk-type

Syntax:

chunk-type { *[new-name* | **(***new-name* **(:include** *parent-name***)**$^{+}$**)**] {*doc-string*} [*slot-name* |
(*slot-name default-value*)]*} -> [type-name | (type-name*) | **nil**]

chunk-type-fct [**nil** | ([*new-name* | **(***new-name* **(:include** *parent-name***)**$^{+}$**)**] {*doc-string*} [*slot-name* |
(*slot-name default-value*)]*)] -> [type-name | (type-name*) | **nil**]

Remote command name:

chunk-type [**nil** | ([*new-name* | **(***new-name* **(:include** *parent-name***)**$^{+}$**)**] {'*doc-string*'} [*slot-name* |
(*slot-name 'default-value*')]*)] -> [type-name | (type-name*) | **nil**]

Arguments and Values:

new-name ::= the name of the new chunk-type
type-name ::= the name of a chunk-type
parent-name ::= the name of a chunk-type to be a parent type of this new chunk-type
doc-string ::= a string that is used as documentation for this chunk-type
slot-name ::= the name of a slot which will be part of this chunk-type
default-value ::= any value which specifies the value that will be used as the default value for the corresponding slot-name

Description:

The chunk-type command creates a new chunk-type for the current model or displays all of the currently defined chunk-types for the current model.

If no parameters are passed to the chunk-type command (or **nil** to the function) then all of the existing chunk-types in the current model are printed to the command-trace as described by pprint-chunk-type and a list of their names is returned (in no particular order).

If a valid chunk-type specification is provided then a new chunk-type is created for the current model and the name of that chunk-type is returned. If the chunk-type provides the same specification as an existing chunk-type in the model then a warning will be displayed.

If there is no current model, the given new-name already names an existing chunk-type in the current model, or there is an error in the specification of the chunk-type then a warning is printed and **nil** is returned.

Examples:

```
> (chunk-type)

SOUND
   KIND
   CONTENT
   EVENT


AUDIO-COMMAND

MOVE-CURSOR <- MOTOR-COMMAND
   OBJECT
   LOC
   DEVICE

...

(SOUND AUDIO-COMMAND MOVE-CURSOR ...)

1> (chunk-type goal slot1 state)
GOAL

2> (chunk-type-fct '(other-type slot1 slot2))
OTHER-TYPE

3> (chunk-type (subgoal1 (:include goal)) new-slot)
SUBGOAL1

4> (chunk-type-fct '((subgoal2 (:include goal) (:include other-type))))
SUBGOAL2

5> (chunk-type new-type (slot default-value) (other-slot 4))
NEW-TYPE

6> (chunk-type detailed-type "The chunk-type detailed-type" slot)
DETAILED-TYPE


7> (chunk-type-fct nil)
...

GOAL
   SLOT1
   STATE


OTHER-TYPE
   SLOT1
   SLOT2


SUBGOAL1 <- GOAL
```

```
   NEW-SLOT
   SLOT1
   STATE


SUBGOAL2 <- GOAL, OTHER-TYPE
   SLOT2
   SLOT1
   STATE


NEW-TYPE
   SLOT (DEFAULT-VALUE)
   OTHER-SLOT (4)


DETAILED-TYPE "The chunk-type detailed-type"
   SLOT


(CHUNK CONSTANT-CHUNKS CLEAR AUDIO-EVENT SET-AUDLOC-DEFAULT SOUND GENERIC-ACTION ...)

8E> (chunk-type repeat slot1 state)
#|Warning: Chunk-type REPEAT has the same specification as the chunk-type GOAL. |#
REPEAT

E> (chunk-type (new-type (:include bad-type)))
#|Warning: Non-existent chunk-type BAD-TYPE specified as an :include in NEW-TYPE chunk-
type definition. |#
NIL

E> (chunk-type (bad :include goal))
#|Warning: Invalid modifier list specified with the chunk-type name: (:INCLUDE GOAL) |#
NIL

E> (chunk-type no-model)
#|Warning: chunk-type called with no current model. |#
NIL
```

pprint-chunk-type

Syntax:

pprint-chunk-type *type-name* -> [type-name | **nil**]

pprint-chunk-type-fct *type-name* -> [type-name | **nil**]

Remote command name:

pprint-chunk-type

Arguments and Values:

type-name ::= the name of a chunk-type

Description:

The pprint-chunk-type command is used to print a description of a chunk-type. The output is sent to the command-trace.

If the parameter provided is the name of a chunk-type in the current model then that chunk-type is printed like this: the chunk-type name is printed and if the chunk-type has any parent types specified then the name is followed by "<-" and the names of the parent chunk-types are printed separated by commas, the documentation string for the chunk-type, if it has one, is printed, and then the slot names of the chunk-type are printed one per line with the slot's default value in parentheses after the slot name if one was provided.

If there is no current model or the given type-name does not name an existing chunk-type in the current model then a warning is printed and **nil** is returned.

Examples:

```
1> (chunk-type test slot1 (slot2 2))
TEST

2> (chunk-type (subtest (:include test)) "a subtype of test" slot3)
SUBTEST

3> (pprint-chunk-type test)
TEST
   SLOT1
   SLOT2 (2)


TEST

4> (pprint-chunk-type-fct 'subtest)
SUBTEST <- TEST "a subtype of test"
   SLOT1
   SLOT2 (2)
   SLOT3


SUBTEST

E> (pprint-chunk-type not-a-chunk-type)
#|Warning: NOT-A-CHUNK-TYPE does not name a chunk-type in the current model. |#
NIL

E> (pprint-chunk-type chunk)
#|Warning: pprint-chunk-type called with no current model. |#
NIL
```

chunk-type-p

Syntax:

chunk-type-p *chunk-type-name?* -> [**t** | **nil**]
chunk-type-p-fct *chunk-type-name?* -> [**t** | **nil**]

Remote command name:

chunk-type-p

Arguments and Values:

chunk-type-name? ::= a symbol to be tested to determine if it names a chunk-type

Description:

The chunk-type-p command returns **t** if chunk-type-name? is a symbol that names a chunk-type in the current model and returns **nil** if it does not. If there is no current model then a warning is printed and **nil** is returned.

Examples:

```
> (chunk-type-p clear)
T

> (chunk-type-p-fct 'chunk)
T

> (chunk-type-p bad-name)
NIL

> (chunk-type-p-fct 'non-chunk-type)
NIL

E> (chunk-type-p chunk)
#|Warning: get-chunk-type called with no current model. |#
NIL
```

all-chunk-type-names

Syntax:

all-chunk-type-names -> (type-name*)

Remote command name:

all-chunk-type-names

Arguments and Values:

type-name ::= the name of a chunk-type

Description:

All-chunk-type-names takes no parameters and returns a list of all the chunk-type names in the current model. The type names are ordered based on the order in which they were defined (first name in the list is the first one defined).

If there is no current model a warning is printed and **nil** will be returned.

Examples:

```
> (all-chunk-type-names)
(CHUNK CONSTANT-CHUNKS CLEAR QUERY-SLOTS AUDIO-EVENT SET-AUDLOC-DEFAULT SOUND ...)

E> (all-chunk-type-names)
#|Warning: all-chunk-type-names called with no current model. |#
NIL
```

chunk-type-possible-slot-names-fct

Syntax:

chunk-type-possible-slot-names-fct *chunk-type-name* -> [(slot-name*) | **nil**]

Remote command name:

chunk-type-possible-slot-names-fct

Arguments and Values:

chunk-type-name ::= the name of a chunk-type
slot-name ::= the name of a slot usable in the specified chunk-type

Description:

Chunk-type-possible-slot-names-fct takes one parameter which should be the name of a chunk-type. It returns a list of all the names of slots which are valid for use with that chunk-type in the current model along with all of the request parameters which have been defined for the buffers. A slot is valid for the chunk-type if it is specified in that chunk-type's definition, is specified in a chunk-type which has the specified chunk-type as a parent, or is a slot which has been added to chunks through extension with extend-possible-slots.

If there is no current model or the specified name does not name a chunk-type in the current model then a warning is printed and **nil** is returned.

Examples:

```
> (chunk-type-possible-slot-names-fct 'clear)
(CLEAR :MP-VALUE :RECENTLY-RETRIEVED :CENTER :NEAREST :FINISHED :ATTENDED)

> (chunk-type-possible-slot-names-fct 'chunk)
(SCALE RIGHT LEFT TYPE SET-VISLOC-DEFAULT SIZE DISTANCE SCREEN-Y SCREEN-X COLORS ...)

E> (chunk-type-possible-slot-names-fct 'bad-name)
#|Warning: Invalid chunk-type name BAD-NAME passed to chunk-type-possible-slot-names-fct.
|#
NIL

E> (chunk-type-possible-slot-names-fct 'chunk)
#|Warning: get-chunk-type called with no current model. |#
#|Warning: Invalid chunk-type name CHUNK passed to chunk-type-possible-slot-names-fct. |#
NIL
```

Chunk Commands

define-chunks

Syntax:

define-chunks [chunk-description* | chunk-name*] -> (chunk*)
define-chunks-fct (chunk-description* | chunk-name*) -> (chunk*)

Remote command name:

define-chunks ['chunk-description '* | chunk-name*]

Arguments and Values:

chunk-description ::= ({*chunk-name*}{[*doc-string* **isa** *chunk-type* | **isa** *chunk-type*]} {*slot value*}*)
chunk-name ::= the name of the chunk to create
doc-string ::= a string that will be the documentation for the chunk
chunk-type ::= a name of a chunk-type in the model
slot ::= the name of a slot for the chunk
value ::= any value which will be the contents of the correspondingly named slot for this chunk
chunk ::= the name of a chunk that was created

Description:

The define-chunks command creates a new chunk in the current model for each valid chunk description list provided or all the chunk names provided and then returns a list of the names of the chunks that were created.

Within a chunk description list the chunk name is optional. If a chunk-name is provided, it must not name an existing chunk in the current model and must be a non-keyword, non-nil symbol that begins with an alphanumeric character. If a chunk-name is not provided, a new name will be generated for the chunk, and that name is guaranteed to be unique.

The name may be followed by an optional chunk-type specification and if it does it may also include a documentation string for the chunk. If a chunk-type is specified it must name a valid chunk-type in the current model.

That may then be followed by any number of slot and value pairs for the chunk. If a given slot is named more than once in the definition then the last value it is given (rightmost) will be the one set for the chunk. If the value for a slot is non-nil then that slot is added to the chunk being created with the value specified.

If a chunk-type is specified then each of the slots specified will be tested to see if it is a valid slot for the type indicated. If it is not then a warning will be printed, but the chunk will still be created. If it is not a valid slot for any chunk-type then it will automatically extend the valid slots for chunks with that slot name.

If a chunk-type is specified and there are slots with default values in that chunk-type's definition which are not included in the chunk definition the chunk will get all of those unspecified slots with their corresponding default values.

If a value for a slot is a non-nil symbol other than the Lisp true symbol t then it is assumed to be the name of a chunk. If there is not already a chunk by that name, then one is created automatically which has no slots and a warning is printed to indicate that.

However, within a call to define-chunks one can use the names of the chunks that are being defined in the other chunks without having them created as default chunks. Here is an example to clarify that:

```
(define-chunks (a slot b)
               (b slot a)
               (c slot d))
```

Because both a and b are being defined in the same call to define-chunks neither will need to be created automatically. However, unless d already names a chunk in the model a chunk with that name will be created automatically in the process of creating chunk c.

If the syntax is incorrect or any of the components are invalid in a description list then a warning is displayed and no chunk is created for that chunk description, but any other valid chunks defined will still be created.

If there is no current model no chunks are created and **nil** is returned.

Examples:

```
1> (chunk-type test1 slot1)
TEST1

2> (chunk-type test2 slot1 (slot2 2))
TEST2

3> (define-chunks (a isa test1) (b isa test2))
(A B)

4> (define-chunks-fct '((c slot1 a) (d slot2 c)))
(C D)

5> (define-chunks ("this is chunk e" isa test1 slot1 100))
(TEST10)

6E> (define-chunks-fct '((isa test1 slot2 "value")))
#|Warning: Invalid slot SLOT2 specified when creating chunk with type TEST1, but creating
chunk TEST11 anyway. |#
(TEST11)

7> (define-chunks ())
(CHUNK0)

8> (define-chunks c1 c2 c3)
(C1 C2 C3)

9E> (define-chunks (slot1 new-name))
#|Warning: Creating chunk NEW-NAME with no slots |#
(CHUNK1)
```

```
10E> (define-chunks ("not allowed" slot2 t))
#|Warning: Invalid chunk definition: ("not allowed" SLOT2 T) chunk name is not a valid
symbol. |#
NIL

11E> (define-chunks (slot1 t new-slot 10))
#|Warning: Extending chunks with slot named NEW-SLOT because of chunk definition (SLOT1 T
NEW-SLOT 10) |#
(CHUNK2)

E> (define-chunks (z isa chunk))
#|Warning: define-chunks called with no current model. |#
NIL
```

pprint-chunks & pprint-chunks-plus

Syntax:

pprint-chunks *chunk-name** -> [chunk-name-list | **nil**]
pprint-chunks-fct (*chunk-name**) -> [chunk-name-list | **nil**]
pprint-chunks-plus *chunk-name** -> [chunk-name-list | **nil**]
pprint-chunks-plus-fct (*chunk-name**) -> [chunk-name-list | **nil**]

Remote command name:

pprint-chunks
pprint-chunks-plus

Arguments and Values:

chunk-name ::= the name of a chunk
chunk-name-list ::= ([chunk-name | :error]*)

Description:

The pprint-chunks family of commands are used to print a description of each of the chunks specified, or all of the chunks in the model if no names are provided. The output is sent to the command-trace.

For each chunk specified, on one line it will print the chunk's name followed by its "true name" in parentheses if the chunk's true name differs from the chunk's current name (see merge-chunks and true-chunk-name below for more details on a chunk's true name). If a documentation string was provided for the chunk that is printed on the next line. Then one per line, each of the chunk's slots is printed followed by that slot's value.

The pprint-chunks-plus command prints all of the chunk's parameters after the description of the chunk is printed. The parameters are printed one per line with the name of the parameter and its current value. Note, that these chunk parameters are the ones that have been added to the chunks (typically by a module as described in the extending chunks section) and may not have any direct significance to the model or modeler. For example, the declarative memory parameters of chunks used by the declarative module to compute and record the activation of chunks should be viewed using the declarative module's sdp command because the values shown with pprint-chunks-plus are

values used internally by the declarative module and may not adequately reflect the current value of activations as would be shown by calling the module's command for inspecting the declarative memory chunk's parameters (sdp).

These commands return a list with the names of all the chunks that were printed in the same order as they were specified. If an invalid chunk-name is given nothing is printed for that item and the value **:error** is returned in its place in the list.

If there is no current model then a warning is printed and **nil** is returned.

Examples:

These examples assume that the chunks created in the examples for define-chunks exist.

```
> (pprint-chunks)
TEST10
"this is chunk e"
   SLOT1  100

BUSY
   NAME  BUSY

SPEAK
   NAME  SPEAK

CURRENT
   NAME  CURRENT

SUBVOCALIZE
   NAME  SUBVOCALIZE

AUDIO-EVENT
   NAME  AUDIO-EVENT

D
   SLOT2  C

CHUNK0

...

(TEST10 BUSY SPEAK CURRENT SUBVOCALIZE AUDIO-EVENT D CHUNK0 B MAGENTA ...)

> (pprint-chunks a b test10)
A

B
   SLOT2  2

TEST10
"this is chunk e"
   SLOT1  100

(A B TEST10)

> (pprint-chunks-fct '(c d))
C
   SLOT1  A

D
   SLOT2  C
```

```
(C D)

> (pprint-chunks-plus chunk0)
CHUNK0

  --chunk parameters--
   VISUAL-APPROACH-WIDTH-FN  NIL
   REAL-VISUAL-VALUE  NIL
   SPECIAL-VISUAL-OBJECT  NIL
   VISUAL-OBJECT  NIL
   VISUAL-TSTAMP  NIL
   VISUAL-FEATURE-NAME  NIL
   VISICON-ENTRY  NIL
   VISUAL-NEW-P  NIL
   SYNTH-FEAT  NIL
   FAST-MERGE-KEY  NIL
   RETRIEVAL-TIME  NIL
   RETRIEVAL-ACTIVATION  NIL
   SJIS  NIL
   PERMANENT-NOISE  0.0
   SIMILARITIES  NIL
   REFERENCE-COUNT  0
   REFERENCE-LIST  NIL
   SOURCE-SPREAD  0
   LAST-BASE-LEVEL  0
   BASE-LEVEL  NIL
   CREATION-TIME  0
   FAN-IN  NIL
   C-FAN-OUT  0
   FAN-OUT  0
   IN-DM  NIL
   ACTIVATION  0
   BUFFER-SET-INVALID  NIL


(CHUNK0)

E> (pprint-chunks a bad-name b)
A

B
   SLOT2  2

(A :ERROR B)

E> (pprint-chunks)
#|Warning: pprint-chunks called with no current model. |#
NIL
```

chunk-p

Syntax:

chunk-p *chunk-name?* -> [**t** | **nil**]
chunk-p-fct *chunk-name?* -> [**t** | **nil**]

Remote command name:

chunk-p

Arguments and Values:

chunk-name? ::= a value to be tested to determine if it names a chunk

Description:

The chunk-p command returns **t** if chunk-name? is the name of a chunk in the current model and returns **nil** if it does not. If there is no current model then a warning is printed and **nil** is returned.

Examples:

These examples assume that chunks named a and b have been created.

```
> (chunk-p a)
T

> (chunk-p not-chunk)
NIL

> (chunk-p-fct 'b)
T

E> (chunk-p-fct 'a)
#|Warning: get-chunk called with no current model. |#
NIL
```

chunk-documentation

Syntax:

chunk-documentation *chunk-name* -> [doc-string | **nil**]
chunk-documentation-fct *chunk-name* -> [doc-string | **nil**]

Remote command name:

chunk-documentation

Arguments and Values:

chunk-name ::= the name of a chunk
doc-string ::= a string of the documentation provided when chunk-name was created

Description:

Chunk-documentation returns the documentation string of the chunk chunk-name from the current model if it names a valid chunk and has a documentation string. If it does not have a documentation string it returns **nil**. If chunk-name is not the name of a chunk in the current model or there is no current model then a warning is printed and **nil** is returned.

Examples:

These examples assume that the chunks created in the examples for define-chunks exist.

```
> (chunk-documentation test10)
"this is chunk e"

> (chunk-documentation a)
NIL

> (chunk-documentation-fct 'test10)
"this is chunk e"

E> (chunk-documentation-fct 'not-a-chunk)
#|Warning: NOT-A-CHUNK does not name a chunk in the current model. |#
NIL

E> (chunk-documentation c)
#|Warning: get-chunk called with no current model. |#
NIL
```

chunk-slot-value

Syntax:

chunk-slot-value *chunk-name slot-name* -> [slot-value | **nil**]
chunk-slot-value-fct *chunk-name slot-name* -> [slot-value | **nil**]

Remote command name:

chunk-slot-value *chunk-name slot-name* -> ['slot-value' | **nil**]

Arguments and Values:

chunk-name ::= the name of a chunk
slot-name ::= the name of a slot in the chunk chunk-name
slot-value ::= the value from slot-name in chunk chunk-name

Description:

Chunk-slot-value is used to get the value of a slot in a chunk. If chunk-name is the name of a chunk in the current model and slot-name is the name of a slot in chunk-name then the value in the slot-name slot of the chunk chunk-name is returned. If chunk-name is the name of a chunk but it does not have a slot named slot-name then **nil** will be returned.

If chunk-name does not name a chunk in the model or there is no current model then a warning is printed and **nil** is returned.

Examples:

These examples assume that the chunks created in the examples for define-chunks exist.

```
> (chunk-slot-value c slot1)
A
```

```
> (chunk-slot-value c slot2)
NIL

>(chunk-slot-value-fct 'd 'slot2)
C

> (chunk-slot-value a other-slot)
NIL

E> (chunk-slot-value bad-chunk-name slot1)
#|Warning: BAD-CHUNK-NAME does not name a chunk in the current model. |#
NIL

E> (chunk-slot-value c slot1)
#|Warning: get-chunk called with no current model. |#
NIL
```

set-chunk-slot-value

Syntax:

set-chunk-slot-value *chunk-name slot-name slot-value* -> [slot-value | **nil**]
set-chunk-slot-value-fct *chunk-name slot-name slot-value* -> [slot-value | **nil**]

Remote command name:

set-chunk-slot-value *chunk-name slot-name* '*slot-value*' -> ['slot-value' | **nil**]

Arguments and Values:

chunk-name ::= the name of a chunk
slot-name ::= the name of a slot
slot-value ::= a value for slot-name in chunk chunk-name

Description:

Set-chunk-slot-value is used to set the value of the slot slot-name in the chunk chunk-name in the current model to the value slot-value. If successful, slot-value is returned.

If slot-value is a name and that name is not the name of a chunk in the current model then it is created as a new chunk with no slots and a warning is displayed.

If a slot-value of **nil** is specified for a slot that will remove that slot from the chunk.

If the chunk chunk-name has been marked as immutable then a warning is printed, no changes are made to the chunk and **nil** is returned.

If either chunk-name or slot-name is invalid or there is no current model then a warning is printed and **nil** is returned.

Examples:

These examples assume that the chunks created in the examples for define-chunks exist.

```
> (set-chunk-slot-value a slot1 10)
10

> (set-chunk-slot-value-fct 'b 'slot2 "value")
"value"

> (set-chunk-slot-value a slot2 new-chunk)
#|Warning: Creating chunk NEW-CHUNK with no slots |#
NEW-CHUNK

1> (make-chunk-immutable 'b)
T

2E> (set-chunk-slot-value b slot1 10)
#|Warning: Cannot change contents of chunk B. |#
NIL

E> (set-chunk-slot-value-fct 'not-a-chunk 'slot1 t)
#|Warning: NOT-A-CHUNK does not name a chunk in the current model. |#
NIL

E> (set-chunk-slot-value c not-a-slot b)
#|Warning: NOT-A-SLOT is not a valid slot name.  You can use extend-possible-slots to add
it first if needed. |#
NIL

E> (set-chunk-slot-value a slot1 b)
#|Warning: get-chunk called with no current model. |#
NIL
```

mod-chunk

Syntax:

mod-chunk *chunk-name* {*slot-name slot-value*}* -> [chunk-name | **nil**]
mod-chunk-fct *chunk-name* ({*slot-name slot-value*}*) -> [chunk-name | **nil**]

Remote command name:

mod-chunk *chunk-name* '{*slot-name slot-value*}'*

Arguments and Values:

chunk-name ::= the name of a chunk
slot-name ::= the name of a slot in the chunk chunk-name
slot-value ::= a value for the corresponding slot-name in chunk chunk-name

Description:

Mod-chunk is used to set the value of multiple slots in the chunk named chunk-name in the current model. It is essentially a short hand for multiple calls to set-chunk-slot-value.

If chunk-name is the name of a chunk in the current model and there are an even number of items specified thereafter, then those items are considered pair-wise to be the name of a slot and a value for

that slot in that chunk. All of those slots in the chunk are set to the values specified and chunk-name is returned.

If any slot-value is a name and not the name of a chunk in the current model then it is created as a new chunk with no slots and a warning is displayed.

A slot name may only be specified once in the set of slot-names. If a slot name is specified more than once a warning is printed, no changes are made to the chunk, and **nil** is returned.

If any slot name provided is not a valid slot for chunks no changes are made to the chunk, and **nil** is returned.

If the chunk chunk-name has been marked as immutable then a warning is printed, no changes are made to the chunk and **nil** is returned.

If chunk-name does not name a chunk in the current model or there are an odd number of items provided after the chunk-name then a warning is displayed, no changes are made, and **nil** is returned.

Examples:

These examples assume that the chunks created in the examples for define-chunks exist.

```
> (mod-chunk a slot1 b slot2 c)
A

> (mod-chunk-fct 'b '(slot1 10 new-slot t))
B

> (mod-chunk a slot1 new-chunk-name)
#|Warning: Creating chunk NEW-CHUNK-NAME with no slots |#
A

1> (make-chunk-immutable 'b)
T

2E> (mod-chunk b slot1 10)
#|Warning: Cannot modify chunk B because it is immutable. |#
NIL

E> (mod-chunk a slot1 1 slot1 2)
#|Warning: Slot name used more than once in modifications list. |#
NIL

E> (mod-chunk-fct 'a '(slot1 b slot2))
#|Warning: Odd length modifications list in call to mod-chunk. |#
NIL

E> (mod-chunk a slot1 b)
#|Warning: get-chunk called with no current model. |#
NIL
```

copy-chunk

Syntax:

copy-chunk *chunk-name* -> [new-name | **nil**]

copy-chunk-fct *chunk-name* -> [new-name | **nil**]

Remote command name:

copy-chunk

Arguments and Values:

chunk-name ::= the name of a chunk
new-name ::= a unique name for a new chunk

Description:

Copy-chunk creates a copy of the chunk chunk-name in the current model and returns the name of the newly created chunk. The newly created copy has the same slots and values as the chunk chunk-name. The values of the parameters defined for the new chunk will have the default value unless the parameter was specified with a copy-function, in which case, the value will be the one returned by that function.

If chunk-name does not name a chunk in the current model or there is no current model then a warning is displayed and **nil** is returned.

Examples:

These examples assume that there are chunks named a and b in the current model.

```
> (copy-chunk a)
A-0

> (copy-chunk-fct 'b)
B-0

E> (copy-chunk not-a-chunk)
#|Warning: NOT-A-CHUNK does not name a chunk in the current model. |#
NIL

E> (copy-chunk a)
#|Warning: get-chunk called with no current model. |#
NIL
```

chunk-copied-from

Syntax:

chunk-copied-from *chunk-name* -> [original-name | **nil**] {other}
chunk-copied-from-fct *chunk-name* -> [original-name | **nil**] {other}

Remote command name:

chunk-copied-from

Arguments and Values:

chunk-name ::= the name of a chunk
original-name ::= the name of a chunk
other ::= a generalized boolean indicating whether this chunk was a copy and is still unmodified

Description:

The chunk-copied-from command returns one or two values. If chunk-name is the name of a chunk in the current model then two values will be returned. If chunk-name was created with copy-chunk, it has not been modified since its creation, and the original chunk has not been modified such that it now differs from the copy (the original could have been modified but if it is still a match using equal-chunks it is still considered the same) then the name of the chunk from which chunk-name was copied is returned as both the first and second value. If it was not created using copy-chunk, it has since been modified, or the original chunk has been modified in such a way that the two now differ (including being deleted) then **nil** is returned for the first value. If the chunk was created using copy-chunk and has not been modified then the second value will be the name of the chunk from which it was copied (which may no longer be an interned symbol in Lisp if that chunk was purged) otherwise the second value will be **nil**.

If chunk-name does not name a chunk in the current model or there is no current model then a warning is displayed and a single value of **nil** is returned.

This command is rarely used by modelers because needing to copy chunks and keep track of how they came about are not typical actions. However, it can be important to those creating new modules where it can be used to determine if a chunk passed in as part of a request is a copy of a chunk which the module had placed into a buffer i.e. the request is using a copy of a chunk for which the module has created the original.

Examples:

```
1> (chunk-type test slot1 slot2)
TEST

2> (define-chunks (a slot1 10 slot2 "answer") (b slot1 a))
(A B)

3> (copy-chunk a)
A-0

4> (copy-chunk b)
B-0

5> (chunk-copied-from a-0)
A
A

6> (chunk-copied-from a)
NIL
NIL

7> (mod-chunk a slot1 5)
A

8> (chunk-copied-from-fct 'a-0)
NIL
A
```

```
9> (chunk-copied-from-fct 'b-0)
B
B

10> (mod-chunk b-0 slot2 10)
B-0

11> (chunk-copied-from b-0)
NIL
NIL

E> (chunk-copied-from-fct 'not-a-chunk)
#|Warning: NOT-A-CHUNK does not name a chunk in the current model. |#
NIL

E> (chunk-copied-from b-0)
#|Warning: get-chunk called with no current model. |#
NIL
```

chunks

Syntax:

chunks -> [(chunk-name*) | **nil**]

Remote command name:

chunks

Arguments and Values:

chunk-name ::= the name of a chunk in the current model

Description:

The chunks command returns a list of the names of all the chunks defined in the current model in no particular order.

If there is no current model then a warning is printed and **nil** is returned.

Examples:

```
> (chunks)
(GREEN CYAN SPEECH C DARK-CYAN RED-COLOR B-0 OVAL ...)

E> (chunks)
#|Warning: chunks called with no current model. |#
NIL
```

chunk-slot-equal

chunk-slot-equal *val-1 val-2* -> equal-result

Remote command name:

chunk-slot-equal ‘*val-1* ‘ ‘*val-2* ‘

Arguments and Values:

val-1 ::= any value
val-2 ::= any value
equal-result ::= a generalized boolean indicating whether the values are equal slot contents

Description:

The chunk-slot-equal function is used to determine if two values are considered equivalent for the contents of slots in chunks. It relies upon three Lisp equality functions, and the values will be equivalent if one of the following is true:

- the values are eq (the same Lisp object)
- both values are names of chunks in the current model and eq-chunks for the names is true
- both values are strings and those strings return true from string-equal (case insensitive match)
- if the values are not both chunk names and not both strings and they return true from equalp (a general equivalency test in Lisp)

If the two values are equivalent, then a true value is returned. Otherwise, **nil** will be returned.

Examples:

```
> (chunk-slot-equal 1 1)
T

> (chunk-slot-equal 1 1.5)
NIL

> (chunk-slot-equal "String1" "strING1")
T

> (chunk-slot-equal 'not-a-chunk 'not-a-chunk)
T

> (chunk-slot-equal 'not-a-chunk :not-a-chunk)
NIL

1> (define-chunks (c1)(c2))
(C1 C2)

2> (chunk-slot-equal 'c1 'c2)
NIL

3> (merge-chunks c1 c2)
C1

4> (chunk-slot-equal 'c1 'c2)
T
```

equal-chunks

equal-chunks *chunk-name-1 chunk-name-2* -> equal-result
equal-chunks-fct *chunk-name-1 chunk-name-2* -> equal-result

Remote command name:

equal-chunks

Arguments and Values:

chunk-name-1 ::= the name of a chunk
chunk-name-2 ::= the name of a chunk
equal-result ::= a generalized boolean indicating whether the chunks are equal

Description:

The equal-chunks command can be used to determine if the chunks named by chunk-name-1 and chunk-name-2 in the current model are equivalent chunks. They will be equivalent if they are eq-chunks or if they have the same set of slots and for each slot the values of those slots in the two chunks are the same as determined by the chunk-slot-equal test. If the two chunks are equivalent, then a true value is returned. Otherwise, **nil** will be returned.

If either name does not name a chunk or there is no current model, then a warning is printed and **nil** is returned.

Examples:

```
1> (chunk-type test1 slot1 slot2)
TEST1

2> (chunk-type test2 slot2 slot3)
TEST2

3> (define-chunks (c1 isa test1)
                  (c2 isa test2)
                  (c3 isa test1 slot1 10 slot2 "value")
                  (c4 isa test1 slot1 10 slot2 "VALUE")
                  (c5 isa test1 slot2 10)
                  (c6 isa test2 slot2 10))
(C1 C2 C3 C4 C5 C6)

4> (equal-chunks c1 c2)
T

5> (equal-chunks-fct 'c1 'c3)
NIL

6> (equal-chunks-fct 'c3 'c4)
T

7> (equal-chunks c5 c6)
T

8> (mod-chunk c5 slot3 t)
C5
```

```
9> (equal-chunks c5 c6)
NIL

E> (equal-chunks not-a-chunk free)
#|Warning: NOT-A-CHUNK does not name a chunk in the current model. |#
NIL

E> (equal-chunks c1 c2)
#|Warning: get-chunk called with no current model. |#
#|Warning: get-chunk called with no current model. |#
NIL
```

eq-chunks

Syntax:

eq-chunks *chunk-name-1 chunk-name-2* -> equal-result
eq-chunks-fct *chunk-name-1 chunk-name-2* -> equal-result

Remote command name:

eq-chunks

Arguments and Values:

chunk-name-1 ::= the name of a chunk
chunk-name-2 ::= the name of a chunk
equal-result ::= a generalized boolean indicating whether the chunks are the same

Description:

Eq-chunks is used to determine if the chunks named by chunk-name-1 and chunk-name-2 are the exact same chunk in the current model. They will be the same chunk if chunk-name-1 and chunk-name-2 are the same name or if the two named chunks have been merged. If they are the same chunk, then a true value is returned. Otherwise **nil** will be returned.

If either name does not name a chunk or there is no current model, then a warning is printed and **nil** is returned.

Examples:

```
1> (chunk-type test1 slot1 slot2)
TEST1

2> (chunk-type test2 slot2 slot3)
TEST2

3> (define-chunks (c1) (c2)
                  (c3 isa test1 slot2 10)
                  (c4 isa test2 slot2 10))
(C1 C2 C3 C4)

4> (eq-chunks c1 c1)
T
```

```
5> (eq-chunks-fct 'c1 'c2)
NIL

6> (merge-chunks c1 c2)
C1

7> (eq-chunks c1 c2)
T

8> (eq-chunks c3 c4)
NIL

E> (eq-chunks c1 not-a-chunk)
#|Warning: NOT-A-CHUNK does not name a chunk in the current model. |#
NIL

E> (eq-chunks c1 c2)
#|Warning: get-chunk called with no current model. |#
#|Warning: get-chunk called with no current model. |#
NIL
```

delete-chunk

Syntax:

delete-chunk *chunk-name* -> [chunk-name | **nil**]
delete-chunk-fct *chunk-name* -> [chunk-name | **nil**]

Remote command name:

delete-chunk

Arguments and Values:

chunk-name ::= the name of a chunk

Description:

Delete-chunk removes the chunk named chunk-name from the set of chunks in the current model. If chunk-name is the name of a chunk in the current model then after that chunk is deleted chunk-name is returned.

If chunk-name has been marked as immutable then it cannot be deleted, a warning will be printed and **nil** will be returned.

If chunk-name does not name a chunk in the current model or there is no current model then a warning is printed and **nil** is returned.

Note: there is no additional clean-up done in conjunction with deleting the chunk. Thus, if it is used as a slot value in other chunks or currently residing in a buffer the consequences of deleting it are undefined and warnings or errors could result from later actions involving such chunks or buffers. Delete-chunk should be used rarely and only when it is certain that the chunk being deleted is not referenced elsewhere.

Examples:

These examples assume that chunks named a, b, and c exist.

```
> (delete-chunk a)
A

1> (delete-chunk-fct 'b)
B

2E> (delete-chunk b)
#|Warning: B does not name a chunk in the current model. |#
NIL

1> (make-chunk-immutable 'c)
T

2E> (delete-chunk c)
#|Warning: Cannot delete chunk C because it is marked as immutable. |#
NIL

E> (delete-chunk c)
#|Warning: get-chunk called with no current model. |#
NIL
```

purge-chunk

Syntax:

purge-chunk *chunk-name* -> [**t** | **nil**]
purge-chunk-fct *chunk-name* -> [**t** | **nil**]

Remote command name:

purge-chunk

Arguments and Values:

chunk-name ::= the name of a chunk

Description:

Purge-chunk removes the chunk named chunk-name from the set of chunks in the current model using delete-chunk and releases the name of that chunk using the release-name command as described under the naming module. If chunk-name is the name of a chunk in the current model and its name was released then **t** is returned.

If chunk-name does not name a chunk in the current model or there is no current model then a warning is printed and **nil** is returned.

If the chunk is deleted, but the name is not released **nil** is returned without a warning being printed.

As with delete-chunk, there is no additional clean-up done in conjunction with purging the chunk. Thus, if it is used as a slot value in another chunk or currently residing in a buffer undefined consequences could arise.

Because purge-chunk also attempts to unintern the name of the chunk it should only be used for chunks for which the name was automatically generated by ACT-R or explicitly generated with the new-name command. This is not going to be a command used by most modelers. However, in situations where (computer) memory usage is important in long running models or models which generate a lot of temporary chunks, explicitly freeing some of that space may be necessary.

Examples:

These examples assume that there are chunks named a and b.

```
1> (copy-chunk b)
B-0

2> (purge-chunk-fct 'b-0)
T

3E> (purge-chunk b-0)
#|Warning: B-0 does not name a chunk in the current model. |#
NIL

> (purge-chunk a)
NIL

E> (purge-chunk a)
#|Warning: get-chunk called with no current model. |#
NIL
```

merge-chunks

Syntax:

merge-chunks *chunk-name-1 chunk-name-2* -> [chunk-name-1 | **nil**]
merge-chunks-fct *chunk-name-1 chunk-name-2* -> [chunk-name-1 | **nil**]

Remote command name:

merge-chunks

Arguments and Values:

chunk-name-1 ::= the name of a chunk
chunk-name-2 ::= the name of a chunk

Description:

If the chunks named by chunk-name-1 and chunk-name-2 are equivalent chunks as determined by equal-chunks then both chunks are replaced by a single chunk. Effectively, the two chunks are merged into one chunk. The “true name” of the merged chunk will be chunk-name-1, but references which use either name will still be valid and now refer to the single chunk resulting from the merge.

If the chunks are merged, then any additional chunk parameters that have been added to the chunks will remain those that existed for chunk-name-1 unless there is a merge-function defined for the parameter.

If either chunk is later deleted, both of the chunks will become unavailable i.e. deleting any one of a set of merged chunks deletes all of those merged chunks since there is only one underlying chunk.

If the chunks are equivalent as tested by eq-chunks then no actions are taken and chunk-name-1 is returned.

If the chunks are successfully merged, then chunk-name-1 is returned.

If the chunks are not equal-chunks **nil** is returned.

If either name does not name a chunk in the current model or there is no current model then a warning is displayed and **nil** is returned.

The merge-chunks command is primarily for use by the declarative memory module, and it is not expected to be used elsewhere but is available if one finds a need. As with delete-chunk, it should be used carefully to avoid circumstances were chunks to which other modules already have references are merged which could result in unexpected consequences.

It is safe to merge a chunk which is not storable with another existing chunk when the storable chunk is the second chunk provided. In that case only the parameters of the existing chunk will be updated – the name of the non-storable chunk will not be associated with the existing chunk. However, using a non-storable chunk as the first chunk in a merging pair may not always perform as desired (given how merging as the second chunk is handled) and should typically be avoided.

Examples:

```
1> (chunk-type test slot1 slot2)
TEST

2> (define-chunks (a slot1 10)
                  (b slot1 10)
                  (c slot1 10 slot2 t))
(A B C)

3> (merge-chunks a a)
A

4> (eq-chunks a b)
NIL

5> (merge-chunks-fct 'a 'b)
A

6> (eq-chunks a b)
T

7> (merge-chunks a c)
NIL

E> (merge-chunks a not-a-chunk)
#|Warning: NOT-A-CHUNK does not name a chunk in the current model. |#
NIL
```

```
E> (merge-chunks a b)
#|Warning: get-chunk called with no current model. |#
#|Warning: get-chunk called with no current model. |#
NIL
```

create-chunk-alias

Syntax:

create-chunk-alias *chunk-name alias* -> [alias | **nil**]
create-chunk-alias-fct *chunk-name alias* -> [alias | **nil**]

Remote command name:

create-chunk-alias

Arguments and Values:

chunk-name ::= the name of a chunk
alias ::= a name that is not the name of a chunk

Description:

If the chunk specified by chunk-name exists in the current model and the name provided as an alias is not the name of a chunk in the current model then alias will be added as a reference to the chunk chunk-name. This works essentially the same as if a chunk named alias had been merged with the chunk named chunk-name.

If the alias is successfully created, then alias is returned.

If chunk-name does not name a chunk in the current model, alias is not a valid name, alias is already the name of a chunk in the model, or there is no current model then a warning is displayed and **nil** is returned.

This command is not likely to be used often, but it may be helpful if a chunk which has a long name is generated automatically by the model and one needs to perform lots of actions or tests using that chunk.

Examples:

```
1> (define-chunks (a) (b))
(A B)

2> (chunk-p alias)
NIL

3> (create-chunk-alias a alias)
ALIAS

4> (eq-chunks a alias)
T
```

```
5E> (create-chunk-alias-fct 'a 'b)
#|Warning: B is already the name of a chunk in the current model and cannot be used as an
alias. |#
NIL

E> (create-chunk-alias c new-chunk-name)
#|Warning: C is not the name of a chunk in the current model. |#
NIL

E> (create-chunk-alias a alias)
#|Warning: create-chunk-alias called with no current model. |#
NIL
```

make-chunk-immutable

Syntax:

make-chunk-immutable *chunk-name* -> [**t** | **nil**]

Remote command name:

make-chunk-immutable

Arguments and Values:

chunk-name ::= the name of a chunk

Description:

The make-chunk-immutable command (which is a Lisp function despite the lack of a –fct) can be used to prevent a chunk's contents from being modified. The parameters of that chunk may still be modified, but the slot contents will remain fixed in the model – the immutability is not reversible. This is not a command which will likely ever be needed when creating a model, but it can be important for the implementation of a module. The declarative memory model relies on this to prevent changes from occurring to the stored chunks.

If chunk-name names a chunk in the current model then it is marked as immutable and **t** is returned. If chunk-name does not name a chunk in the current model or there is no current model then **nil** is returned, and a warning will be printed in the case of no current model.

Examples:

```
1> (define-chunks (a value 1))
(A)

2> (chunk-slot-value a value)
1

3> (mod-chunk a value 2)
A

4> (chunk-slot-value a value)
2
```

```
5> (make-chunk-immutable 'a)
T

6E> (mod-chunk a value 3)
#|Warning: Cannot modify chunk A because it is immutable. |#
NIL

7> (chunk-slot-value a value)
2

E> (make-chunk-immutable 'not-a-chunk)
NIL

E> (make-chunk-immutable 'a)
#|Warning: get-chunk called with no current model. |#
NIL
```

true-chunk-name

Syntax:

true-chunk-name *chunk-name* -> [true-name | chunk-name]
true-chunk-name-fct *chunk-name* -> [true-name | chunk-name]

Remote command name:

true-chunk-name

Arguments and Values:

chunk-name ::= any value
true-name ::= the name of a chunk in the current model

Description:

True-chunk-name is used to find the “true name” of a chunk in the current model. The true name of a chunk which has not been merged with another chunk is its own name. The true name of a chunk that has been merged with another chunk is the true name of the chunk that was returned from a merging of that chunk with another. The true name of a chunk alias is the true name of the chunk to which it was aliased.

If chunk-name is the name of a chunk in the current model then its true name is returned. If chunk-name is any other value, then chunk-name is returned.

If there is no current model then a warning is printed and chunk-name is returned.

Examples:

```
1> (define-chunks (a) (b) (c))
(A B C)

2> (merge-chunks a b)
```

```
A

3> (create-chunk-alias b alias)
ALIAS

4> (true-chunk-name a)
A

5> (true-chunk-name-fct 'c)
C

6> (true-chunk-name b)
A

7> (true-chunk-name alias)
A

8> (true-chunk-name d)
D

> (true-chunk-name 100)
100

E> (true-chunk-name t)
#|Warning: get-chunk called with no current model. |#
T
```

normalize-chunk-names

normalize-chunk-names { *unintern* } -> **nil**

Remote command name:

normalize-chunk-names

Arguments and Values:

unintern ::= a generalized boolean indicating whether to delete the merged chunks and release the names

Description:

The normalize-chunk-names command will iterate through all chunks in the current model and replace all chunk references in slots with the true name of that chunk. That may be useful for debugging purposes and the naming module has a parameter (:ncnar) which can trigger this call automatically.

In addition, if the unintern parameter is true then all chunks which have been merged with other chunks (those for which their name is not the chunk's true name) will be deleted from the model and the chunk name will be released using release-name.

The command will always return **nil**. If there is no current model then a warning will be printed indicating that.

Notes: This command may take a long time to run if the model has a large number of chunks. Also, the unintern option is generally not recommended because it may cause problems for modules which have stored internal references to those temporary names. However, in some extreme circumstances (a very long continuous run or a model which does a lot of buffer manipulations over a long run) a model can generate so many chunk name symbols than it can become unable to continue running (the Lisp heap or the physical memory of the machine is exhausted) thus calling normalize-chunk-names periodically with the unintern option would be necessary to continue running. If you are encountering such situations, please let me know about it because there may be other options or changes that could be made.

Examples:

To show the command in use, there must be a chunk which has been merged with another and also used in a slot value.

```
1> (chunk-type test slot1 slot2)
TEST

2> (define-chunks (c1 slot1 10 slot2 t)
                  (c2 slot1 1 slot2 t)
                  (c3 slot1 c2))
(C1 C2 C3)

3> (pprint-chunks c3)
C3
   SLOT1  C2

(C3)

4> (merge-chunks c1 c2)
C1

5> (normalize-chunk-names)
NIL

6> (pprint-chunks c3)
C3
   SLOT1  C1

(C3)

7> (pprint-chunks c2)
C2 (C1)
   SLOT1  1
   SLOT2  T

(C2)
8> (normalize-chunk-names t)
NIL

9> (pprint-chunks c2)
(:ERROR)

E> (normalize-chunk-names)
#|Warning: No current model in which to normalize chunk names. |#
NIL
```

chunk-filled-slots-list

Syntax:

chunk-filled-slots-list *chunk-name* {*sorted*} -> [(slot-name*) | **nil**]
chunk-filled-slots-list-fct *chunk-name* {*sorted*} -> [(slot-name*) | **nil**]

Remote command name:

chunk-filled-slots-list

Arguments and Values:

chunk-name ::= the name of a chunk
slot-name ::= the name of a slot
sorted ::= a generalized boolean indicating whether the returned list should be in a canonical order

Description:

Chunk-filled-slots-list is used to get a list of the slots which contain values in the chunk specified by chunk-name in the current model. If the optional sorted parameter is provided with a non-nil value then the list returned will be sorted so that if two chunks have the same set of slots with values then this command will return the same list for both. If the sorted parameter is not provided or specified as **nil** then there is no guarantee on the ordering of the list returned – two calls with the same chunk may return lists in different orders and different chunks with the same set of slots may return lists in different orders.

If chunk-name is invalid or there is no current model then a warning is printed and **nil** is returned.

Examples:

```
1> (define-chunks
     (a color blue value "a")
     (b value "b" color green)
     (c)
     (d size 100))
(A B C D)

2> (chunk-filled-slots-list a)
(COLOR VALUE)

3> (chunk-filled-slots-list-fct 'b)
(VALUE COLOR)

4> (chunk-filled-slots-list c)
NIL

5> (chunk-filled-slots-list-fct 'd)
(SIZE)

6> (chunk-filled-slots-list a t)
(VALUE COLOR)

7> (chunk-filled-slots-list b t)
(VALUE COLOR)
```

```
E> (chunk-filled-slots-list "not-a-chunk")
#|Warning: "not-a-chunk" does not name a chunk in the current model. |#
NIL

E> (chunk-filled-slots-list a)
#|Warning: get-chunk called with no current model. |#
NIL
```

chunk-not-storable

Syntax:

chunk-not-storable *chunk-name* -> [**t** | **nil**]

Remote command name:

chunk-not-storable

Arguments and Values:

chunk-name ::= the name of a chunk

Description:

Chunk-not-storable is used to check whether the chunk specified by chunk-name in the current model is safe to store for later use or should be copied before being stored for later use. The chunks which are not storable are chunks which are reused by buffers. If the chunk is not storable then this command will return **t**. Otherwise it will return **nil**, and it will print a warning if there is no current model.

This is not something that is likely to be used by a modeler, but those creating new modules, particularly something that functions like declarative memory, may require checking chunks with this command.

Examples:

```
1> (load-act-r-model "ACT-R:tutorial;unit1;addition.lisp")

2> (run 1)
…

3> (chunk-not-storable 'seven)
NIL

4> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   ARG1  FIVE
   ARG2  TWO
   SUM  SEVEN

(GOAL-CHUNK0)

5> (chunk-not-storable 'goal-chunk0)
T
```

```
6> (chunk-not-storable :not-a-chunk)
NIL

E> (chunk-not-storable 'a)
#|Warning: get-chunk called with no current model. |#
NIL
```

General Parameters

General parameters are the primary means of configuring the operation of ACT-R both from a usability standpoint and at the level of controlling the performance of a model. They can be used to control how much output is shown when a model runs or to adjust how long it takes a model to retrieve a chunk from its declarative memory as well as many other things. Each module in the system can make available any number of general parameters that are relevant to its operation. The specific parameters of each module will be described in that module's section. In this section, the common aspects of those parameters will be described along with the commands that can be used to set, get, and show them.

The general parameters are each referenced by a name which is a Lisp keyword (a symbol that starts with a colon character) e.g. :v or :trace-detail, and can be set to some value which is meaningful to the module that owns the parameter. Each one has a default value specified by the owning module and often there are limits as to what values can be given to a particular parameter. Attempting to set an invalid value will result in a warning and no change in the parameter. In most cases the parameter values are specific to the model in which it is set i.e. two concurrent models could have different values for the same general parameter. However, there can be exceptions to that. For example, a module created to provide models with an interface to an external simulation might provide parameters to specify the details for connecting to that simulation, and all models which use that module will be using the same parameter values, regardless of which model set them, to connect to the same simulation. None of the provided modules operate that way, but it is worth noting that modules could be added which have parameters that are linked between models.

One final thing to note about general parameters is that it is possible for modules other than the parameter's owning module to monitor the parameter setting and possibly modify the parameter. The details of doing that are covered in the module creation section. Because of that, one should be aware that it is possible for parameters to start with values other than their specified default after a model is reset or to be set to a value different than one the user requests if a monitoring module changes it. An example of the first situation (a starting value other than the default) exists in the main ACT-R system with the :do-not-harvest parameter. The procedural module owns that parameter and specifies a default value of **nil**, but the goal module will change that parameter at reset time to include the goal buffer. Also, if one is using the ACT-R Environment many of the tools it makes available will set parameters to get the information so that they can get the desired information. There are no modules in the provided set which modify the values a user specifies, but an example where such a situation could be used might be a module which provides support for modeling alertness or sleepiness. It could automatically adjust the parameters that a user specifies for controlling other modules to take into account the current alertness setting. Of course it would not have to work that way, but it is a possibility.

Commands

sgp

Syntax:

sgp {[*param-name*| *param-value-pair**]} -> [**nil** | ([param-value | **:bad-parameter-name** | **:invalid-value**]*)]

sgp-fct ({[*param-name*| *param-value-pair**]}) -> [**nil** | ([param-value | **:bad-parameter-name** | **:invalid-value**]*)]

Arguments and Values:

param-name ::= the name of a parameter
param-value-pair ::= *param-name new-param-value*
new-param-value ::= a value to which the preceding param-name is to be set
param-value ::= the current value of a param-name

Description:

Sgp is used to set or get the value of the parameters from the modules of the current model.

If no parameters are provided, all of the current model's parameters are printed to the command-trace. They are organized alphabetically by module name and then by parameter name within a module, and **nil** is returned. For each parameter, its name and current value is printed followed by the default value and any documentation provided by the module that owns the parameter.

If all of the parameters passed to sgp are keywords, then it is a request for the current values of those general parameters' values in the current model. Those parameters are printed and a list of their values in the order requested is returned. If any of the names are not of valid parameters then a warning is displayed and the keyword :bad-parameter-name is returned for that position in the list. Note: because the test to determine that a call to sgp is a request for parameter values is that all the values passed to sgp are keywords, a module should never have a parameter accept a keyword as a possible value because it will not be possible to set such a parameter value on its own.

If there are any non-keyword parameters in the call to sgp and the total number of elements is even, then they are assumed to be pairs of a parameter name and a parameter value. Each of those parameter values will be passed to the corresponding parameter's owning module and all monitoring modules. The return value will be the current settings of those parameters in the order given (the values may or may not be the same as the values passed in to set them depending on the module) unless a parameter value was not of the appropriate type as required by the module. In that case, a warning is printed and the value returned in that position will be the keyword :invalid-value.

If there are non-keywords passed to sgp and the number of items is odd or if there is no current model at the time of the call, then a warning is displayed and **nil** is returned.

Examples:

```
> (sgp)
--------------------------------
:AUDIO module
--------------------------------
:DIGIT-DETECT-DELAY 0.3   default: 0.3   : Lag between onset and detectability for digits
:DIGIT-DURATION     0.6   default: 0.6   : Default duration for digit sounds.
:DIGIT-RECODE-DELAY 0.5   default: 0.5   : Recoding delay for digit sound content.
:HEAR-NEWEST-ONLY   NIL   default: NIL   : Whether to stuff only the newest unattended ...
:SOUND-DECAY-TIME   3.0   default: 3.0   : The amount of time after a sound has ...
:TONE-DETECT-DELAY  0.05  default: 0.05  : Lag between sound onset and detectability ...
:TONE-RECODE-DELAY  0.285 default: 0.285 : Recoding delay for tone sound content.
--------------------------------
```

```
BOLD module
--------------------------------
...


> (sgp :v :lf)
:V T (default T) : Verbose controls model output
:LF 1.0 (default 1.0) : Latency Factor
(T 1.0)

> (sgp-fct '(:v nil :lf 4.5))
(NIL 4.5)

E> (sgp-fct '(:v t :lf nil))
#|Warning: Parameter :LF cannot take value NIL because it must be a positive number. |#
(T :INVALID-VALUE)

E> (sgp :not-a-parameter 10)
#|Warning: Parameter :NOT-A-PARAMETER is not the name of an available parameter |#
(:BAD-PARAMETER-NAME)

E> (sgp :esc t :v)
#|Warning: Odd number of parameters and values passed to sgp. |#
NIL

E> (sgp)
#|Warning: sgp called with no current model. |#
NIL
```

get-parameter-default-value

Syntax:

get-parameter-default-value *param-name* -> [param-default | **:bad-parameter-name**]

Arguments and Values:

param-name ::= the name of a parameter
param-default ::= the default value specified for param-name when it was defined

Description:

The get-parameter-default-value command is used to get the default value that a parameter was given when it was defined. If param-name is the name of a general parameter then the default value specified for that parameter is returned. If param-name does not name a general parameter then a warning is printed and **:bad-parameter-name** is returned.

Examples:

```
> (get-parameter-default-value :v)
T

E> (get-parameter-default-value :not-a-param)
#|Warning: Invalid parameter name :NOT-A-PARAM in call to get-parameter-default-value. |#
:BAD-PARAMETER-NAME
```

with-parameters

Syntax:

with-parameters *parameter-list form** -> [result | **nil**]
with-parameters-fct *parameter-list form** -> [result | **nil**]

Arguments and Values:

parameter-list ::= ({*param-name value*}*)
param-name ::= the name of a parameter
value ::= a value to which the preceding parameter should temporarily be set
form ::= a valid Lisp expression to evaluate
result ::= the value returned from the last form evaluated

Description:

The with-parameters command is used to temporarily set some parameters in the current model and then execute some commands. If all of the param-name values provided name valid parameters then each will be set to the corresponding value given before evaluating the forms. After those forms have been evaluated each of those parameters will be set back to the value it had previously and the result of the last form evaluated will be returned. The forms are evaluated in an unwind-protect so that the restoring of the parameters occurs even if the forms result in an error.

If any of the param-name values do not name a valid parameter or there is no current model then a warning will be printed, the forms will not be evaluated, and **nil** is returned.

The difference between with-parameters and with-parameters-fct is not quite the same as it is for other commands. In this case both are macros, but with-parameters-fct evaluates the items on the parameter-list and with-parameters does not. Thus the parameter-list for with-parameters will look similar to what one would provide to sgp whereas the parameter-list for with-parameters-fct may contain expressions and variables which need to be evaluated.

Examples:

This example sequence assumes that the count model from unit 1 of the tutorial is loaded.

```
1> (reset)
T

CG-USER(42): (run .05)
     0.000   GOAL                 SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL           CONFLICT-RESOLUTION
     0.000   PROCEDURAL           PRODUCTION-SELECTED START
     0.000   PROCEDURAL           BUFFER-READ-ACTION GOAL
     0.050   PROCEDURAL           PRODUCTION-FIRED START
     0.050   PROCEDURAL           MOD-BUFFER-CHUNK GOAL
     0.050   PROCEDURAL           MODULE-REQUEST RETRIEVAL
     0.050   PROCEDURAL           CLEAR-BUFFER RETRIEVAL
     0.050   DECLARATIVE          start-retrieval
     0.050   PROCEDURAL           CONFLICT-RESOLUTION
     0.050   ------               Stopped because time limit reached
0.05
```

```
13
NIL

2> (with-parameters (:v nil)
              (run .05))
0.05
6
NIL

3> (with-parameters-fct (:trace-detail 'low)
              (run .05))
     0.150   PROCEDURAL            PRODUCTION-FIRED INCREMENT
TWO
     0.150   ------                Stopped because time limit reached
0.05
7
NIL

4> (run .05)
     0.200   DECLARATIVE           RETRIEVED-CHUNK THREE
     0.200   DECLARATIVE           SET-BUFFER-CHUNK RETRIEVAL THREE
     0.200   PROCEDURAL            CONFLICT-RESOLUTION
     0.200   PROCEDURAL            PRODUCTION-SELECTED INCREMENT
     0.200   PROCEDURAL            BUFFER-READ-ACTION GOAL
     0.200   PROCEDURAL            BUFFER-READ-ACTION RETRIEVAL
     0.200   ------                Stopped because time limit reached
0.05
7
NIL

E> (with-parameters (:not-valid 10)
     (run .05))
#|Warning: :NOT-VALID is not the name of a parameter. with-parameters body ignored. |#
NIL

E> (with-parameters-fct (:v)
     (run .05))
#|Warning: Odd length parameters list in call to with-parameters. The body is ignored. |#
NIL

E> (with-parameters (:v t)
     (run 1))
#|Warning: with-parameters called with no current model. |#
NIL
```

get-parameter-value

Syntax:

get-parameter-value *param-name* -> [param-value | **:bad-parameter-name** | **:no-model**]

Remote command name:

get-parameter-value *param-name* -> ['param-value' | **:bad-parameter-name** | **:no-model**]

Arguments and Values:

param-name ::= the name of a parameter
param-value ::= the current value for the parameter param-name

Description:

The get-parameter-value command is used to get the current value that a parameter has in the current model. If param-name is the name of a parameter then the current value for that parameter is returned. If param-name does not name a general parameter then a warning is printed and **:bad-parameter-name** is returned. If there is no current model then a warning is printed and **:no-model** is returned.

Examples:

```
> (get-parameter-value :lf)
0.05

E> (get-parameter-value 'bad)
#|Warning: Invalid parameter name BAD in call to get-parameter-value. |#
:BAD-PARAMETER-NAME

E> (get-parameter-value :v)
#|Warning: get-parameter-value called with no current model. |#
:NO-MODEL
```

set-parameter-value

Syntax:

set-parameter-value *param-name new-value* -> [param-value | **:bad-parameter-name** | **:invalid-value** | **:no-model**]

Remote command name:

set-parameter-value *param-name* '*new-value*' -> ['param-value' | **:bad-parameter-name** | **:invalid-value** | **:no-model**]

Arguments and Values:

param-name ::= the name of a parameter
new-value ::= a value which will be set as the new value for param-name
param-value ::= the current value for the parameter param-name

Description:

The set-parameter-value command is used to set the current value for a parameter in the current model. If param-name is the name of a parameter and param-value is a valid value for that parameter then the current value for that parameter is set to the new-value provided and the current value reported by the module is returned (that might not be the same as new-value depending on the module). If param-name does not name a general parameter then a warning is printed and **:bad-parameter-name** is returned. If param-value is not a valid value for param-name then a warning is printed and **:invalid-value** is returned. If there is no current model then a warning is printed and **:no-model** is returned.

Examples:

```
> (set-parameter-value :v t)
T

> (set-parameter-value :do-not-harvest 'visual)
(VISUAL TEMPORAL GOAL)

E> (set-parameter-value :bad-name t)
#|Warning: Parameter :BAD-NAME is not the name of an available parameter |#
:BAD-PARAMETER-NAME

E> (set-parameter-value :lf t)
#|Warning: Parameter :LF cannot take value T because it must be a non-negative number. |#
:INVALID-VALUE

E> (set-parameter-value :v t)
#|Warning: set-parameter-value called with no current model. |#
:NO-MODEL
```

System Parameters

System parameters are similar to general parameters, but they are only used for configuring the operation of the ACT-R software itself. They do not have to be connected to any particular module or model and changing one will affect all models. They also retain their settings across a reset or clear-all therefore they will generally only need to be set once if one needs to use them and probably will not be included in a model definition.

Commands

ssp

Syntax:

ssp {[*param-name** | *param-value-pair**]} -> [**nil** | ([param-value | **:bad-parameter-name** | **:invalid-value**]*)]
ssp-fct ({[*param-name** | *param-value-pair**]}) -> [**nil** | ([param-value | **:bad-parameter-name** | **:invalid-value**]*)]

Arguments and Values:

param-name ::= the name of a system parameter
param-value-pair ::= *param-name new-param-value*
new-param-value ::= a value to which the preceding param-name is to be set
param-value ::= the current value of a param-name

Description:

The ssp command is used to set or get the value of the system parameters.

If no parameters are provided, all of the current system parameters are printed to the general-trace and **nil** is returned. For each parameter, its name and current value is printed followed by the default value and any documentation it has.

If all of the parameters passed to ssp are keywords, then it is a request for the current values of those parameters. Those parameters are printed and a list of their values in the order requested is returned. If any of the names are not of valid parameters then a warning is displayed and the keyword :bad-parameter-name is returned for that position in the list.

If there are any non-keyword parameters in the call to ssp and the total number of elements is even, then they are assumed to be pairs of a parameter name and a parameter value. Each of those parameters will be set to the provided value. The return value will be the current settings of those parameters in the order given unless a parameter value was not an appropriate value. In that case, a warning is printed and the value returned in that position will be the keyword :invalid-value.

If there are non-keywords passed to ssp and the number of items is odd then a warning is displayed and **nil** is returned.

Examples:

```
> (ssp)
:ACT-R-VERSION              "7.26-<internal>"                          default: ...
:ACT-R-MAJOR-VERSION        26                                         default: ...
:STARTING-PARAMETERS        NIL                                        default: ...
:ACT-R-MINOR-VERSION        0                                          default: ...
:MCTRT                      NIL                                        default: ...
:MCTS                       NIL                                        default: ...
:SAFE-PERCEPTUAL-BUFFERS    (TEMPORAL VISUAL-LOCATION AURAL-LOCATION) default: ...
:ACT-R-ARCHITECTURE-VERSION 7                                          default: ...
:HIGH-PERFORMANCE           NIL                                        default: ...
:CHECK-ACT-R-VERSION        T                                          default: ...
NIL

> (ssp :mcts)
(NIL)

> (ssp :mcts 10000)
(10000)

E> (ssp :mcts 'this)
#|Warning: System parameter :MCTS cannot take value (QUOTE THIS) because it must be
positive number or nil. |#
(:INVALID-VALUE)

E> (ssp :bad-name)
(:BAD-PARAMETER-NAME)

E> (ssp :mcts 100 :mctrt)
#|Warning: Odd number of parameters and values passed to ssp. |#
NIL
```

get-system-parameter-value

Syntax:

get-system-parameter-value *param-name* -> [param-value | **:bad-parameter-name**]

Remote command name:

get-system-parameter-value *param-name* -> ['param-value' | **:bad-parameter-name**]

Arguments and Values:

param-name ::= the name of a system parameter
param-value ::= the current value for the system parameter param-name

Description:

The get-system-parameter-value command is used to get the current value of a system parameter. If param-name is the name of a parameter then the current value for that parameter is returned. If param-name does not name a system parameter then a warning is printed and **:bad-parameter-name** is returned.

Examples:

```
> (get-system-parameter-value :act-r-version)
"7.10-<internal>"

E> (get-system-parameter-value :does-not-exist)
:BAD-PARAMETER-NAME
```

set-system-parameter-value

Syntax:

set-system-parameter-value *param-name new-value* -> [param-value | **:bad-parameter-name** | **:invalid-value**]

Remote command name:

set-system-parameter-value *param-name* '*new-value*' -> ['param-value' | **:bad-parameter-name** | **:invalid-value**]

Arguments and Values:

param-name ::= the name of a system parameter
new-value ::= a value which will be set as the new value for param-name
param-value ::= the current value for the parameter param-name

Description:

The set-system-parameter-value command is used to set the current value for a system parameter. If param-name is the name of a system parameter and param-value is a valid value for that parameter then the current value for that parameter is set to the new-value provided and the current value is returned (that might not be the same as new-value depending on the parameter). If param-name does not name a system parameter then a warning is printed and **:bad-parameter-name** is returned. If param-value is not a valid value for param-name then a warning is printed and **:invalid-value** is returned.

Examples:

```
> (set-system-parameter-value :mcts 400)
400

E> (set-system-parameter-value :bad-name 1)
#|Warning: Parameter :BAD-NAME is not the name of an available system parameter |#
:BAD-PARAMETER-NAME

E> (set-system-parameter-value :mcts "a")
#|Warning: System parameter :MCTS cannot take value a because it must be positive number
or nil. |#
:INVALID-VALUE
```

Parameters

:high-performance

The high-performance system parameter can be set to change the default values for several of the normal parameters as well as to disable the system output (more thoroughly than just setting the :v parameter to **nil**).

The possible values for :high-performance are:

- **nil –** normal system operation (the default value)
- **t –** disables ACT-R output commands and sets the default values of these parameters as shown: (:ncnar nil :style-warnings nil :model-warnings nil :cmdt nil :lhst nil :rhst nil :stable-loc-names nil :visual-movement-tolerance 0).

The default value is **nil**. This system parameter can only be changed when there are no models defined.

Generating Output

Many of the commands in ACT-R result in output being printed. There is a printing module which can be used to control where and when certain things are printed, and that is described in detail in a separate section. For now the general aspects of the output will be described as well as the commands that are used to generate the output. The generated output is sent through the appropriate signal of the dispatcher described in the ACT-R Output section.

Model Output

Model output is essentially all the things that are printed by a running model. The trace of the model is considered model output as are various internal module specific traces and notices. Model output is usually sent using the model-trace signal, but the printing module has a parameter named :v which allows one to redirect the output elsewhere or disable it.

Command Output

Command output is what gets printed when one calls one of the ACT-R commands, for example the parameter listing when one calls sgp. Command output depends upon there being a current model. By default this is sent using the command-trace signal, but like model output, it is configurable by a separate printing module parameter named :cmdt. Thus, one could have model output going one place and command output going elsewhere if desired. Often, one does not need or want the printed output from an ACT-R command because only the returned value is important. In those situations, there is a command called no-output that can be used to temporarily disable command output in Lisp.

Warnings

Warnings from ACT-R are always enclosed inside of a Lisp comment block (between the characters #| and |#) and start with "Warning:". The reason they are inside a comment block is so they do not create a problem if someone is using Lisp to read an output file generated by a model trace which might contain warnings. It also distinguishes them from any other warnings that may be generated by the system in Lisp or some other language when accessed remotely. There are two general classes of warnings and they are created with different commands. The first is referred to as model warnings. These are things like "undefined chunk FOO being created with no slots." They inform the modeler of something that was under specified or unusual within a model. They are generally just hints or suggestions and can often be ignored. In fact, there is a parameter to automatically suppress such warnings if desired (though if the model is not working as one would expect turning the model warnings back on and reading them carefully is probably a good first thing to check). The other type is just referred to as a warning, and they are generated when an ACT-R command receives invalid parameters or a more serious issue has occurred e.g. the "… called with no current model" warning. These are usually more important issues and cannot be turned off with a simple switch. Warnings are sent using the warning-trace signal.

Other Output

If one needs to create other output which does not depend upon a model and/or is not a warning, then there is a command for that as well. That output will be sent using the general-trace signal.

Commands

model-output

Syntax:

model-output *control-string* {*args**} -> **nil**

Remote command name:

model-output *output-string*

Arguments and Values:

control-string ::= a Lisp format control (a format string or function as returned by the formatter macro)
args ::= arguments as required by the control-string provided
output-string ::= a string to be output

Description:

Model-output is used to print model related output based on the settings of the current model. Typically, that output will go to the model-trace, but can be redirected by the printing module. The Lisp command will pass the provided control-string and args to format to generate the string to output, but the remote version requires specifying the string to display completely. The output created will be followed by a new line. The Lisp version does not test the control-string or args for correctness, so any problems will likely trigger an error or warning from the format function.

If there is no current model a warning is printed and no other output is generated.

It always returns **nil**.

Examples:

```
> (model-output "This is ~A the ACT-R ~d model-output command" "output from" 7)
This is output from the ACT-R 7 model-output command
NIL

E> (model-output "This is ~A the ACT-R ~d model-output command" "output from" 7)
#|Warning: get-module called with no current model. |#
NIL
```

meta-p-output

Syntax:

meta-p-output *control-string* {*args**} -> **nil**

Arguments and Values:

control-string ::= a Lisp format control (a format string or function as returned by the formatter macro)
args ::= arguments as required by the control-string provided

Description:

Meta-p-output is used to send the same output to all of the currently defined models. It sends that output using model-output for each model, but only sending out once to each different output destination i.e. if all models are configured to send output to the default location then only one output will occur. It does not test the control-string or args for correctness, so any problems will likely trigger an error or warning from the format function.

It always returns **nil**.

Meta-p-output is used internally for printing the trace because there can be multiple models running concurrently. It is not likely that users or module writers will have need for meta-p-output because it is above the level of a model or module, but it is described because its results are seen when using simultaneous multiple models.

One thing to note about meta-p-output is that it will evaluate the args separately for each stream to which the output is written. If there are no output streams (all models have :v set to **nil** for example) then the args are not evaluated. Thus, if there are any actions with side effects in the args the results could differ when the number of different locations to which output is written changes.

Examples:

```
> (meta-p-output "This is from ~s" "meta-p-output")
This is from "meta-p-output"
NIL
```

command-output

Syntax:

command-output *control-string* {*args**} -> **nil**

Remote command name:

command-output *output-string*

Arguments and Values:

control-string ::= a Lisp format control (a format string or function as returned by the formatter macro)
args ::= arguments as required by the control-string provided
output-string ::= a string to be output

Description:

Command-output is used to print model related output from user commands based on the settings of the current model. Typically, that output will go to the command-trace but can be redirected by the

printing module. The Lisp command will pass the provided control-string and args to format to generate the string to output, but the remote version requires specifying the string to display completely. The output created will be followed by a new line. The Lisp version does not test the control-string or args for correctness, so any problems will likely trigger an error or warning from the format function.

If there is no current model a warning is printed and no other output is generated.

It always returns **nil**.

Command-output is intended for use by things that print in response to being called outside of a model run, like the display of parameters from sgp or the chunk printing from pprint-chunks and can be turned off by the modeler using a parameter or the no-output command.

Examples:

```
> (command-output "A command-output ~s" 'example)
A command-output EXAMPLE
NIL

E> (command-output "A command-output ~s" 'example)
#|Warning: get-module called with no current model. |#
NIL
```

no-output

Syntax:

no-output {*form**} -> [result | **nil**]

Remote command name:

no-output *command {param**}* -> [remote-result | **nil**]

Arguments and Values:

form ::= a Lisp form to evaluate
result ::= the return value from the last form evaluated
command ::= a string naming an ACT-R command
param ::= any value which will be passed as a parameter to command
remote-result ::= the return value calling command with the param values

Description:

No-output can be useful if one wants to get the results from an ACT-R command without having to see any of its output and without needing to explicitly disable and then possibly re-enable the command output parameter.

This command works slightly differently when used in Lisp compared to the remote command.

In Lisp, no-output is used to disable the command output of the current model while evaluating the forms provided.

When used remotely it must be passed a command-name and any parameters to pass to that command. It will then disable the command output of the current model while evaluating that command, passing it the parameters provided.

For both versions, if there is no current model a warning is printed and **nil** is returned.

For the remote version, if the command name is not valid or is one of the commands which run the system a warning will be printed and **nil** will be returned.

For the Lisp version, it returns the value returned by the last form evaluated, and for the remote version it returns the value returned by the command which was called.

Examples:

```
> (no-output (pprint-chunks))
(EXTERNAL LIGHT-GRAY INTERNAL DIGIT CURRENT FULL FREE BLACK ...)

> (no-output (sgp-fct '(:v :lf)))
(T 1.0)

E> (no-output (sgp-fct '(:v :lf)))
#|Warning: get-module called with no current model. |#
NIL
```

print-warning

Syntax:

print-warning *control-string* {*args**} -> **nil**

Remote command name:

print-warning *output-string*

Arguments and Values:

control-string ::= a Lisp format control (a format string or function as returned by the formatter macro)
args ::= arguments as required by the control-string provided
output-string ::= a string to be output

Description:

Print-warning is used to print a warning message using the warning-trace. The Lisp command will pass the provided control-string and args to format to generate a string to output, but the remote version requires specifying the string to display completely. The generated output string is printed after "#| Warning:" and followed by "|#" and a new line. It does not test the control-string or args for correctness, so any problems will likely trigger an error or warning from the format function.

It always returns **nil**.

Print-warning is intended for use in printing important notices of problems or errors that occurred within a module or command.

Examples:

```
> (print-warning "This is a warning from ACT-R ~a" "!!")
#|Warning: This is a warning from ACT-R !! |#
NIL
```

model-warning

Syntax:

model-warning *control-string* {*args**} -> **nil**

Remote command name:

model-warning *output-string*

Arguments and Values:

control-string ::= a Lisp format control (a format string or function as returned by the formatter macro)
args ::= arguments as required by the control-string provided
output-string ::= a string to be output

Description:

Model-warning is used to print a warning message using the warning-trace. The Lisp command will pass the provided control-string and args to format to generate a string to output, but the remote version requires specifying the string to display completely. The generated output string is printed after "#| Warning:" and followed by "|#" and a new line. It does not test the control-string or args for correctness, so any problems will likely trigger an error or warning from the format function. If there is more than one model currently defined then the warning will also include the name of the model in which the warning was generated. If there is no current model then a warning about that situation is printed instead of the specified warning.

Model-warning differs from print-warning in that it requires a current model and the printing module of that model can suppress the model-warning output through the :model-warnings parameter.

It always returns **nil**.

Model-warning is intended for use when the model causes a problem within a module or a less serious situation has occurred which the modeler might want to be informed about but which may often be safely ignore.

Examples:

```
> (model-warning "This may not be what you wanted: ~s" 'bad-value)
#|Warning: This may not be what you wanted: BAD-VALUE |#
NIL

> (with-model bar (model-warning "There is more than one model defined."))
#|Warning (in model BAR): There is more than one model defined. |#
NIL

E> (model-warning "This may not be what you wanted: ~s" 'bad-value)
#|Warning: get-module called with no current model. |#
NIL
```

one-time-model-warning

Syntax:

one-time-model-warning *tag control-string* {*args**} -> **nil**

Remote command name:

one-time-model-warning *tag output-string*

Arguments and Values:

tag ::= any Lisp value
control-string ::= a Lisp format control (a format string or function as returned by the formatter macro)
args ::= arguments as required by the control-string provided
output-string ::= a string to be output

Description:

One-time-model-warning operates like the model-warning command, except that it also requires specifying a tag which identifies the warning. One-time-model-warning will only output the given warning if this is the first time that tag has been used (as tested with the Lisp equal function) in a call to one-time-model-warning in the current model since the system has been reset.

It always returns **nil**.

Like model-warning, one-time-model-warning is intended for use when the model causes a problem within a module or a less serious situation has occurred which the modeler might need to be informed about but which may often be safely ignore. One-time-model-warning can be used if that situation may occur repeatedly to avoid a new warning being printed each time.

Examples:

```
1> (one-time-model-warning :demo "This is a warning")
#|Warning: This is a warning |#
NIL

2> (one-time-model-warning :demo "This is a warning")
NIL
```

```
3> (one-time-model-warning "different tag" "Another warning")
#|Warning: Another warning |#
NIL

> (with-model bar (one-time-model-warning :other "the ~s warning" 'first))
#|Warning (in model BAR): the FIRST warning |#
NIL

E> (one-time-model-warning :demo "This is a warning")
#|Warning: get-module called with no current model. |#
NIL
```

Running the system

Running the system means executing the events that are in the queue of the meta-process. Those events may lead to other events being scheduled and that will continue until the stopping condition specified for the command used to run the system is met. There are several commands for running the system which have various stopping conditions, which include allowing users to specify an arbitrary stopping condition. Because it is the meta-process which is run, all of the models that are defined will be running together, and information about using more than one model at a time is included in the multiple models section.

The system can run in either a simulated time frame where the events are processed as fast as possible or in "real time mode" where the execution of the events is synchronized with the passing of time from some other source. By default, running in real time mode is associated with the actual passage of time (with a scale factor which can be specified by the modeler) and the model is constrained to that, but it is possible to synchronize it with other time sources. For now, we will focus mostly on the simulated time operation.

When running in simulated time the time stamps on the events control the advancement of the clock in the meta-process. When the meta-process is initialized and whenever it is reset the current time is set to 0.0. The event with the lowest time stamp is always the next one executed and if that time is greater than the current time the clock is updated. This allows the system to run much faster than real time for most models. The important thing to remember is that the timing of the events is produced by the modules which instantiate the ACT-R theory and thus the predictions of a model do not depend on how the model is run or the source of the clock.

While the meta-process is running it will print out the events which it executes as they occur. What is displayed for an event is dependent upon the details of the event itself and the settings of the printing module for the model which generated the event. That output is referred to as the trace of the run. That output will be sent to the model-trace using meta-p-output.

Commands & signals

run-start

Signal:

run-start time

Arguments and Values:

time ::= the current model time in milliseconds

Description:

The run-start signal is generated every time that the system starts running and provides the current time.

run-stop

Signal:

run-stop time

Arguments and Values:

time ::= the current model time in milliseconds

Description:

The run-stop signal is generated every time that the system stops running and provides the current time.

run

Syntax:

run *run-time* {*real-time?*} -> [**nil** | time-passed event-count break?]

Remote command name:

run

Arguments and Values:

run-time ::= a number greater than 0 indicating the number of seconds to run
real-time? ::= a generalized boolean to indicate whether to run in real time and possibly the scale for the real time clock (default is **nil**)
time-passed ::= a number indicating the number of seconds in model time which passed during the run
event-count ::= a number indicating how many events were executed during this run
break? ::= [**t** | **nil**] indicating whether the run terminated due to a break event

Description:

Run will run the meta-process until there are either no events remaining to execute, run-time seconds have passed, or a break event is executed. If the optional real-time? value is provided with a non-**nil** value then the model will be run in real time mode. If real-time? is a positive number that will be used as a scale for the real time clock (a number greater than one would cause the meta-process to run faster than real time and a number less than one would cause it to run slower than real time).

If run-time is not a number greater than 0 then the meta-process is not run, a warning is printed, and **nil** is returned.

If the meta-process is run, then when one of the end conditions has been met, run will output a line in the trace to indicate which condition terminated the run and it will return three values.

The first value is the number of seconds that passed during this run. The second is a count of the number of events that were executed (which could be greater than the number of lines shown in the trace because some events may have no output), and the last indicates whether or not the run was terminated by a break event. If it was, then the third value will be **t** otherwise it will be **nil**.

Examples:

For these examples the count model from unit 1 of the ACT-R tutorial is the only model defined.

```
> (run 10)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     ...
     0.350   ------                  Stopped because no events left to process
0.35
53
NIL

> (run .1 t)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   PROCEDURAL              PRODUCTION-SELECTED START
...
     0.100   PROCEDURAL              BUFFER-READ-ACTION GOAL
     0.100   PROCEDURAL              BUFFER-READ-ACTION RETRIEVAL
     0.100   ------                  Stopped because time limit reached
0.1
20
NIL

1> (schedule-break .075)
6

2> (run 10)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   PROCEDURAL              PRODUCTION-SELECTED START
...
     0.050   PROCEDURAL              CONFLICT-RESOLUTION
     0.075   ------                  BREAK-EVENT
0.075
14
T

E> (run 0)
#|Warning: run-time must be a number greater than zero. |#
NIL

E> (run 'foo)
#|Warning: run-time must be a number greater than zero. |#
NIL
```

run-full-time

Syntax:

run-full-time *run-time* {*real-time?*} -> [**nil** | time-passed event-count break?]

Remote command name:

Arguments and Values:

run-time ::= a number greater than 0 indicating the number of seconds to run
real-time? ::= a generalized boolean to indicate whether to run in real time and possibly the scale for the real time clock (default is **nil**)
time-passed ::= a number indicating the number of seconds in model time which passed during the run
event-count ::= a number indicating how many events were executed during this run
break? ::= [**t** | **nil**] indicating whether the run terminated due to a break event

Description:

Run-full-time will run the meta-process until either run-time seconds have passed or a break event is executed. This differs from the run command because unless there is a break event run-full-time will always run for the full run-time specified. If the optional real-time? value is provided with a non-**nil** value then the model will be run in real time mode. If real-time? is a positive number that will be used as a scale for the real time clock (a number greater than one would cause the meta-process to run faster than real time and a number less than one would cause it to run slower than real time).

If run-time is not a number greater than 0 then the meta-process is not run, a warning is printed, and **nil** is returned.

If the meta-process is run, then when one of the end conditions has been met, run-full-time will output a line in the trace to indicate which condition terminated the run and it will return three values.

The first value is the number of seconds that passed during this run. The second is a count of the number of events that were executed (which could be greater than the number of lines shown in the trace because some events may have no output), and the last indicates whether or not the run was terminated by a break event. If it was, then the third value will be **t** otherwise it will be **nil**.

Examples:

For these examples the count model from unit 1 of the ACT-R tutorial is the only model defined.

```
> (run-full-time 1.0)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   PROCEDURAL              PRODUCTION-SELECTED START
...
     0.350   PROCEDURAL              CLEAR-BUFFER RETRIEVAL
     0.350   PROCEDURAL              CONFLICT-RESOLUTION
     1.000   ------                  Stopped because time limit reached
1.0
54
NIL

1> (schedule-break .55)
3

2> (run-full-time 2.0 t)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
```

```
     0.000   PROCEDURAL             PRODUCTION-SELECTED START
...
     0.350   PROCEDURAL             CONFLICT-RESOLUTION
     0.550   ------                 BREAK-EVENT
0.55
54
T

E> (run-full-time -1)
#|Warning: run-time must be a number greater than zero. |#
NIL

E> (run-full-time "2.0")
#|Warning: run-time must be a number greater than zero. |#
NIL
```

run-until-time

Syntax:

run-until-time *end-time* {*real-time?*} -> [**nil** | time-passed event-count break?]

Remote command name:

run-until-time

Arguments and Values:

end-time ::= a number greater than 0 indicating the explicit time at which the run should stop
real-time? ::= a generalized boolean to indicate whether to run in real time and possibly the scale for the real time clock (default is **nil**)
time-passed ::= a number indicating the number of seconds in model time which passed during the run
event-count ::= a number indicating how many events were executed during this run
break? ::= [**t** | **nil**] indicating whether the run terminated due to a break event

Description:

Run-until-time will run the meta-process until either the specified end-time is reached (which includes the current time already having passed the specified time) or a break event is executed. This differs from the run and run-full-time commands because an explicit time is provided instead of a duration. If the optional real-time? value is provided with a non-**nil** value then the model will be run in real time mode. If real-time? is a positive number that will be used as a scale for the real time clock (a number greater than one would cause the meta-process to run faster than real time and a number less than one would cause it to run slower than real time).

If end-time is not a number greater than 0 then the meta-process is not run, a warning is printed, and **nil** is returned.

If the meta-process is run, then when one of the end conditions has been met, run-until-time will output a line in the trace to indicate which condition terminated the run and it will return three values.

The first value is the number of seconds that passed during this run. The second is a count of the number of events that were executed (which could be greater than the number of lines shown in the trace because some events may have no output), and the last indicates whether or not the run was terminated by a break event. If it was, then the third value will be **t** otherwise it will be **nil**.

Examples:

For these examples the count model from unit 1 of the ACT-R tutorial is the only model defined.

```
1> (run-until-time .125)
     0.000   GOAL                 SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL           CONFLICT-RESOLUTION
     0.000   PROCEDURAL           PRODUCTION-SELECTED START
...
     0.100   PROCEDURAL           BUFFER-READ-ACTION RETRIEVAL
     0.125   ------               Stopped because time limit reached
0.125
21
NIL

2> (run-until-time .1)
     0.125   ------               Stopped because end time already passed
0
0
NIL

3> (run-until-time 10)
     0.150   PROCEDURAL           PRODUCTION-FIRED INCREMENT
TWO
     0.150   PROCEDURAL           MOD-BUFFER-CHUNK GOAL
...
     0.350   PROCEDURAL           CONFLICT-RESOLUTION
    10.000   ------               Stopped because time limit reached
9.875
34
NIL

1> (schedule-break .4)
2

2> (run-until-time .5)
     0.000   GOAL                 SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL           CONFLICT-RESOLUTION
     0.000   PROCEDURAL           PRODUCTION-SELECTED START
...
     0.350   PROCEDURAL           CONFLICT-RESOLUTION
     0.400   ------               BREAK-EVENT
0.4
54
T

E> (run-until-time -10)
#|Warning: end-time must be a number greater than zero. |#
NIL
```

run-until-condition

Syntax:

run-until-condition *condition* {*real-time?*} -> [**nil** | time-passed event-count break?]

Remote command name:

run-until-condition

Arguments and Values:

condition ::= a command identifier
real-time? ::= a generalized boolean to indicate whether to run in real time and possibly the scale for the real time clock (default is **nil**)
time-passed ::= a number indicating the number of seconds in model time which passed during the run
event-count ::= a number indicating how many events were executed during this run
break? ::= [**t** | **nil**] indicating whether the run terminated due to a break event

Description:

Run-until-condition will run the meta-process until either the command specified as the condition returns a non-**nil** value when called, there are no events to process, a break event is executed, or an error occurs calling that command. The command provided will be called before every event that is to be executed and it will be passed one parameter which is the time of the next event in milliseconds. If the optional real-time? value is provided with a non-**nil** value then the model will be run in real time mode. If real-time? is a positive number that will be used as a scale for the real time clock (a number greater than one would cause the meta-process to run faster than real time and a number less than one would cause it to run slower than real time).

If condition is not a valid command identifier then the meta-process is not run, a warning is printed, and **nil** is returned.

If the meta-process is run, then when one of the end conditions has been met, run-until-condition will output a line in the trace to indicate which condition terminated the run and it will return three values.

The first value is the number of seconds that passed during this run. The second is a count of the number of events that were executed (which could be greater than the number of lines shown in the trace because some events may have no output), and the last indicates whether or not the run was terminated by a break event. If it was, then the third value will be **t** otherwise it will be **nil**.

Examples:

For these examples the count model from unit 1 of the ACT-R tutorial is the only model defined. The Lisp function symbolp used in the examples returns a true value if the parameter passed to it is a symbol and **nil** if it is not, and since the value passed to the condition will always be a number it is always going to return **nil**.

```
> (run-until-condition 'symbolp)

     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   PROCEDURAL            PRODUCTION-SELECTED START
...
     0.350   PROCEDURAL            CONFLICT-RESOLUTION
```

```
     0.350   ------                 Stopped because no events to process
0.35
53
NIL

1> (schedule-break .275)
5

2> (run-until-condition 'symbolp)
     0.000   GOAL                   SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.000   PROCEDURAL             PRODUCTION-SELECTED START
...
     0.250   PROCEDURAL             CONFLICT-RESOLUTION
     0.275   ------                 BREAK-EVENT
0.275
42
T

1> (defvar *count* 0)
*COUNT*

2> (defun stop-at-10 (x)
     (> (incf *count*) 10))
STOP-AT-10

3> (run-until-condition 'stop-at-10)
     0.000   GOAL                   SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.000   PROCEDURAL             PRODUCTION-SELECTED START
     0.000   PROCEDURAL             BUFFER-READ-ACTION GOAL
     0.050   PROCEDURAL             PRODUCTION-FIRED START
     0.050   PROCEDURAL             MOD-BUFFER-CHUNK GOAL
     0.050   PROCEDURAL             MODULE-REQUEST RETRIEVAL
     0.050   ------                 Stopped because condition is true
0.05
10
NIL

1> (defun always-nil (x))
ALWAYS-NIL

2> (add-act-r-command "always-nil" 'always-nil "Test fn for run-until-condition example")
T
"always-nil"

3> (run-until-condition "always-nil")
     0.000   GOAL                   SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.000   PROCEDURAL             PRODUCTION-SELECTED START
  ...
     0.350   PROCEDURAL             CONFLICT-RESOLUTION
     0.350   ------                 Stopped because no events to process
0.35
53
NIL

E>: (run-until-condition "not-a-valid-command")
#|Warning: condition must be a function or valid dispatch command string. |#
NIL
```

run-until-action

Syntax:

run-until-action *action* {*real-time?*} -> [**nil** | time-passed event-count break?]

Remote command name:

run-until-action '*action*' {*real-time?*}

Arguments and Values:

action ::= a symbol or string indicating an event action to stop after
real-time? ::= a generalized boolean to indicate whether to run in real time and possibly the scale for the real time clock (default is **nil**)
time-passed ::= a number indicating the number of seconds in model time which passed during the run
event-count ::= a number indicating how many events were executed during this run
break? ::= [**t** | **nil**] indicating whether the run terminated due to a break event

Description:

Run-until-action will run the meta-process until either an event with an action that matches the one specified has been executed, there are no events to process, or a break event is executed. If the optional real-time? value is provided with a non-**nil** value then the model will be run in real time mode. If real-time? is a positive number that will be used as a scale for the real time clock (a number greater than one would cause the meta-process to run faster than real time and a number less than one would cause it to run slower than real time).

If action is not a valid command identifier then the meta-process is not run, a warning is printed, and **nil** is returned.

If the meta-process is run, then when one of the end conditions has been met, run-until-action will output a line in the trace to indicate which condition terminated the run and it will return three values.

The first value is the number of seconds that passed during this run. The second is a count of the number of events that were executed (which could be greater than the number of lines shown in the trace because some events may have no output), and the last indicates whether or not the run was terminated by a break event. If it was, then the third value will be **t** otherwise it will be **nil**.

Because an action for an event can be specified in multiple ways, there are some subtleties in how the given action is compared to an event's action. First, although when running in Lisp only mode one can provide event actions using Lisp function objects (instead of just a function name) actions of that type cannot be tested by run-until-action. If the command identifier condition is provided as a symbol it will be tested in a case-insensitive way to the action of the event regardless of whether that event action is a symbol or string. If the command identifier condition is a string it will be tested with a case insensitive test to an event action symbol and case sensitive to an event action that is a string. That can be seen in the example below where the production-fired event has a symbol as the event action whereas the "get-time" event has a string as an action.

One final thing to note is that what is shown in the trace for an event may not actually be the action itself if the event was scheduled with details to display instead of the action. Therefore, it is possible

for the run to continue past an event which has trace output that matches the action provided if that event's true action was different from the details displayed by the event.

Examples:

For these examples the following model is the only model defined and it schedules an event that has a command string as the action:

```
(define-model test
  (goal-focus-fct (car (define-chunks (value 1))))

 (p repeat
      =goal>
       < value 5
        value =v
     ==>
      !bind! =x (1+ =v)
      =goal> value =x)

  (schedule-event-relative .175 "get-time" :output nil))

> (run-until-action 'production-fired)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL CHUNK0 NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.050   PROCEDURAL              PRODUCTION-FIRED REPEAT
     0.050   ------                  Stopped because PRODUCTION-FIRED action occurred
0.05
8
NIL

> (run-until-action "production-fired")
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL CHUNK0 NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.050   PROCEDURAL              PRODUCTION-FIRED REPEAT
     0.050   ------                  Stopped because production-fired action occurred
0.05
8
NIL

> (run-until-action "Production-Fired")
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL CHUNK0 NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.050   PROCEDURAL              PRODUCTION-FIRED REPEAT
     0.050   ------                  Stopped because Production-Fired action occurred
0.05
8
NIL

> (run-until-action 'get-time)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL CHUNK0 NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.050   PROCEDURAL              PRODUCTION-FIRED REPEAT
     0.050   PROCEDURAL              CONFLICT-RESOLUTION
     0.100   PROCEDURAL              PRODUCTION-FIRED REPEAT
     0.100   PROCEDURAL              CONFLICT-RESOLUTION
     0.150   PROCEDURAL              PRODUCTION-FIRED REPEAT
     0.150   PROCEDURAL              CONFLICT-RESOLUTION
     0.175   ------                  Stopped because GET-TIME action occurred

> (run-until-action "get-time")
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL CHUNK0 NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
```

```
     0.050   PROCEDURAL             PRODUCTION-FIRED REPEAT
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
     0.100   PROCEDURAL             PRODUCTION-FIRED REPEAT
     0.100   PROCEDURAL             CONFLICT-RESOLUTION
     0.150   PROCEDURAL             PRODUCTION-FIRED REPEAT
     0.150   PROCEDURAL             CONFLICT-RESOLUTION
     0.175   ------                 Stopped because get-time action occurred
0.175
26
NIL

> (run-until-action "Get-Time")
     0.000   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0 NIL
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.050   PROCEDURAL             PRODUCTION-FIRED REPEAT
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
     0.100   PROCEDURAL             PRODUCTION-FIRED REPEAT
     0.100   PROCEDURAL             CONFLICT-RESOLUTION
     0.150   PROCEDURAL             PRODUCTION-FIRED REPEAT
     0.150   PROCEDURAL             CONFLICT-RESOLUTION
     0.200   PROCEDURAL             PRODUCTION-FIRED REPEAT
     0.200   PROCEDURAL             CONFLICT-RESOLUTION
     0.200   ------                 Stopped because no events left to process
0.2
29
NIL

E> (run-until-action 2)
#|Warning: run-until-action must be given a name(symbol) or a string, but given 2 which is
a FIXNUM. |#
NIL
```

run-n-events

Syntax:

run-n-events *num-events* {*real-time?*} -> [**nil** | time-passed event-count break?]

Remote command name:

run-n-events

Arguments and Values:

num-events ::= a number greater than 0 indicating the number of events to run
real-time? ::= a generalized boolean to indicate whether to run in real time and possibly the scale for the real time clock (default is **nil**)
time-passed ::= a number indicating the number of seconds in model time which passed during the run
event-count ::= a number indicating how many events were executed during this run
break? ::= [**t** | **nil**] indicating whether the run terminated due to a break event

Description:

Run-n-events will run the meta-process until either num-events have been executed, there are no events to process, or a break event is executed. If the optional real-time? value is provided with a non-**nil** value then the model will be run in real time mode. If real-time? is a positive number that

will be used as a scale for the real time clock (a number greater than one would cause the meta-process to run faster than real time and a number less than one would cause it to run slower than real time).

If num-events is not a number greater than 0 then the meta-process is not run, a warning is printed, and **nil** is returned.

If the meta-process is run, then when one of the end conditions has been met, run-n-events will output a line in the trace to indicate which condition terminated the run and it will return three values.

The first value is the number of seconds that passed during this run. The second is a count of the number of events that were executed (which could be greater than the number of lines shown in the trace because some events may have no output), and the last indicates whether or not the run was terminated by a break event. If it was, then the third value will be **t** otherwise it will be **nil**.

Examples:

For these examples the count model from unit 1 of the ACT-R tutorial is the only model defined.

```
> (run-n-events 10)
     0.000   GOAL                 SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL           CONFLICT-RESOLUTION
     0.000   PROCEDURAL           PRODUCTION-SELECTED START
     0.000   PROCEDURAL           BUFFER-READ-ACTION GOAL
     0.050   PROCEDURAL           PRODUCTION-FIRED START
     0.050   PROCEDURAL           MOD-BUFFER-CHUNK GOAL
     0.050   PROCEDURAL           MODULE-REQUEST RETRIEVAL
     0.050   ------               Stopped because event limit reached
0.05
10
NIL

> (run-n-events 100)
     0.000   GOAL                 SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL           CONFLICT-RESOLUTION
     0.000   PROCEDURAL           PRODUCTION-SELECTED START
...
     0.350   PROCEDURAL           CONFLICT-RESOLUTION
     0.350   ------               Stopped because no events to process
0.35
53
NIL

1> (schedule-break .225)
5

2> (run-n-events 50)
     0.000   GOAL                 SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL           CONFLICT-RESOLUTION
     0.000   PROCEDURAL           PRODUCTION-SELECTED START
...
     0.200   PROCEDURAL           BUFFER-READ-ACTION RETRIEVAL
     0.225   ------               BREAK-EVENT
0.225
35
T

E> (run-n-events "count")
```

```
#|Warning: event-count must be a number greater than zero. |#
NIL
```

run-step

Syntax:

run-step -> time-passed event-count break?

Arguments and Values:

time-passed ::= a number indicating the number of seconds in model time which passed during the run
event-count ::= a number indicating how many events were executed during this run
break? ::= [**t** | **nil**] indicating whether the run terminated due to a break event

Description:

Run-step is only available from a Lisp prompt, and it will run the meta-process one event at a time. For each event a summary of the event is printed to *standard-output* and the user is prompted to respond as to whether that event should be executed, deleted, or the run terminated. This will stop for all events, even those which do not get displayed in the trace. The user can also show various debugging information before deciding what to do with the current event. The response is read from *standard-input* and should be one of the characters indicated in the prompt. It will continue to run the model until the user requests it to stop, there are no events remaining, or a break event is executed. Run-step cannot run the model in real time mode.

When one of the end conditions has been met, run-step will output a line in the trace to indicate which condition terminated the run and it will return three values.

The first value is the number of seconds that passed for the model. The second is a count of the number of events that were executed (which could be greater than the number of lines shown in the trace because some events may have no output), and the last indicates whether or not the trial was terminated by a break event. If it was, then the third value will be **t** otherwise it will be **nil**.

Run-step can be a useful function for debugging a model because it allows one to walk through the events one at a time and to inspect the state of the system before every one.

Examples:

For these examples the count model from unit 1 of the ACT-R tutorial is the only model defined.

```
> (run-step)
Next Event:      0.000   NONE                    CHECK-FOR-ESC-NIL
[A]bort (or [q]uit)
[D]elete
[S]how event queue
[W]aiting events
[B]uffer contents
[V]isicon
[R]eport buffer status
```

```
[E]xecute
e
Next Event:      0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
[A]bort (or [q]uit)
[D]elete
[S]how event queue
[W]aiting events
[B]uffer contents
[V]isicon
[R]eport buffer status
[E]xecute
b
RETRIEVAL: empty
IMAGINAL: empty
MANUAL: empty
GOAL: empty
IMAGINAL-ACTION: empty
VOCAL: empty
AURAL: empty
PRODUCTION: empty
VISUAL-LOCATION: empty
AURAL-LOCATION: empty
TEMPORAL: empty
VISUAL: empty
Next Event:      0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
[A]bort (or [q]uit)
[D]elete
[S]how event queue
[W]aiting events
[B]uffer contents
[V]isicon
[R]eport buffer status
[E]xecute
q
     0.000   ------                Stepping stopped
0.0
1
NIL
```

Scheduling Events

The event system that drives ACT-R models is also available to the modeler for use in writing experiments or other interactive tasks for the models. In fact, because ACT-R relies on the events to trigger actions such as conflict-resolution, this is the recommended mechanism for creating experiments or making other run-time changes. It is also essential when adding new modules. That is because for other modules to be able to detect that a change has occurred (especially the procedural module) those changes need to happen during an event. Therefore any change to a buffer, change of the internal state of a module, or outside action performed by a module should be done through a scheduled event.

When writing experiments for a model, one useful approach is to have the model's actions trigger the events that make changes in such a way that one only needs to call one of the ACT-R "run" functions to execute both the model and the task. That has the benefit of not introducing any discrepancies into the model timing relative to the task and also allows for the task to be run using the provided stepping tools or continued after a break in the model. That is not always practical for a simple model/task and often one may instead use a run, stop, change, run again approach (sometimes referred to as run-stop-run or "trial at a time"). However, even when using the run-stop-run approach for a task, it is still important to schedule any direct effects that one makes to buffers or chunks so that the model properly notes the changes.

In general, most of the module commands will schedule some event as a response, but many of the general commands which perform similar actions may not. For example, mod-chunk (a general command) does not generate an event, but mod-focus (a similar command provided by the goal module for updating its buffer) does.

Details of events

Each event has several attributes associated with it that are specified when the event is created with one of the scheduling functions provided. Most of the time the user will not need to work with the events directly, but there are some situations where access to the details of an event may be useful (for instance the event hooks allow one to add commands which see each event before or after it is executed). Here are the attributes which an event has that are accessible by the user.

time

The simulation time at which the event will occur. All times are rounded to the millisecond when the event is created.

priority

When multiple events are scheduled to occur at the same time they are ordered by their priorities. The priority is either a number or one of the keywords :max or :min. An event with a priority of :max will occur before any event at the same time which has a priority other than :max. An event with a priority of :min will occur after any event at the same time which has a priority other than :min. An event with a numeric priority will be executed before any other events at the same time which have a lower numeric priority i.e. numeric priorities are ordered from highest to lowest with no bounds on

the numbers given. Events which have both the same time and same priority will occur in the order which they were scheduled – the earlier scheduled item will occur before the later scheduled one.

action

The command that will be called when this event is executed. It is possible when creating an event to specify **nil** as the action to just provide details in the trace, but such an event will have an action that is indicated as internal-dummy-event-fn.

parameters

The list of values which will be passed to the action command when the event is executed.

model

The name of the model in which the event was generated and in which the action will be evaluated.

module

The name of the module indicated as creating the event or the keyword **:none** if no module was specified when the event was created.

destination

If this action is to be sent *to* a specific module, then that module's name can be given as the destination and the instance of that module will be passed as the first parameter to the action. Using this is can be simpler and more informative than just making the instance of the module the first element in the parameters list.

details

The details can be a string which will be output in the trace for the event. If details are specified that is all that is printed after the time, model and module. If the details are not specified then the action and parameters are printed in the trace.

output

Output controls under which trace-detail levels the event will be displayed. It can have a value of **t**, **high, medium**, **low**, or **nil**. A value of **t** or **high** means it will be displayed only for the high trace detail setting. **Nil** means not to show it at all. **Medium** means that it should be shown under both medium and high trace details, and a value of **low** means it will be shown for any trace detail setting. The output value effectively specifies the lowest detail setting for which the output will be displayed.

Event Implementation

The specific implementation of an event is not part of the API for ACT-R. The value returned when creating an event and the values passed through a hook function that provide events will be an integer

that can be used to access the information about that event (referred to as an event-id). There is no way to modify an event directly once it has been created.

Event Accessors

To access the information from an event using the event-id, a set of accessors are provided. Because all of the accessors operate the same way they are all presented in one description, and there is a remote version of each one.

Syntax:

evt-time *event-id* -> [time | **nil**], valid
evt-mstime *event-id* -> [mstime | **nil**], valid
evt-priority *event-id* ->[priority | **nil**], valid
evt-action *event-id* -> [action | **nil**], valid
evt-params *event-id* -> [parameters | **nil**], valid
evt-model *event-id* -> [model | **nil**], valid
evt-module *event-id* -> [module | **nil**], valid
evt-destination *event-id* -> [destination | **nil**], valid
evt-details *event-id* -> [details | **nil**], valid
evt-output *event-id* -> [output | **nil**], valid

Arguments and Values:

event-id ::= an integer
time ::= the time of the event in seconds
mstime ::= the time of the event in milliseconds
priority ::= the event's priority
action ::= the event's action
parameters ::= the event's parameters list
model ::= the name of the model in which the event was generated or **nil**
module ::= the name of the module which generated the event or **:none**
destination ::= the name of the module which is the destination for the event or **nil**
details ::= the details string of the event or **nil**
output ::= the output value of the event
valid ::= [**t** | **nil**]

Description:

Each of the event accessors returns two values. The second one indicates whether there was an event which corresponds to the id provided. If it is **t** then the first value provided will be the appropriate attribute from that event. If there is no event with the event-id provided then both return values will be **nil**.

For the remote version of evt-action the result will be an embedded string with the value of the action, and the remote version of evt-params will return a list which uses embedded strings to differentiate between names and actual strings.

Examples:

```
1> (define-model foo)
FOO

2> (schedule-event 1 "set-buffer-chunk" :module :vision :output 'low
                   :params '(visual-location chunk1) :priority 10)
7

3> (evt-time 7)
1.0
T

4> (evt-mstime 7)
1000
T

5> (evt-priority 7)
10
T

6> (evt-action 7)
"set-buffer-chunk"
T

7> (evt-model 7)
FOO
T

8> (evt-module 7)
:VISION
T

9> (evt-destination 7)
NIL
T

10> (evt-params 7)
(VISUAL-LOCATION CHUNK1)
T

11> (evt-details 7)
NIL
T

> (evt-output 7)
LOW
T

E> (evt-time -4)
NIL
NIL
```

General Event Commands

These commands allow for getting additional information about events related to whether they will be displayed in the trace and how their output will look.

event-displayed-p

Syntax:

event-displayed-p *event-id* -> [**t** | **nil**]

Remote command name:

event-displayed-p

Arguments and Values:

event-id ::= an integer

Description:

Event-displayed-p can be used to determine whether or not an event will be printed in the trace given the current setting of the :trace-detail and :trace-filter parameters for the model in which it was generated. If the event indicated by the given id will be printed with the current settings of that model's parameters, then **t** is returned and if not then **nil** is returned. If the id does not reference a valid event then **nil** is returned.

This command might be useful when working with the event hooks or for developing an interactive stepper or tracing tool.

Examples:

```
> (let ((event (schedule-event-now nil :output 'medium)))
                (with-parameters (:trace-detail high)
                  (act-r-output ":trace-detail high and :output medium : ~s"
                                (event-displayed-p event)))
                (with-parameters (:trace-detail medium)
                  (act-r-output ":trace-detail medium and :output medium : ~s"
                                (event-displayed-p event)))
                (with-parameters (:trace-detail low)
                  (act-r-output ":trace-detail low and :output medium : ~s"
                                (event-displayed-p event))))

:trace-detail high and :output medium : T
:trace-detail medium and :output medium : T
:trace-detail low and :output medium : NIL

E> (event-displayed-p 'not-an-event)
NIL
```

format-event

Syntax:

format-event *event-id* -> [event-string | **nil**]

Remote command name:

format-event

Arguments and Values:

event-id ::= an integer identifying an ACT-R event
event-string ::= a string that contains the text that would be printed for this event in the trace

Description:

Format-event can be used to get a string with the representation of what the provided event will look like in the trace when it is executed. If the event-id does not correspond to a valid ACT-R event then **nil** is returned.

This would likely be used with the development of additional stepping tools or a data logger which was tied into the event hooks to be able to record and/or display an event independently of the trace.

Examples:

```
> (let ((event (schedule-event 20 "set-buffer-chunk" :params '(goal c0))))
               (format-event event))
"    20.000   NONE                  set-buffer-chunk GOAL C0"

> (format-event 'not-event)
NIL
```

Scheduling Commands

Events can be generated using a variety of scheduling functions described here, as well as automatically by certain module commands. There are three different types of events that can be generated: model events, maintenance events, and break events. Model events are actions which are generated by the cognitive modules or outside actions which the model may need to detect. Maintenance events are used for actions which are not of importance to the model itself. Break events are a special type of maintenance event which have no actions other than to terminate the current run of the model.

Events can be scheduled to occur at a specified time, or their scheduling can be delayed until a specified condition is met (referred to as waiting events). A waiting event may also specify whether it should respond to only the first event that satisfies its condition or whether it will continue to respond to new events that are scheduled and possibly change its scheduling as new events occur. A waiting event which continues to update its scheduled position as new events occur is referred to as a dynamic event. A dynamic event will always follow the earliest event (closest to the current time) which satisfies its waiting condition.

There are two differences between model and maintenance events. The first is an indirect difference. Waiting events can be specified to consider any event or only model events when determining whether to stop waiting and actually be scheduled. The events which are scheduled by the cognitive modules that might need to wait for other events (in particular the conflict-resolution event of the procedural module) will only consider model events because those are the actions which are meaningful to the model. The other difference is that a maintenance event may specify a command as a precondition to determine whether or not it will occur. When a maintenance event with a precondition is the next event in the queue its precondition is called with the parameters for the event. If the precondition returns a value other than **nil** then the event is executed as normal. If the precondition returns **nil** then the event is removed from the queue and not executed. That is another reason why waiting events should typically only check model events. With the current implementation of the scheduling system, a waiting event stops waiting and gets scheduled when an event which satisfies its waiting condition is scheduled. If the event which caused the waiting event

to be scheduled is a maintenance event and its precondition causes it to be ignored when it is its time to be executed the scheduler does not currently have a way to return the waiting event which was scheduled because of that maintenance event back to a waiting state, and it will be executed even though the event it was waiting on did not actually occur.

When a new event is scheduled all of the waiting events will be tested to determine if the new event satisfies the conditions for which those events are waiting and may schedule them to occur. If any were scheduled, then the waiting events will be tested again based on those scheduled events, and that will continue until no new events are scheduled. In addition to that, any waiting event which was marked as being dynamic and which has already been scheduled will test the new events to see if the dynamic event should be rescheduled because of the new events.

When an event's action is executed the current model will be set to the model which generated the event if there was one (only break events can be created without a current model). When working with a single model that does not make a difference, but in the context of multiple models it means that the action function does not typically need to use with-model or make any explicit checks to ensure that it is working in the proper context.

The Lisp versions of the scheduling functions take keyword parameters for providing the features of the event and the remote commands use an options list.

schedule-event, schedule-event-relative, schedule-event-now

Syntax:

schedule-event time action {**:module** *module-value*} {**:destination** *destination-value*} {**:priority** *priority-value*}
{**:params** *params-value*} {**:time-in-ms** *time-units*} {**:details** *details-value*}
{**:maintenance** *maintenance-value*} {**:precondition** *precondition-value*}
{**:output** *output-value*} -> [event-id | **nil**]

schedule-event-relative *delta-time action* {**:module** *module-value*} {**:destination** *destination-value*}
{**:priority** *priority-value*} {**:params** *params-value*} {**:time-in-ms** *time-units*}
{**:details** *details-value*} {**:maintenance** *maintenance-value*}
{**:precondition** *precondition-value*} {**:output** *output-value*} -> [event-id | **nil**]

schedule-event-now *action* {**:module** *module-value*} {**:destination** *destination-value*} {**:priority** *priority-value*}
{**:params** *params-value*} {**:details** *details-value*}
{**:maintenance** *maintenance-value*} {**:precondition** *precondition-value*}
{**:output** *output-value*} -> [event-id | **nil**]

Remote command name:

schedule-event *time action* { < **module** *module-value*, **destination** *destination-value*, **priority** *priority-value*,
params *params-value*, **time-in-ms** *time-units*, **details** *details-value*,
maintenance *maintenance-value*, **precondition** *precondition-value*,
output *output-value* > }

schedule-event-relative *delta-time action* { < **module** *module-value*, **destination** *destination-value*,
priority *priority-value*, **params** *params-value*, **time-in-ms** *time-units*,
details *details-value*, **maintenance** *maintenance-value*,
precondition *precondition-value*, **output** *output-value* > }

schedule-event-now *action* { < **module** *module-value*, **destination** *destination-value*, **priority** *priority-value*,

params *params-value*, **details** *details-value*,
maintenance *maintenance-value*, **precondition** *precondition-value*,
output *output-value* > }

Arguments and Values:

time ::= a number representing an absolute time for the event in seconds or milliseconds
delta-time ::= a number in seconds or milliseconds indicating the delay before executing the event
action ::= a command identifier of the action to perform or **nil**
module-value ::= the module's name which is scheduling the event (default **:none**)
destination-value ::= the name of a module
priority-value ::= [**:max** | **:min** | a number] (default 0)
params-value ::= a list of values to pass to the action (default **nil**)
time-units ::= a generalized boolean indicating whether the time is set in milliseconds (default is **nil**)
maintenance-value ::= generalized boolean indicating whether this is a maintenance event (default **nil**)
precondition-value ::= [**nil** | precondition] (default **nil**)
precondition ::= a command identifier specifying a pretest to try before the action
details-value ::= a string to output in the trace or **nil** (default **nil**)
output-value ::= [**t** | **high** | **medium** | **low** | **nil**] (default **t**)
event-id ::= an integer which can be used to reference the event created

Description:

These functions schedule events to occur at particular times in the current model using the attributes provided, and an id which can be used to access the event will be returned. Schedule-event creates the event at the specific time provided, schedule-event-relative creates the event to occur at the indicated time from the current time, and schedule-event-now creates the event at the current time.

If the action is **nil** then no command is executed when the event occurs. This can be useful if one wants to use an event's details to provide information in the trace without having to create a command to do so.

If any of the parameters are invalid or there is no current model then a warning is printed, no event is scheduled, and **nil** is returned.

Examples:

```
1> (mp-time)
3.0

2> (mp-show-queue)
Events in the queue:
0

3> (schedule-event 3.5 'goal-focus-fct :priority :min :params '(new-goal) :output nil)
5

4> (schedule-event 3.5 'define-chunks-fct :priority 0 :params '((new-goal)))
6

NOTE: in the single-threaded version of ACT-R one can use lambda functions as the action
as noted in the description of a command identifier, but not in the normal version.  The a
version of these examples show the results in single threaded mode and the b version in
the normal version.

a5> (schedule-event-relative 1.0 (lambda()) :details "Dummy function" :maintenance t)
```

```
7

b5E> (schedule-event-relative 1.0 (lambda()) :details "Dummy function" :maintenance t)
#|Warning: Can't schedule #<Interpreted Function> because it is not a valid command
identifier. |#
NIL

a6> (schedule-event-now nil)
8

b6> (schedule-event-now nil)
7

a7> (mp-show-queue)
Events in the queue:
     3.000   NONE                  INTERNAL-DUMMY-EVENT-FN
     3.000   PROCEDURAL            CONFLICT-RESOLUTION
     3.500   NONE                  DEFINE-CHUNKS-FCT (NEW-GOAL)
     3.500   NONE                  GOAL-FOCUS-FCT
     4.000   NONE                  Dummy function
5

b7> (mp-show-queue)
Events in the queue:
     3.000   NONE                  INTERNAL-DUMMY-EVENT-FN
     3.000   PROCEDURAL            CONFLICT-RESOLUTION
     3.500   NONE                  DEFINE-CHUNKS-FCT (NEW-GOAL)
     3.500   NONE                  GOAL-FOCUS-FCT
4

E> (schedule-event 'bad-time nil)
#|Warning: Time must be non-negative number. |#
NIL

E> (schedule-event 0 'bad-name)
#|Warning: Can't schedule BAD-NAME because it is not a valid command identifier. |#
NIL

E> (schedule-event 10 'goal-focus :priority :min :params '(new-goal-chunk) :output nil)
#|Warning: Can't schedule GOAL-FOCUS because it is a macro and not a function. |#
NIL

E> (schedule-event 0 nil :priority 'value)
#|Warning: Priority must be a number or :min or :max. |#
NIL

E> (schedule-event 0 nil :params 10)
#|Warning: params must be a list. |#
NIL

E> (schedule-event 0 'pprint)
#|Warning: schedule-event called with no current model. |#
NIL
```

schedule-event-after-module

Syntax:

schedule-event-after-module *after-module action* {**:module** *module-value*} {**:destination** *destination-value*} {**:params** *params-value*} {**:details** *details-value*} {**:delay** *delay-value*} {**:maintenance** *maintenance-value*} {**:dynamic** *dynamic-value*} {**:precondition** *precondition-value*} {**:output** *output-value*} {**:include-maintenance** *include-maintenance-value*}

-> [event-id | **nil**] {[**t** | **nil** | **:abort**]}

Remote command name:

schedule-event-after-module *after-module action* { < **module** *module-value*, **destination** *destination-value*,
params *params-value*, **details** *details-value*,
delay *delay-value,* **maintenance** *maintenance-value*,
dynamic *dynamic-value,* **output** *output-value,*
precondition *precondition-value*,
include-maintenance *include-maintenance-value* > }

Arguments and Values:

after-module ::= the name of a module
action ::= a command identifier of the action to perform or **nil**
module-value ::= the name of the module scheduling the event (default **:none**)
destination-value ::= the name of a module
params-value ::= a list of values to pass to the action (default **nil**)
maintenance-value ::= generalized boolean indicating whether this is a maintenance event (default **nil**)
precondition-value ::= [**nil** | precondition] (default **nil**)
precondition ::= a command identifier specifying a pretest to try before the action
details-value ::= a string to output in the trace or **nil** (default **nil**)
output-value ::= [**t** | **high** | **medium** | **low** | **nil**] (default **t**)
delay-value ::= [**t** | **nil** | **:abort**] (default **t**)
include-maintenance-value ::= a generalized boolean indicating whether to consider maintenance events when determining when to schedule this event (default **nil**)
dynamic-value ::= generalized boolean indicating whether to allow rescheduling (default **nil**)
event-id ::= an integer which can be used to reference the event created

Description:

Schedule-event-after-module creates a new event using the supplied parameters for its corresponding attributes and the current model for its model.

If there is an event currently in the event queue with the module name of after-module and the same model as the current model and either include-maintenance-value is true or the event is not a maintenance event, then this new event is placed into the event queue at the time of the next such matching event (lowest time) with a priority of **:min**.

If there is no event in the event queue that matches on model and module of the appropriate event type (model or maintenance), then the value of delay-value determines what happens to the new event.

If delay-value is **t** then the new event is placed into the set of waiting events to be scheduled after an event which matches the conditions necessary to schedule this new event.

If delay-value is **nil** then the new event is added to the event queue for immediate execution. Its time will be set to the current time and its priority will be **:max**.

If delay-value is **:abort** then the new event is discarded without being scheduled or placed into the waiting queue.

If the action is **nil** then no command is executed when the event occurs. This can be useful if one wants to use an event's details to provide information in the trace without having to create a command to do so.

A successful schedule-event-after-module returns two values. The first value will be the event id and the second value will be **t** if the event is in the waiting queue, **nil** if it is in the event queue, and **:abort** if it was not scheduled. If there is no current model or any of the parameters are invalid, then no event is scheduled and a single value of **nil** is returned.

Examples:

```
1> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
2

2> (schedule-event-after-module 'procedural nil :details "Matches event")
3
NIL

3> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   NONE                  Matches event
3

4> (schedule-event-after-module :vision nil :details "no event and wait" :delay t)
4
T

5> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   NONE                  Matches event
3

6> (mp-show-waiting)
Events waiting to be scheduled:

   NONE                  no event and wait Waiting for: (:MODULE :VISION NIL)

1

7> (schedule-event-after-module :motor nil :details "go now" :delay nil)
5
NIL

8> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   NONE                  go now
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   NONE                  Matches event
4

9> (schedule-event-after-module :motor nil :details "aborted" :delay :abort)
```

```
NIL
:ABORT

10> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   NONE                  go now
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   NONE                  Matches event
4

11> (mp-show-waiting)
Events waiting to be scheduled:

   NONE                  no event and wait Waiting for: (:MODULE :VISION NIL)

1

E> (schedule-event-after-module 'bad-name nil)
#|Warning: after-module must name a module. |#
NIL
```

schedule-event-after-change

Syntax:

schedule-event-after-change *action* {**:module** *module-value*} {**:destination** *destination-value*}
{**:params** *params-value*} {**:details** *details-value*} {**:delay** *delay-value*}
{**:maintenance** *maintenance-value*} {**:dynamic** *dynamic-value*}
{**:precondition** *precondition-value*} {**:output** *output-value*}
{**:include-maintenance** *include-maintenance-value*}
-> [event-id | **nil**] {[**t** | **nil** | **:abort**]}

Remote command name:

schedule-event-after-change *action* { < **module** *module-value*, **destination** *destination-value*,
params *params-value*, **details** *details-value*,
delay *delay-value,* **maintenance** *maintenance-value*,
dynamic *dynamic-value,* **output** *output-value,*
precondition *precondition-value*,
include-maintenance *include-maintenance-value* > }

Arguments and Values:

action ::= a command identifier of the action to perform or **nil**
module-value ::= the name of the module scheduling the event (default **:none**)
destination-value ::= the name of a module
params-value ::= a list of values to pass to the action (default **nil**)
maintenance-value ::= generalized boolean indicating whether this is a maintenance event (default **nil**)
precondition-value ::= [**nil** | precondition] (default **nil**)
precondition ::= a command identifier specifying a pretest to try before the action
details-value ::= a string to output in the trace or **nil** (default **nil**)
output-value ::= [**t** | **high** | **medium** | **low** | **nil**] (default **t**)
delay-value ::= [**t** | **nil** | **:abort**] (default **t**)
include-maintenance-value ::= a generalized boolean indicating whether to consider maintenance events when determining when to schedule this event (default **nil**)

dynamic-value ::= generalized boolean indicating whether to allow rescheduling (default **nil**)
event-id ::= an integer which can be used to reference the event created

Description:

Schedule-event-after-change creates a new event using the supplied parameters for its corresponding attributes and the current model for its model. If there is any event currently in the event queue with the same model as the current model and either include-maintenance-value is true or the event is not a maintenance event, then this new event is placed into the event queue at the time of the next such matching event (lowest time) with a priority of **:min**.

If there is no event in the event queue that matches on model and is of the appropriate event type (model or maintenance), then the value of delay-value determines what happens to the new event.

If delay-value is **t** then the new event is placed into the set of waiting events to be scheduled after an event which matches the conditions necessary to schedule this new event.

If delay-value is **nil** then the new event is added to the event queue for immediate execution. Its time will be set to the current time and its priority will be **:max**.

If delay-value is **:abort** then the new event is discarded without being scheduled or placed onto the waiting queue.

If the action is **nil** then no command is executed when the event occurs. This can be useful if one wants to use an event's details to provide information in the trace without having to create a command to do so.

A successful schedule-event-after-change returns two values. The first value will be the event id and the second value will be **t** if the event is in the waiting queue, **nil** if it is in the event queue, and **:abort** if it was not scheduled. If there is no current model or any of the parameters are invalid, then no event is scheduled and a single value of **nil** is returned.

Examples:

see schedule-even-after-module for similar examples

schedule-periodic-event

Syntax:

schedule-periodic-event *period action* {**:module** *module-value*} {**:destination** *destination-value*}
{**:params** *params-value*} {**:details** *details-value*}
{**:initial-delay** *initial-delay-value*} {**:priority** *priority-value*}
{**:maintenance** *maintenance-value*} {**:output** *output-value*}
{**:time-in-ms** *time-units*}
-> [event-id | **nil**] {[**t** | **nil** | **:abort**]}

Remote command name:

schedule-periodic-event *period action* { < **module** *module-value*, **destination** *destination-value*,
params *params-value*, **details** *details-value*,
initial-delay *initial-delay-value,* **maintenance** *maintenance-value*,
priority *priority-value,* **output** *output-value,*
time-in-ms *time-units* > }

Arguments and Values:

period ::= a number indicating the time after which this action should be evaluated again
action ::= a command identifier of the action to perform or **nil**
module-value ::= the name of the module which is scheduling the event (default **:none**)
destination-value ::= the name of a module
priority-value ::= [**:max** | **:min** | a number] (default 0)
params-value ::= a list of values to pass to the action (default **nil**)
time-units ::= a generalized boolean indicating whether the time is set in milliseconds (default **nil**)
maintenance-value ::= generalized boolean indicating whether this is a maintenance event (default **nil**)
details-value ::= a string to output in the trace or **nil** (default **nil**)
output-value ::= [**t** | **high** | **medium** | **low** | **nil**] (default **t**)
initial-delay-value ::= a number indicating time before the first such event (default 0)
event-id ::= an integer which can be used to reference the event created

Description:

Schedule-periodic-event creates a new event with a time that is equal to the current time plus initial-delay and using the other supplied parameters for its corresponding attributes and the current model for its model. After that event occurs a new event will automatically be scheduled to occur period seconds (or milliseconds if :time-in-ms is specified as true) after that time with the same parameters as the initial one. That rescheduling will continue every period seconds (or milliseconds) until the event id this function returned is deleted.

If any of the parameters are invalid or there is no current model or current meta-process then a warning is printed, no event is scheduled, and **nil** is returned.

Note that there are actually two events generated for each occurrence of the event described. The first is a maintenance event with the priority provided. It schedules the actual event described with the parameters specified with a priority of **:max** (so that it should be the next event to execute) and also schedules the next periodic event at the appropriate delay.

If the action is **nil** then no command is executed when the event occurs. This can be useful if one wants to use an event's details to provide information in the trace without having to create a command to do so.

Examples:

```
1> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
```

```
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
2

2> (schedule-periodic-event 1 "model-output" :params (list "now") :initial-delay .5)
3

3> (mp-show-queue)
Events in the queue:
     0.000   NONE                   CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.500   NONE                   Periodic-Action model-output 1
3

4> (run 2)
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
now
     0.500   PROCEDURAL             CONFLICT-RESOLUTION
now
     1.500   PROCEDURAL             CONFLICT-RESOLUTION
     2.000   ------                 Stopped because time limit reached
2.0
8
NIL

E> (schedule-periodic-event nil "model-output")
#|Warning: period must be greater than 0. |#
NIL
```

schedule-break, schedule-break-relative

Syntax:

schedule-break *time* {**:details** *details-value*}{**:priority** *priority-value*}{**:time-in-ms** *time-units*} -> [event-id | **nil**]

schedule-break-relative *delta-time* {**:details** *details-value*}{**:priority** *priority-value*}{**:time-in-ms** *time-units*}
-> [event-id | **nil**]

Remote command name:

schedule-break *time* {< **details** *details-value,* **priority** *priority-value,* **time-in-ms** *time-units* >}
schedule-break-relative *delta-time* {< **details** *details-value,* **priority** *priority-value,* **time-in-ms** *time-units* >}

Arguments and Values:

time ::= a number representing an absolute time for the event
delta-time ::= a number representing a time delay before executing the event
details-value ::= a string to output in the trace or **nil** (defaults to **nil**)
priority-value ::= [**:max** | **:min** | a number] (defaults to **:max**)
time-units ::= a generalized boolean indicating whether the time is in milliseconds (default **nil**)
event-id ::= an integer which can be used to reference the event created

Description:

Schedule-break creates a new break event at the specified time with the priority-value and details-value provided. Schedule-break-relative creates a new break event at the specified amount of time from the current time with the priority-value and details-value provided. The model of those events

will be **nil** (a break event does not exist within a specific model), the module is set to :none, and the output for that event is set to low. A break event does not have an action and is only used to stop the scheduler. That new event is then added to the event queue and its id is returned.

If any of the parameters are invalid then a warning is printed, no event is scheduled, and **nil** is returned.

Examples:

```
1> (schedule-break 5.5 :details "Stop by this break")
3

2> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     5.500   ------                BREAK-EVENT Stop by this break
3

3> (run-full-time 10)
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     5.500   ------                BREAK-EVENT Stop by this break
5.5
3
T

E> (schedule-break 'bad)
#|Warning: Time must be non-negative number. |#
NIL

E> (schedule-break 10 :priority 'bad)
#|Warning: Priority must be a number or :min or :max. |#
NIL
```

schedule-break-after-module

Syntax:

schedule-break-after-module *after-module* {**:details** *details-value*} {**:delay** *delay-value*}
{**:dynamic** *dynamic-value*} -> [event-id | **nil**] {[**t** | **nil** | **:abort**]}

Remote command name:

schedule-break-after-module *after-module* {< **details** *details-value,* **delay** *delay-value,*
dynamic *dynamic-value* >}

Arguments and Values:

after-module ::= the name of a module
details-value ::= a string to output in the trace or **nil** (defaults to **nil**)
delay-value ::= [**t** | **nil** | **:abort**] (defaults to **t**)
dynamic-value ::= generalized boolean indicating whether to allow rescheduling (defaults to **nil**)
event-id ::= an integer which can be used to reference the event created

Description:

Schedule-break-after-module creates a new event using the supplied parameters for its corresponding attributes and the current model as its model. That event will be scheduled to occur after the next event of the specified module in the same model as the current one.

If there is an event currently in the event queue with the module name of after-module for the current model then this new break event is placed into the event queue at the time of the next such matching event (lowest time) with a priority of **:min**.

If there is no event in the event queue that matches the model and module, then the delay value determines what happens to the new break event.

If delay-value is **t** then the new break event is placed into the set of waiting events to be scheduled after an event which matches the conditions necessary to schedule this new event.

If delay-value is **nil** then the new break event is added to the event queue for immediate execution. Its time will be set to the current time and its priority will be **:max**.

If delay-value is **:abort** then the new break event is discarded without being scheduled or placed onto the waiting queue.

A successful schedule-break-after-module returns two values. The first value will be the event id and the second value will be **t** if the event is in the waiting queue or **nil** if it is in the event queue. If the event is aborted, the first value will be **nil** and the second value will be **:abort**. If there is an invalid parameter provided then no event is scheduled, a warning is output, and a single value of **nil** is returned.

Examples:

```
1> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
2

2> (schedule-break-after-module 'procedural :details "after procedural")
3
NIL

3> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   ------                BREAK-EVENT after procedural
3

4> (schedule-break-after-module :vision :details "waiting for vision")
4
T

5> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   ------                BREAK-EVENT after procedural
3

6> (mp-show-waiting)
```

```
Events waiting to be scheduled:

   ------                 BREAK-EVENT waiting for vision Waiting for: (:MODULE :VISION T)

1

7> (schedule-break-after-module :vision :details "not waiting on vision" :delay nil)
5
NIL

8> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   ------                BREAK-EVENT not waiting on vision
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   ------                BREAK-EVENT after procedural
4

9> (schedule-break-after-module :vision :delay :abort)
NIL
:ABORT

10> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   ------                BREAK-EVENT not waiting on vision
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   ------                BREAK-EVENT after procedural
4

11> (mp-show-waiting)
Events waiting to be scheduled:

   ------                 BREAK-EVENT waiting for vision Waiting for: (:MODULE :VISION T)

1

E> (schedule-break-after-module :bad)
#|Warning: after-module must name a module. |#
NIL
```

schedule-break-after-all

Syntax:

schedule-break-after-all {*details*} -> event-id

Remote command name:

schedule-break-after-all

Arguments and Values:

details ::= a string to output in the trace or **nil** (defaults to **nil**)
event-id ::= an integer which can be used to reference the event created

Description:

Schedule-break-after-all creates a new break event with the provided details. The time for this new event is the greatest time of any event currently in the event queue and its priority is :min. It will be inserted into the event queue such that it will occur after all of the events currently scheduled. The id of the event created is returned.

Examples:

```
1> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     9.000   NONE                  future event
3

2> (schedule-break-after-all "at the end")
4

3> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     9.000   NONE                  future event
     9.000   ------                BREAK-EVENT at the end
4
```

delete-event

Syntax:

delete-event *event-id* -> [**t** | **nil**]

Remote command name:

delete-event

Arguments and Values:

event-id ::= an integer which was returned by one of the scheduling functions to represent an event

Description:

If event-id represents an event which is currently in either the event queue or the waiting queue then delete-event removes that event from the queue it is in and returns **t**.

If the item is not in either event queue no action is taken and **nil** is returned. If an invalid value is provided a warning is printed and **nil** is returned.

Examples:

```
1> (schedule-event 4 nil :details "the event")
3

2> (mp-show-queue)
Events in the queue:
```

```
     0.000   NONE                    CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     4.000   NONE                    the event
3

3> (delete-event 3)
T

4> (mp-show-queue)
Events in the queue:
     0.000   NONE                    CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
2

5> (delete-event 3)
NIL

E> (delete-event -1)
NIL

E> (delete-event 'bad)
#|Warning: BAD is not a valid event identifier. |#
NIL
```

Event Hooks

In addition to being able to schedule events it is possible to add commands which can monitor the events as they are executed. One can add what is called an "event hook" command which will be passed the event id of each event in the queue either before or after it is executed. The event hook can be used for recording information about what has happened in the model (for instance if one wanted to add an alternate tracing mechanism) or for checking for particular events to occur for data collection or other purposes. When created, a hook command is added to the meta-process and persists across a reset. They are only removed if they are explicitly deleted with the delete-event-hook command or when a call to clear-all happens.

add-pre-event-hook, add-post-event-hook

Syntax:

add-pre-event-hook *hook-fn* {*warn-for-duplicate*} -> [hook-id | **nil**]
add-post-event-hook *hook-fn* {*warn-for-duplicate*} -> [hook-id | **nil**]

Remote command name:

add-pre-event-hook
add-post-event-hook

Arguments and Values:

hook-fn ::= a command identifier of the action to perform
hook-id ::= a number which is the reference for the hook function that was added
warn-for-duplicate ::= a generalized boolean which indicates whether or not to show a warning if the same function is attempted to be put on the event hook again (default is **t**)

Description:

If hook-fn is a valid command which is not already in the set of event hooks indicated (either pre or post) for the meta-process then it will be added to the appropriate set of event hooks. The commands for the pre-event hooks will be called before each event on the queue is evaluated and the post-hook commands will be called after each event is evaluated. The hook command will be passed the event id of that event as its only parameter.

If the hook command is added to one of the meta-process event hook sets, then a unique hook-id is returned which can be used to explicitly remove that command from the set of event hooks.

If hook-fn is invalid then a warning is printed and **nil** is returned. If hook-fn is already in the indicated set of event hooks then **nil** is also returned and a warning is printed unless warn-for-duplicate is provided as **nil.**

The return value of the hook-fn set as a post-event is ignored. The return value of the hook-fn set as a pre-event it tested by the scheduler and if it is the string “break” then that will force the schedule to stop running as if a break event had been scheduled before the event that triggered the calling of the pre-event hook-fn.

Examples:

This example assumes that the count model from unit 1 of the tutorial is loaded.

```
1> (defun show-event (id)
      (model-output "Hook sees event from module: ~s" (evt-module id)))
SHOW-EVENT

2> (add-pre-event-hook 'show-event)
0

3> (run .05)
Hook sees event from module: :NONE
Hook sees event from module: GOAL
     0.000   GOAL                 SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
Hook sees event from module: PROCEDURAL
     0.000   PROCEDURAL           CONFLICT-RESOLUTION
Hook sees event from module: PROCEDURAL
     0.000   PROCEDURAL           PRODUCTION-SELECTED START
Hook sees event from module: PROCEDURAL
Hook sees event from module: PROCEDURAL
     0.000   PROCEDURAL           BUFFER-READ-ACTION GOAL
Hook sees event from module: GOAL
Hook sees event from module: PROCEDURAL
     0.050   PROCEDURAL           PRODUCTION-FIRED START
Hook sees event from module: PROCEDURAL
     0.050   PROCEDURAL           MOD-BUFFER-CHUNK GOAL
Hook sees event from module: PROCEDURAL
     0.050   PROCEDURAL           MODULE-REQUEST RETRIEVAL
Hook sees event from module: PROCEDURAL
     0.050   PROCEDURAL           CLEAR-BUFFER RETRIEVAL
Hook sees event from module: DECLARATIVE
     0.050   DECLARATIVE          start-retrieval
Hook sees event from module: PROCEDURAL
     0.050   PROCEDURAL           CONFLICT-RESOLUTION
     0.050   ------               Stopped because time limit reached
0.05
13
```

```
NIL

4E> (add-pre-event-hook 'show-event)
#|Warning: SHOW-EVENT is already on the pre-event-hook list not added again |#
NIL

5> (add-pre-event-hook 'show-event nil)
NIL


1> (defvar *e-count* 0)
0

2> (defun pre-event-break (e)
    (declare (ignore e))
    (when (> (incf *e-count*) 6)
      "break"))
PRE-EVENT-BREAK

3> (add-pre-event-hook 'pre-event-break)
0

4> (run 1)
     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   PROCEDURAL            PRODUCTION-SELECTED START
     0.000   PROCEDURAL            BUFFER-READ-ACTION GOAL
     0.000   ------                BREAK-EVENT forced by a pre-event hook
0.0
6
T

E> (add-pre-event-hook 'bad)
#|Warning: parameter BAD to add-pre-event-hook is not a function |#
NIL
```

delete-event-hook

Syntax:

delete-event-hook *hook-id* -> [hook-fn | **nil**]

Remote command name:

delete-event-hook

Arguments and Values:

hook-id ::= a hook function id returned by one of the add event hook functions
hook-fn ::= the command identifier that was removed from the event hook

Description:

If the event hook command associated with hook-id is still a member of the set of event hooks in the current meta-process then it is removed from the set of hook commands and the command identifier that was used to create the event hook is returned.

If hook-id does not correspond to the id of an event hook or the command has already been removed from the set of event hooks then **nil** is returned.

Examples:

This example assumes that the count model from unit 1 of the tutorial is loaded.

```
1> (defun show-event (id)
      (model-output "Hook sees event from module: ~s" (evt-module id)))
SHOW-EVENT

2> (add-post-event-hook 'show-event)
0

3> (run .01)
Hook sees event from module: :NONE
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
Hook sees event from module: GOAL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
Hook sees event from module: PROCEDURAL
     0.000   PROCEDURAL              PRODUCTION-SELECTED START
Hook sees event from module: PROCEDURAL
Hook sees event from module: PROCEDURAL
     0.000   PROCEDURAL              BUFFER-READ-ACTION GOAL
Hook sees event from module: PROCEDURAL
Hook sees event from module: GOAL
Hook sees event from module: :NONE
     0.010   ------                  Stopped because time limit reached
0.01
7
NIL

4> (delete-event-hook 0)
SHOW-EVENT

5> (run .05)
     0.050   PROCEDURAL              PRODUCTION-FIRED START
     0.050   PROCEDURAL              MOD-BUFFER-CHUNK GOAL
     0.050   PROCEDURAL              MODULE-REQUEST RETRIEVAL
     0.050   PROCEDURAL              CLEAR-BUFFER RETRIEVAL
     0.050   DECLARATIVE             start-retrieval
     0.050   PROCEDURAL              CONFLICT-RESOLUTION
     0.060   ------                  Stopped because time limit reached
0.05
6
NIL

6> (delete-event-hook 0)
NIL

E> (delete-event-hook 'bad)
NIL
```

About the Included Modules and Components

The modules that are included with ACT-R fall into three general categories. The first is system or control modules and components which are not based on the theory and only serve to provide functionality in the software. The second and third categories are the cognitive modules which represent the theory of ACT-R. Those are subdivided into modules which provide the perceptual and motor actions which allow models to interact with an environment and modules which represent cognitive capabilities completely within the model. The only reason for distinguishing between the two types of cognitive modules is that the perceptual and motor modules include an interface for interacting with the world whereas the purely cognitive modules do not.

In addition to the modules there are also components which provide important functionality for the software. The components operate independently of models (unlike modules where each model has its own instance of a module) and are not based on the ACT-R theory – they are all purely a construct of the software system.

Most of the remaining sections of this manual will be describing the modules and components of the system. When describing those items the general operation will be provided along with any parameters and commands that it makes available. For the modules, it will also indicate the buffers which the module has (if any) and the requests and queries which are available through those buffers.

Printing module

The printing module provides the modeler with some control over the level of output which the system provides as well as some options for redirecting output instead of using the standard trace signals. That control is provided through several parameters to configure the output. The commands available for outputting information are described in the Generating Output section. This is a software module and thus does not have a buffer or affect the results of a model's operation.

This module is named printing-module and will always be available.

Parameters

:cbct

The copy buffer chunk trace parameter. This parameter controls whether or not an event will be shown in the trace indicating that a buffer has made a copy of a chunk. It can take a value of **t** or **nil**.

The default is **nil**.

If it is set to **t** then an event like this will be shown in the trace each time a buffer makes a copy of a chunk:

```
0.000   BUFFER            Buffer GOAL copied chunk FIRST-GOAL to GOAL-CHUNK0
```

It is always attributed to a module named "buffer" and indicates which buffer made the copy along with the name of the original chunk and the name of the copy. Those events will be shown with the high and medium trace detail settings. Note that the chunk copied to is not always a new chunk as shown here from the count model in unit 1 of the tutorial:

```
0.100   BUFFER            Buffer RETRIEVAL copied chunk TWO to RETRIEVAL-CHUNK0
0.200   BUFFER            Buffer RETRIEVAL copied chunk THREE to RETRIEVAL-CHUNK0
```

See the buffers section for more information about copying.

:cmdt

The command trace parameter controls where the command output is displayed.

The possible values for :cmdt are:

- **nil –** this turns off the command output for this model
- **t –** send the command output to the command trace
- a string – it attempts to open a file using that string as the name and if successful appends all command output to that file
- a Lisp stream – the command output is sent to that stream
- a Lisp pathname – it attempts to open the specified file and if successful it appends all command output to that file

The default value is **t.**

If a file is used, it will be opened when the parameter is set and closed when either the parameter is changed again or the model is deleted. Note that for file output the actual output to the file may be buffered in Lisp before being written. Thus, that output file should not be opened or read by anything else until the model is done with its output. Resetting or deleting the model will signal that it is done as will setting the :cmdt parameter to some other value, and setting it to **nil** is a safe way to signal that the output is done and have the file closed safely.

When a string or pathname is used to set the parameter the value that is returned will be that string or the namestring of that pathname. Setting it to a Lisp stream is not recommended if the remote interface is enabled because such a value cannot be accessed through the remote interface.

:model-warnings

The model-warnings parameter controls whether or not model warnings are displayed. It can be set to **t** or **nil**. If it is set to **t**, then the model warnings are shown and if it is set to **nil** then they are not.

The default value is **t**.

:trace-detail

The trace-detail parameter controls which events are shown in the model's trace. It can be set to one of the values: **high**, **medium**, or **low**. The default value is **medium**.

If it is set to **high**, then all events which have a non-**nil** output setting are displayed. If it is set to **medium** then only those events with a **medium** or **low** output setting are shown, and if it is set to **low**, then only those events with a **low** output setting are shown.

:trace-filter

The trace-filter parameter allows one more detailed control over which events are displayed in the trace. It can be set to a function, function name, string which names a command, or **nil**.

The default is **nil**.

If it is set to a function or command (which we will refer to as the trace-filter) then the trace-filter must accept one parameter. For each event that will be displayed in the trace given the current **:trace-detail** setting the trace-filter will be called with the event id of that event as its parameter. If the trace-filter returns **nil** then that event will not be displayed in the trace. Otherwise, the event will be displayed as usual.

There is one filtering function available with the system which is often useful, called **production-firing-only**. If that is set as the value of :trace-filter it will restrict the trace output to only the production-fired events.

:v

The verbose parameter. The :v parameter controls where the model output is displayed. The trace of the model is included in model output.

The possible values for :v are:

- **nil –** this turns off the model output for this model
- **t –** send the command output to the model trace
- a string – it attempts to open a file using that string as the name and if successful appends all model output to that file
- a Lisp stream – the model output is sent to that stream
- a Lisp pathname – it attempts to open the specified file and if successful it appends all model output to that file

The default value is **t**.

If a file is used, it will be opened when the parameter is set and closed when either the parameter is changed or the model is deleted. Note that for file output the actual output to the file may be buffered in Lisp before being written. Thus, that output file should not be opened or read by anything else until the model is done with its output. Resetting or deleting the model will signal that it is done as will setting the :v parameter to some other value, and setting it to **nil** is a safe way to signal that the output is done and have the file closed safely.

When a string or pathname is used to set the parameter the value that is returned will be that string or the namestring of that pathname. Setting it to a Lisp stream is not recommended if the remote interface is enabled because such a value cannot be accessed through the remote interface.

Naming Module and Component

There is both a naming module and a naming component to provide the system with a consistent means of generating names of things, particularly chunks. The module is used within models to create names and the component is available outside of the context of a model for generating names. These items guarantee that the system does not duplicate names within a model and that the name returned does not already name a chunk. It also allows for the appropriate garbage collection of names (the uninterning of the underlying symbols) that were generated when the model is reset or deleted if they are not also in use in other models. This module and component only provide functionality for the system – it is not a cognitive module.

The names are generated by appending an increasing counter to the end of a provided name prefix (each prefix has its own counter). An additional benefit of the naming module is that the counters are reset to 0 when the model is reset. Thus, a deterministic model will always result in the same sequence of names being created when it is run after being reset, which can be very useful for debugging a model. Because the random module allows one to set the seed for the pseudo-random numbers the model generates, one can also temporarily make a stochastic model deterministic for debugging purposes.

The module is named naming-module and will always be available.

Parameters

:dcnn

The dynamic chunk name normalizing parameter. The :dcnn parameter works in conjunction with the :ncnar parameter to normalize chunk names. If :ncnar is set to **t** or **delete** then :dcnn controls whether the model will normalize the chunk names while the model runs in addition to normalizing at the end of the run. If :dcnn is set to **t** then the chunk names stored in slots of chunks will be automatically updated whenever chunks are merged such that all chunks hold only the true chunk names of chunks in their slots. It essentially spreads the normalizing out during the run instead of performing it all at the end, but it will not delete any chunks until the end of the run if :ncnar is set to do so. This may be more efficient for some models and may also make debugging easier when a model breaks or while stepping through a run. If :ncnar is set to **nil** then the setting of the :dcnn parameter has no effect on the system.

The default value is **t**.

:dcsc-hook

The dynamic chunk slot change hook parameter. The :dcsc-hook parameter provides a way for modules or other code to be notified if a chunk is dynamically changed as a result of chunk normalizing. This parameter can be set using a command identifier to add it to the commands which are called. The reported value of this parameter is a list of all the commands which have been set. Whenever a chunk is modified by normalizing, after the normalizing has changed a slot value, each of the items set for this parameter will be called with the name of the chunk that had a slot modified

through normalizing regardless of what triggered the normalizing (whether it was automatic or explicitly called).

To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed.

If the parameter is set to **nil** then all items are removed from the dcsc-hook.

The default value is **nil**.

:ncnar

The normalize chunk names after run parameter. The :ncnar parameter controls whether the model will call normalize-chunk-names after every call to one of the model running functions. If it is set to **t** then normalize-chunk-names will be called (without specifying the unintern parameter). If it is set to the value **delete** then normalize-chunk-names will be called with the unintern parameter true. If it is set to **nil** then normalize-chunk-names will not be called.

Having normalize-chunk-names called can be useful for debugging, but if the model generates a lot of chunks it may take a significant amount of time to complete. Thus for models that generate a lot of chunks, or for which there are several calls to model running functions, setting this parameter to **nil** may improve the system performance.

The value of **delete** is provided as an option for extreme cases where the model is exhausting the computer memory and unable to run. Setting it to **delete** is not recommended for general use because some modules may have internal references to the chunk names which will be made invalid when the uninterning option is used. Extra caution should therefore be used when specifying a value of **delete** for :ncnar.

The default value is **t**.

:short-copy-names

The :short-copy-names parameter controls how chunk names are created when a chunk is copied. The most common place for this to occur is when a chunk is placed into a buffer which copies it automatically. If the parameter is set to **nil** then the copy will have a hyphen and a number appended to it. The number is typically 0, but if that would conflict with another name it will be incremented until it is “safe” (see the new-name command). If this parameter is set to **t** then instead of adding a new hyphen and number when copying a chunk which is itself a copy only the number will be incremented as needed.

Assuming there are no conflicts, with this parameter set to **nil** if a chunk named “chunk” is copied it will be named chunk-0 and if chunk-0 is copied that new chunk will be named chunk-0-0. If this parameter is set to **t** then copying chunk will still result in chunk-0, but copying chunk-0 will result in the name chunk-1. In either case, if a chunk named chunk-0 is created explicitly by the model (it is not a copy of a chunk named chunk) then a copy of that chunk will be named chunk-0-0.

This parameter only really matters if copies of chunks are being made from copies – either directly or through the actions of modules like declarative or vision which may reuse copies of chunks. Its

setting should not affect how the model operates with the standard modules because they do not rely on specific chunk names.

The default value is **nil**.

Commands

new-name

Syntax:

new-name {*prefix*} -> [name-symbol | **nil**]
new-name-fct {*prefix*} -> [name-symbol | **nil**]

Remote command name:

new-name

Arguments and Values:

prefix ::= if provided should be a string or symbol (defaults to “CHUNK” if not given)
name-symbol ::= a symbol created by appending a number onto the prefix

Description:

New-name is used to generate unique name symbols (which have been interned) within a model, similar to the Lisp function gentemp. Unlike gentemp, it does not guarantee that the symbol does not already exist. What it does guarantee is that it was not previously returned by new-name within the current run of the model and that it is not currently used to name a chunk in the current model.

When the module is deleted or reset it clears its name space and uninterns any symbols it has generated which are no longer "necessary". By necessary, it means that no instance of the naming module has generated such a name, nor was that symbol interned prior to new-name generating it for the first time.

If there is no current model or a parameter other than a symbol or string is provided then a warning is printed and **nil** is returned.

Anywhere a modeler working in Lisp would consider using gentemp, new-name should probably be used instead to guarantee the automatic cleanup upon reset or model deletion and for consistency when the :seed parameter is set to make a model deterministic. Note that it is typically not necessary to generate a name for a new chunk because omitting a name in the call to define-chunks results in the chunk getting a name generated by new-name automatically.

Examples:

```
> (new-name)
CHUNK0

> (new-name temp)
```

```
TEMP0

1> (new-name-fct 'fact)
FACT0

2> (new-name-fct "FACT")
FACT1

1> (new-name "temp")
TEMP1

2> (define-chunks (temp2 isa chunk))
(TEMP2)

3> (new-name "temp")
TEMP3

E> (new-name 10)
#|Warning: Invalid parameter passed to new-name.  Must be a string or symbol. |#
NIL

E> (new-name)
#|Warning: get-module called with no current model. |#
#|Warning: No naming module available cannot create new name. |#
NIL
```

release-name

Syntax:

release-name *name* -> [**t** | **nil**]
release-name-fct *name* -> [**t** | **nil**]

Remote command name:

release-name

Arguments and Values:

name ::= a symbol which was generated by new-name

Description:

Release-name can be used to possibly unintern symbols which have been generated by new-name. This is the same process which occurs on a reset or deletion of the naming module for symbols generated by new-name, but in some circumstances one may want to perform such a cleanup without resetting. Thus, if the symbol given in name was generated by the new-name command and no instance of the naming module other than the one in the current model has generated such a name and that symbol was not interned prior to new-name generating it for the first time then it is uninterned.

If the symbol is uninterned, then **t** is returned otherwise **nil** is returned.

If there is no current model then a warning is printed and **nil** is returned.

Generally, this command is not necessary because a reset or clear-all will automatically clear out the symbols. However, if one is generating an extremely large number of temporary names with new-name it can lead to issues with the size of the symbol table in Lisp and explicitly removing names prior to a reset may be useful.

Examples:

```
1> (find-symbol "CHUNK0")
NIL
NIL

2> (new-name)
CHUNK0

3> 'chunk1
CHUNK1

4> (find-symbol "CHUNK1")
CHUNK1
:INTERNAL

5> (new-name)
CHUNK1

6> (release-name-fct 'chunk0)
T

7> (release-name chunk1)
NIL

8> (release-name-fct 'chunk0)
NIL

E> (release-name chunk0)
#|Warning: get-module called with no current model. |#
#|Warning: No naming module available cannot release name CHUNK0. |#
NIL
```

new-symbol

Syntax:

new-symbol {*prefix*} -> [new-symbol | **nil**]
new-symbol-fct {*prefix*} -> [new-symbol | **nil**]

Remote command name:

new-symbol

Arguments and Values:

prefix ::= if provided should be a string or symbol (defaults to “CHUNK” if not given)
new-symbol ::= a newly interned symbol created by appending a number onto the prefix

Description:

New-symbol is used to generate and intern a unique symbol, similar to the Lisp function gentemp and the new-name command. Like gentemp, it guarantees that the symbol does not already exist. Unlike the command new-name, it does not guarantee that the numbering is reset within a model because new-symbol operates outside of the context of a model.

When a clear-all happens all of the symbols generated by new-symbol are uninterned.

New-symbol should only be used when one needs a completely new symbol and the name of that symbol is not meaningful to a model (for instance something that might show up in the trace should use new-name), or when names are needed outside of the context of a model.

Examples:

```
> (new-symbol)
CHUNK-0

1> (new-symbol "temp")
TEMP-0

2> (new-symbol-fct 'temp)
TEMP-1

3> (let (temp-2 temp-3))
NIL

4> (new-symbol temp)
TEMP-4
```

Random module

The random module provides a consistent pseudorandom number generator for the system. It is not dependent on the Lisp random function or the Lisp *random-state* global variable. This makes it consistent across all instances of ACT-R regardless of the Lisp application or OS being used. This is very useful for teaching because it guarantees the output of the tutorial material will be the same for all users. It also makes models and modules easier to debug and verify because the random state can be set with an ACT-R parameter for testing to make the model deterministic. It also serves to protect the model from any potential weaknesses in the random function of a particular Lisp.

The particular pseudorandom number generator chosen is the Mersenne Twister (as implemented by the mt19937ar.c code) because it is designed for Monte-Carlo simulations. Details can be found at:

http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html

That algorithm is used by some Lisps for the random function already. However, because the internal representations of state differ among Lisps it is still necessary to use the ACT-R random module implementation for consistency of ACT-R across systems.

This module is named random-module and will always be available.

Parameters

:randomize-time

This parameter can be set to **t**, **nil**, or an integer. It is used by the randomize-time command to determine the range in which a specified time will be randomized. The randomize-time command is used mainly by the perceptual and motor modules to add noise to the action times.

The default value is **nil** which means not to randomize the times. A value of **t** is the same as setting the value to 3.

:seed

This is the current seed for the pseudorandom number generator. It must be a list of two numbers. The first is used to initialize the array used by the Mersenne Twister algorithm and the second is an offset from that starting point where the model should start (or where it currently is if the value is read after the model has been run). Thus, if one is specifying a seed explicitly, the second number should probably be kept "small" because that many pseudorandom numbers will be generated when the parameter is set to get to the offset point.

There is no default value for the seed parameter. When the module is created in a model it generates a new seed based on the current result of get-internal-real-time. Resetting the model does not return the seed to that point – the random module will continue generating new pseudorandom numbers from the point where it last left off.

Commands

act-r-random

Syntax:

act-r-random *limit* -> [value | **nil**]

Remote command name:

act-r-random

Arguments and Values:

limit ::= a positive number (either an integer or floating point)
value ::= a pseudorandom number which is non-negative and less than limit

Description:

Act-r-random will operate like random as defined in the ANSI Lisp specification, except without the optional parameter for a random-state. It uses the seed value from the current model to generate the next random number. Thus unless models explicitly set the same seed value each model will have a different sequence of pseudorandom numbers returned by act-r-random.

It returns a pseudorandom number that is a non-negative number less than limit and of the same type as limit. An approximately uniform choice distribution is used. If limit is an integer, then each of the possible results occurs with (approximate) probability 1/limit.

If an invalid value is passed to act-r-random then a warning is printed and **nil** is returned.

If there is no current model a warning will be printed and a pseudorandom number generated from a special instance of the random module will be returned.

Examples:

```
1> (sgp :seed)
:SEED (94875970549 0) (default NO-DEFAULT) : Current seed of the random number generator
((94875970549 0))

2> (act-r-random 100)
46

3> (act-r-random 34.5)
11.947622

4> (act-r-random 1000)
679

5> (act-r-random 0.5)
0.31684825

6> (sgp :seed (94875970549 1))
((94875970549 1))

7> (act-r-random 34.5)
11.947622
```

```
8> (act-r-random 1000)
679

9> (act-r-random 0.5)
0.31684825

E> (act-r-random 'a)
#|Warning: Act-r-random called with an invalid value A |#
NIL

E> (act-r-random 2)
#|Warning: get-module called with no current model. |#
0
```

act-r-noise

Syntax:

act-r-noise *s* -> [value | **nil**]

Remote command name:

act-r-noise

Arguments and Values:

s ::= a non-negative number
value ::= a pseudorandom number generated as described below

Description:

Act-r-noise generates a value from a logistic distribution (approximation of a normal distribution) with a mean of 0 and an s value as given. It does this using the act-r-random function. The s value is related to the variance of the distribution, σ^2, by this equation:

$$\sigma^2 = \frac{\pi^2}{3} s^2$$

If s is invalid a warning is printed and **nil** is returned.

If there is no current model a warning will be printed and the noise will be based on a pseudorandom number generated from a special instance of the random module (as indicated by act-r-random).

Examples:

```
> (act-r-noise 0)
0.0

> (act-r-noise .5)
0.15807568

> (act-r-noise .5)
```

```
1.4271247

E> (act-r-noise 'a)
#|Warning: Act-r-noise called with an invalid s A |#
NIL

E> (act-r-noise .5)
#|Warning: get-module called with no current model. |#
-1.131652
```

randomize-time, randomize-time-ms

Syntax:

randomize-time *time* -> [time | rand-time]
randomize-time-ms *ms-time* -> [ms-time | ms-rand-time]

Remote command name:

randomize-time
randomize-time-ms

Arguments and Values:

time ::= a number
rand-time ::= a randomized time value
ms-time ::= an integer
ms-rand-time ::= an integer randomized time value

Description:

Randomize-time and randomize-time-ms are used to return a number randomly chosen from a uniform distribution around the provided time. They depend on the setting of the :randomize-time parameter in the current model. If the parameter is set to **nil** then no randomization is done and the given time is returned.

If the :randomize-time parameter is a number or **t** (which means use the default value of 3) then a number randomly chosen from the uniform distribution in the range of:

$$\left[time * \frac{n-1}{n}, time * \frac{n+1}{n}\right)$$

where n is the value of :randomize-time, will be returned. The difference between randomize-time and randomize-time-ms is that the latter requires an integer value and will return an integer result with the bounds being rounded and inclusive of the upper bound.

If time is not a number or there is no current model or meta-process, then a warning is printed and time is returned.

Examples:

```
1> (sgp :randomize-time nil)
(NIL)

2> (randomize-time 10)
10

1> (sgp :randomize-time t)
(T)

2> (randomize-time 50)
65.277435

3> (randomize-time 50.0)
58.443718

1> (sgp :randomize-time 100)
(100)

2> (randomize-time 100)
100.1965

3> (randomize-time 100)
99.349

4> (randomize-time-ms 100)
101

5> (randomize-time-ms 100)
99

6> (randomize-time-ms 100)
100

E> (randomize-time 'a)
#|Warning: Invalid value passed to randomize-time: A |#
A

E> (randomize-time-ms 1.0)
#|Warning: Invalid value passed to randomize-time-ms: 1.0. Value must be an integer. |#
1.0

E> (randomize-time 10)
#|Warning: get-module called with no current model. |#
10
```

History Recorder

There is a module and a component in the system which together provide a consistent mechanism that other modules and components can use to provide the user access to information which has been recorded including the ability to save and retrieve that information to/from files. These are not cognitive mechanisms of the system, but may be used by cognitive modules to allow users to access their data. The module is named :history-recorder and will always be available.

The basic usage of the history recording is for a module to create a named history "source" to make that data available. Using that name the modeler can start or stop the recording as needed and get any currently available recorded data from that source, save that data to a file, or read the data from a file. The specific format of the returned or saved data is dependent upon the creator of the history source, but it will be encoded in a string using JSON when returned or saved. [Note however, that when the system is in single-threaded mode JSON encoding will not be used because it does not load the Quicklisp libraries for JSON parsing. Also, writing data to files and reading saved files will not be available in single-threaded mode to avoid any inconsistency in the data files between the normal and single-threaded versions.]

When the data is saved to a file that data will always be encoded in a JSON object of this form:

```
{"name":  "<history-source>",
 "date": "YYYY/MM/DD HH:MM:SS",
 "comment": "<comment>",
 "data": <data>}
```

Where <history-source> is the name of the history source, the date information is the current time when the file is saved, the comment attribute is only included if a comment string was provided when saving the data, and <data> is the JSON string of the current data in the same format as is normally returned for that history source.

Modules and components which have history data that can be recorded will provide the details of that information in their sections of this manual.

This module is named :history-recorder.

Commands

define-history

Syntax:

define-history *name enable disable status get* {*model-based*} -> [**t** | **nil**]
define-history-fct *name enable disable status get* {*model-based*} -> [**t** | **nil**]

Remote command name:

define-history

Arguments and Values:

name ::= a string which is used to access this history information
enable ::= a command identifier
disable ::= a command identifier
status ::= a command identifier
get ::= a command identifier
model-based ::= a generalized boolean which indicates whether the data is saved separately by model

Description:

Define-history is used to create a new history source for recording information. It must be passed a string which indicates the name for this history source. It also requires four commands for using that data source. The enable command will be called with no parameters when the record-history command is called for this history source, and the disable command will be called with no parameters when the stop-recording-history command is called. The return value from those commands is ignored and they should start and stop the recording of the history data as appropriate. The status command must return three values which are generalized booleans that represent whether the history source is currently enabled, whether there is any data recorded, and whether the underlying data source is still available. It will be called with no parameters when record-history and stop-recording-history are called to determine if the source is still alive and whether it is currently active. It will be called with all of the optional parameters provided to history-data-available and get-history-data to determine if there is any data available. The get command will be called with all of the optional parameters passed to get-history-data and it must return a list of data, where each item in that list is also a list with the first item in each list being a number (which is typically a timestamp, but that is not required). That data must also be encodeable in JSON.

If a data source, data processor, or data source constituent part with the given name exists or one or more of the interface parameters is not a valid command then no new history source is created, a warning is printed, and **nil** is returned. Otherwise, the new data source is created and a value of **t** is returned.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (define-history 2 valid-fn valid-fn valid-fn valid-fn)
#|Warning: Name for a history source must be a string, but given 2. |#
NIL

E> (define-history "test" bad-fn valid-fn valid-fn valid-fn)
#|Warning: Enable function for a history source must be a valid command, but given BAD-FN. |#
NIL

E> (define-history "test" valid-fn bad-fn valid-fn valid-fn)
#|Warning: Disable function for a history source must be a valid command, but given BAD-FN. |#
NIL

E> (define-history "test" valid-fn valid-fn bad-fn valid-fn)
#|Warning: Status function for a history source must be a valid command, but given BAD-FN. |#
NIL
```

```
E> (define-history "test" valid-fn valid-fn valid-fn bad-fn)
#|Warning: Get data function for a history source must be a valid command, but given BAD-FN. |#
NIL

1> (define-history "test" valid-fn valid-fn valid-fn valid-fn)
T

E> (define-history "test" valid-fn valid-fn valid-fn valid-fn)
#|Warning: Cannot create a history source with name TEST because it is already used. |#
NIL
```

define-history-constituent

Syntax:

define-history-constituent *history name enable disable status* -> [**t** | **nil**]
define-history-constituent-fct *history name enable disable status* -> [**t** | **nil**]

Remote command name:

define-history-constituent

Arguments and Values:

history::= a string which is the name of a history source
name ::= a string which names a new constituent of the indicated history source
enable ::= a command identifier
disable ::= a command identifier
status ::= a command identifier

Description:

Define-history-constituent is used to create a new sub-component of a history source for recording information. It must be passed a string which indicates the name of the history source and a name for this new constituent. It also requires three commands for using that constituent part of the history source. The enable command will be called with no parameters when the record-history command is called for this constituent, and the disable command will be called with no parameters when the stop-recording-history command is called. The return value from those commands is ignored and they should start and stop the recording of the indicated constituent part of the history source as appropriate (starting or stopping a constituent part does not automatically start or stop the parent history source). The status command must return three values which are generalized booleans that represent whether the constituent part is currently enabled, whether there is any data recorded, and whether the underlying data source is still available (currently the second result is never used by any of the history data commands for a constituent because the parent source is always consulted instead). It will be called with no parameters when record-history and stop-recording-history are called to determine if the source is still alive and whether it is currently active. It will be called with all of the optional parameters provided to history-data-available and get-history-data to determine if there is any data available.

There is no function for getting the data from a constituent part directly. Only the history source can be used to get data, and attempting to get data using a constituent will get the data for its parent history source.

If history does not name an existing data source, a data source, data processor, or constituent with the given name exists, or one or more of the interface parameters is not a valid function or command then no new constituent is created, a warning is printed, and **nil** is returned. Otherwise, the new data source constituent is created and a value of **t** is returned.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (define-history-constituent 3 "new" valid-fn valid-fn valid-fn)
#|Warning: Name for a history stream must be a string, but given 3. |#
NIL

E> (define-history-constituent "buffer-trace" not-string valid-fn valid-fn valid-fn)
#|Warning: Name for a history stream constituent must be a string, but given NOT-STRING. |#
NIL

E> (define-history-constituent "bad" "new-part" valid-fn valid-fn valid-fn)
#|Warning: Cannot create a history stream constituent with name NEW-PART for history stream
BAD because that stream does not exist. |#
NIL

E> (define-history-constituent "buffer-trace" "buffer-trace" valid-fn valid-fn valid-fn)
#|Warning: Cannot create a history stream constituent with name BUFFER-TRACE because it is
already used. |#
NIL

E> (define-history-constituent "buffer-trace" "new" bad-fn valid-fn valid-fn)
#|Warning: Enable function for a history stream constituent must be a valid command, but
given BAD-FN. |#
NIL

E> (define-history-constituent "buffer-trace" "new" valid-fn bad-fn valid-fn)
#|Warning: Disable function for a history stream constituent must be a valid command, but
given BAD-FN. |#
NIL

E> (define-history-constituent "buffer-trace" "new" valid-fn valid-fn bad-fn)
#|Warning: Status function for a history stream constituent must be a valid command, but
given BAD-FN. |#
NIL
```

define-history-processor

Syntax:

define-history-processor *history processor-name processor* -> [**t** | **nil**]
define-history-processor-fct *history processor-name processor* -> [**t** | **nil**]

Remote command name:

define-history-processor

Arguments and Values:

history::= a string which is the name of a history source
processor-name ::= a string which names a new processor for that history source data
processor ::= a command identifier

Description:

Define-history-processor is used to create a data processor for history source data. It must be passed a string which indicates the name of the history source and a name for this new processor. It also requires a command for processing the data of the history source. When getting data from a history source using a processor the processor command will be called with the current data from that source and the result of that processing will be returned. Additional parameters can also be passed to that processor function if the process-history-data command is used.

If history does not name an existing data source, a data source, processor, or constituent with the given name exists, or the processor is not a valid command then no new processor is created, a warning is printed, and **nil** is returned. Otherwise, the new data source processor is created and a value of **t** is returned.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (define-history-processor 4 "new" valid-fn)
#|Warning: Name for a history source must be a string, but given 4. |#
NIL

E> (define-history-processor "bad" "new" valid-fn)
#|Warning: Cannot create a history source processor named NEW for stream BAD because that
stream is not defined. |#
NIL

E> (define-history-processor "buffer-trace" bad valid-fn)
#|Warning: Name for a history source processor must be a string, but given BAD. |#
NIL

E> (define-history-processor "buffer-trace" "goal" valid-fn)
#|Warning: Cannot create a history source processor with name GOAL because that is already
the name of a history source item. |#
NIL

E> (define-history-processor "buffer-trace" "new" bad-fn)
#|Warning: Processor function for a history source processor must be a valid command, but
given BAD-FN. |#
NIL
```

history-data-available

Syntax:

history-data-available *history* {*param**} -> [**t** | **nil**]

history-data-available-fct *history* {*param**} -> [**t** | **nil**]

Remote command name:

history-data-available

Arguments and Values:

history::= a string which is the name of a history source, history constituent, or processor
param ::= parameter to pass to the history source

Description:

History-data-available is used to check whether there is currently any data available from a data source. Any parameters provided are passed to the status function of that data source to determine if there is data available. If the given history name is the name of a processor or a constituent then it is the source which is associated with those items which is checked.

If history does not name an existing data source, processor, or constituent or the data source requires a current model and there is not one then a warning is printed, and **nil** is returned.

If the status function of the named history source (or associated history source when a processor or constituent is given) returns a true second value then **t** is returned, otherwise **nil**. is returned.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (history-data-available 3)
#|Warning: History-data-available given name 3 but names must be strings. |#
NIL

E> (history-data-available "bad")
#|Warning: BAD does not name a history data item in call to history-data-available. |#
NIL

E> (history-data-available "buffer-trace")
#|Warning: Model based history BUFFER-TRACE requires a current model to check for available
data. |#
NIL
```

record-history

Syntax:

record-history {*history**} -> [**t** | **nil**]*
record-history-fct {*history**} -> [**t** | **nil**]*

Remote command name:

record-history

Arguments and Values:

history::= a string which is the name of a history source, history constituent, or processor

Description:

Record-history is used to indicate that one wants data sources to record history information. For each valid name provided the given source (or associated source if a processor is given) will be enabled if it is not already enabled, and the history system will increment its count of requests to record that source. Recording a constituent of a source does not automatically trigger the recording of that source itself, and a warning will be printed if a constituent is enabled to record when the parent source is not enabled. A source will stay enabled until an equal number of stop-recording-history calls are made for it or until a clear-all happens – reset does not stop the recording but may clear the data depending upon the source.

Record-history will return as many values as names it is given, with each return value being associated with the corresponding given item. If a given item is a valid name and that source is successfully enabled then that return value will be **t**. Otherwise it will be **nil** and a warning as to why it was not enabled will be printed.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (record-history 1)
#|Warning: Record-history given name 1 but names must be strings. |#
NIL

E> (record-history "bad")
#|Warning: "bad" does not name a history data source in call to record-history. |#
NIL

E> (record-history "buffer-trace" "bad")
#|Warning: "bad" does not name a history data source in call to record-history. |#
T
NIL

E> (record-history "goal")
#|Warning: Data source constituent GOAL enabled but parent source BUFFER-TRACE is not. |#
T

E> (record-history "buffer-trace")
#|Warning: Cannot enable model-based history data source BUFFER-TRACE when no model is
available. |#
NIL
```

stop-recording-history

Syntax:

stop-recording-history {*history**} -> [**t** | **nil**]*

stop-recording-history-fct {*history**} -> [**t** | **nil**]*

Remote command name:

stop-recording-history

Arguments and Values:

history::= a string which is the name of a history source, history constituent, or processor

Description:

Stop-recording-history is used to indicate that one no longer wants data sources to record history information. For each valid name provided the given source (or associated source if a processor is given) will have its count of enabling requests (from record-history) decremented, and if there are no longer any pending requests it will be disabled. Stopping the recording a constituent of a source does not affect the recording of that source itself.

Stop-recording-history will return as many values as names it is given, with each return value being associated with the corresponding given item. If a given item is a valid name and that source is now disabled then that return value will be **t**, otherwise it will be **nil**. If there are any problems or unusual situations while stopping a history source a warning will be printed.

Examples:

See the examples/history-source directory for real examples.

```
1E> (stop-recording-history "buffer-trace")
#|Warning: Attempting to stop recording history source BUFFER-TRACE but it hasn't explicitly
been started. |#
T

2> (record-history "buffer-trace")
T

3> (record-history "buffer-trace")
T

4> (stop-recording-history "buffer-trace")
NIL

5> (stop-recording-history "buffer-trace")
T
E> (stop-recording-history 5)
#|Warning: Stop-recording-history given name 5 but names must be strings.|#
NIL

E> (stop-recording-history "bad")
#|Warning: "bad" does not name a history data source in call to stop-recording-history. |#
NIL

E> (stop-recording-history "buffer-trace")
#|Warning: Cannot disable model-based history data source BUFFER-TRACE when no model is
available. |#
NIL
```

get-history-data

Syntax:

get-history-data *history* {*file* {*param**}} -> [data | **nil**] {comment}
get-history-data-fct *history* {*file* {*param**}} -> [data | **nil**] {comment}

Remote command name:

get-history-data

Arguments and Values:

history ::= a string which is the name of a history source, history constituent, or processor
file ::= a string containing a pathname for a file, a Lisp pathname, or **nil**
param ::= parameter to pass to the history source
data ::= a string containing a JSON encoding of the data
comment ::= a string

Description:

Get-history-data is used to get the current data from a data source or the saved data from that source that was written to a file. If the name of a data source constituent is provided the parent source is used to get the data, and if a history processor name is provided the data is processed as described for process-history-data with no processor parameters.

If history does not name an existing data source, processor, or constituent or the data source requires a current model and there is not one then a warning is printed, and **nil** is returned.

If the file name is provided as a non-nil value then that value will be used to attempt to open a file and read the data. If there is an error attempting to open or read that file a warning will be printed and **nil** returned. If the file can be read and it contains valid data for the history source indicated then one or two values will be returned. The first value returned will be the data read from that file. If that data was saved with a comment then a second value will be returned which contains the string of that comment. If the file cannot be read or the data it contains is not valid then a warning is printed and **nil** will be returned.

If a file name is not provided or provided as **nil** then the data source is tested to see if it has data available. If it does not have data available a warning is printed and **nil** is returned. If it does have data available then the get data function for that source is passed any parameters which were provided and if that returns valid data then it is converted to a JSON string and returned. Otherwise, a warning will be printed and **nil** returned.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (get-history-data "buffer-trace")
#|Warning: Model based history BUFFER-TRACE requires a current model to get data. |#
```

```
NIL

E> (get-history-data 1)
#|Warning: Get-history-data given name 1 but names must be strings. |#
NIL

E> (get-history-data "bad")
#|Warning: BAD does not name a history data source in call to get-history-data. |#
NIL

E> (get-history-data "buffer-trace" bad)
#|Warning: Error #<TYPE-ERROR BAD cannot be converted to a pathname.> encountered while
trying to open file BAD for get-history-data. |#
NIL

E> (get-history-data "buffer-trace" "bad-name")
#|Warning: File "bad-name" could not be found in attempt to get-history-data for BUFFER-
TRACE. |#
NIL

E> (get-history-data "buffer-trace")
#|Warning: There is no data available for history data source BUFFER-TRACE because recording
was never started. |#
NIL
```

process-history-data

Syntax:

process-history-data *processor* {*file* {(*data-param**) {(*processor-param**)}}} -> [data | **nil**]
process-history-data-fct *processor* {*file* {(*data-param**) {(*processor-param**)}}}-> [data | **nil**]

Remote command name:

process-history-data

Arguments and Values:

processor ::= a string which is the name of a history source processor
file ::= a string containing a pathname for a file, a Lisp pathname, or **nil**
data-param ::= a parameter to pass to the history source get data function
processor-param ::= a parameter to pass to the processors processing function
data ::= a string containing a JSON encoding of the processed data
comment ::= a string

Description:

Process-history-data is used to get a processed form of the current data from a data source or the saved data from that source that was written to a file. If the name of a data source processor is provided the current data from the parent source is acquired using get-history-data passing it the file and list of data-param values (if provided).

If history does not name an existing data source processor or no valid history data is available then a warning is printed, and **nil** is returned.

If valid data is available then that data along with any processor-params provided are passed to the processors function. If that function returns valid data then it is returned otherwise a warning is printed and **nil** is returned.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (process-history-data 2)
#|Warning: Process-history-data given name 2 but names must be strings. |#
NIL

E> (process-history-data "bad")
#|Warning: BAD does not name a history data processor in call to process-history-data |#
NIL

E> (process-history-data "production-graph-utility")
#|Warning: There is no data available for history data source PRODUCTION-HISTORY because
recording was never started. |#
#|Warning: No history data available from the source for processor PRODUCTION-GRAPH-UTILITY |#
NIL
```

save-history-data

Syntax:

save-history-data *history file* {*comment* {*param**}} -> [**t** | **nil**]
save-history-data-fct *history file* {*comment* {*param**}} -> [**t** | **nil**]

Remote command name:

save-history-data

Arguments and Values:

history ::= a string which is the name of a history source, history constituent, or processor
file ::= a string containing a pathname for a file or a Lisp pathname
comment ::= a string
param ::= parameter to pass to the history source

Description:

Save-history-data is used to save the current data from a data source to a file. If history names an existing data source, processor, or constituent then that name and any parameters provided are passed to get-data-history along with **nil** for the file parameter to get the current data for that item. If it returns valid data then it attempts to open the file indicated for writing (superseding an existing file if there is one) and if that is successful it writes a JSON object to that file with this format (omitting the comment if one is not provided):

```
{"name":  "<history>",
 "date": "YYYY/MM/DD HH:MM:SS",
 "comment": "<comment>",
```

```
 "data": <data>}
```

and returns **t**. Otherwise it will print a warning and return **nil**.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (save-history-data 1 "file")
#|Warning: Save-history-data given name 1 but names must be strings. |#
NIL

E> (save-history-data "bad" "file")
#|Warning: BAD does not name a history data source item in call to save-history-data. |#
NIL

E> (save-history-data "buffer-trace" "file")
#|Warning: There is no data available for history data source BUFFER-TRACE because recording
was never started. |#
#|Warning: No history data available for BUFFER-TRACE in call to save-history-data. |#
NIL
```

start-incremental-history-data, get-incremental-history-data

Syntax:

start-incremental-history-data-fct *history size* {*file* {*param**}} -> [id | **nil**]
get-incremental-history-data-fct *id* -> [data-segment | **nil**]

Remote command name:

start-incremental-history-data
get-incremental-history-data

Arguments and Values:

history ::= a string which is the name of a history source, history constituent, or processor
size ::= a number indicating approximate maximum size of data to send
file ::= a string containing a pathname for a file, a Lisp pathname, or **nil**
param ::= parameter to pass to the history source
id ::= an integer for accessing data incrementally
data-segment ::= a string containing a JSON encoding of a portion of the data

Description:

Start-incremental-history-data and get-incremental-history-data can be used to access the data from a data source in segments. That may be necessary when the data from a data source is very large – it is used by the ACT-R Environment because the JSON encoding of some of the history tools' data is several mega-bytes long and difficult to send via the RPC interface.

Calling start-incremental-history-data will pass the history, file, and any parameters to get-history-data to acquire the current data. If that is successful then an integer id value is returned, otherwise it returns **nil**. When that id is passed to get-incremental-history-data it will return a segment of the data where that segment is the next n elements. To compute n, first compute how many segments there are by taking the ceiling of the length of the JSON encoding and dividing by the given size, then n is the floor of the number of elements in the data divided by the number of segments. Thus, it does not guarantee that only size characters will be sent at a time because the individual elements may vary in size, but on average it will send size characters per increment. Once all of the data is sent, further calls will result in a value of **nil**.

If a file is provided then the first call to get-incremental-history-data with the id will return only the comment string from that file or the empty string if it does not have a comment, and after that it will return the data subsegments.

If an invalid id is provided to get-incremental-history-data then a warning is printed and **nil** is returned.

Examples:

See the examples/history-source directory for real examples. Only the warning messages for invalid use are shown here.

```
E> (start-incremental-history-data-fct 1 10)
#|Warning: Start-incremental-history-data given name 1 but names must be strings. |#
NIL

E> (start-incremental-history-data-fct "bad" 10)
#|Warning: BAD does not name a history data source in call to get-history-data. |#
NIL

E> (get-incremental-history-data-fct 1)
#|Warning: Invalid id 1 given for get-incremental-history-data. |#
NIL
```

Buffer trace module

The buffer trace module provides a history source called “buffer-trace” which records the actions which occur through the buffers while a model runs. It also includes a history constituent for each of the buffers of the system that controls whether the data for that buffer is recorded. By default none of the buffers will be recorded. The module is named buffer-trace.

The data is recorded at each time in the model at which some event occurs for a buffer. The data format for each record is a list of two items. The first is the time-stamp of the data in milliseconds, and the second is a list of buffer record lists for each of the buffers being recorded. Each buffer record list consists of 11 items:

- A string with the name of the buffer
- A Boolean indicating whether the buffer was busy (as indicated by a ‘state busy’ query)
- A Boolean indicating whether the buffer was cleared
- A Boolean indicating whether the buffer transitioned from busy to free (‘state busy’ was true and after that ‘state free’ became true)
- A Boolean indicating whether the buffer reported an error (‘state error’ query)
- A Boolean indicating whether the buffer transitioned from error to no error (‘state error’ was true and after that ‘state error’ was not true)
- A Boolean indicating whether there was a chunk in the buffer (‘buffer full’ query)
- A Boolean indicating whether there was a change to the chunk in the buffer (a mod-buffer-chunk action)
- A string containing the details of the last request made to the buffer at that time
- A string containing the name of the last chunk set in the buffer at that time
- A string containing the last buffer notes which were recorded at that time

That history information is used by the graphic tracing tools of the ACT-R Environment and the BOLD computation module, but is also available for the modeler to use as needed.

There are two optional parameters available when getting the buffer-trace data which can be specified as times in seconds to restrict the range of data returned to only those which occurs between those times (inclusive).

This module is named buffer-trace.

Commands

add-buffer-trace-notes

Syntax:

add-buffer-trace-notes *buffer notes* -> [notes | **nil**]

Remote command name:

add-buffer-trace-notes

Arguments and Values:

buffer ::= a string or symbol which should be the name of a buffer
notes ::= data which one wants to have stored in the buffer-trace history

Description:

The add-buffer-trace-notes command takes two parameters. The first is a symbol or string which should name a buffer and the second is some data to store in the buffer-trace history of the current model at the current time. If buffer is the name of a buffer in the current model then the given notes will be recorded in the buffer-trace history for the named buffer at the current time and notes will be returned. If there is no current model or buffer does not name a valid buffer then the command will print a warning and return **nil**.

If multiple notes are added for the same buffer at the same time only the last one added will be recorded by the buffer-trace. Any notes which are added will also be displayed in the graphic tracing tools of the ACT-R Environment when one places the cursor over an event box in the image.

Examples:

This example was run after loading the count model from unit 1 of the ACT-R tutorial.

```
1> (record-history "buffer-trace" "goal")
T
T
2> (run 1)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
...
     0.350   PROCEDURAL              CONFLICT-RESOLUTION
     0.350   ------                  Stopped because no events left to process
0.35
53
NIL

3> (get-history-data "buffer-trace")
"[[0,[[\"GOAL\",null,null,null,null,null,true,null,\"\",\"FIRST-GOAL\",\"\"]]],
 [50,[[\"GOAL\",null,null,null,null,null,true,true,\"\",\"\",\"\"]]],
 [100,[[\"GOAL\",null,null,null,null,null,true,null,\"\",\"\",\"\"]]],
 [150,[[\"GOAL\",null,null,null,null,null,true,true,\"\",\"\",\"\"]]],
 [200,[[\"GOAL\",null,null,null,null,null,true,null,\"\",\"\",\"\"]]],
 [250,[[\"GOAL\",null,null,null,null,null,true,true,\"\",\"\",\"\"]]],
 [300,[[\"GOAL\",null,null,null,null,null,true,null,\"\",\"\",\"\"]]],
 [350,[[\"GOAL\",null,true,null,null,null,true,null,\"\",\"\",\"\"]]]]"

4> (reset)
T
5> (add-buffer-trace-notes 'goal "Added notes")
"Added notes"

6> (run .1)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   PROCEDURAL              PRODUCTION-SELECTED START
  ...
     0.100   PROCEDURAL              BUFFER-READ-ACTION RETRIEVAL
     0.100   ------                  Stopped because time limit reached
```

```
0.1
21
NIL

7> (get-history-data "buffer-trace")
"[[0,[[\"GOAL\",null,null,null,null,null,true,null,\"\",\"FIRST-GOAL\",\"Added notes\"]]],
 [50,[[\"GOAL\",null,null,null,null,null,true,true,\"\",\"\",\"\"]]],
 [100,[[\"GOAL\",null,null,null,null,null,true,null,\"\",\"\",\"\"]]]]"

8> (reset)
T

9> (add-buffer-trace-notes 'goal "Lost note")
"Lost note"

10> (add-buffer-trace-notes 'goal "Stored note")
"Stored note"

11> (run .1)
     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   PROCEDURAL            PRODUCTION-SELECTED START
   ...
     0.100   PROCEDURAL            BUFFER-READ-ACTION RETRIEVAL
     0.100   ------                Stopped because time limit reached
0.1
22
NIL

12> (get-history-data "buffer-trace")
"[[0,[[\"GOAL\",null,null,null,null,null,true,null,\"\",\"FIRST-GOAL\",\"Stored note\"]]],
 [50,[[\"GOAL\",null,null,null,null,null,true,true,\"\",\"\",\"\"]]],
 [100,[[\"GOAL\",null,null,null,null,null,true,null,\"\",\"\",\"\"]]]]"

E> (add-buffer-trace-notes 'badname nil)
#|Warning: BADNAME does not name a buffer in the current model no notes added. |#
NIL

E> (add-buffer-trace-notes 'goal "note")
#|Warning: No current model so cannot add notes. |#
NIL
```

Central Parameters Module

This module maintains three parameters of the system and provides no other model relevant components. These parameters are used by more than one of the cognitive modules to control how they operate. Thus, they need to exist outside of any one of them in particular, and may also be referred to by new modules as well. It also provides a system parameter which can be used to effectively overwrite the default value for any parameter.

The name of the module is central-parameters and it will always be available (if loaded).

Technically, this module is not automatically loaded by ACT-R because it is provided in the support directory of the distribution and thus only loaded when needed. Therefore, any module or other file which uses the parameters in this module should ensure that it is available by making a require-compiled call to be safe:

```
(require-compiled "CENTRAL-PARAMETERS")
```

Since the declarative and procedural modules use it that is not actually necessary, but still recommended if one is using these parameters when defining a new module.

This module provides a way for other modules to register that they are using the :esc parameter and note which of their parameters rely on :esc being set to **t**. It will output a warning if :esc is **nil** at the start of a model run when any of those registered parameters have been changed from their default values – the assumption is that for a parameter which uses :esc that parameter's default value is valid when :esc is set to **nil** and any other setting would require :esc to be **t**.

This section will provide the basic details of these parameters. The specific modules which use them will describe the details of how these parameters modify their operations.

This module is named central-parameters and will always be available if it has been loaded.

This module has no buffer.

Parameters

:er

This is the enable randomness parameter. It specifies how deterministically modules should operate. It can be set to **t** which means act non-deterministically or **nil** which means act deterministically. The default value is **nil**. Generally, the setting of this parameter is used to determine how to break "ties" in a module's processing and it has more impact when :esc is **nil** because when the subsymbolic parameters are enabled there are not often ties that need to be broken because of the noise typically added to those computations.

:esc

This is the enable subsymbolic computations parameter. It specifies whether modules should work in a purely symbolic fashion or whether they should use their subsymbolic processing mechanisms. The default value is **nil** which means that modules should be purely symbolic. If it is set to **t**, then modules should use whatever subsymbolic computations they provide.

:ol

This is the optimized learning parameter. It specifies whether modules should use their full computational forms of subsymbolic quantities or use some simplified approximation. Currently, it is only used by the declarative system to control the base-level learning equation, but other modules could also check it as a guide. It can be set to **t**, which means use the optimized (or simplified) form of the computation, **nil**, which means use the full computation, or a positive number, which can be used as a parameter specifying how much optimization to apply. The default value is **t**.

System Parameters

:starting-parameters

The :starting-parameters parameter allows one to set parameters which will be applied at the start of all models that are defined. It can be set to a list of parameter values which are valid for passing to sgp-fct and those parameter values will be set before the code in a model definition is evaluated. If this parameter is set in a .lisp file that is placed into the user-loads directory then those settings will always be made, and that is the recommended use for this parameter.

To be completely safe, one should also make sure that the central-parameters module is loaded using this call before setting the parameter:

```
(require-compiled "CENTRAL-PARAMETERS")
```

particularly if it is being done within the context of a module or extension that is loaded prior to the user-loads directory being processed. However, since the declarative and procedural modules currently also use the central-parameters module it should always be available even without explicitly requiring it.

Commands

register-subsymbolic-parameters

Syntax:

register-subsymbolic-parameters { *param** } -> **nil**

Remote command name:

register-subsymbolic-parameters

Arguments and Values:

param ::= a keyword or string containing a keyword which should name a valid parameter

Description:

The register-subsymbolic-parameters command is used to indicate when a module's parameters depend on the :esc parameter being set to **t**. When a model first starts running (time 0) if :esc is set to **nil** and any of the parameters which have been registered in this way have a value other than their default value a warning will be printed like this:

```
#|Warning: Subsymbolic parameters have been set but :esc is currently nil. |#
```

This command only needs to be called once for a given parameter. It does not need to go into the creation or reset functions of a module, and should be called directly after the module definition.

It always returns **nil**.

Examples:

```
> (register-subsymbolic-parameters :ul :alpha)
NIL
```

The Procedural System

The procedural system implements the procedural cognitive module of the theory. The procedural system is implemented as three separate modules in the code. Those three modules are the procedural module, the utility module, and the production-compilation module. The procedural module handles the productions' specification and matching at the symbolic level and the conflict resolution among productions which relies on the utility module. The utility module handles the computation of the subsymbolic quantity Utility for the productions and maintains the parameters and history information necessary to do so. Finally, the production-compilation module is responsible for the learning of new productions by the model when it is enabled.

Procedural Module

The procedural module implements the procedural memory system. It provides the commands for specifying productions, a pattern matcher that works in conjunction with the utility module to choose which production to fire, and tools for inspecting and debugging the productions of a model. This module holds a central role in the system because the productions coordinate the interaction between all of the other modules of the theory.

The module is named procedural.

Production

A production is a condition-action pair. The condition consists of a conjunction of patterns to match against the current contents of the buffers and the states of the buffers and modules, and the action is a set of actions to perform which typically consists of modifications to the chunks in the buffers and requests to modules. When all of the constraints in the condition of a production are satisfied it may be selected to fire, and when it fires all of its actions are executed. See the ACT-R tutorial for more details on specifying and using productions.

Conflict Resolution

Only one production can be selected and fired at any time. The process by which the next production to fire is chosen is called conflict resolution. When conflict resolution occurs all productions have their conditions checked to determine which ones match the current state (see the p command and ACT-R tutorial unit 1 for more information on how the matches occur). Among those that match, the one that has the highest utility value will be chosen (see the utility module for details on the utility calculations). If there is a tie for the highest utility value then the setting of the :er parameter determines how that tie is broken. If :er is **t** then the tie is broken randomly. If :er is **nil** then a deterministic process is used such that the same production will be chosen for a given model each time the same tie condition occurs. However, that deterministic process is not specified as part of the procedural module's definition because it is not intended to be a process which one relies on for production ordering or model control, and any change to a model's definition could affect that choice.

The procedural module will automatically schedule conflict-resolution events to perform the conflict resolution process. The first one is scheduled at time 0 and a new one is scheduled after each production fires. If no production is selected during a conflict-resolution event then a new conflict-resolution event is scheduled to occur after the next change occurs. A change in this context is any other non-maintenance event. The module also schedules production-selected and production-fired events as a result of conflict resolution. Those events will indicate the specific production which was selected and fired and will look like this in the trace:

```
0.000   PROCEDURAL              CONFLICT-RESOLUTION
0.000   PROCEDURAL              PRODUCTION-SELECTED START
0.050   PROCEDURAL              PRODUCTION-FIRED START
```

There is also a procedural module request event scheduled after the production-selected event. That event will not be shown in the trace and serves to indicate that the procedural module has started an action for purposes of the buffer trace module (the event itself performs no actions). Several other

events are scheduled as a result of the production selection and production firing processes. Those will be described under the production creation command p.

The production-fired event is scheduled based on the production's specified action time. That defaults to 50ms, but can be changed with parameters (see the utility module). In addition, if one sets the :vpft parameter to **t** then that time has noise added to it using the randomize-time command.

Parameters

:add-production-hook

This parameter allows one to specify commands which will be called when a production is added to the model. This parameter can be set with a command identifier and that command must accept one parameter. Any number of commands may be added (the reported value of this parameter is a list of all items which have been added). Note, when setting the parameter remotely an embedded string will be required to name a command. When a new production is being added to the model the commands on this list will be passed either the name of the production (if it is a command string) or the internal production structure if it is a Lisp function or symbol naming a Lisp function (note however that the internal production structure is not a part of the ACT-R code specification which means that it can change at any time without a corresponding version update and any modifications made to that structure will likely cause problems for the procedural system). The return value from the called commands are ignored.

To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed.

If the parameter is set to **nil** then all functions are removed from the list.

:conflict-set-hook

This parameter allows one to specify commands which can intervene in the production selection process. This parameter can be set with a command identifier and that command must accept one parameter. Any number of commands may be added (the reported value of this parameter is a list of all items which have been added). Note, when setting the parameter remotely an embedded string will be required to name a command. During conflict-resolution, after all productions have been matched and have had their utilities calculated, a list of the names of the productions which matched in order of utility (highest first – thus the first production on the list is the one which will be selected unless something intervenes) will be passed to each of the items on the conflict-set-hook list. The return values from the items on the conflict-set-hook list are used as follows:

- If it is the name of a production in the conflict set then that production will be the one selected regardless of the normal conflict resolution mechanism.
- If it is an embedded string, no production will be selected and a warning will be output to the trace indicating that conflict resolution was canceled and the embedded string returned will be provided as a reason in that warning. The next conflict resolution event will be scheduled to occur after the default action time (see the :dat parameter).
- If it is **nil** then the normal conflict resolution mechanism is used.
- If it is anything else, a warning will be output and the normal mechanism will be used.

If multiple hook commands are set and more than one returns a non-**nil** value a warning will be displayed and the result of one of those non-**nil** values will be used. Which one gets used is picked by an unspecified mechanism. No assumptions should be made as to which will be applied and it may vary from run to run. In general one should not have more than one conflict-set-hook command returning non-**nil**.

To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed.

If the parameter is set to **nil** then all functions are removed from the conflict-set-hook list.

:crt

The conflict resolution trace parameter can be used to include the details of the conflict resolution process in the trace. If it is set to **t** then after each conflict-resolution event, for each production, it will print out either that the production matches the current state or that it fails to match along with the first condition which failed to match as would be shown by the whynot command.

:cst

The conflict set trace parameter can be used to print the details of the productions in the conflict set during conflict resolution. If it is set to **t** then after each conflict-resolution event the current instantiation of each production that matches is printed in the command trace. The instantiation of a production is the production text with the variables replaced by the specific values they have based on the current buffer contents.

:cycle-hook

This parameter allows one to specify commands to be called automatically when productions fire. This parameter can be set with a command identifier and that command must accept one parameter. Any number of such commands may be set (the reported value of this parameter is a list of all commands which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. During the production-fired event each of the commands on the cycle-hook list will be called with the name of the production that is firing as the parameter. The return values of those functions are ignored. If the parameter is set to **nil** then all functions are removed from the cycle-hook list. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A command should only be set once. If a specific command is specified more than once as a value for the :cycle-hook parameter a warning will be displayed.

:dat

The default action time parameter specifies the default time that it takes to fire a production in seconds. That is the amount of time that passes between a production's selection and fired events. The default value is .05 (50ms) and generally that value is not changed.

:do-not-harvest

This parameter controls the strict harvesting mechanism of the productions. By default all buffers are subjected to the strict harvesting practice, but buffers can be exempted from that by specifying them with the :do-not-harvest parameter. The parameter is set one buffer at a time. The reported value for the parameter is a list of all the buffers which have been set using the parameter. To remove a specific buffer from the list set the parameter to the list **(:remove** buffer **)** where buffer is the name of the buffer to be removed. If it is set to **nil** then all buffers will be subjected to strict harvesting. A particular buffer should only be set once and if it is specified again a warning will be displayed.

:do-not-query

This parameter controls the strict safety mechanism of the productions. By default all buffers are subjected to the strict safety practice, but buffers can be exempted from that by specifying them with the :do-not-query parameter. The parameter is set one buffer at a time. The reported value for the parameter is a list of all the buffers which have been set using the parameter. To remove a specific buffer from the list set the parameter to the list **(:remove** buffer **)** where buffer is the name of the buffer to be removed. If it is set to **nil** then all buffers will be subjected to strict safety. A particular buffer should only be set once and if it is specified again a warning will be displayed.

:lhst

The left hand side trace parameter controls whether the matching conditions from the selected production are shown in the trace. If this parameter is set to **t** (which is the default) and the :trace-detail parameter is set to high then the matching conditions are displayed. If this parameter is set to **nil** or the :trace-detail is medium or low, then such events are not shown.

:ppm

The procedural partial matching parameter controls whether productions are allowed to be selected and fired even if they are not a perfect match to the buffers' current contents. If this parameter is set to a number then production matching is allowed to occur for buffer tests which are not a perfect match to the chunk in the buffer. The default value is **nil** which means productions will only match when the buffer tests are exact matches.

If the procedural partial matching is enabled, then slots tested for equality (slots without a modifier and those with an explicit = modifier) in buffer tests of productions may be considered a match even if the value is not chunk-slot-equal to the current value in the slot of the chunk in the buffer. The partial match will occur if there is a similarity value between the value specified for the slot in the production and the value currently in that slot of the buffer, as returned from the declarative module's similarity command, and that similarity is greater than the maximum similarity difference.

A production which is not a perfect match will have its utility value decremented for purposes of determining which production to fire, but the production's utility parameters and the learning of utility are not affected by that decrementing. The default decrement will be that for each slot which is not a perfect match, the matching utility of the production will be adjusted by adding the similarity difference (a negative value) between the specification and the current buffer chunk's slot value multiplied by the value of the :ppm parameter. Thus, when the procedural partial matching is enabled

the utility used to determine whether production i should be selected among those that match would be:

$$U'_i(t) = U_i(t) + \varepsilon + \sum_j ppm * similarity(s_j, v_j)$$

Ui(t) is the production's current true utility value
ε is the noise which may be added to the utility
j is the set of slots for which production i had a partial match
s_j is the specification for the slot j in production i
v_j is the value in the slot j of the chunk in the buffer

Alternatively, one can use the :ppm-hook parameter to specify a function for computing a custom penalty for mismatched production tests. In that case the expression used in the summation above is overridden by a user specified function.

:ppm-hook

The procedural partial matching hook parameter allows one to specify a command identifier for a command that will compute the utility offset added to a production which does not match the current state exactly when procedural partial matching is enabled. The default value for the parameter is **nil** which results in the offset being computed as described for the :ppm parameter. However, if the parameter is set to a command then that command will be passed a production name and a list of mismatch lists, one for each mismatch which occurred while testing the named production. A mismatch list will be a 5 element list consisting of: a buffer name, a slot name, the specified slot value, the actual value in the slot of the chunk in the buffer, and the reported similarity between those two items. If the command called from the hook returns a number that will be added to the production's utility, any other return value will result in the default calculation being added.

:rhst

The right hand side trace parameter controls whether the actions from the fired production are shown in the trace. If this parameter is set to **t** (which is the default) and the :trace-detail parameter is set to high then the production's actions are displayed. If this parameter is set to **nil** or the :trace-detail is medium or low, then such events are not shown. Note that this only controls the direct actions made by the procedural module. Whether any events generated by other modules as a result of those actions are displayed is controlled by those modules.

:style-warnings

The style warnings parameter controls whether the procedural module reports warnings about possible production issues which do not prevent the production from being created, like multiple requests to the same buffer. Style warnings also indicate possible issues among the productions, like requests to a buffer which is not tested in the conditions of other productions or setting/modifying slots which are never tested in any production. If the parameter is **t** (the default value) then additional

warnings may be displayed when a model is defined and reset (they will be output using the model-warning command). If it is set to **nil** then those additional warnings will not be displayed.

:use-tree

The use tree parameter controls whether a decision tree is created to use during production matching. If the parameter is **nil** (the default value) then each production is tested individually to determine if it matches. If :use-tree is set to **t**, then when the model is loaded a decision tree is created based on the conditions among the productions and that tree is consulted first in production matching to potentially reduce the set of productions that need to be tested further. This can result in a faster model run time, but it does have an initial tree creation cost, requires additional memory to store the tree, and there is the extra cost of searching the tree first. Thus, it is not guaranteed to improve the performance for all models, and one case which can be particularly bad for this is if the model must be reloaded instead of being reset since that will incur the cost of building the tree at each reload (whereas a reset can typically reuse the previously built tree).

:vpft

The variable production firing time parameter controls whether the time of a production's firing is constant or variable. If the parameter is **nil** (the default value) then each production takes its specified action time exactly each time it fires. If :vpft is **t**, then the randomize-time command is used to randomize the production's action time. Note that randomize-time depends on the setting of the :randomize-time parameter and if it is **nil** then there will be no randomization.

Production buffer

The procedural module has a buffer called production. It exists for the purpose of allowing the module to have its state tracked. It never has any chunks placed into it and practically speaking it does not accept any requests. There is no reason to use the production buffer other than for tracking the state of the procedural module (typically through the buffer trace module).

Activation spread parameter: :production-activation
Default value: 0.0

Queries

The production buffer only responds to the default queries.

'State busy' will be **t** when a production is firing (the time between the production-selected and production-fired events). It will be **nil** at all other times.

'State free' will be **nil** when a production is firing and **t** at all other times.

'State error' will always be **nil**.

Requests

{*slot value*}*

The production buffer will accept any request without a warning or error, but the request is completely ignored – no actions are performed regardless of the slots specified.

Commands

p/define-p

Syntax:

p production-definition -> [p-name | **nil**]
p-fct (production-definition) -> [p-name | **nil**]
define-p production-definition -> [p-name | **nil**]
define-p-fct (production-definition) -> [p-name | **nil**]

Arguments and Values:

production-definition ::= p-name {doc-string} condition* ==> action*
p-name ::= a symbol that serves as the name of the production for reference
doc-string ::= a string which can be used to document the production
condition ::= [buffer-test | query | eval | binding | multiple-value-binding]
action ::= [buffer-modification | request | buffer-clearing | modification-request | buffer-overwrite | eval | binding | multiple-value-binding | output | **!stop!**]
buffer-test ::= **=**buffer-name**>** {**isa** chunk-type} slot-test*
buffer-name ::= a symbol which is the name of a buffer
chunk-type ::= a symbol which is the name of a chunk-type in the model
slot-test ::= {slot-modifier} [slot-name | strict-bound-variable] slot-value
slot-modifier ::= [**=** | **-** | **<** | **>** | **<=** | **>=**]
slot-name ::= a symbol which names a slot
slot-value ::= [variable | value]
value ::= any Lisp value
query ::= **?**buffer-name**>** query-test*
query-test ::= {**-**} queried-item query-value
queried-item ::= a symbol which names a valid query for the specified buffer
query-value ::= [bound-variable | value]
buffer-modification ::= **=**buffer-name**>** [direct-value | {**isa** chunk-type} slot-value-pair*]
direct-value ::= [variable | Lisp symbol]
slot-value-pair ::= [slot-name | strict-bound-variable] bound-slot-value
bound-slot-value ::= [bound-variable | value]
request ::= **+**buffer-name**>** [direct-value | **(**direct-value request-spec***)** | {**isa** chunk-type} request-spec*]
request-spec ::= {slot-modifier} [slot-name | strict-bound-variable | request-parameter] slot-value
request-parameter ::= a Lisp keyword naming a request parameter provided by the specified buffer
buffer-clearing ::= **-**buffer-name**>**
modification-request ::= *****buffer-name**>** [direct-value | {**isa** chunk-type} slot-value-pair*]
buffer-overwrite ::= @buffer-name**>** [direct-value | {**isa** chunk-type} slot-value-pair*]

eval ::= [**!eval!** | **!safe-eval!**] form
binding ::= [**!bind!** | **!safe-bind!**] variable form
multiple-value-binding ::= **!mv-bind! (**variable^{+}**)** form
output ::= **!output!** [output-value | **(** format-string format-arg***)** | **(**output-value***)**]
output-value ::= [bound-variable | value]
format-string ::= a Lisp string which may contain format processing characters
format-arg ::= an output-value which will be processed by the format-string
variable ::= a symbol which starts with the character =
strict-bound-variable ::= [a variable which is used in the slot-value position of a slot-test which has
either no slot-modifier or the = slot-modifier |
the variable naming a buffer at the head of a buffer-test]
bound-variable ::= [strict-bound-variable | a variable bound through binding or multiple-value-binding]
form ::= [a valid Lisp form | remote-form]
remote-form ::= **(**"command" {argument}***)**
command ::= the name of a command available through the remote dispatcher
argument ::= any values to pass to command

Description:

The p family of commands is used to create the productions for a model. The "define-" commands are provided as a convenience for those using Lisp editors which provide special operations for use with Lisp forms that start with "define-", and do the same as the corresponding command without the "define-" on the front.

A production must be given a name and can be given an optional documentation string. Then it contains a set of conditions to be tested and a set of actions to be executed when the production is fired. If the specification of the production is syntactically correct, then that production is entered into the procedural memory of the current model, as maintained by the procedural module, and the production's name is returned.

If the name given for a production is already used by a production in the procedural memory of the current model then a warning is printed, the old production is removed, and it is replaced with the newly defined production.

If there is an error in parsing the production then one or more warnings will be output indicating what was wrong, no new production is entered into the procedural memory, and **nil** is returned.

Within a production there are many possible components and each will be described in detail below.

Variables

Productions contain variables to allow for more general matching and actions. The variables are symbols which start with an "=" character e.g. =slot, =answer, =goal. The variables are only relevant within the context of a single production and essentially serve three purposes. The first is to compare two or more values. The second is to copy a value from a condition into an action or specific query. The last is a process referred to as dynamic pattern matching and it allows a variable to be used in the specification of a slot for a buffer test, modification, modification request, or request. A single variable may be used for any/all of those purposes within a production i.e. it could compare two slots

to determine that they have the same value, copy that value into a request action, and modify a slot using that variable as the slot name in a different action.

With respect to the dynamic pattern matching there are some restrictions on how the variables can be used. First, there is no search performed in the matching and all variable slot names must be "grounded" by being used as a slot value in an explicitly named slot condition. This means the dynamic pattern matching cannot be used to "find a slot which has a specific value" like this:

```
(p invalid
    =buffer>
      =slot  150
==>
  ...
)
```

Also, there is only one level of indirection allowed in the use of variablized slot names. Thus it is not possible to do something like this:

```
(p also-invalid
   =buffer>
     slot1 =val
     =val =val2
     =val2 300
==>
   ...
)
```

However, one may go one level deep across multiple buffers:

```
(p valid
  =buffer1>
   slot1 =s1
   =s2 =value
  =buffer2>
    slot2 =s2
    =s1 =value
==>
  ...
)
```

Constants

Any symbols used in the production for values which are not variables are assumed to be the names of chunks. If there is not a chunk with such a name at the time the production is created then a new chunk with no slots will automatically be created with that name. Other non-symbol values (strings, numbers, etc) are treated as the corresponding Lisp value.

Modifiers

When testing slot values in conditions and checking queries in a production there are several modifiers which can be used: =, - , <, >, <=, and >=. The = modifier is used to check that the value in the buffer chunk's slot and the value given in the production are equal as determined by the chunk-slot-equal command. If no modifier is provided, then the = modifier is assumed (one usually never sees the = modifier in a production). The – modifier means to negate the test. In a buffer test that

means that the buffer chunk's slot does not equal the value specified in the production and for a query it means that the match should succeed if the specified query returns false. The inequality tests (<, >, <=, and =>) can only be used when the values are numbers (the test fails if either of the elements being tested is not a number). If the values are numbers then the test is true if the inequality holds between the value in the specified slot of the chunk in the buffer and the value specified in the production in that order i.e. if the test is < slot1 10 then the condition matches if the value in the slot1 chunk of the buffer is less than 10.

isa

In many of the conditions and actions of a production it is possible to specify an optional chunk-type using the symbol isa. That chunk-type specification is only used during the definition of the production and does not directly affect the condition or action in which it occurs. It is effectively a declaration for the slots to be used, and unless the chunk-type has default slot-value pairs the same production would result without the chunk-type being specified.

When a chunk-type is specified in that way it allows the production to perform additional syntax checking to determine if the slots specified for that condition or action conform to the slots available for the chunk-type indicated. It also adds any default slot-value pairs specified for that chunk-type into the corresponding condition or action if such a slot is not specified explicitly within the condition or action. If a slot which is not valid for a specified chunk-type is used in a condition or action that will result in a warning being output, but it does not prevent the production from being specified.

Conditions

The conditions of the production are also referred to as the production's left hand side (LHS). They are a conjunction of tests which must all be true for the production to be selected. The order in which the conditions are specified does not matter – there are no ordering constraints and the order in which the tests are performed will not necessarily be the same as they are specified in the production. The only ordering which will be maintained is that eval and binding conditions will be performed in the order specified if possible, and if they have to be reordered a warning will be displayed when the production is defined.

Here is the general description of the conditions that can be tested in a production. When a production is selected during conflict resolution it will generate an event to indicate each buffer match and buffer query condition that it contains and those events are shown in the trace under the conditions indicated with the :lhst parameter.

buffer test

The buffer-test is the primary condition used in productions. It is comparing the chunk currently in a specific buffer to a pattern provided in the production. Each buffer may have one test specified per production. The slot values in the buffer's chunk are compared to the values specified in the condition using the chunk-slot-equal command, and all of the slots must satisfy the conditions specified for the production to match (except when the :ppm parameter is set which allows imperfect matches). If a value of **nil** is specified for a slot in a buffer test that indicates a test for the absence of the slot – a slot cannot actually have a value of **nil**.

In a production which is selected, a buffer test is also referred to as “harvesting” the chunk in the buffer. Here is an example of a buffer-test:

```
=goal>
   slot1  =value
   state   start
 - slot2  =value
```

Every buffer test starts with a variable that names the buffer followed by the ‘>’ character. Thus, this is testing the chunk in the model’s goal buffer. That variable will be bound to the chunk currently in the buffer and can be used like any other variable in the production. This condition requires that the chunk have slots named slot1 and state. The state slot must have the chunk start as its value and the slot1 slot can hold any value which will be bound to the =value variable. The other constraint here is that if the chunk has a slot named slot2 it must not have the same value as the slot1 slot.

In the trace a buffer test will show up as a buffer-read-action event like this:

```
     0.000   PROCEDURAL             BUFFER-READ-ACTION GOAL
```

indicating which buffer was tested by the production.

query

A query is one or more tests of a buffer and/or its owning module. There are several default queries which may be made for every buffer and a module may provide many more queries to which it will respond. Each query will produce either a true or false result. The production will only match if the result of each query is true, or if the result is false and the negative test modifier, ‘-’, is used. The queries that can be specified for every buffer are:

```
buffer empty
buffer full
buffer failure
buffer requested
buffer unrequested
state free
state busy
state error
error t
error nil
```

The first five are tests of the buffer itself and the module is not involved in that process. The rest, and any others which a module provides, are tests which are relayed to the module to get its response. For the first five, the semantics of the queries are the same for all buffers and are as follows:

- buffer full: true if there is currently a chunk in the buffer
- buffer failure: true if the failure flag has been set for the buffer and it does not hold a chunk
- buffer empty: true if there is not a chunk currently in the buffer and the failure flag is clear
- buffer requested: true only if there currently is a chunk in the buffer and the module has indicated that it was put there as a result of a request to the module

- buffer unrequested: is true only if there currently is a chunk in the buffer and it has been marked as not having been put there as a result of a request to the module

The other queries are dependent on the how the module responds to them and thus one needs to check the particular module description to determine how they are used. Generally, they have the following semantics, but some modules may not follow this convention:

- state free: true if the module is ready for new requests
- state busy: true if the module is currently handling a request
- state error: true if the last request resulted in some sort of error
- error t: this is the same as a test of state error (which is the query which will actually be sent to the module) and is provided as a shorthand notation for production syntax
- error nil: this is the same as a query for "– state error" thus checking that the module is not currently reporting that "state error" is true and again is a shorthand notation in the production syntax

Here is an example query to the goal buffer:

```
?goal>
  state free
  buffer full
 - state error
```

A query starts with a symbol composed of a '?', the name of the buffer being queried, and the symbol '>'. This query is testing that the goal module is currently reporting that its state is free, there is currently a chunk in the goal buffer, and that the goal module is not currently reporting an error.

In the trace each buffer queried by the selected production will show up as a query-buffer-action:

```
     0.450   PROCEDURAL              QUERY-BUFFER-ACTION GOAL
```

eval

The !eval! condition is provided to allow the modeler to add any arbitrary conditions to the LHS of a production or to perform some side effects (like data collection or model tracking information). In the testing of the production's conditions the form provided to evaluate will be called during conflict resolution (if it is a list with the first item being a string then it will call that command through the dispatcher). If the result of the evaluation is **nil**, then the production cannot be selected, but any other return value will allow the production to continue with the pattern matching of the LHS. Using !eval! is something that should be considered carefully when modeling. Generally, they should be used for abstracting away components of the model or task which are unnecessary for the current modeling objective or for performing non-model related actions.

Here is an example of a call to !eval!:

```
!eval! (special-test =var1 =var2 start)
```

This would pass three parameters to the function called special-test. Those parameters will be the current bindings for the =var1 and =var2 variables in the production and the symbol start. If that function returns a non-**nil** value then this production can continue in conflict resolution, but if it returns **nil** then it will be removed from the current conflict set.

There are actually two forms of the eval condition !eval! and !safe-eval!. Both do the same thing, and the difference is how they are processed by the production compilation mechanism.

One note about using !eval! in conditions is that their evaluation may or may not occur during every conflict-resolution event. They will only be evaluated as needed to determine if a production matches. Thus not every !eval! within a production may be evaluated during a given conflict-resolution event and possibly none of the !eval! actions in any of the productions may be evaluated during a conflict-resolution event. Of the !eval! actions which are evaluated the only guarantee on the order of their evaluation is that those provided within a production will be evaluated in the order specified, but there is no guarantee on the order in which the !eval! actions from different productions will be evaluated. Because of the uncertainty in when and whether or not !eval! conditions will be evaluated it is recommended that the functions called have no side effects.

binding

The !bind! condition is very similar to the !eval! condition. However, with !bind! the return value of the evaluation is saved in a variable of the production which can then be used like other variables in the production with the exception of not being able to use it in a slot name position. As with !eval! the return value must be non-**nil** for the production to successfully match.

Here is an example of a !bind!:

```
!bind! =test-value (convert-value =var)
```

This will pass the current binding of the =var variable to the function convert-value and then bind the result to the =test-value variable in the production if it is non-**nil**.

Just like !eval!, there is also a second binding condition called !safe-bind! which operates exactly like the !bind! condition for conflict resolution purposes and only has a difference with respect to how production compilation occurs.

It is also possible to bind multiple return values in a single test with the !mv-bind! condition. This works the same as !bind! except a list of variables is specified and each is bound to the corresponding return value from the evaluation. If there are fewer return values than variables to be bound the production will not match, and if any of the return values which are to be bound to a variable is **nil** then the production will also not match. Here is an example of !mv-bind!:

```
!mv-bind! (=value1 =value2) (split-values =var)
```

The same constraints on ordering and evaluation as described for eval conditions generally apply to binding conditions as well, and again the recommendation is to not have any side effects in the functions used. However, because the variables bound by a binding condition may be used in other

eval or binding conditions, the ordering of binding conditions may be performed in an order other than specified in the production if that is necessary to create the appropriate bindings e.g. these conditions in a production would have to be reordered as indicated in the comments following them to get the bindings necessary but the relative ordering of the !eval! conditions would be maintained:

```
(p bind-ordering
  !eval! (+ =y =x)  ; 3rd
  !bind! =x (1+ =y) ; 2nd
  !bind! =y 3       ; 1st
  !eval! (= =x =y)  ; 4th
  ==>)
```

Automatic query conditions

In addition to the conditions specified in the production there is an automatic process which may add additional queries to the production.

strict safety

Strict safety applies when a production makes a request or modification request to a buffer on its RHS and does not already have a query for that buffer on the LHS. In that situation, if the buffer is not among those that are specified using the :do-not-query parameter, then the production will automatically add a "state free" query for that buffer to the conditions.

Actions

When a production fires it executes all of its actions, which are also referred to as its right hand side (RHS). Those actions are executed in a specific order regardless of how they are specified within the production definition. Except for the eval, output, and bind actions, the actions are processed through individual events scheduled to occur at the same time as the production's firing. The ordering of those events is determined using the priority of the scheduling of the events. Whether those events will be shown in the trace is determined by the :rhst parameter. Those actions may result in other events being scheduled (either by the module processing the action or possibly by something monitoring those actions) whose output is not controlled by :rhst.

The ordering of the actions, along with their specific priorities, is as follows:

1. All eval, output, and bind calls occur during the production-fired event
2. The production-fired event schedules all of the other events
3. buffer modification actions [priority 100]
4. buffer overwrite actions [priority 90]
5. modification requests [priority 60]
6. module requests [priority 50]
7. buffer clearings [priority 10]
8. a !stop! action generates a break event [priority :min]

In general the production actions fall into three categories: cognitive actions performed directly by the production (those which begin with an =, @, or -), actions that are passed off to a module to handle (those that begin with a + or *), and debugging/modeler extension actions (those that begin with an !). The different actions possible are described in the following sections.

buffer modification

A buffer modification action is used to change the slot values of a chunk in a buffer. This is done directly by the production and works the same for every buffer (the buffer's module is not involved in the process). It is essentially the same as using the mod-chunk command on the chunk in the buffer. Here is an example of a buffer modification:

```
=goal>
   state next-step
   slot1 =value
```

The buffer modification must first name the buffer to be modified by using a symbol composed of the '=' character, the name of the buffer and the '>' character. That is followed by pairs of slot names and values. Thus, that example will change the state slot of the chunk in the goal buffer to now contain the chunk next-step and the slot1 slot will now hold whatever the variable =value is bound to in the production.

Alternatively, one can also specify what is referred to as an indirect modification. Instead of specifying the slots and values to modify, a chunk can be specified instead (either as a constant or through a variable). Specifying a chunk is equivalent to specifying all the slots and values of that chunk in the modification. Thus, if one has a chunk defined like this:

```
(define-chunks (test-chunk slot1 10 state finish))
```

then this modification action:

```
=goal> test-chunk
```

will do the same thing as this one:

```
=goal>
  slot1 10
  state finish
```

It is also possible to specify a modification with no slots and values:

```
=goal>
```

That will not change the chunk in the buffer, but may be useful to prevent the strict harvesting mechanism from automatically clearing the buffer.

In order to perform a buffer modification action, that buffer must have also been tested with a buffer-test in the conditions of the production to guarantee that it contains a chunk to be modified.

The buffer modification actions will show up in the trace as mod-buffer-chunk events indicating the buffer that is modified:

```
0.050   PROCEDURAL             MOD-BUFFER-CHUNK GOAL
```

buffer clearing

A buffer clearing action is used to remove a chunk from a buffer. As with buffer modification actions, this is done directly by the production without consulting the buffer's module. However, modules may be monitoring for buffer clearing events and perform some action whenever a buffer is cleared (their own buffer or any other). Once the action completes the buffer will be empty. Here is an example that would clear the goal buffer:

```
-goal>
```

The action shows up in the trace as a clear-buffer event indicating which buffer was cleared:

```
0.150   PROCEDURAL             CLEAR-BUFFER GOAL
```

A buffer can be cleared regardless of whether or not it was tested on the production's LHS. Note that often one does not need to explicitly clear a buffer because there are two situations which result in buffers being cleared automatically as described below under implicit production clearing actions.

buffer overwrite

A buffer overwrite action is used to replace the contents of a buffer without clearing it first. As with the buffer modification and buffer clearing actions, this is performed directly by the production without notifying the buffer's module. The chunk which was in the buffer is essentially lost when this action occurs. Here is an example of an indirect buffer overwrite action:

```
@goal> =value
```

This will replace the chunk in the goal buffer with the chunk that is bound to the =value variable (a constant chunk name could also be used in place of the variable). It will show up in the trace as an overwrite-buffer-chunk event indicating the buffer and the chunk being copied into it:

```
0.600   PROCEDURAL             OVERWRITE-BUFFER-CHUNK GOAL CHUNK-10 NIL
```

Even though the overwrite action was generated by a production, the resulting chunk in the buffer is still marked as being unrequested.

If the item provided is not a valid chunk name then a warning will be printed at run time and no change will be made to the buffer:

```
#|Warning: overwrite-buffer-chunk called with an invalid chunk name BAD-NAME |#
```

If slot and value pairs are provided for an overwrite action like this:

```
@goal>
  slot1 10
  state finish
```

Then the chunk in the buffer is overwritten with a chunk that has only the slots and values specified. That will show an event like this in the trace indicating that the specification of a chunk was used instead of a specific chunk:

```
      0.050   PROCEDURAL              OVERWRITE-BUFFER-CHUNK-FROM-SPEC GOAL  NIL
```

If an overwrite action does not have any components provided:

```
@goal>
```

then it performs a slightly different operation. In that case it will erase the buffer instead of overwriting it with a chunk that has no slots (which would be the consistent extension from providing slots and values), and when the buffer is erased it will be empty. The difference between erasing the buffer and clearing it is that no modules are notified of the erasing action whereas modules will be notified when a buffer clears (if they have indicated that they want such notifications). That will show up in the trace like this:

```
     0.150   PROCEDURAL              ERASE-BUFFER GOAL
```

module request

A module request (usually just referred to as a request) is how the production asks a module to perform some action. It is indicated by specifying a buffer name with a "+" on the front and a ">" on the end. Syntactically, a request can be specified using any slots and values for any buffer. Semantically, what a request actually does is specific to the module. Some modules may not even accept requests through their buffers, or may have a more restrictive syntax than the general syntax available in the production (for example only allowing a slot to be specified once in the request). Thus, to know what can be requested, how it needs to be specified, and how that will then be processed one needs to know the details of the modules. A syntactically correct production may make semantically invalid requests which would typically generate warnings at run time from the module receiving the request.

In the production, a module request can be specified in the same ways as a modification action. It may directly include all of the details of the request (which may include modifiers unlike the modification actions) or create the request indirectly by specifying a chunk. As far as the module which receives the request is concerned, there is no difference between the different specifications in the production i.e. the module does not know whether explicit slot and value specifications were provided or if the production specified a single chunk which resulted in the slot value pairs of the request.

In addition to specifying slots in the request one may also include additional labels called request parameters. A request parameter is used like a slot in the request, but it is not actually the name of a slot. It is indicated with a Lisp keyword which has been specified by the module as allowed for use with its buffer to provide additional information in a request without having to use slots in chunks.

Here is an example of specifying a request which includes slot modifiers and a request parameter:

```
+retrieval>
   slot1 =value
   - slot1 10
   slot2  start
   <= count =count
   :recently-retrieved nil
```

That request would be sent to the retrieval buffer's module for handling, and what happens based on that request depends on the module which gets the request.

Here is an example of an indirect request:

```
+retrieval> =value
```

If =value is bound to a chunk name in the instantiation of the production being fired, then that chunk is essentially expanded to its slot value pairs to make the request. Thus, if =value were bound to the chunk A and the chunk A were defined like this:

```
 (define-chunks (a state start slot2 10))
```

Then that would be equivalent to specifying this in the production:

```
+retrieval>
   state start
   slot2 10
```

It is also possible to include request parameters in an indirect request by specifying a list which has the chunk as the first element and the request parameters and values as the remaining items:

```
+retrieval> (=value :recently-retrieved t)
```

If a variable used in an indirect request is not bound to the name of a chunk in the production's instantiation, then warnings are printed and no request is made (note that the implicit clearing described below is still performed even if such a warning is encountered). The warnings will look like this in the trace:

```
#|Warning: define-chunk-spec's 1 parameter doesn't name a chunk: (not-a-chunk) |#
#|Warning: schedule-module-request called with an invalid chunk-spec NIL |#
```

A valid request action will show up in the trace as a module-request event specifying the buffer to which the request was sent:

```
     0.800   PROCEDURAL             MODULE-REQUEST GOAL
```

Typically, that will be followed by events from the module to which the request was made performing the requested action.

modification request

A modification request is similar to both the module request and buffer modification actions, and it is another way for a production to ask a module to perform some action. The differences between a

modification request and a module request are that a modification request does not include an implicit clearing of the buffer and it is restricted to the same specification style as a buffer modification (no slot modifiers are allowed, no request parameters are accepted, and the buffer to which this request is made must have been used in a buffer test on the production's LHS). As with a request, what the module does in response to a modification request is entirely up to the module.

To create a modification request the buffer name is preceded by the "*" character. Here is an example of a modification request:

```
*imaginal>
   slot1 =value
   slot2 start
```

This would send those slot and value pairs off to the imaginal buffer's module to process. It is also possible to make an indirect modification request just like an indirect buffer modification:

```
*imaginal> =chunk
```

A modification request will show up in the trace as a module-mod-request event specifying the buffer to which the request is made:

```
     1.000   PROCEDURAL             MODULE-MOD-REQUEST IMAGINAL
```

An empty modification request is also allowed syntactically, but may not be meaningful to the module which receives it.

If a module does not accept modification requests then a warning like this will be displayed when the production is fired:

```
#|Warning: Module XXXXX does not support buffer modification requests. |#
```

eval

The eval action works just like the eval condition except that the return value does not matter.

binding

The binding action works just like the binding condition except that a returned value of **nil** is allowed, but it will not be used as the binding for a variable. If a binding to **nil** is attempted then a warning will be printed and the variable will be bound to **t** instead. Additionally, if the binding actions must be reordered for proper evaluation a warning will be output when the production is defined.

output

The !output! action allows one to embed additional text in the model's trace. The output will be shown when the :v parameter is non-**nil** under any of the :trace-detail setting.

There are three ways to use the output action. It can be used to print a single value like this:

```
!output! =value
!output! started
```

In that case the item specified will be output followed by a newline in the trace. If the item is a variable then it is the binding of the variable which is output.

It can also output several items if they are placed into a list:

```
!output! (the value is =value)
```

In that case all of the items will be printed on one line followed by a newline. Again, variables will be replaced with their current bindings before outputting.

Finally, it can use the Lisp format control mechanisms to output the text. If the first item given in a list to an !output! action is a string then that string is assumed to be a format specification. It is used to generate the output text using the remaining arguments in the same way that the Lisp format command would:

```
!output! ("The count is ~6,3f.~%The value is ~a~%" =count =value)
```

stop

The stop action is used to force the model to stop after firing that production. A stop action is created with this:

```
!stop!
```

A break event will be generated by the stop action that will cause the current run to terminate.

Implicit production clearing actions

In addition to the events specified in the production there are two situations where a buffer clearing action will be implicitly executed when the production fires. They are referred to as strict harvesting and implicit clearing.

strict harvesting

Strict harvesting means that when a production tests a buffer on its LHS (harvests the chunk) it will automatically clear that buffer in the actions of the production. That will occur unless either: a modification is performed on that buffer (either a buffer modification with an = or a modification request with a *) or the buffer has been specified as one which should not be strict harvested using the :do-not-harvest parameter.

request clearing

For each buffer which has a module request on the RHS of a production there is an implicit buffer clearing action performed on that buffer. There is no mechanism provided for suppressing this clearing action.

Buffer variable usage

If a production uses the buffer variable which is bound in the conditions during a buffer test e.g. the =goal variable bound when testing the contents of the goal buffer, anywhere else in the production then the procedural module will mark that buffer as always requiring copies using the buffer-requires-copies command since the name of that chunk is being used in a way that is meaningful to the model.

Examples:

For examples of productions in actual models see the example models in the ACT-R tutorial.

Here is an example production that assumes there are buffers named goal, retrieval, imaginal, visual, and visual-location, that the retrieval buffer has a request parameter called :recently-retrieved, that these chunk-types have been defined:

```
(chunk-type goal-type slot1 value test buffer state step)
(chunk-type visual-location screen-x screen-y color)
```

and that there are functions defined called check-value, get-a-state, and a dispatched command named record-results.

This production uses most of the available syntax and is purely for demonstration – it does not represent any particular usage from a real model.

```
(p example-production "a production showing most syntactic elements"
  =goal>
    isa goal-type
      state start
      test =test
      < value 4
      value =value
      - slot1 =test
      slot1 =last-loc
      buffer =check

  ?visual>
      state =check
      buffer empty

  =visual-location>
    isa visual-location
      >= screen-x =value
      <= screen-x 100
      >  screen-y =value
      <  screen-y =max-value
      =value =current-value

  =imaginal>

  !eval! (check-value =value)
  !bind! =max-value (+ =value 100)
  !mv-bind! (=quotient =remainder) (floor =max-value)
==>
  !safe-bind! =new-state (get-a-state)

  =goal>
      =check =new-state
      value =quotient
```

```
      step continue

  *visual-location>
     isa visual-location
     screen-x =max-value

  +retrieval>
      :recently-retrieved nil
      < screen-x =max-value
      - value =current-value
      color blue

  +visual-location> =last-loc

  +imaginal>
     isa goal-type
      state  done

  @visual> =imaginal

  !output! (Moving to state =new-state with max-value of =max-value)
  !safe-eval! ("record-results" =check 75 =quotient =remainder)
  !stop!
)
```

The examples below will show some of the warnings which may result when trying to define productions. Only those examples which result in no production being defined are indicated as errors.

For these examples the following chunk-type is assumed to have been defined:

```
(chunk-type goal-type slot slot2 state)
```

and the :style-warnings parameter has been turned off to avoid the warnings which may result because of the productions being defined individually.

```
1> (p test
    "Automatically creating a chunk which is referenced"
    =goal>
     isa goal-type
      state start
    ==>
   )
#|Warning: Creating chunk START with no slots |#
TEST

2> (p test
    "Redefining the production test"
    =goal>
     isa goal-type
      state start
    ==>
   )
#|Warning: Production TEST already exists and it is being redefined. |#
TEST

E> (p test
    "No current model"
    =goal>
     isa goal-type
      state start
    ==>
```

```
   )
#|Warning: get-module called with no current model. |#
#|Warning: No procedural module found cannot create production. |#
NIL

> (p test2
    "Slot name doesn't match chunk-type specified"
    =goal>
     isa goal-type
     bad-slot t
   ==>
  )
#|Warning: Production TEST2 uses previously undefined slots (BAD-SLOT). |#
TEST2

E> (p test2
    "Invalid buffer name in condition"
    =buffer>
     isa goal-type
      state start
    ==>
   )

#|Warning: No production defined for (TEST2 "Invalid buffer name in condition" =BUFFER>
ISA GOAL-TYPE STATE START ==>). |#
#|Warning: First item on LHS is not a valid command |#
#|Warning: --- end of warnings for undefined production TEST2 --- |#
NIL

E> (p test2
    "Invalid buffer in query after a valid buffer test"
     =goal>
       isa goal-type
     ?buffer>
       buffer empty
     ==>
   )

#|Warning: No production defined for (TEST2 "Invalid buffer in query after a valid buffer
test" =GOAL> ISA GOAL-TYPE ?BUFFER> BUFFER EMPTY ==>). |#
#|Warning: Invalid syntax in (=GOAL> ISA GOAL-TYPE ?BUFFER> BUFFER EMPTY) condition. |#
#|Warning: Invalid slot-name ?BUFFER> in call to define-chunk-spec. |#
#|Warning: --- end of warnings for undefined production TEST2 --- |#
NIL

E> (p test2
    "Buffer not tested on LHS for modification action"
    ==>
     =goal>
       state start
    )

#|Warning: No production defined for (TEST2 "Buffer not tested on LHS for modification
action" ==> =GOAL> STATE START). |#
#|Warning: Buffer modification action for untested buffer (=GOAL> STATE START). |#
#|Warning: --- end of warnings for undefined production TEST2 --- |#
NIL
```

all-productions

Syntax:

all-productions -> (production-name*)

Remote command name:

all-productions

Arguments and Values:

production-name ::= a name of a production

Description:

The all-productions command takes no parameters. It returns a list of the names of all the productions defined in the current model. If there is no current model it prints a warning and returns **nil**.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
> (all-productions)
(START INCREMENT STOP)

E> (all-productions)
#|Warning: get-module called with no current model. |#
NIL
```

pp

Syntax:

pp *production-name** -> (production-name*)
pp-fct (*production-name**) -> (production-name*)

Remote command name:

pp

Arguments and Values:

production-name ::= a name of a production

Description:

The pp command is used to print the procedural module's representation of a production. It takes any number of production names and for each one prints out the representation of the named production in the current model to the command trace. If no names are provided it prints out all of the productions in the current model (which can be useful when production compilation is enabled to see what productions the model has learned). It returns a list of the names of the productions that were printed.

Note that the representation printed for a production may not exactly match the text which was used to define the production. In particular, any chunk-types specified in the original definition will not be shown in the printed representation since the chunk-type information is only used for the definition and does not represent an actual component of the production. Also, there may be additional queries that were added automatically because of the requests in the production.

If there is no current model a warning is printed and **nil** is returned. If an invalid production name is given a warning is printed.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
> (pp)
(P START
   =GOAL>
        START =NUM1
        COUNT NIL
 ==>
   =GOAL>
        COUNT =NUM1
   +RETRIEVAL>
        NUMBER =NUM1
)
(P INCREMENT
   =GOAL>
        COUNT =NUM1
    -   END =NUM1
   =RETRIEVAL>
        NUMBER =NUM1
        NEXT =NUM2
 ==>
   =GOAL>
        COUNT =NUM2
   +RETRIEVAL>
        NUMBER =NUM2
   !OUTPUT! (=NUM1)
)
(P STOP
   =GOAL>
        COUNT =NUM
        END =NUM
   =RETRIEVAL>
        NUMBER =NUM
 ==>
   -GOAL>
   !OUTPUT! (=NUM)
)
(START INCREMENT STOP)

E> (pp-fct (list 'not-production 'start))
#|Warning: No production named NOT-PRODUCTION is defined |#
(P START
   =GOAL>
        START =NUM1
        COUNT NIL
 ==>
   =GOAL>
        COUNT =NUM1
   +RETRIEVAL>
        NUMBER =NUM1
)
```

```
(START)

E> (pp)
#|Warning: get-module called with no current model. |#
#|Warning: No procedural module found |#
NIL
```

pbreak/punbreak

Syntax:

pbreak *production-name** -> (break-production*)
pbreak-fct (*production-name**) -> (break-production*)
punbreak *production-name** -> (break-production*)
punbreak-fct (*production-name**) -> (break-production*)

Remote command name:

pbreak
punbreak

Arguments and Values:

production-name ::= a name of a production
break-production ::= a name of a production which is currently set to generate a break event

Description:

The pbreak command can be used to force a break event to occur when particular productions are selected during conflict resolution. Each production which is specified in a call to pbreak will force a break event if it is selected. Before the break, the current instantiation of the production will be output to the model trace.

The punbreak command is used to remove the break status of productions. Each production passed to punbreak will no longer force a break event upon its selection. If no productions are specified for punbreak then all productions have their break status cleared.

Both commands return a list of all productions which currently have a break status set in the current model.

If there is no current model or a production name provided is invalid a warning is printed.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
1> (pbreak)
NIL

2> (pbreak start)
(START)
```

```
3> (run 10)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   PROCEDURAL              PRODUCTION-SELECTED START
(P START
   =GOAL>
       START TWO
       COUNT NIL
 ==>
   =GOAL>
       COUNT TWO
   +RETRIEVAL>
       NUMBER TWO
)
0.000   ------                  BREAK-EVENT PRODUCTION START

4> (pbreak-fct '(start increment))
(INCREMENT START)

5> (punbreak start)
(INCREMENT)

6> (pbreak start stop)
(STOP INCREMENT START)

7> (punbreak-fct '(increment stop))
(START)

8E> (pbreak bad-name)
#|Warning: BAD-NAME is not the name of a production |#
(START)

9E> (punbreak-fct '(not-a-production))
#|Warning: NOT-A-PRODUCTION is not the name of a production |#
(START)

10> (punbreak)
NIL

11> (pbreak)
NIL

E> (pbreak)
#|Warning: There is no current model - pbreak cannot be used. |#
NIL

E> (punbreak start)
#|Warning: There is no current model - punbreak cannot be used. |#
NIL
```

pdisable/penable

Syntax:

pdisable *production-name** -> (disabled-production*)
pdisable-fct (*production-name**) -> (disabled-production*)
penable *production-name** -> (disabled-production*)
penable-fct (*production-name**) -> (disabled-production*)

Remote command name:

pdisable
penable

Arguments and Values:

production-name ::= a name of a production
disabled-production ::= a name of a production which is currently disabled

Description:

The pdisable command can be used to disable productions in the current model. A production which is disabled will not participate in conflict resolution. Each production which is specified in a call to pdisable will be disabled.

The penable command is used to enable productions which have been disabled in the current model. Each production passed to penable will no longer be disabled. If no productions are specified for penable then all productions will be enabled.

Both commands return a list of all productions which currently have been disabled in the current model.

If there is no current model or a production name is invalid a warning is printed.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
1> (pdisable)
NIL

2> (pdisable start stop)
(STOP START)

3> (penable-fct '(start))
(STOP)

4> (pdisable-fct '(start increment))
(STOP INCREMENT START)

5> (penable)
NIL

E> (penable)
#|Warning: There is no current model - penable cannot be used. |#
NIL

E> (pdisable bad-name)
#|Warning: BAD-NAME is not the name of a production |#
NIL

E> (penable-fct '(not-a-production))
#|Warning: NOT-A-PRODUCTION is not the name of a production |#
NIL
```

whynot

Syntax:

whynot *production-name** -> (matching-production*)
whynot-fct (*production-name**) -> (matching-production*)

Remote command name:

whynot

Arguments and Values:

production-name ::= a name of a production
matching-production ::= a name of a production which matches at the current time

Description:

The whynot command is a useful model debugging tool. For each of the named productions passed to it (or all productions if no names are provided) it will print out whether that production in the current model matches the current state or not. If it does match, then the instantiation of the production is printed to the command trace and if it does not match then the production is printed to the command trace and the first condition that is unsatisfied at the current time is also printed.

If the :ppm parameter is enabled to allow for imperfect matching then the instantiation of a production which is a partial match will indicate the current slot value, the imperfectly matching buffer slot value and the similarity between those values.

It returns a list of all the productions which do match the current state in the current model regardless of whether they were passed into whynot for display.

If there is no current model then a warning is printed and **nil** is returned. If an invalid production-name is provided a warning will be displayed.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
1> (reset)
T

2> (whynot)

Production START does NOT match.
(P START
   =GOAL>
       START =NUM1
       COUNT NIL
 ==>
   =GOAL>
       COUNT =NUM1
   +RETRIEVAL>
       NUMBER =NUM1
)
It fails because:
The GOAL buffer is empty.

Production INCREMENT does NOT match.
(P INCREMENT
```

```
   =GOAL>
       COUNT =NUM1
    -  END =NUM1
   =RETRIEVAL>
       NUMBER =NUM1
       NEXT =NUM2
 ==>
   =GOAL>
       COUNT =NUM2
   +RETRIEVAL>
       NUMBER =NUM2
   !OUTPUT! (=NUM1)
)
It fails because:
The GOAL buffer is empty.

Production STOP does NOT match.
(P STOP
   =GOAL>
       COUNT =NUM
       END =NUM
   =RETRIEVAL>
       NUMBER =NUM
 ==>
   -GOAL>
   !OUTPUT! (=NUM)
)
It fails because:
The GOAL buffer is empty.
NIL

3> (run-n-events 2)
     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000   ------                Stopped because event limit reached
0.0
2
NIL

4> (whynot-fct '(increment))

Production INCREMENT does NOT match.
(P INCREMENT
   =GOAL>
       COUNT =NUM1
    -  END =NUM1
   =RETRIEVAL>
       NUMBER =NUM1
       NEXT =NUM2
 ==>
   =GOAL>
       COUNT =NUM2
   +RETRIEVAL>
       NUMBER =NUM2
   !OUTPUT! (=NUM1)
)
It fails because:
The RETRIEVAL buffer is empty.
(START)

5> (whynot start)

Production START matches:
(P START
   =GOAL>
       START TWO
       COUNT NIL
 ==>
```

```
   =GOAL>
       COUNT TWO
   +RETRIEVAL>
       NUMBER TWO
)
(START)
```

This example uses a simple model definition to show a production which is a partial match with :ppm enabled:

```
1> (define-model test
     (sgp :esc t :ppm 1)
     (chunk-type test slot)
     (define-chunks (buffer-value) (production-test))
     (set-similarities (buffer-value production-test -.5))
     (set-buffer-chunk 'goal (car (define-chunks (slot buffer-value))))

     (p test
        =goal>
           isa test
           slot production-test
      ==>))
TEST

2> (whynot)

Production TEST partially matches the current state:
(P TEST
   =GOAL>
       SLOT [PRODUCTION-TEST, BUFFER-VALUE, -0.5]
 ==>
)
(TEST)

E> (whynot)
#|Warning: Whynot called with no current model. |#
NIL

E> (whynot bad-name)

BAD-NAME does not name a production.
(START)
```

production-firing-only

Syntax:

production-firing-only *event* -> production-firing-event?

Arguments and Values:

event ::= an ACT-R event
production-firing-event? ::= a generalized boolean that is true if event has an action of production-fired and is false otherwise

Description:

This is not a command which should be called by the modeler directly. It is provided as a possible value for the :trace-filter parameter to restrict the trace to only the production-fired events.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
> (with-parameters (:trace-filter production-firing-only)
   (run 10))
     0.050   PROCEDURAL             PRODUCTION-FIRED START
     0.150   PROCEDURAL             PRODUCTION-FIRED INCREMENT
TWO
     0.250   PROCEDURAL             PRODUCTION-FIRED INCREMENT
THREE
     0.350   PROCEDURAL             PRODUCTION-FIRED STOP
FOUR
     0.350   ------                 Stopped because no events left to process
0.35
53
NIL
```

un-delay-conflict-resolution

Syntax:

un-delay-conflict-resolution -> **nil**

Remote command name:

un-delay-conflict-resolution

Arguments and Values:

Description:

The un-delay-conflict-resolution command takes no parameters and will cause a new conflict-resolution event to be scheduled in the current model if the procedural module is currently waiting for some change in the system to schedule the next conflict-resolution event. If there is no current model then this command has no effect and a warning is output.

This is not a command which one will typically need to use. Right now, it is only used by the procedural system modules (procedural, utility, and production-compilation) to ensure that conflict resolution gets rescheduled if necessary when parameters are changed or new productions are created. However, in rare circumstances other modules could put the system in such situations and thus may need to use this command (though typically the other module should just be able to schedule an event which would allow conflict resolution to occur normally).

Examples:

```
> (un-delay-conflict-resolution)
NIL

E> (un-delay-conflict-resolution)
#|Warning: get-module called with no current model. |#
```

```
NIL
```

clear-productions

Syntax:

clear-productions -> **nil**

Remote command name:

clear-productions

Arguments and Values:

Description:

The clear-productions command will delete all of the productions from the current model. It is not recommended, but there may be times where one finds doing so necessary. It will also print out a warning indicating that it is not recommended. If there is no current model then a warning is printed.

It always returns **nil**.

Examples:

```
> (clear-productions)
#|Warning: Clearing the productions is not recommended |#
NIL

E> (clear-productions)
#|Warning: get-module called with no current model. |#
#|Warning: No procedural module was found. |#
NIL
```

declare-buffer-usage

Syntax:

declare-buffer-usage *buffer type-name* { [**:all** | *slot**] } -> [**t** | **nil**]
declare-buffer-usage-fct *buffer type-name* { [**:all** | (*slot**)] } -> [**t** | **nil**]

Arguments and Values:

buffer ::= the name of a buffer
type-name ::= the name of a chunk-type
slot ::= a name of a slot of the chunk-type type-name

Description:

The declare-buffer-usage command is used to indicate a chunk-type and any slots from that chunk-type that are going to be used with a particular buffer but which are not created by the productions

nor set initially in the model definition. By declaring those slots as used it will prevent style warnings from the production definitions for those slots. This will typically be needed when chunks are being placed into buffers from code. In that situation using this command in the model definition to indicate the items which are being set from outside of the model definition will avoid possible style warnings.

If buffer names a valid buffer, type-name names a valid chunk-type, and all slots specified are valid for the chunk-type given then style warnings related to those items will be avoided and a value of **t** will be returned. If the keyword **:all** is provided instead of slot names then that will be equivalent to specifying all of the slots of the chunk-type given.

If any of the parameters are invalid or there is no current model then a warning will be printed and **nil** will be returned.

Examples:

```
> (declare-buffer-usage goal chunk)
T

> (declare-buffer-usage imaginal text screen-pos value)
T

> (declare-buffer-usage-fct 'imaginal 'visual-object '(value color))
T

> (declare-buffer-usage retrieval text :all)
T

> (declare-buffer-usage-fct 'imaginal 'visual-object :all)
T

E> (declare-buffer-usage not-a-buffer visual-location)
#|Warning: Cannot declare usage for NOT-A-BUFFER because it does not name a buffer in the
model. |#
NIL

E> (declare-buffer-usage-fct 'goal 'not-a-chunk-type)
#|Warning: Cannot declare usage for buffer GOAL because NOT-A-CHUNK-TYPE does not name a
chunk-type in the model. |#
NIL

E> (declare-buffer-usage goal chunk not-a-slot)
#|Warning: Cannot declare usage for buffer GOAL because the slots (NOT-A-SLOT) are not
valid for chunk-type CHUNK. |#
NIL

E> (declare-buffer-usage goal type)
#|Warning: get-module called with no current model. |#
#|Warning: No procedural module found.  Cannot declare buffer usage. |#
NIL
```

Utility module

The utility module provides the support for the productions' subsymbolic utility value which is used in conflict resolution.

The name of the module is utility and it will be available whenever the procedural module is used.

Utility

Utility is a numeric quantity associated with each production, and we will refer to the utility of a production with the letter U. The utility value of a production can be specified in advance and/or learned while the model runs. Of the productions in the conflict set (those which match the current state) the one with the highest current U will be the one selected. When utility learning is enabled, the U value is based on the rewards that a production receives and will change as the model runs. The learning of utilities is controlled by the following equation for a production *i* after its nth usage:

$$U_i(n) = U_i(n-1) + \alpha[R_i(n) - U_i(n-1)]$$

α is the learning rate set by the :alpha parameter
Ri(n) is the effective reward value given to production i for its nth usage
Ui(0) is either set by the modeler with the spp command or is the value of the :iu or :nu parameter

The learning occurs when a reward is triggered, at which time productions which have been used since the last reward may have their utility values updated (see the trigger-reward command for details on how the used productions are determined). The effective reward for a production *i* is the reward value received after its nth usage minus the time since that nth selection of production *i*.

When the :esc parameter is enabled the utility values may also have a noise component added to them (regardless of whether the learning mechanism is enabled). If :esc is enabled and the :egs parameter is set then each time a production's utility is calculated it will also have a noise component added to it. That noise is generated using the act-r-noise command with the s value being the current setting of the :egs parameter.

Parameters

:alpha

The α parameter in the utility learning equation. The default value is .2.

:egs

The expected gain s parameter. It specifies the s parameter for the noise added to the utility values. It defaults to 0 which means there is no noise in utilities.

:iu

The initial utility value for a user defined production. This is the U(0) value for a production if utility learning is enabled and the default utility for those productions if learning is not enabled. The default value is 0.

:nu

This is the starting utility for a newly learned production (those created by the production compilation mechanism). This is the U(0) value for such a production if utility learning is enabled and the default utility of those productions if learning is not enabled. The default value is 0.

:reward-hook

The reward-hook parameter allows the modeler to override the default calculation for effective reward, $R_i(n)$. It can be set to a command identifier for a command which must accept three parameters. Note, when setting the parameter remotely an embedded string will be required to name a command. If the :reward-hook parameter is not **nil** (which is the default value) then each time a reward is propagated back to a production the reward-hook command will be called. It will be passed the name of the production as the first parameter, the reward value being propagated as the second, and the time since the production was selected (in seconds) as the third. If that command returns a number then that number is used as the $R_i(n)$ value in updating the production's utility instead of the normal calculation (which is the reward minus the time since the production's selection). If any other value is returned, then the standard calculation for $R_i(n)$ is used. Only one reward-hook command may be specified at a time and if the parameter is changed from one command to another a warning will be output.

:reward-notify-hook

This parameter is now deprecated because the trigger-reward command can be monitored through the dispatcher, which is the recommended way to detect a reward. This parameter allows one to specify commands which will be called whenever there is a reward provided to the model. This parameter can be set to a command identifier for a command that takes one parameter and any number of such commands may be set (the reported value of this parameter is a list of all items which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. Whenever trigger-reward is called the commands set with this parameter will be called during the propagate-reward event that gets generated as a result of that trigger-reward. Each of the commands that has been set for this parameter will be called with one parameter which is the reward value passed to trigger-reward. The return values from the commands called through this hook are ignored. If the parameter is set to **nil** then all items are removed from the reward-notify-hook list. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A function should only be set once. If an item is specified more than once as a value for the reward-notify-hook a warning will be displayed.

:ul

This is the utility learning flag. If it is set to **t** then the utility learning equation shown above will be used to learn the utilities as the model runs. If it is set to **nil** then the explicitly set utility values for

the productions are used (though the noise will still be added if :egs is non-zero). The default value is **nil**.

:ult

This is the utility learning trace flag. If it is set to **t** then when a reward is received and utilities are updated the corresponding changes will be output in the model trace. If it is set to **nil** then there will be no additional trace output from utility updating. The default value is **nil**.

:ut

This is the utility threshold. If it is set to a number then that is the minimum utility value that a production must have to compete in conflict resolution. Productions with a lower utility value than that will not be selected. The default value is **nil** which means that there is no threshold value and all productions will be considered.

:utility-hook

The utility-hook parameter allows the modeler to override or bypass the default utility calculation. It can be set to a command identifier for a command which must take one parameter. If the :utility-hook parameter is not **nil** (which is the default value) then each time a production's utility is to be calculated, first this hook command is called with the name of the production as the parameter. If that command returns a number then that number is used as the production's utility instead of using the normal mechanisms. Only one utility-hook command may be specified at a time and if the parameter is changed from one command to another a warning will be output.

:utility-offsets

This parameter allows one to specify commands which can extend the utility equation with new terms. This parameter can be set to a command identifier for a command which takes one parameter and any number of such commands may be set (the reported value of this parameter is a list of all values which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. Whenever a production's utility is computed each of the commands that has been set for this parameter will be called with one parameter which is the name of the production. If a command called returns a number then that value will be added to the utility of the production. If a command returns any other value then it does not result in a change to the utility of the production because of that command. If the parameter is set to **nil** then all items are removed from the utility-offsets list. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A command should only be set once. If a command is specified more than once as a value for the utility-offsets a warning will be displayed.

Commands

trigger-reward

Syntax:

trigger-reward reward {maintenance} -> [**t** | **nil**]

Remote command name:

trigger-reward

Arguments and Values:

reward ::= [a number which indicates the amount of reward to apply | any non-nil value]
maintenance ::= a generalized boolean which indicates whether the propagate-reward event should be marked as a maintenance event or not

Description:

The trigger-reward command allows the modeler to present rewards to the current model for the purposes of utility learning. If the reward specified is a number then that value is used in computing the updated utility for the productions which need to be updated. If the reward is any other non-**nil** value then no utilities are updated but this still indicates when the last reward was given – effectively an indication of an empty reward. This command can be called at any time to introduce a reward to the model – it does not need to be called synchronously with a production's firing. If there is a current model and the reward value is valid, then a propagate-reward event will be scheduled at the current time to perform the computations to update production utilities and **t** will be returned. The event will show the value of the reward being used like this:

```
     0.000   UTILITY                PROPAGATE-REWARD 10
```

If utility learning is not enabled, then that will be followed by a warning indicating that no change has occurred:

```
#|Warning: Trigger-reward can only be used if utility learning is enabled. |#
```

That event will be marked as a maintenance event if a non-**nil** maintenance value is provided otherwise it will be a model event. One may want to have the reward be a maintenance event if a single model is being used both with and without learning enabled to avoid the introduction of the rewards for the learning case adding additional changes relative to the non-learning situation.

If the :ul parameter is set to **t** then all productions which have been selected since the last reward was provided will receive an update. If there is no current model or the parameter provided is invalid then a warning is printed, no utilities are changed, and **nil** is returned.

Examples:

```
> (trigger-reward 10)
T

> (trigger-reward "No updates now.")
T

> (trigger-reward -1 t)
T
```

```
E> (trigger-reward nil)
#|Warning: Trigger-reward must be called with a non-null value -- nil does not indicate a
null reward anymore. |#
T

E> (trigger-reward 10)
#|Warning: No current model.  Trigger-reward has no effect. |#
NIL
```

spp

Syntax:

spp [{ [*production-name* | (*production-name**) } { [*param-name** | *param-value-pair**] } |
(*production-name* [*param-name** | *param-value-pair**])*] -> (param-values*)
spp-fct ([{ [*production-name* | (*production-name**) } { [*param-name** | *param-value-pair**] } |
(*production-name* [*param-name** | *param-value-pair**])*]) -> (param-values*)

Remote command name:

spp ' [{ [*production-name* | (*production-name**) } { [*param-name** | *param-value-pair**] } |
(*production-name* [*param-name** | *param-value-pair**])*] ' -> ' (param-values*) '

Arguments and Values:

production-name ::= the name of a production in the current model
param-name ::= the name of a production parameter
param-value-pair ::= param-name new-param-value
new-param-value ::= a value to which the preceding param-name is to be set
param-values ::= [(param-value*) | (production-name*) | **:error**]
param-value ::= the current value of a requested production parameter or **:error**

Description:

Spp is used to set or get the value of the parameters of the productions in the current model. It is similar to the sgp command which is used to set and get the module parameter.

Each production has six parameters associated with it. Two of them are read only, but the others can be adjusted by the modeler. Those parameters are:

:at

The action time of the production. This is how much time passes (in seconds) between the production's selection and when it fires. This can be set explicitly for each production and defaults to the value of the :dat parameter at the time the production was created.

:name

The name parameter returns the name of the production. This cannot be changed. Requesting this parameter is useful for annotating the results that are returned as shown in the examples.

:u

The u parameter returns the current U(n) value for the production. This may be set directly only when the utility learning mechanism is not enabled. It defaults to the value of the :iu parameter at the time the production is created unless it is created through production compilation in which case it defaults to the value of the :nu parameter.

:utility

The last computed utility value of the production during conflict resolution (including any noise which was added). This cannot be changed by the modeler. If the production has not yet been a member of the conflict set, then the value will be **nil**.

:reward

This is a reward value to apply when this production fires. The default is **nil** which means the production does not provide a reward. If it is set to a number or **t** then after this production fires a trigger-reward call will be made using that reward value.

:fixed-utility

This parameter can be set to exclude a production from having its utility updated by the utility learning mechanism. The default value is **nil** which means that the production's :u parameter will be adjusted when rewards are received. If it is set to **t** then this production's utility will not change and will remain fixed at the current :u parameter value.

If no parameters are provided to spp, then all of the current model's productions' parameters are output to the command trace and a list of all the production names is returned. For each production it prints the production's name followed by the parameters which are currently appropriate based on the settings of :esc and :ul. If :esc is **nil**, then the :u and :at parameters are printed. If :esc is **t** and :ul is **nil** :utility, :u and :at are printed, and if :esc is **t** and :ul is **t**, then :utility, :u, :at , :reward, and :fixed-utility are printed.

If a production or list of productions is specified as the first parameter to spp then the parameters which follow that are set or retrieved from only those productions. If no production names are provided then the settings are applied to or retrieved from all productions that exist at the time of the call to spp.

If production names are specified but no specific parameters are specified then the parameters for those productions are printed and the list of those production names is returned. If any of the production names provided are invalid a warning will be printed and the corresponding element of the return list will be **:error**.

If all of the parameters passed to spp (after any production names) are keywords, then it is a request for the current values of the parameters named. Those parameters are printed for the productions specified and a list containing a list for each production specified is returned. Each sub-list contains the values of the parameters requested in the order requested and the sub-lists are in the order of the

productions which were requested. If an invalid parameter is requested, then a warning is printed and the value returned in that position will be the keyword **:error**.

If there are any non-keyword parameters in the call to spp and the number of parameters (not counting the production names) is even, then they are assumed to be pairs of a parameter name and a parameter value. For all of the specified productions (or all productions if none are specified) those parameters will be set to the provided values. The return value will be a list containing a list for each production specified. Each sub-list contains the values of the parameters set in the order they were set and the sub-lists are in the order of the productions which were specified. If a particular parameter value was not of the appropriate type, then a warning is printed and the value returned in that position will be the keyword **:error**.

It is also possible to pass lists of production-name and parameter settings to spp. Essentially, each list provided must be formatted as something that could be passed to spp on its own and they will each be processed as appropriate.

If there is no current model at the time of the call then a warning is displayed and **nil** is returned.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
1> (sgp :esc nil :ul nil)
 (NIL NIL)

2> (spp)
Parameters for production START:
 :u   0.000
 :at  0.050
Parameters for production INCREMENT:
 :u   0.000
 :at  0.050
Parameters for production STOP:
 :u   0.000
 :at  0.050
(START INCREMENT STOP)

3> (sgp :esc t)
 (T)

4> (spp)
Parameters for production START:
 :utility    NIL
 :u   0.000
 :at  0.050
Parameters for production INCREMENT:
 :utility    NIL
 :u   0.000
 :at  0.050
Parameters for production STOP:
 :utility    NIL
 :u   0.000
 :at  0.050
(START INCREMENT STOP)

5> (sgp :ul t)
 (T)

6> (spp)
```

```
Parameters for production START:
 :utility    NIL
 :u   0.000
 :at  0.050
 :reward    NIL
 :fixed-utility    NIL
Parameters for production INCREMENT:
 :utility    NIL
 :u   0.000
 :at  0.050
 :reward    NIL
 :fixed-utility    NIL
Parameters for production STOP:
 :utility    NIL
 :u   0.000
 :at  0.050
 :reward    NIL
 :fixed-utility    NIL
(START INCREMENT STOP)

7> (spp start)
Parameters for production START:
 :utility    NIL
 :u   0.000
 :at  0.050
 :reward    NIL
 :fixed-utility    NIL
(START)

> (spp-fct '((increment stop) :name :u))
Parameters for production INCREMENT:
 :NAME INCREMENT
 :U  0.000
Parameters for production STOP:
 :NAME   STOP
 :U  0.000
((INCREMENT 0) (STOP 0))

1> (spp :at 10)
((10) (10) (10))

2> (spp-fct nil)
Parameters for production START:
 :utility    NIL
 :u   0.000
 :at 10.000
 :reward    NIL
 :fixed-utility    NIL
Parameters for production INCREMENT:
 :utility    NIL
 :u   0.000
 :at 10.000
 :reward    NIL
 :fixed-utility    NIL
Parameters for production STOP:
 :utility    NIL
 :u   0.000
 :at 10.000
 :reward    NIL
 :fixed-utility    NIL
(START INCREMENT STOP)


1> (sgp :esc t :egs 3)
 (T 3)

2> (run 10)
```

```
…
0.35
53
NIL

4> (spp-fct '(:name :utility :u))
Parameters for production START:
 :NAME  START
 :UTILITY -1.806
 :U  0.000
Parameters for production INCREMENT:
 :NAME INCREMENT
 :UTILITY -1.594
 :U  0.000
Parameters for production STOP:
 :NAME   STOP
 :UTILITY -3.252
 :U  0.000
((START -1.80585 0) (INCREMENT -1.5941277 0) (STOP -3.2521996 0))

5> (spp (start) (stop :name :utility) (increment :at 10))
Parameters for production START:
 :utility -1.806
 :u   0.000
 :at  0.050
Parameters for production STOP:
 :NAME   STOP
 :UTILITY -3.252
(START (STOP -3.2521996) (10))

E> (spp (start end))
Parameters for production START:
 :utility    NIL
 :u   0.000
 :at 10.000
 :reward    NIL
 :fixed-utility    NIL
#|Warning: Spp cannot adjust parameters because production END does not exist |#
(START :ERROR)

E> (spp start :u :ve)
Parameters for production START:
 :U  0.000
#|Warning: NO PARAMETER VE DEFINED FOR PRODUCTIONS. |#
 :VE  ERROR
((0 :ERROR))

E> (spp)
#|Warning: get-module called with no current model. |#
NIL
```

Production Compilation Module

The production compilation module implements the process of learning new productions. Only the basic mechanisms of the module will be described here. Additional details on the production compilation process can be found in tutorial unit 7, the document named "compilation" in the docs/notes directory of the source code, and the spreadsheet named compilation in the docs directory provides the details of all the possible uses of a buffer in the two productions and whether it can or cannot then be composed.

The name of the module is production-compilation and it will be available whenever the procedural module is used.

Production Compilation

Production compilation works by composing two productions that fire in sequence into one new production. When enabled, it will attempt to create a new production for each pair of productions that fire. To determine if two productions can be composed into one production all of the buffers that are referenced in those productions (in any condition or action) are checked to see if they have a compatible usage between the two productions. If any buffer does not have a compatible usage between the two productions then the productions cannot be composed.

Compatible usage is determined by the "compilation type" of the buffer. The compilation type also controls how the usage of that buffer in the productions gets composed into the new production. The provided module specifies five different compilation types, and each of the buffers in the system is considered to be of one of those types. The five types are goal, imaginal, retrieval, perceptual, and motor. The details of what constitutes valid usage for those compilation types are described in the excel spreadsheet compilation.xls and the mechanism used to create the new production based on the compilation type is described in the compilation document. It is possible to change the compilation type of a buffer using the specify-compilation-buffer-type command and it is also possible to add new compilation types to the system. For the buffers provided in the default system this is the assignment of buffer to compilation type:

Buffer Name	Compilation Type
goal	Goal
imaginal	Imaginal
retrieval	Retrieval
aural	Perceptual
aural-location	Perceptual
visual	Perceptual
visual-location	Perceptual
temporal	Perceptual
imaginal-action	Motor
production	Motor
manual	Motor
vocal	Motor

Any buffer added with a new module will be of the motor compilation type by default, but may be changed with the specify-compilation-buffer-type command.

If all of the buffers have a compatible usage between two successive productions which fire then the following situations are checked. If any of these are true the productions cannot be composed:

- is the time between the productions greater than the threshold time?
- does either production have a !eval! condition or action?
- does either production have a !bind! condition or action?
- does either production use !mv-bind! in either the conditions or actions?
- does either production have a buffer overwrite action?
- does either production use any indirect actions and the :cia parameter is nil?
- does either production have any indirect actions using the variable from a !safe-bind! and the :cia parameter is t and the :rir parameter is nil?
- does either production have any indirect actions using the variable from a !safe-bind! for buffers which are not using the retrieval style and the :cia parameter is t and the :rir parameter is t?
- does either production use slot modifiers other than = in its conditions?
- does the first production make multiple requests using the same buffer?
- does the first production have a RHS !stop! action?
- does either production use variables bound in a !safe-bind! in other !safe-bind! statements?
- does the first make a request to a buffer and the second use the variable bound to the name of the chunk in that buffer?

If none of those situations are true, then the two productions are composed into one new production.

After creating the new production, it is compared against the other productions in the procedural memory of the model. If the new production is not semantically equivalent to an existing production then the new production is also added to the procedural memory of the model. The parameters for the new production are set as follows:

- The :utility is the value of the :nu parameter.
- The :at parameter is set to the max of the :at parameters from its two parent productions.
- If both of the parent productions have a numeric :reward
  - The new production gets the max of those two as its :reward.
- If only one of the parents has a numeric :reward
  - The new production gets that value as its :reward.
- If neither parent has a numeric :reward, but at least one has a value of **t** for the :reward
  - The new production will get a value of **t**.
- If both parents have a **nil** :reward value
  - The new production also gets a **nil** :reward value.

If the newly formed production is semantically equivalent to an existing production then what happens depends on whether the production to which it is equivalent was also created by production compilation or whether it was one of the explicitly specified productions of the model and also whether utility learning is enabled.

If the production is equivalent to one of the explicitly specified productions or utility learning is not enabled, then nothing happens and the newly created production is ignored.

If the production is equivalent to one which was previously created by production compilation and utility learning is enabled then that production receives an update to its utility. The effective reward which it receives is the current :u value of the first of the two productions which fired to create it.

Parameters

:cia

The compile indirect actions parameter controls whether the production compilation process will attempt to compile productions which contain indirect actions. If :cia is set to **t** then productions with indirect actions will have those actions instantiated before starting the composition process (unless the :rir parameter is also set), and if it is set to **nil** then productions with indirect actions cannot be compiled. The default value is **nil**.

:epl

The enable production learning parameter controls whether the production compilation process is enabled or disabled. If :epl is set to **t** then the process is enabled and if it is set to **nil** then it is disabled. The default value is **nil**.

:pct

The production compilation trace parameter controls whether information about the production compilation process is output to the model trace. If it is set to **t** then after each production fires a notice about the production compilation process will be displayed. If a new production was created then that production will be printed along with its parameter values. If a new production was not created then information indicating why not will be displayed. If the parameter is set to **nil** then no output will be given for production compilation. The default value is **nil**.

:rir

The retain indirect retrievals parameter works in conjunction with the :cia parameter. If :cia is set to **nil** then the setting of :rir does not matter. If :cia is set to **t** then :rir controls whether indirect requests made to a retrieval style buffer are instantiated before composition or whether they remain as indirect actions in the composed production. If it is set to **nil** then they will be instantiated. If it is set to **t** then, when possible, indirect actions for a retrieval style buffer will remain indirect in the composed production. The default value is **nil**.

:tt

The threshold time parameter specifies the maximum amount of time in seconds that is allowed to pass between the firing of two productions and still allow them to be composed through production compilation. The default value is 2 seconds.

Commands

show-compilation-buffer-types

Syntax:

show-compilation-buffer-types -> **nil**

Remote command name:

show-compilation-buffer-types

Description:

The show-compilation-buffer-types command can be used to print out the current assignments of all the buffers' compilation types in the current model to the command trace. If there is no current model a warning is printed.

Examples:

```
> (show-compilation-buffer-types)
  Buffer                Type
VISUAL                PERCEPTUAL
TEMPORAL              PERCEPTUAL
AURAL-LOCATION        PERCEPTUAL
VISUAL-LOCATION       PERCEPTUAL
PRODUCTION            MOTOR
AURAL                 PERCEPTUAL
VOCAL                 MOTOR
IMAGINAL-ACTION       MOTOR
MANUAL                MOTOR
GOAL                  GOAL
IMAGINAL              IMAGINAL
RETRIEVAL             RETRIEVAL
NIL

E> (show-compilation-buffer-types)
#|Warning: get-module called with no current model. |#
#|Warning: No production compilation module found |#
NIL
```

compilation-buffer-type

Syntax:

compilation-buffer-type *buffer-name* -> [buffer-type | **nil**]
compilation-buffer-type-fct *buffer-name* -> [buffer-type | **nil**]

Remote command name:

compilation-buffer-type

Arguments and Values:

buffer-name ::= the name of a buffer
buffer-type ::= the compilation type of buffer-name

Description:

Compilation-buffer-type will return the compilation type for a buffer in the current model. If there is no current model or the buffer name is invalid then **nil** is returned.

Examples:

```
> (compilation-buffer-type-fct 'manual)
MOTOR

> (compilation-buffer-type goal)
GOAL

> (compilation-buffer-type not-a-buffer)
NIL

E> (compilation-buffer-type goal)
#|Warning: get-module called with no current model. |#
#|Warning: No production compilation module found |#
NIL
```

specify-compilation-buffer-type

Syntax:

specify-compilation-buffer-type *buffer-name buffer-type* -> [**t** | **nil**]
specify-compilation-buffer-type-fct *buffer-name buffer-type* -> [**t** | **nil**]

Remote command name:

specify-compilation-buffer-type

Arguments and Values:

buffer-name ::= the name of a buffer
buffer-type ::= the name of a valid compilation type

Description:

Specify-compilation-buffer-type allows one to change the compilation type for the buffers of the current model. If buffer-name and buffer-type are both valid, then that buffer will now be treated as a buffer-type buffer for compilation purposes, and **t** will be returned. If either parameter is invalid or there is no current model then a warning is printed and **nil** is returned.

Note that this setting is only valid until the model is reset because the production compilation module will return all buffers to their default types when it is reset. For that reason, if one wants to make a new module's buffer's default type something other than motor without needing to specify this call in each model definition that uses the buffer then this setting must be placed into the secondary reset function for that module to ensure that the setting is not overwritten by the resetting of the production compilation module (it uses the primary reset function to set the default values).

Examples:

```
1> (specify-compilation-buffer-type goal motor)
T

2> (specify-compilation-buffer-type-fct 'visual-location 'retrieval)
T

3> (show-compilation-buffer-types)
  Buffer                 Type
VISUAL                PERCEPTUAL
TEMPORAL              PERCEPTUAL
AURAL-LOCATION        PERCEPTUAL
VISUAL-LOCATION       RETRIEVAL
PRODUCTION            MOTOR
AURAL                 PERCEPTUAL
VOCAL                 MOTOR
IMAGINAL-ACTION       MOTOR
MANUAL                MOTOR
GOAL                  MOTOR
IMAGINAL              IMAGINAL
RETRIEVAL             RETRIEVAL
NIL

E> (specify-compilation-buffer-type visual bad-type)
#|Warning: Invalid compilation buffer type BAD-TYPE. |#
NIL

E> (specify-compilation-buffer-type-fct 'bad-buffer 'motor)
#|Warning: No buffer named BAD-BUFFER found. |#
NIL

E> (specify-compilation-buffer-type goal perceptual)
#|Warning: get-module called with no current model. |#
#|Warning: No production compilation module found |#
NIL
```

Goal Module

The goal module provides the system with a goal buffer which is typically used to maintain the current task state of a model and to hold relevant information for the current task. The only action which the goal module provides a model is the creation of new chunks.

The module is named goal.

Goal buffer

The goal module sets the goal buffer to **not** be strict harvested and **not** subject to strict safety.

Activation spread parameter: :ga
Default value: 0.0

Queries

The goal buffer only responds to the default queries.

'State busy' will always be **nil**.

'State free' will always be **t**.

'State error' will always be **nil**.

Requests

All

{*slot value*}*

Each slot in the request should be specified at most once.

The request is used to create a new chunk which is placed into the goal buffer immediately. It will result in an event which looks like this in the trace with the :trace-detail parameter set to high:

```
0.000   GOAL                    SET-BUFFER-CHUNK-FROM-SPEC GOAL
```

Modification Requests

All

{*slot value*}*

The goal buffer accepts modification requests and those specified buffer modifications are passed to mod-buffer-chunk for the goal buffer at the time of the request. It is assumed that the chunk will still be there at that time.

The event below will show up in the trace as a result of such an action being made by a production (always at the same time as the procedural request):

```
0.050   GOAL                    MOD-BUFFER-CHUNK GOAL
```

If there are slots specified which are not valid slot names they will be added as extended slots prior to sending the modification request. If such a slot is explicitly specified in the production then the extension will occur when the production is defined, but if the extension occurs because of a variablized slot name it will happen when the production fires and result in an event which looks like this indicating that the procedural module extended the possible slots:

```
0.050   PROCEDURAL              EXTEND-BUFFER-CHUNK GOAL
```

A modification request for the goal buffer is equivalent to performing the same buffer modification action in the production. The only difference is that by using a modification request to perform the change to the chunk the effort is attributed to the goal module instead of the procedural module which may be important for purposes of predicting the BOLD response or for tracing purposes.

Commands

goal-focus

Syntax:

goal-focus { [*chunk-name* | *chunk-description*] } -> [result | **nil**]
goal-focus-fct { [*chunk-name* | *chunk-description*] } -> [result | **nil**]

Remote command name:

goal-focus { [*chunk-name* | '*chunk-description*'] }

Arguments and Values:

chunk-name ::= the name of a chunk
chunk-description ::= (slot-value-pair*)
slot-value-pair ::= slot-name slot-value
slot-name ::= the name of a slot
slot-value ::= the value to set as the value of the corresponding slot-name
result ::= [chunk-name | goal-chunk | chunk-description]
goal-chunk ::= the name of the chunk in the goal buffer

Description:

If a chunk-name or chunk-description list is provided, then goal-focus will schedule an event to put that chunk into the goal buffer of the current model at the current time with a priority of :max. This will result in the unrequested query being true for the buffer because this chunk was not placed into the buffer as a result of a module request. There will also be a maintenance event scheduled with an action of clear-delayed-goal following the set-buffer-chunk event which updates some internal information for the goal module but which will not show up in the trace. If an event is created to place this chunk into the buffer then the chunk-name or chunk-description provided is returned. If chunk-name is not a valid chunk, the chunk-description provided is not valid, or there is no current model then a warning is printed and **nil** is returned.

If chunk-name is not provided, then the chunk currently in the goal buffer is printed if there is one and that chunk's name is returned. If the buffer is empty, then a message stating that is printed and **nil** is returned. If there is a pending change to the chunk in the goal buffer (an event generated by goal-focus has been scheduled but not yet executed), then a notice of that is printed along with any chunk which may be in the buffer currently and the name of the chunk which will be copied into the buffer or the description that will be used to create the new goal buffer chunk is returned.

This command typically occurs in a model to set the initial chunk in the goal buffer. If declarative learning of past goals is something that the model will be doing, then one should consider either using define-chunks to create that initial goal instead of add-dm or specifying the description of the chunk instead of explicitly creating it so that it is not in declarative memory prior to the start of the task.

Examples:

```
> (goal-focus)
Goal buffer is empty
NIL

1> (goal-focus black)
BLACK

2> (goal-focus)
Will be a copy of BLACK when the model runs
BLACK
  COLOR BLACK

BLACK

3> (run-n-events 2)
     0.000   GOAL                  SET-BUFFER-CHUNK GOAL BLACK NIL
     0.000   ------                Stopped because event limit reached
0.0
2
NIL

4> (goal-focus)
GOAL-CHUNK0
   COLOR  BLACK

GOAL-CHUNK0

5> (goal-focus-fct 'free)
FREE

6> (goal-focus-fct)
Will be a copy of FREE when the model runs
Currently holds:
```

```
GOAL-CHUNK0
   COLOR  BLACK

FREE

7> (run-n-events 1)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FREE NIL
     0.000   ------                  Stopped because event limit reached
0.0
1
NIL

8> (goal-focus)
GOAL-CHUNK0
   NAME  FREE

GOAL-CHUNK0

9> (reset)
T

10> (goal-focus (color blue value 2))
(COLOR BLUE VALUE 2)

11> (goal-focus)
Will be set to a chunk with this description when model runs:
   COLOR BLUE
   VALUE 2
(COLOR BLUE VALUE 2)

12> (run 1)
     0.000   GOAL                    SET-BUFFER-CHUNK-FROM-SPEC GOAL  NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   ------                  Stopped because no events left to process
0.0
4
NIL

13> (goal-focus)
GOAL-CHUNK0
   VALUE  2
   COLOR  BLUE

GOAL-CHUNK0

E> (goal-focus notchunk)
#|Warning: NOTCHUNK is not the name of a chunk in the current model - goal-focus failed |#
NIL

E> (goal-focus (bad description list))
#|Warning: Invalid slot-name BAD in call to define-chunk-spec. |#
#|Warning: (BAD DESCRIPTION LIST) is not a valid chunk description - goal-focus failed. |#
NIL

E> (goal-focus black)
#|Warning: get-module called with no current model. |#
NIL
```

mod-focus

Syntax:

mod-focus {*slot-name slot-value*}* -> [chunk-name | **nil**]

mod-focus-fct ({*slot-name slot-value*}***)** -> [chunk-name | **nil**]

Remote command name:

mod-focus '{*slot-name slot-value*}'*

Arguments and Values:

slot-name ::= the name of a slot
slot-value ::= the value to set for the value of the corresponding slot-name
chunk-name ::= the name of the chunk in the goal buffer

Description:

Mod-focus is used to modify the chunk currently in the goal buffer or the chunk which will be in the buffer as a result of a goal-focus call. It schedules an event with the action goal-modification and priority :max for the current model. That event calls mod-buffer-chunk for the goal buffer with the slot-name and slot-value pairs provided.

If there is a chunk in the buffer or a pending goal-focus and the modifications are valid for that chunk, then that chunk's name is returned after scheduling the event. If there is no current model, no chunk in the goal buffer and no pending goal-focus, or the modifications are invalid, then a warning is printed and **nil** is returned without scheduling the event.

Examples:

```
1> (define-model test
     (chunk-type test color state)
     (goal-focus-fct (car (define-chunks (state start) (start)))))
TEST

2> (run 1)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL CHUNK0 NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   ------                  Stopped because no events left to process
0.0
4
NIL

3> (mod-focus color green)
GOAL-CHUNK0

4> (goal-focus)
GOAL-CHUNK0
   STATE  START

GOAL-CHUNK0

5> (run 1)
     0.000   GOAL                    GOAL-MODIFICATION
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   ------                  Stopped because no events left to process
0.0
2
NIL

6> (goal-focus)
```

```
GOAL-CHUNK0
   STATE  START
   COLOR  GREEN

GOAL-CHUNK0

7> (mod-focus-fct '(state busy))
GOAL-CHUNK0

8> (goal-focus)
GOAL-CHUNK0
   STATE  START
   COLOR  GREEN

GOAL-CHUNK0

9> (run 1)
     0.000   GOAL                    GOAL-MODIFICATION
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   ------                  Stopped because no events left to process
0.0
2
NIL

10> (goal-focus)
GOAL-CHUNK0
   STATE  BUSY
   COLOR  GREEN

GOAL-CHUNK0

11> (clear-buffer 'goal)
GOAL-CHUNK0

12E> (mod-focus color green)
#|Warning: No chunk currently in the goal buffer and no pending goal-focus chunk to be
modified. |#
NIL

E> (mod-focus slot)
#|Warning: Odd length modifications list in call to mod-focus. |#
NIL

E> (mod-focus bad-slot green)
#|Warning: Invalid slot name BAD-SLOT specified for mod-focus. |#
NIL

E> (mod-focus state start)
#|Warning: get-module called with no current model. |#
NIL
```

Imaginal Module

The imaginal module provides the system with an imaginal buffer which is typically used to maintain context relevant to the current task and a buffer called imaginal-action which can be used to call user created commands for manipulating the contents of the imaginal buffer. A request to the imaginal buffer operates like the goal buffer's request does to create a new chunk. However, unlike the goal module, requests to create chunks using the imaginal module take time. It also accepts modification requests which it also handles the same way the goal buffer does, except again there is a cost for doing that with the imaginal module.

The name of the module is imaginal.

Parameters

:imaginal-delay

The imaginal-delay parameter controls how long it takes a request or modification request to the imaginal buffer to complete. It can be set to a non-negative time (in seconds) and defaults to .2.

:vidt

The variable imaginal delay time parameter controls whether the actions of the imaginal buffer take exactly the amount of time specified by :imaginal-delay or if they are randomized with the randomize-time command. If it is set to **t**, then randomize-time is used to adjust the delay time, and if it is set to **nil**, which is the default, then the delay times are fixed at the :imaginal-delay time.

Chunk-types & Chunks

The imaginal module defines the following two chunk-type:

```
(chunk-type generic-action action slots result)
(chunk-type simple-action action slots (simple t)))
```

It creates no initial chunks.

Imaginal buffer

The imaginal buffer is typically used to create and hold task relevant information. It operates similar to the goal buffer except that there is a time cost associated with creating and manipulating the chunks.

Activation spread parameter: :imaginal-activation
Default value: 1.0

Queries

The imaginal buffer only responds to the default queries.

'State busy' will be **t** after a new request or modification request is received (through either of the module's buffers). If the request came through the imaginal buffer the state will return to **nil** once the request is completed. If the request came through the imaginal-action buffer then the busy state will remain **t** until the set-imaginal-free command is used to clear the busy state back to **nil**.

'State free' will be **t** when the 'state busy' flag is **nil** i.e. when the module is not currently handling a request, and it will be **nil** when the module is handling a request.

'State error' will be **nil** unless set by the user with the set-imaginal-error command which will cause it to be **t**. If set with the command, it will stay **t** until the next request is made to either of the module's buffers. When the error state is set the imaginal buffer's failure flag will also be set.

Requests

All

{*slot value*}*

Each slot should be specified at most once and no modifiers are allowed.

The request is used to create a new chunk which is placed into the imaginal buffer after :imaginal-delay seconds. That will result in and event like this showing up in the trace:

```
0.200   IMAGINAL              SET-BUFFER-CHUNK-FROM-SPEC IMAGINAL
```

There are two other maintenance events generated which will occur at the same time as the action shown above but which will not show up in the trace. The first occurs before that event, and it will have an action of goal-style-request. The other has the action set-imaginal-free which will happen after the action shown above, and it serves to set the module back to state free after it has created the new chunk.

The module can only handle one request at a time. If a request is made while the module is busy processing a previous request it will print a warning and ignore the newer request.

```
#|Warning: Imaginal request made to the IMAGINAL buffer while the imaginal module was
busy. New request ignored. |#
```

Modification requests

All

{*slot value*}*

The imaginal buffer accepts modification requests and those specified buffer modifications are passed to mod-buffer-chunk for the imaginal buffer after :imaginal-delay seconds have passed. It is assumed that the chunk will still be there at that time.

This event will show up in the trace as a result of such an action:

```
1.000   IMAGINAL                MOD-BUFFER-CHUNK IMAGINAL
```

If there are slots specified which are not valid slot names they will be added as extended slots prior to sending the modification request. If such a slot is explicitly specified in the production then the extension will occur when the production is defined, but if the extension occurs because of a variablized slot name it will happen when the production fires and result in an event which looks like this indicating that the procedural module extended the possible slots:

```
0.800   PROCEDURAL              EXTEND-BUFFER-CHUNK IMAGINAL
```

There will also be a maintenance event generated which will not be output to the trace. It will have the action of set-imaginal-free and occur after the mod-buffer-chunk event. It serves to set the module back to the free state after the buffer-modification is complete.

Imaginal-action buffer

The imaginal-action buffer is available for users to extend the capabilities of the imaginal module. It does not perform any actions on its own nor does the module place any chunks into the buffer. It essentially provides a hook for the modeler to perform actions on the imaginal buffer's chunk which are attributed to the imaginal module.

Activation spread parameter: :imaginal-action-activation
Default value: 0.0

Queries

The imaginal-action buffer only responds to the default queries.

'State busy' will be **t** after a new request or modification request is received (through either of the module's buffers). If the request came through the imaginal buffer the state will return to **nil** once the request is completed. If the request came through the imaginal-action buffer then the busy state will remain **t** until the set-imaginal-free command is used to clear the busy state back to **nil**.

'State free' will be **t** when the 'state busy' flag is **nil** i.e. when the module is not currently handling a request and it will be **nil** when the module is handling a request.

'State error' will be **nil** unless set by the user with the set-imaginal-error command which will cause it to be **t**. If set with the command, it will stay **t** until the next request is made to either of the module's buffers. When the error state is set the imaginal-action buffer's failure flag will also be set.

Requests

Generic action

action *command-name*
{**slots (***slot-name********)}

This request to the imaginal-action buffer requires the action slot be specified and its value must name a command. An optional list of slot names may be provided as the value of the slots slot in the request. Every slot-name provided must be the name of a slot of the chunk currently in the imaginal buffer. When the request is received by the module the state busy query for the module will be set to **t**, the state error query will be set to **nil**, and the command specified by command-name will be called. If there is a list of slot names provided they will be passed to the command, otherwise the command will be called with no parameters. No chunks will be placed into the buffer by default and the command which is called must return the module to the state free using the set-imaginal-free command either directly or by scheduling an event to do so at a later time. The command may also call the set-imaginal-error command to set the state error to **t** for the module if that is needed.

This action allows users to manipulate the chunk which is in the imaginal buffer via arbitrary code and have the action attributed to the imaginal module i.e. it is essentially the same as a call to !eval! in a production except that the request is marked as going to the imaginal module and the module indicates "state busy" during that time. This allows modelers to add commands which they feel should be attributed to the imaginal module (for example rotations, translations or other manipulations of the representation) without having to change the code for the module.

No events are explicitly generated by this request, but the function which is called should generate events for any changes it makes to the buffer and to schedule the call to set-imaginal-free.

Simple action

action *command-name*
simple t
{**slots (***slot-name********)}

This request to the imaginal-action buffer is very similar to the generic action described above. The distinction between the two is that the simple action requires that an additional slot named simple be specified with the value t in the request. The difference between the two is that the simple action handles some of the event scheduling automatically.

When the request is received by the module the state busy query for the module will be set to **t**, the state error query will be set to **nil**, and the command specified by command-name will be called. If there is a list of slot names provided the command will be passed those names, otherwise the command will be called with no parameters. That command should return either the name of a chunk or **nil**. If it returns the name of a chunk then after the current :imaginal-delay time passes that chunk will be copied into the imaginal buffer, and the module will be returned to the free state. If the function returns **nil** then after the imaginal-delay time passes the module will be set to the free state and it will be marked as also being in the error state. This request provides an easy way to have code create arbitrary chunks for the imaginal buffer without having to schedule any events or manage the internal imaginal state flags directly.

A valid request of this type will generate two events. One will be an event with the action of set-imaginal-free. The other depends on whether the action function returned a chunk or **nil**. If it returns a chunk then an event with the action set-buffer-chunk will be generated, but if **nil** was returned an event with the action set-imaginal-error will be created.

Commands

set-imaginal-free

Syntax:

set-imaginal-free -> [**t** | **nil**]

Remote command name:

set-imaginal-free

Description:

Set-imaginal-free is used to clear the busy state of the imaginal module in the current. It should only be used by commands that are called as a result of a generic action request to the imaginal-action buffer.

If there is a current model then it returns **t**. If there is no current model then it returns **nil** and no change is made.

Examples:

```
> (set-imaginal-free)
T

E> (set-imaginal-free)
#|Warning: get-module called with no current model. |#
#|Warning: Call to set-imaginal-free failed |#
NIL
```

set-imaginal-error

Syntax:

set-imaginal-error -> [**t** | **nil**]

Remote command name:

set-imaginal-error

Description:

Set-imaginal-error is used to set the error state of the imaginal module in the current model. It should only be used by commands that are called as a result of a generic action request to the imaginal-action buffer. It causes queries of either of the imaginal module's buffers for 'state error' to return **t** and also sets the failure flags for both buffers as requested failures using set-buffer-failure. The module's error state will remain until another request is made to either of the module's buffers.

If there is a current model then it returns **t**. If there is no current model then it prints a warning, returns **nil**, and no change is made.

Examples:

```
> (set-imaginal-error)
T

E> (set-imaginal-error)
#|Warning: get-module called with no current model. |#
#|Warning: Call to set-imaginal-error failed |#
NIL
```

Declarative module

The declarative module provides the model with a declarative memory which stores the chunks that are generated by the model and it provides a mechanism for retrieving those chunks through its retrieval buffer. The retrieval of chunks from the declarative memory depends on many factors that affect the accuracy and speed with which a chunk can be retrieved based on research of human memory performance.

The module is named declarative.

Declarative Memory

The model's declarative memory (DM) consists of all the chunks which are explicitly added to it by the modeler as well as all of the chunks which are cleared from the buffers. Whenever a chunk is cleared from a buffer the declarative module merges that chunk into the model's DM. The merging process compares the chunk being added to the chunks already in DM. If the chunk being added is equivalent to a chunk which is already in DM, then the new chunk is merged with the existing chunk using the merge-chunks command and that chunk is strengthened by giving it another reference at the time of the merging. If the chunk being added is not equivalent to any chunk in DM then that chunk is added to DM (or a copy is added if the buffer is reusing chunks as indicated by the result of the chunk-not-storable command).

Retrieval of chunks from DM is done through requests to the module. A request specifies a description of a chunk which is desired and if there are chunks in DM which match the specification request, then one of those chunks is placed into the retrieval buffer as a response. If no such chunk is found then it signals that a failure to retrieve occurred by signaling the state error, setting the buffer's failure flag, and leaving the buffer empty.

The time it takes to complete the request and how a single chunk is chosen among possibly many which match the request are controlled by several parameters. First, the setting of the :esc parameter determines very coarsely what process is used.

If the :esc parameter is **nil** then only the symbolic matching is considered. The chunks are always retrieved immediately and if there is more than one chunk which matches the request the setting of :er determines how a chunk is chosen. If :er is **t** then the choice is made randomly. If :er is **nil** then a deterministic process is used such that the same chunk will be chosen for that model each time the same set of possible chunks could be retrieved. However, that process is not specified as part of the declarative module's definition because it is not intended to be a process which one relies upon for chunk preferences.

If the :esc parameter is **t** then the selection of which chunk is retrieved and how long it takes is controlled by a quantity called activation. Each chunk in DM has an activation value associated with it and among the chunks which match the request the one with the highest activation value, above a parameterized threshold, is the one that will be retrieved. If no matching chunk has an activation above the threshold then a failure to retrieve occurs. The activation of the chunk retrieved also determines how long the request takes to complete. If multiple matching chunks have the same

highest activation, then the :er parameter determines how one of those chunks is chosen in the same way it happens when :esc is **nil**.

Activation

How the activation of a chunk is computed is based on the setting of several parameters which determine which mechanisms are to be used and those will be discussed in the specific sections which follow. Here is the general equation for the activation (A) of a chunk i:

$$A_i = B_i + S_i + P_i + \varepsilon_i$$

***B_i*:** This is the base-level activation and reflects the recency and frequency of use of the chunk.

***S_i*:** This is the spreading activation value computed for the chunk which reflects the effect that the current contents of the buffers have on the retrieval process.

***P_i*:** This is the partial matching value computed for the chunk which reflects the degree to which the chunk matches the specification requested.

ε_i: A noise value with both a transient and permanent component.

Each of those components will be described in more detail below. Note that for each of those components it is possible for the modeler to replace the mechanism as described with their own mechanism using the hook function parameters available in the declarative module.

Base-level

The base-level component, B_i, is computed differently based on the setting of the :bll and :ol parameters.

If :bll is **nil** then the setting of :ol does not matter and the base-level is a constant value determined by the :blc parameter or specific user settings for the chunk.

$$B_i = \beta_i$$

β_i: A constant offset which is determined by the :blc parameter or the chunk's :base-level parameter.

If :bll is set to a number, then the setting of :ol determines how the base-level is computed.

If :ol is **nil** then this equation is used:

$$B_i = \ln(\sum_{j=1}^{n} t_j^{-d}) + \beta_i$$

***n*:** The number of presentations for chunk *i*.
***t*$_j$**: The time since the *jth* presentation. A presentation is either the chunk's initial entry into DM or when another chunk is merged with a chunk which is in DM (these are also called the chunk's references).
d: The decay parameter which is set using the :bll parameter.
βi: A constant offset determined by the :blc parameter.

If :ol is **t** then this approximation to that equation is used which does not require recording the complete history of the chunk:

$$B_i = \ln(n/(1-d)) - d * \ln(L) + \beta_i$$

***n*:** The number of presentations of chunk *i*.
***L*:** The lifetime of chunk *i* (the time since its creation).
***d*:** The decay parameter (the value of :bll).
βi: A constant offset determined by the :blc parameter.

If :ol is set to a number, then a hybrid of those is used such that the specified number of true references are used and the approximation is used for any remaining references (if there are not more total references than the parameter setting for :ol (n <= k) then the full equation is used and the extra term in this equation is not computed):

$$B_i = \ln(\sum_{j=1}^{k} t_j^{-d} + \frac{(n-k) * (t_n^{1-d} - t_k^{1-d})}{(1-d) * (t_n - t_k)}) + \beta_i$$

k: is the value of the :ol parameter.
***t*$_j$**: The time since the *jth* presentation (for this equation t_1 is the time since the most recent presentation and t_n the time since the first presentation)
***n*:** The total number of presentations of chunk *i*.
***d*:** The decay parameter (the value of :bll).
βi: A constant offset determined by the :blc parameter.

Spreading Activation

Whether spreading activation is used is determined by the setting of the :mas parameter. If it is **nil**, which is the default value, then the value of S_i is 0 in the activation equation. If :mas is set to a number, then this equation determines the spreading activation component of chunk *i*'s activation:

$$S_i = \sum_k \sum_j W_{kj} S_{ji}$$

The elements *k* being summed over are all of the buffers in the model which currently contain a chunk and which have a non-zero source activation setting.

The elements *j* being summed over are the chunks which are in the slots of the chunk in buffer *k* (these are referred to as the sources of activation).

***W_{kj}*:** This is the amount of activation from source *j* in buffer *k*. It is the source activation of buffer *k* divided by the number of sources *j* in that buffer by default.

***S_{ji}*:** This is the strength of association from source *j* to chunk *i*.

strength of association

The strength of association, ***S_{ji}***, between two chunks is computed using the following equations by default, but can also be set explicitly by the modeler using the add-sji command or through the sji-hook parameter, and there is also a currently experimental mechanism through which that value can be learned available in the extras/associative-learning directory (which will not be described in this manual).

If chunks *j* and *i* are not the same chunk and *j* is not in a slot of chunk *i*:

$$S_{ji} = 0$$

If chunks *j* and *i* are the same chunk or chunk *j* is in a slot of chunk *i*:

$$S_{ji} = S - \ln(fan_{ji})$$

S: The maximum associative strength set with the :mas parameter.

***fan_{ji}*:** a measure of how many chunks are associated with chunk j.

The fan is typically thought of as the number of chunks in which *j* is the value of a slot plus one for chunk *j* being associated with itself. However, because *j* may appear in more than one slot of the chunk *i*, this is the specific calculation which is used to compute the fan:

$$fan_{ji} = \frac{1 + slots_j}{slotsof_{ji}}$$

***slots*$_j$:** the number of slots in which *j* is the value across all chunks in DM.
***slotsof*$_{ji}$:** the number of slots in chunk *i* which have *j* as the value (plus 1 when chunk *i* is chunk *j*).

The S_{ji} value can become negative as the fan_{ji} value grows, but that is generally an undesirable situation. By default the declarative module will print a warning if S_{ji} becomes negative due to that calculation and use 0.0 instead of the negative value, but that can be changed using the :nsji parameter.

Partial Matching

When the partial matching process is enabled it is possible for a chunk that is not a perfect match to the retrieval specification to be the one that is retrieved. To enable the partial matching one needs to set the :mp parameter to a number instead of its default of **nil**. When enabled, the similarity of the values requested to those in the slots of the chunks in DM are computed to determine the activation value. If partial matching is disabled then P_i is 0, but if it is enabled it is computed with this equation:

$$P_i = \sum_k PM_{ki}$$

The elements *k* being summed over are the slot values of the retrieval specification for slots with an = or – modifier only.

***P*:** This is a match scale parameter (set with :mp) that reflects the amount of weighting given to the similarity.
***M*$_{ki}$:** The similarity between the value *k* in the retrieval specification and the value in the corresponding slot of chunk *i*.

similarities

The possible range of default similarity values is configurable using the maximum similarity parameter (:ms) and the maximum difference parameter (:md). The default range is from 0 to -1 with 0 being the most similar and -1 being the largest difference. In general, the similarity can be thought of more as a difference penalty because the concept is not to boost the similar items, but to penalize the different ones. Since it gets added to the activation value, the values should be negative for items that are not the same and using positive similarities is not recommended (though not prohibited).

By default, a chunk has a maximum similarity to itself and a maximum difference to all other chunks. Any other similarities must be set explicitly by the modeler either using the set-similarities command or the sim-hook parameter. For non-chunk slot values in a retrieval request, the similarity is the maximum similarity if the values are equal using the chunk-slot-equal command and the maximum difference if they are not. The only way to set non-default similarity values for items which are not chunks is through the sim-hook capability. Similarities set explicitly with the declarative commands or through the sim-hook function are not constrained by the :ms and :md parameters.

One final note on the computation of the M_{ki} values. If the retrieval specification is requesting the value using the negation modifier, then the M_{ki} value for that slot test *k* is not the specific similarity value between the items involved. If the similarity between those items is equal to the maximum similarity then M_{ki} is set to the maximum difference. Otherwise, M_{ki} is set to 0 for that slot. Essentially, if they are the same (or perfectly similar items), then the chunk is given the maximum penalty since the request specified that it not have that value and if they are different (any similarity other than a perfect match) then no penalty is applied.

Noise

The noise calculation has two components. There is a transient component which is computed each time a retrieval request is made and there is a permanent component which is associated with each chunk when it is entered into DM. The total noise added to the activation is the sum of the two components. Often, the transient component is sufficient for modeling and the permanent noise is left disabled.

Each one is generated using the act-r-noise command. Thus they are generated from a logistic distribution with a mean of 0 and an s as specified by the corresponding parameter of the declarative module. The parameter for the transient noise s value is :ans and the parameter for the permanent noise s value is :pas. The default value for each parameter is **nil**. For the transient noise that means to not generate any transient noise and for the permanent noise it means to leave the chunk's permanent noise set to 0. The permanent noise is always added to the activation of the chunk and can be set by the modeler using the sdp command for creating specific offset values when needed.

Retrieval time

The time that it takes the declarative module to respond to a request for a chunk, *i*, is determined by the activation that the chunk has using this equation when the subsymbolic computations are enabled:

$$RT = Fe^{-(f*A_i)}$$

RT: The time to retrieve the chunk in seconds
$\boldsymbol{A_i}$: The activation of the chunk *i* which is being retrieved
F: The latency factor parameter
f : The latency exponent parameter

If there is no chunk found in response to a request or the chunk with the highest activation is below the retrieval threshold then the time required to indicate a failure to retrieve any chunk is determined by this equation when subsymbolic computations are enabled:

$$RT = Fe^{-(f*\tau)}$$

RT: The time until the failure is noted in seconds.
τ : The retrieval threshold parameter
F: The latency factor parameter
f : The latency exponent parameter

Declarative finsts

The declarative module maintains a record of the chunks which have been retrieved and provides a mechanism which allows one to indicate whether a retrieval request should search only those which have or have not been so marked. This is done through the use of a set of finsts (fingers of instantiation) which mark those chunks. The finsts are limited in the number that are available and how long they persist specified by the parameters :declarative-num-finsts and :declarative-finst-span respectively. If more finsts are required than are available, then the oldest one (the one marking the chunk retrieved at the earliest time) is removed and used to mark the most recently retrieved chunk. The details on how to use the finsts are found in the description of the retrieval buffer requests.

Parameters

The declarative module has a lot of parameters which can be set and they fall into four general categories. The first category contains the parameters which are used in the activation equations as described above. The next category contains the parameters which control basic functionality of the module. The third category is parameters which allow the user to adjust the chunk activation equation: each of the four primary components may be replaced by the user, the default computations for strengths of association and similarities can be replaced, and additional terms may be added to the equation. The final set of parameters allow the user to install commands to monitor the operations of the module.

Note on parameters for the declarative module. There are some parameters which should not be adjusted once chunks have entered DM. The reason for this is that the module does not attempt to reconcile differences in interpretations which may result due to such changes i.e. chunks which have had their internal parameters set under one set of parameters may no longer be valid under different settings. A warning will be printed if one does change such parameters after there are chunks in DM. That warning does not mean that things will necessarily break (there are some situations where the warning can be safely ignored), but one should be cautious when using things in that manner. The critical parameters are the :bll and :mas parameters of the declarative module as well as the parameters :esc and :ol.

:act

The activation trace parameter controls whether or not the declarative module should print the details of a chunk's activation computation when it is computed (whether during a retrieval request or otherwise). If it is set to **t** then all of the components of the equation are output to the model trace when a chunk's activation is computed, and if it is set to **nil** then no extra trace is generated. The default value is **nil**.

There are also two lesser output levels available for the activation trace if one specifies a setting of **medium** or **low** for the parameter value. The medium output level does not print the information about chunks which did not match a retrieval request and the low level only prints the final activation values computed for the chunks.

:activation-offsets

This parameter allows one to specify commands which can extend the activation equation with new terms. This parameter can be set to a command which takes one parameter and any number of such commands may be set (the reported value of this parameter is a list of all commands which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. Whenever a chunk's activation is computed each of the commands that has been set for this parameter will be called with one parameter which is the name of the chunk. If a command called returns a number then that value will be added to the activation of the chunk and if the activation trace is enabled a line will be shown indicating the name of the command and the offset added. If a command returns any other value then no change is made to the activation of the chunk. If the parameter is set to **nil** then all commands are removed from the activation-offsets list. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A commands should only be set once. If a commands is specified more than once as a value for the activation-offsets a warning will be displayed.

:ans

The activation noise s parameter specifies the s value used to generate the instantaneous noise added to the activation equation if it is set to a positive number. If it is set to **nil**, which is the default, then no instantaneous noise is added to the activation of chunks. Recommended values for the noise parameter are in the range [.2,.8].

:bl-hook

This parameter allows one to override the base-level calculation. If it is set to a command identifier then that command will be passed one parameter which is the name of the chunk for which a base-level is needed. If the command returns a number then that will be the B_i value used in the activation equation, otherwise the standard base-level calculation will be used.

:blc

The base-level constant parameter specifies the default value for the βi component of the base-level equations. If base-level learning is disabled (:bll is **nil**) and the :base-level parameter for the chunk is set through the sdp command then that overrides the :blc setting. The default value is 0.0.

:bll

The base-level learning parameter controls whether base-level learning is enabled, and also sets the value of the decay parameter, d. It can be set to any positive number or the value **nil**. The value **nil** means do not use base-level learning and is the default value, a number means that base-level is enabled and the given value is the decay parameter. The recommended value for :bll is .5, and it is one of the few parameters which have a strong recommended value.

:cache-sim-hook-results

This parameter can be used to help improve the performance of the system when using a similarity hook function (set using the :sim-hook parameter). If this parameter is set to **t** then results from calling a similarity hook function will be stored by the declarative module and if a similarity is needed between those same values again it will use the recorded value instead of calling the function. That means this should only be set if the similarity hook always provides the same similarity value for a pair of items, and the set of items themselves are expected to be repeated/reused. Those cached values will persist across a reset as long as the same sim-hook value is set in the model. The default value is **nil** which means that similarity hook function values are not recorded for future use.

:chunk-add-hook

This parameter allows one to specify commands to be called automatically when chunks are added to the current model's DM. This parameter can be set with a command identifier and that command must take one parameter. Any number of such commands may be set (the reported value of this parameter is a list of all commands which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. Whenever a chunk is added into DM each of the commands that has been set will be called with one parameter which is the name of the chunk that was added into DM. This call is made after the chunk has been added to DM and its declarative parameters updated appropriately. The return values of these commands are ignored. If the parameter is set to **nil** then all commands are removed from the chunk-add-hook. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A command should only be set once. If a specific command is specified more than once as a value for the chunk-add-hook a warning will be displayed.

:chunk-merge-hook

This parameter allows one to specify commands to be called automatically when chunks are merged into to the current model's DM. This parameter can be set with a command identifier and that command must take one parameter. Any number of such commands may be set (the reported value of this parameter is a list of all commands which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. Whenever a chunk is merged into DM each of the commands that has been set will be called with one parameter which is the name of the chunk that was merged into DM. This call is made after the chunk has been merged into DM and its declarative parameters updated appropriately. The return values of these commands are ignored. If the parameter is set to **nil** then all commands are removed from the chunk-merge-hook. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A command should only be set once. If a specific

command is specified more than once as a value for the chunk-merge-hook a warning will be displayed.

:declarative-finst-span

This parameter controls how long a finst can mark a chunk as having been recently retrieved. After a finst has been marking a chunk for this amount of time the finst is removed and the chunk is no longer marked as recently retrieved. It can be set to any positive number and defaults to 3.0.

:declarative-num-finsts

This parameter controls how many finsts are available in the declarative module. It can be set to any positive number and the default is 4.

:declarative-stuffing

This parameter controls whether or not the declarative module will place chunks into the retrieval buffer without a corresponding request i.e. stuff the buffer. The default value is **nil** which means to disable the mechanism. If it is set to a number that enables the mechanism and sets the period of time in seconds for the potential stuffing actions to occur.

When it is enabled, at time 0 and again whenever the module is not busy and either the buffer empties or the specified time period has passed a new stuffing attempt will occur. The chunk that will be stuffed into the buffer is the chunk with the current highest activation. That stuffing will not interrupt an ongoing retrieval request nor overwrite a requested chunk in the buffer. This mechanism is a very speculative bottom-up approach which needs further refinement based on use – if you use this parameter please let me know how it worked out and any recommendations or comments you have about it.

:ignore-buffers

This parameter allows the modeler to specify buffers that the declarative module will ignore i.e. it will not add or merge chunks that are cleared from those buffers into DM. This is primarily intended as a way to improve the software performance when running a model, but it can also be used to temporarily disable a buffer from adding or updating chunks as well. It can be set to a list of buffer names, and the named buffers will be ignored. The default value is **nil** (no buffers are ignored).

:le

The latency exponent value, f, in the equation for retrieval times. It can be set to any non-negative value and defaults to 1.0.

:lf

The latency factor value, F, in the equation for retrieval times. It can be set to any non-negative value and defaults to 1.0.

:mas

The maximum associative strength parameter controls whether the spreading activation calculation is used, and if so, what the S value in the Sji calculations will be. It can be set to any number or the value **nil.** The value **nil** means do not use spreading activation and is the default value, any number means that spreading activation is enabled.

:md

The maximum difference. This is the default similarity value between two items which are not chunk-slot-equal. It can be set to any number and defaults to -1.0.

:mp

The mismatch penalty parameter controls whether the partial matching system is enabled, and if so, specifies the value of the penalty parameter, P, in the activation equation. It can be set to any number or the value **nil**. The value **nil** means do not use partial matching (only exact matches can be retrieved), and is the default. If it is set to a number then partial matching is enabled.

:ms

The maximum similarity. This is the default similarity value between items which are chunk-slot-equal. It can be set to any number and defaults to 0.0.

:noise-hook

This parameter allows one to override the noise calculation. If it is set to a command then that command will be passed one parameter which is the name of the chunk for which a noise value is needed. If the command returns a number then that will be the noise value used in the activation equation.

:nsji

Whether or not to allow negative Sji values from the strength of association calculation. Can be set to **t** which means that they are allowed, **warn** which means that negative values will be treated as 0 and a warning will be displayed, or **nil** which means that negative values will be treated as 0 and no warning will be displayed. A value of **warn** or **nil** does not prevent the user from setting explicit negative values if desired. The default is **warn**.

:partial-matching-hook

This parameter allows one to override the partial matching calculation. If it is set to a command then that command will be passed two parameters. The first will be the name of the chunk for which a partial matching value is needed and the second will be the chunk-spec id of the request. If the function returns a number then that will be the P_i value used in the activation equation.

:pas

The permanent activation noise s parameter specifies the s value used to generate the permanent noise added to the activation equation of a chunk if it is set to a positive number. The permanent noise is only generated once when the chunk is added to DM. If :pas is set to **nil**, which is the default, then no permanent noise is automatically generated for the chunks, but it may still have such a value set explicitly using the sdp command.

:retrieval-request-hook

This parameter allows one to specify commands to be called automatically when a retrieval request is made. This parameter can be set with a command identifier and that command must accept one parameter. Any number of such commands may be set (the reported value of this parameter is a list of all commands which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. When there is a start-retrieval event these commands will be called with the chunk-spec id of the request as the only parameter. The return values of those commands are ignored. If the parameter is set to **nil** then all commands are removed from the retrieval-request-hook. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A command should only be set once. If a specific command is specified more than once as a value for the retrieval-request-hook a warning will be displayed.

:retrieval-set-hook

This parameter allows one to specify commands to be called during the retrieval process. This parameter can be set with a command identifier and that command must accept one parameter. Any number of such commands may be set (the reported value of this parameter is a list of all commands which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. After the set of chunks which match have been determined and their activations are calculated these commands will be called with the list of the chunk names that match the request. The first chunk on the list is the one that will be retrieved (if its activation is above the threshold). These commands can be used to override the choice of which chunk to retrieve. If a command returns a list of a chunk name and a number, then that chunk will be the one placed in the retrieval buffer after that many seconds pass. If a command returns a number, then the declarative module will signal a retrieval failure after that many seconds pass. If a command returns anything else it is ignored, and the normal retrieval process will occur. If more than one command on the list for this parameter returns a value, then none of those values will be used and the default mechanisms will be applied. If the parameter is set to **nil** then all commands are removed from the retrieval-set-hook. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A command should only be set once. If a specific command is specified more than once as a value for the retrieval-set-hook a warning will be displayed.

:retrieved-chunk-hook

This parameter allows one to specify commands to be called automatically when chunks are retrieved or a failure to retrieve occurs. This parameter can be set with a command identifier and that command must accept one parameter. Any number of such commands may be set (the reported value

of this parameter is a list of all commands which have been set). Note, when setting the parameter remotely an embedded string will be required to name a command. When there is a retrieved-chunk event these commands will be called with the name of the chunk which has been retrieved, and when there is a retrieval-failure event these commands will be called with **nil** as the parameter. The returned values from these commands are ignored. If the parameter is set to **nil** then all commands are removed from the retrieved-chunk-hook list. To remove a specific command from the list set the parameter to the list **(:remove** id **)** where id is the command identifier of the command to be removed. A command should only be set once. If a specific command is specified more than once as a value for the retrieved-chunk-hook a warning will be displayed.

:rt

The retrieval threshold. This is the minimum activation a chunk must have to be able to be retrieved, τ, in the retrieval failure time equation. It can be set to any number and defaults to 0.0.

:sact

The save activation trace parameter controls whether or not the declarative module should save the details of the activation computation when it is computed during a retrieval request. If it is set to a non-nil value then all of the components of the activation calculations are saved and a trace like the one displayed when using the :act parameter can be printed out after a run using the print-activation-trace and print-chunk-activation-trace commands. The default value is **nil**.

The parameter can be set to values like :act i.e. **t**, **medium**, **low**, or **nil**. The output of the print-activation-trace and print-chunk-activation-trace commands will use the specific setting of this parameter to display the requested amount of detail in the traces shown.

This parameter is deprecated now because the history stream “retrieval-history” is the recommended way to record and access the activation history data.

:sim-hook

This parameter allows one to override the similarity calculation. If it is set to a command identifier then that command will be passed two parameters. The first will be the slot contents of the request specification, the *k* from the partial matching equation, and the second will be the considered chunk’s value for that slot. If the command returns a number that will be the M_{ki} value used for that term in the partial matching equation. If the command returns **nil** or a non-numeric value the default M_{ki} value will be used.

:sji-hook

This parameter allows one to override the strength of association calculation. If it is set to a command identifier then that command will be passed two parameters. The first will be the chunk *j* from a slot in a buffer chunk and the second will be the considered chunk *i*. If the command returns a number that will be the S_{ji} value used in the equation of S_i for the chunk *i*. If the command returns **nil** or a non-numeric value the default S_{ji} value will be used.

:spreading-hook

This parameter allows one to override the spreading activation calculation. If it is set to a command identifier then that command will be passed one parameter which is the name of the chunk for which a spreading activation value is needed. If the command returns a number then that will be the S_i value used in the activation equation. If the command returns **nil** or a non-numeric value the default spreading activation calculation will be used.

:w-hook

This parameter allows one to override the default values for W_{kj} in the strength of association calculation. If it is set to a command identifier then that command will be passed two parameters. The first will be the name of the buffer, the *k*, and the second will be the name of a slot for which the source of activation, the *j*, is being spread. If the command returns a number that will be the W_{kj} value used in the equation of S_i at that time. If the command returns **nil** or a non-numeric value the default W_{kj} value will be used.

Retrieval buffer

The retrieval buffer is used to retrieve chunks from the model's declarative memory using the mechanisms described above. The declarative module sets the retrieval buffer to **not** be treated with the strict safety mechanism.

Activation spread parameter: :retrieval-activation
Default value: 0.0

Queries

In addition to the default queries the retrieval buffer can be queried with recently-retrieved which can be checked for the values of **t** or **nil**.

'State busy' will be **t** while a retrieval request is being processed – the time between the start-retrieval event and either the retrieved-chunk or retrieval-failure event. It will be **nil** at all other times.

'State free' will be **nil** while a retrieval request is being processed – the time between the start-retrieval event and either the retrieved-chunk or retrieval-failure event. It will be **t** at all other times.

'State error' will be **t** if no chunk matching the most recent request was found (a retrieval-failure event has occurred) and **nil** otherwise. Once it becomes **t** it will not change back to **nil** until the next retrieval request is made.

'Recently-retrieved t' will be **t** if there is a chunk in the retrieval buffer and there is a chunk in DM from which that chunk was copied which is currently marked with a declarative finst. Otherwise this query will be **nil**.

'Recently-retrieved nil' will be **t** if there is a chunk in the retrieval buffer and there is a chunk in DM from which that chunk was copied which is currently not marked with a declarative finst. Otherwise this query will be **nil**.

Requests

All

{*{modifier} slot value*}*
{:recently-retrieved [**t** | **nil** | **reset**]}
{:mp-value [**nil** | *temp-mp-value*]}
{:rt-value [*temp-rt-value*]}
{:bll-value [**nil** | *temp-bll-value*]}
{:mas-value [**nil** | *temp-mas-value*]}
{:ans-value [**nil** | *temp-ans-value*]}
{:lf-value [*temp-lf-value*]}

A request to the retrieval buffer is a description of a chunk which the declarative module will try to find in DM and place into the retrieval buffer. For the declarative module to consider a chunk in DM as a possible candidate it must have all of the slots specified with non-**nil** values and not have any slots specified with a value of **nil**.

There are seven request parameters which can be used to modify how that request is handled. The :recently-retrieved request parameter can be used to test the declarative finsts associated with the chunks in addition to the chunks' contents. If :recently-retrieved is specified as **t** then the request will only match to chunks which have a finst set for them at the time of the request. If :recently-retrieved is specified as **nil** then the request will only match to chunks which do not have a finst set for them at the time of the request, and if :recently-retrieved is specified as **reset** then all of the declarative finsts are removed before the request is processed.

The remaining request parameters allow one to temporarily adjust declarative module parameters while processing the retrieval request. The parameter that is changed corresponds to the part of the request parameter's name before "-value" e.g. the :mp-value parameter adjusts the :mp parameter. The provided value for the parameter will be used while the request is performed, but it does not explicitly change the value of the parameter itself.

If a chunk which matches the request is found it will be placed into the retrieval buffer. If no chunk is found, or no chunk which matches has an activation which is above the retrieval threshold when the :esc parameter is **t**, then the buffer is left empty, the module signals that its state is error, and the retrieval buffer's failure flag is set.

The declarative module will only process one request at a time. If a new request comes in prior to the completion of a previous request the older request is terminated immediately – no chunk will be placed into the buffer or error signaled as a result of that request. A warning will be output to the trace indicating the early termination of the previous request and the module will remain busy while processing the new request.

A successful request to the declarative module will generate the events start-retrieval, retrieved-chunk, set-buffer-chunk like this:

```
     0.050   DECLARATIVE            START-RETRIEVAL
     ...
     0.100   DECLARATIVE            RETRIEVED-CHUNK C
     0.100   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL C
```

A failed request will generate the events start-retrieval and retrieval-failure:

```
    10.250   DECLARATIVE            START-RETRIEVAL
    ...
    10.300   DECLARATIVE            RETRIEVAL-FAILURE
```

If a request is terminated prematurely by a new request this is the warning that will show in the trace:

```
    10.350   DECLARATIVE            START-RETRIEVAL
    ...
#|Warning: A retrieval event has been aborted by a new request |#
```

History Stream

retrieval-history

The declarative module provides one data history stream called retrieval-history. When it is enabled it will record information about every retrieval request which is made. The data will be recorded based on the time of the retrieval request, and one optional parameter is available when requesting the data to get the history from a specific time (in milliseconds) instead of all the history data. That data is recorded by a module named retrieval-history.

Each list of the data returned will have three elements. The first will be the time of the retrieval request in milliseconds. The second will be a string with the text of the request which was made. The third will be a list of lists where each sublist contains four strings describing either a chunk which matched the request or an indication of a retrieval failure. The first item in that list will be the description of the chunk that was retrieved if there was one retrieved, or it will be a list of the string ":retrieval-failure" followed by three empty lists if there was not a chunk retrieved. The remainder of the items in that list will be descriptions of the chunks which matched the request but were not selected (in no particular order). The four strings in a chunk description list are: the name of the chunk, the print out of that chunk, all of the relevant chunk parameters at the time of the request, and the activation trace for that chunk at the time of the request.

There is also a processor for the retrieval-history called retrieval-times which can be used to get just the times of the requests and the names of the chunks which were matched at that time from the recorded retrieval history.

Commands

add-dm

Syntax:

add-dm [chunk-description* | chunk-name*] -> (chunk*)
add-dm-fct (chunk-description* | chunk-name*) -> (chunk*)

Remote command name:

add-dm ' [chunk-description* | chunk-name*] **'**
add-dm-fct ' (chunk-description* | chunk-name*) **'**

Arguments and Values:

chunk-description ::= ({*chunk-name*}{[*doc-string* **isa** *chunk-type* | **isa** *chunk-type*]} {*slot value*}*)
chunk-name ::= the name of the chunk to create
doc-string ::= a string that will be the documentation for the chunk
chunk-type ::= a name of a chunk-type in the model
slot ::= a name of a slot for the chunk
value ::= a value which will be the contents of the correspondingly named slot for this chunk
chunk ::= the name of a chunk that was created

Description:

The add-dm command functions exactly like the define-chunks command to create new chunks for the model. In addition, add-dm places those chunks into the current model's declarative memory. It returns a list of the names of the chunks that were created.

If the syntax is incorrect or any of the components are invalid for a list describing a chunk then a warning is displayed and no chunk is created for that chunk description, but any other valid chunks defined will still be created.

If there is no current model then a warning is displayed, no chunks are created and **nil** is returned.

Add-dm is typically used to provide the model with a set of initial memories. It should not be used for the creation of general chunks. In particular, it should not be used by other modules to create the chunks to place into their buffers because those chunks will be added to DM automatically when the buffer is cleared and should not be placed there prior to that.

Examples:

```
1> (chunk-type number value)
NUMBER

2> (add-dm (isa number value 1)
           (two value 2))
 (NUMBER0 TWO)

3> (add-dm-fct (list '(three "the number 3" isa number value 3)
                     '(value 4)))
 (THREE CHUNK0)

> (add-dm a b c)
(A B C)
```

```
E> (add-dm (bad-chunk isa invalid-type)
           (bad-slot 10))
#|Warning: Invalid chunk definition: (BAD-CHUNK ISA INVALID-TYPE) chunk-type specified
does not exist. |#
#|Warning: Extending chunks with slot named BAD-SLOT because of chunk definition (BAD-SLOT
10) |#
(CHUNK1)

E> (add-dm (a))
#|Warning: get-module called with no current model. |#
#|Warning: Could not create chunks because no declarative module was found |#
NIL
```

dm

Syntax:

dm *chunk-name** -> (chunk-name*)
dm-fct (*chunk-name**) -> (chunk-name*)

Remote command name:

dm

Arguments and Values:

chunk-name ::= a symbol which names a chunk

Description:

The dm command is used to print out chunks which are in the declarative memory of the current model. For each chunk name provided that chunk will be printed to the current model's command trace. If no chunk names are provided then all of the chunks in DM will be printed. A list of the names of the chunks which are printed will be returned.

If there is no current model then a warning is printed and **nil** is returned.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
> (dm)
FIRST-GOAL
   START  TWO
   END  FOUR

FIVE
   NUMBER  FIVE

FOUR
   NUMBER  FOUR
   NEXT  FIVE
```

```
THREE
   NUMBER  THREE
   NEXT  FOUR

TWO
   NUMBER  TWO
   NEXT  THREE

ONE
   NUMBER  ONE
   NEXT  TWO

(FIRST-GOAL FIVE FOUR THREE TWO ONE)

> (dm one four)
ONE
   NUMBER  ONE
   NEXT  TWO

FOUR
   NUMBER  FOUR
   NEXT  FIVE

(ONE FOUR)

> (dm-fct '(first-goal three))
FIRST-GOAL
   START  TWO
   END  FOUR

THREE
   NUMBER  THREE
   NEXT  FOUR

(FIRST-GOAL THREE)

E> (dm bad-name)
NIL

E> (dm)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL
```

sdm

Syntax:

sdm {**isa** *chunk-type*} *slot-test** -> (chunk-name*)
sdm-fct ({**isa** *chunk-type*} *slot-test**) -> (chunk-name*)

Remote command name:

sdm ‘ {**isa** *chunk-type*} *slot-test** ‘

Arguments and Values:

chunk-type ::= a chunk-type name
slot-test ::= {slot-modifier} slot value

slot-modifier ::= [**=** | **-** | **<** | **>** | **<=** | **>=**]
slot ::= a slot name
value ::= a value
chunk-name ::= the name of a chunk

Description:

The sdm command is used to search the declarative memory of the current model and print out chunks which match the search specification. If no parameters are provided then all chunks in DM are printed. If parameters are provided then all chunks from DM which match the specification provided are printed. If the chunk-type is specified then the slots given must be valid for that chunk-type otherwise a warning will be printed and no chunks returned. As is the case elsewhere, the chunk-type itself is not a constraint in the search, but if it contains default slot values those will be included in the specification unless other values are provided for those slots. If no chunk-type is provided then any slots may be provided. A list of the names of the chunks which are printed is returned.

If there is an error in the specification or there is no current model a warning is printed and **nil** is returned.

Examples:

```
1> (chunk-type test (slot1 t))
TEST

2> (add-dm (t1 isa test slot1 t) (t2 isa test slot1 nil))
(T1 T2)

3> (sdm isa test)
T1
   SLOT1  T

(T1)

1> (chunk-type type1 slot1 slot2)
TYPE1

2> (chunk-type number name value)
NUMBER

3> (chunk-type type2 name slot1)
TYPE2

4> (add-dm (one isa chunk)
           (a isa type1 slot1 1 slot2 a)
           (b isa type1 slot1 2 slot2 a)
           (c isa number name one value 1)
           (d isa type2 name one slot1 3))
(ONE A B C D)

5> (sdm isa type1)
D
   NAME  ONE
   SLOT1  3

C
   NAME  ONE
   VALUE  1
```

```
A
   SLOT1  1
   SLOT2  A

B
   SLOT1  2
   SLOT2  A

ONE

(D C A B ONE)

6> (sdm name one)
D
   NAME  ONE
   SLOT1  3

C
   NAME  ONE
   VALUE  1

(D C)

7> (sdm-fct '(< slot1 2))
A
   SLOT1  1
   SLOT2  A

(A)

8> (sdm - slot2 a)
D
   NAME  ONE
   SLOT1  3

C
   NAME  ONE
   VALUE  1

ONE

(D C ONE)

E> (sdm isa bad-type)
#|Warning: Element after isa in define-chunk-spec isn't a chunk-type. (ISA BAD-TYPE) |#
#|Warning: Invalid chunk specification (ISA BAD-TYPE) passed to sdm |#
NIL

E> (sdm isa type1 value 3)
#|Warning: Invalid slot-name VALUE in call to define-chunk-spec. |#
#|Warning: Invalid chunk specification (ISA TYPE1 VALUE 3) passed to sdm |#
NIL

E> (sdm)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL
```

print-dm-finsts

Syntax:

print-dm-finsts -> ((chunk-name time-stamp)*)

Remote command name:

print-dm-finsts

Arguments and Values:

chunk-name ::= the name of a chunk in DM
time-stamp ::= a number indicating the time the finst was applied to the chunk chunk-name in seconds

Description:

Print-dm-finsts can be used to see which chunks in the DM of the current model have declarative finst markers. It takes no parameters and will print out a table of the chunks with finsts on them showing the time at which the finst was set in seconds. It returns a list of two element lists where each sublist has the name of a chunk with a finst on it as the first element and the creation time of its finst in seconds as the second element.

If there is no current model then a warning is printed and **nil** is returned.

Examples:

This example assumes that the count model from tutorial unit 1 has been loaded.

```
1> (print-dm-finsts)

Chunk name     Time Stamp
-------------------------
NIL

> (run 10)
     0.000   GOAL                  SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
...
     0.350   PROCEDURAL            CONFLICT-RESOLUTION
     0.350   ------                Stopped because no events left to process
0.35
53
NIL

3> (print-dm-finsts)

Chunk name     Time Stamp
------------------------
FOUR              0.300
THREE             0.200
TWO               0.100
((FOUR 0.3) (THREE 0.2) (TWO 0.1))

E> (print-dm-finsts)
#|Warning: get-module called with no current model. |#
NIL
```

sdp

Syntax:

sdp [{ [*chunk-name* | (*chunk-name**)]} {[*param-name** | *param-value-pair**]} |
(*chunk-name* [*param-name** | *param-value-pair**])*] -> (param-values*)
sdp-fct ([{ [*chunk-name* | (*chunk-name**)]} {[*param-name** | *param-value-pair**]} |
(*chunk-name* [*param-name** | *param-value-pair**])*])-> (param-values*)

Remote command name:

sdp ' [{ [*chunk-name* | (*chunk-name**)]} {[*param-name** | *param-value-pair**]} |
(*chunk-name* [*param-name** | *param-value-pair**])*] '

Arguments and Values:

chunk-name ::= the name of a chunk in declarative memory
param-name ::= a keyword which names a declarative parameter
param-value-pair ::= param-name new-param-value
new-param-value ::= a value to which the preceding param-name is to be set
param-values ::= [(param-value*) | (chunk-name*) | **:error**]
param-value ::= the current value of a requested declarative parameter or **:error**.

Description:

Sdp is used to set or get the declarative parameters of the chunks in the current model. It is similar to the spp command which is used to set and get the production parameters.

Each chunk has several declarative parameters associated with it, and most of those are related to the computation of the activation equation. The declarative parameters are only relevant when the :esc parameter is enabled, and even then, some of the parameters are only available when specific options of the declarative module are also enabled.

The declarative parameters available through sdp are listed below. An important thing to note is that while these declarative parameters are maintained using general chunk parameters not all of the general chunk parameters are available through sdp. Only the chunk parameters which are relevant to the declarative module are accessible through the sdp command, and the mapping of declarative parameters onto chunk parameters may not be one-to-one. Thus, the declarative parameters should only be accessed through the sdp command and not be read or changed through the general chunk parameter accessors since their internal representations are not part of the declarative module's API.

- name := the name of the chunk. Cannot be changed.
- activation := the chunk's current activation value. Cannot be changed through sdp.
- permanent-noise := the permanent noise is a value which is added to the activation of the chunk each time it is computed. It defaults to 0.0. If :pas is set to a number, then when a chunk is initially added to DM a random noise value generated using the :pas value as the s parameter to act-r-noise will be generated and set as the chunk's permanent noise. It can be set by the modeler to any number, which will override the default and automatically generated values.

- base-level := the chunk's current base-level value. Cannot be changed directly through sdp when base-level learning is enabled because in that case it is controlled by the chunk's creation-time, reference-count, and/or reference-list. If base-level learning is disabled then it can be set to a number which will be the β_i value for the chunk.
- creation-time := the time (in seconds) when the chunk was first added to DM. Used by the base-level equations to determine the t_j values and the chunk's life time. Can be set to any time (including negative values) which is less than or equal to the current time. This is only applicable when :bll is set to a non-**nil** value.
- reference-count := the number of references which the chunk has received. Can be set to any positive value. It is applicable when :bll is non-**nil** and :ol is either **t** or a number. It is the n value used in the optimized base-level equations. If the reference-count is set by the user then the reference-list for the chunk will be adjusted to contain an appropriate number of references as follows. If the reference-list is as long as the reference-count specified or :ol is **t** then the reference-list will be unchanged. If the reference-list is currently longer than the specified reference-count it will be truncated to that many of the most recent entries. If the reference-list is shorter than the specified reference-count but has as many items as the current setting of :ol it will be unchanged. Otherwise, the reference-list will be set to an evenly distributed set of references as would be done by the set-base-levels command.
- reference-list := the list of times at which the chunk's references have occurred (most recent first). Can be set to a list of times. It is applicable when :bll is non-**nil** and :ol is either **nil** or a number. If :ol is **nil**, then the list will contain all of the reference times of the chunk. If :ol is set to a number then it will only hold that many references (the most recent). If more references are provided than are needed, the list is truncated to the necessary length. When the reference-list is set by the user the reference-count may be adjusted automatically. If :ol is **nil**, then the reference-count will be updated to the length of the reference-list (even though the reference-count is not actually used when :ol is **nil**). If :ol is a number and the reference-count is less than the length of the (possibly truncated) reference-list it will be set to the length of the reference-list. Otherwise, the reference-count will be unchanged.
- references := This parameter is deprecated and should not be used, but is still available for compatibility with older models. This parameter will not be shown for a chunk and modelers should use reference-count and reference-list instead to get/set the relevant values.
- source := the chunk's current activation spread from the current buffer contents. Cannot be changed directly through sdp. Only applicable when the :mas parameter is set to a number.
- sjis := this reports the S_{ji} value for chunks j to the chunk i (where i is the chunk for which the value is being reported). The reported value is a list of two element lists where the first element is the name of a chunk j and the second is the S_{ji} between that chunk j and the chunk i. Only chunks j which have a connection with i are reported – all other S_{ji} values to chunk i will be 0.0 (unless a provided :sji-hook overrides that). This parameter is only relevant when the :mas parameter is set to a number. It is possible to set this parameter using a list of two element lists. Each value specified is effectively added to the set of S_{ji} values for the chunk as if the add-sji command was called (possibly replacing a value which was previously set or overriding a default value). The add-sji command is the recommended way to set S_{ji} values instead of using this parameter through sdp.
- similarities := this reports the similarities (the M_{ki} values) between other chunks k and this chunk, i. The reported value is a list of two element lists where the first element of the list is the name of the chunk k and the second element is the similarity value M_{ki}. Only chunks k for which a similarity value has been set and the similarity of the chunk with itself are reported. All other M_{ki} values will be the maximum difference (the :md parameter setting). This

parameter is only relevant when the :mp parameter is set to a number. It is possible to set this parameter using a list of two element lists. Each value specified is effectively added to the similarity values for the chunk (possibly replacing a value which was previously set or overriding a default value). The set-similarities command is the recommended means of setting similarities, but if one wants asymmetric similarities between chunks they must be set explicitly with sdp per chunk (set-similarities always sets the values symmetrically).

- last-retrieval-activation := the activation that the chunk had the last time that it was attempted to be retrieved. This value is computed during the start-retrieval event and will be updated for all chunks which match the retrieval request. Cannot be changed through sdp.
- last-retrieval-time := the time at which the last attempt to retrieve this chunk occurred i.e. the time at which the last-retrieval-activation value was set. Cannot be changed through sdp.

Note: because parameter settings are applied in the order provided and there are dependencies between the creation-time, reference-count, and reference-list the order in which they are given may affect the resulting values. The ordering to achieve what is typically wanted would be to set creation-time, then reference-count, and then reference-list. That ensures that the creation-time has been updated before any automatic references are generated and that the specified reference-list is not overwritten by one automatically created by the reference-count. It is not required that they be provided in that order however, and one may use other orderings to achieve different resultant values as desired.

If no parameters are provided to sdp, then all of the current model's DM chunks' parameters are printed and a list of all the chunk names is returned.

If a chunk or list of chunks is specified as the first parameter to sdp then the following parameters are set or retrieved from only those chunks. If no chunk names are provided then the settings are applied to or retrieved from all chunks in DM at the time of the call to sdp.

If chunk names are specified but no specific parameters are specified then the parameters for those chunks are printed and the list of those chunk names is returned.

When sdp prints the parameters for a chunk it will be sent to the command trace will contain its name followed by the parameters which are currently appropriate based on the declarative module's parameter settings.

If any of the chunk names provided are invalid a warning will be printed and the corresponding element of the return list will be **:error**.

If all of the parameters passed to sdp (after any chunk names) are keywords, then it is a request for the current values of the parameters named. Those parameters are printed for the chunks specified and a list containing a list for each chunk specified is returned. Each sub-list contains the values of the parameters requested in the order requested and the sub-lists are in the order of the chunks which were requested. If an invalid parameter is requested, then a warning is printed and the value returned in that position will be the keyword **:error**.

If there are any non-keyword parameters in the call to sdp and the number of parameters (not counting the chunk names) is even, then they are assumed to be pairs of a parameter name and a parameter value. For all of the specified chunks (or all chunks in DM if none are specified) those

parameters will be set to the provided values. The return value will be a list containing a list for each chunk specified. Each sub-list contains the values of the parameters set in the order they were set and the sub-lists are in the order of the chunks which were specified. If a particular parameter value was not of the appropriate type, then a warning is printed and the value returned in that position will be the keyword **:error**.

It is also possible to pass lists of a chunk name and parameter settings to sdp. Essentially, each list provided could be formatted as something that could be passed to sdp and they will each be processed as appropriate.

If there is no current model at the time of the call, then a warning is displayed and **nil** is returned.

There is one small issue worth noting about using sdp. If the :activation or :base-level value is returned (either because it is explicitly specified or because no parameters were specified and thus it gets returned automatically) that will cause the chunk's activation to be recomputed at the current time if it is not currently at the time of the chunk's last retrieval attempt (the value of the :last-retrieval-time parameter). That activation computation will include the activation noise if there is any. There are two consequences of that. First, multiple calls to sdp will likely return different :activation values for a given chunk, even if those calls occur at the same model time. The other consequence is that if there is noise in the activations then if sdp has to recomputed the chunk activations it will affect the random sequence which will likely change how a model with a set :seed parameter runs from that point on relative to how it would have run had sdp not been called.

Examples:

The examples assume that this model has been defined:

```
(define-model test
  (sgp :esc t :bll .5 :mas 2 :mp 1)
  (chunk-type test slot1 slot2)
  (add-dm (a isa test)
          (b isa test slot1 a slot2 c)
          (c isa test slot1 a slot2 c)
          (d isa test slot2 b)))

1> (sdp)
Declarative parameters for chunk D:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((D 2.0) (B 1.3068528))
 :Similarities ((D 0.0))
Declarative parameters for chunk C:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((A 0.9013877) (C 1.5945349))
 :Similarities ((C 0.0))
Declarative parameters for chunk B:
 :Activation  2.191
 :Permanent-Noise  0.000
```

```
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((B 1.3068528) (A 0.9013877) (C 0.9013877))
 :Similarities ((B 0.0))
Declarative parameters for chunk A:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((A 0.9013877))
 :Similarities ((A 0.0))
(D C B A)

2> (sdp a :permanent-noise)
Declarative parameters for chunk A:
 :PERMANENT-NOISE  0.000
((0.0))

3> (sdp a :permanent-noise .3)
((0.3))

4> (sdp a)
Declarative parameters for chunk A:
 :Activation  2.491
 :Permanent-Noise  0.300
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((A 0.9013877))
 :Similarities ((A 0.0))
(A)

5> (sdp (a b) :name :activation)
Declarative parameters for chunk A:
 :NAME A
 :ACTIVATION  2.491
Declarative parameters for chunk B:
 :NAME B
 :ACTIVATION  2.191
((A 2.4910133) (B 2.1910133))

6> (sdp-fct '(c))
Declarative parameters for chunk C:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((A 0.9013877) (C 1.5945349))
 :Similarities ((C 0.0))
(C)

7> (sdp-fct '((d b) :sjis))
Declarative parameters for chunk D:
 :SJIS ((D 2.0) (B 1.3068528))
Declarative parameters for chunk B:
 :SJIS ((B 1.3068528) (A 0.9013877) (C 0.9013877))
((((D 2.0) (B 1.3068528))) (((B 1.3068528) (A 0.9013877) (C 0.9013877))))

8> (sdp (a :base-level) (b :creation-time -1.0))
Declarative parameters for chunk A:
```

```
 :BASE-LEVEL  2.191
((2.1910133) (-1.0))

9> (sdp b)
Declarative parameters for chunk B:
 :Activation  0.693
 :Permanent-Noise  0.000
 :Base-Level  0.693
 :Creation-Time -1.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((B 1.3068528) (A 0.9013877) (C 0.9013877))
 :Similarities ((B 0.0))
(B)

10> (sdp-fct '(:reference-count 3))
((3) (3) (3) (3))

11> (sdp-fct '((a b)))
Declarative parameters for chunk A:
 :Activation  3.590
 :Permanent-Noise  0.300
 :Base-Level  3.290
 :Creation-Time 0.000
 :Reference-Count  3
 :Source-Spread  0.000
 :Sjis ((A 0.9013877))
 :Similarities ((A 0.0))
Declarative parameters for chunk B:
 :Activation  1.792
 :Permanent-Noise  0.000
 :Base-Level  1.792
 :Creation-Time -1.000
 :Reference-Count  3
 :Source-Spread  0.000
 :Sjis ((B 1.3068528) (A 0.9013877) (C 0.9013877))
 :Similarities ((B 0.0))
(A B)

E> (sdp bad-chunk)
#|Warning: BAD-CHUNK does not name a chunk in DM. |#
(:ERROR)

E> (sdp a :bad-parameter)
Declarative parameters for chunk A:
#|Warning: BAD-PARAMETER is not a declarative parameter for chunks. |#
((:ERROR))

E> (sdp)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL
```

sji/add-sji

Syntax:

sji *chunk-name-j chunk-name-i* -> [sji | **nil**]
sji-fct *chunk-name-j chunk-name-i* -> [sji | **nil**]
add-sji (*chunk-name-j chunk-name-i sji*)* -> ([sji | **:error**]*)
add-sji-fct ((*chunk-name-j chunk-name-i sji*)*) -> ([sji | **:error**]*)

Remote command name:

sji
sji-fct
add-sji
add-sji-fct

Arguments and Values:

chunk-name-j ::= the name of a chunk
chunk-name-i ::= the name of a chunk
sji ::= a number which is the associative strength (S_{ji} value) from chunk-name-j to chunk-name-i

Description:

The sji command is used to get the S_{ji} value between two chunks in the current model. It takes two parameters which are the names of the chunk j and the chunk i respectively, and it returns the S_{ji} value between them. The S_{ji} value will be either the value determined by the standard equation, the explicit value which has been set using the add-sji command, or the result returned by the sji-hook if it is specified. The sji-hook function overrides an explicit setting and the default calculation, and an explicitly set value will override the default calculation. If either of the chunk names is invalid then a warning is printed and an S_{ji} of 0.0 is returned. If there is no current model then a warning is printed and **nil** is returned.

The add-sji command is used to specify explicit S_{ji} values between chunks. It can be used to set any number of S_{ji} values at a time. Each parameter to add-sji (or element of the list passed to add-sji-fct) should be a list of three items. Those items are the chunk j, the chunk i, and the S_{ji} value between them respectively. It applies the S_{ji} values in order left to right. Thus, if any pair of items is specified more than once it will be the right most setting for the pair that will be their S_{ji}. It returns a list of the S_{ji} values set in the order they were specified. If any of the lists are not three elements long, have bad chunk names, or an invalid S_{ji} value then that item is ignored for purposes of setting an S_{ji}, a warning is printed, and the corresponding element of the return list will be **:error**.

Examples:

The example assumes this initial model is defined.

```
(define-model sji-demo
   (sgp :esc t :mas 2)
   (chunk-type item slot)
   (add-dm (a isa item slot nil)
           (b isa item slot a)
           (c isa item slot d)
           (d isa item slot c)
           (e isa item slot c)
           (f isa item slot f)
           (g isa item slot f)))

> (sji a b)
1.3068528

> (sji b a)
0.0
```

```
> (sji c d)
0.9013877

> (sji d c)
1.3068528

> (sji-fct 'a 'a)
1.3068528

> (sji-fct 'f 'f)
1.5945349

E> (sji-fct 'bad-name 'a)
#|Warning: BAD-NAME does not name a chunk in the current model. |#
0.0

E> (sji a a)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL


1> (add-sji (a b 2.5) (b a 10))
(2.5 10)

2> (sji a b)
2.5

3> (sji b a)
10

4> (add-sji-fct '((f f 1) (d c 0)))
(1 0)

5> (sji f f)
1

6> (sji d c)
0

7> (add-sji (c d 1.0) (c d 2.0))
(1.0 2.0)

8> (sji c d)
2.0

E> (add-sji a b 1.0)
#|Warning: Bad Sji setting in A |#
#|Warning: Bad Sji setting in B |#
#|Warning: Bad Sji setting in 1.0 |#
(:ERROR :ERROR :ERROR)

E> (add-sji (a bad 1.0))
#|Warning: Bad Sji setting in (A BAD 1.0) |#
(:ERROR)

E> (add-sji-fct '(a b 2))
#|Warning: Bad Sji setting in A |#
#|Warning: Bad Sji setting in B |#
#|Warning: Bad Sji setting in 2 |#
(:ERROR :ERROR :ERROR)

E> (add-sji (a a 1))
#|Warning: get-chunk called with no current model. |#
#|Warning: Bad Sji setting in (A A 1) |#
(:ERROR)
```

similarity/set-similarities

Syntax:

similarity *item1 item2* -> [sim | **nil**]
similarity-fct *item1 item2*-> [sim | **nil**]
set-similarities (*chunk-name-k chunk-name-i sim*)* -> ([sim | **:error**]*)
set-similarities-fct ((*chunk-name-k chunk-name-i sim*)*) -> ([sim | **:error**]*)

Remote command name:

similarity ' *item1 item2* '
similarity-fct ' *item1 item2* '
set-similarities ' (*chunk-name-k chunk-name-i sim*)* '
set-similarities-fct ' ((*chunk-name-k chunk-name-i sim*)*) '

Arguments and Values:

item1 ::= any value
item2 ::= any value
chunk-name-k ::= the name of a chunk
chunk-name-i ::= the name of a chunk
sim ::= a number which is the similarity between the specified items

Description:

The similarity command is used to get the similarity value between two items in the current model (the items do not have to be chunks). It takes two parameters which are the items, and it returns the similarity value between them (the M_{ki} from the partial matching equation). The value will be determined either by the default calculation, explicit user settings, or the hook function. The sim-hook function overrides an explicit setting and the default calculation, and an explicitly set value will override the default calculation. If there is no current model then a warning is printed and **nil** is returned.

The set-similarities command is used to specify explicit similarity values between chunks (to use values other than the defaults between non-chunk items one must use the hook function). It can be used to set any number of similarity values at a time. Each parameter to set-similarities (or element of the list passed to set-similarities-fct) should be a list of three items. Those items are the chunk k, the chunk i, and the similarity value between them respectively. It applies the similarity values in order left to right. Thus, if any pair of items is specified more than once it will be the right most setting for the pair that will be their similarity. Note that similarities are set reciprocally with this command, and thus setting the similarity for k,i also sets the same similarity for i,k. It returns a list of the similarity values set in the order they were specified. If any of the lists are not three elements long, have bad chunk names, or an invalid similarity value then that item is ignored for purposes of setting a similarity, a warning is printed, and the corresponding element of the return list will be **:error**. If there is no current model then a warning will be printed and all elements in the list will be **:error**.

Examples:

This example assumes that this initial model is defined.

```
(define-model sim-demo
   (sgp :esc t :mp 1)
   (add-dm (a isa chunk)
           (b isa chunk)
           (c isa chunk)))

1> (sgp :ms :md)
:MS 0.0 (default 0.0) : Maximum Similarity
:MD -1.0 (default -1.0) : Maximum Difference
(0.0 -1.0)

2> (similarity a b)
-1.0

3> (similarity a a)
0.0

4> (similarity-fct 'a 'c)
-1.0

5> (similarity-fct "STRING" "string")
0.0

6> (similarity-fct "STRING" 'string)
-1.0

7> (similarity-fct 1.5 1.5)
0.0

E> (similarity a b)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL

1> (set-similarities (a b -.5) (b c -2))
(-0.5 -2)

2> (similarity a b)
-0.5

3> (similarity b a)
-0.5

4> (similarity b c)
-2

5> (set-similarities-fct '((a a .5) (a c -1) (a c -2)))
(0.5 -1 -2)

6> (similarity a c)
-2

7> (similarity a a)
0.5

E> (set-similarities a b .5)
#|Warning: Bad similarity setting in A |#
#|Warning: Bad similarity setting in B |#
#|Warning: Bad similarity setting in 0.5 |#
(:ERROR :ERROR :ERROR)

E> (set-similarities (d e .5))
#|Warning: Bad similarity setting in (D E 0.5) |#
(:ERROR)
```

```
E> (set-similarities (a b 1) (a d 1) (b c 1))
#|Warning: Bad similarity setting in (A D 1) |#
(1 :ERROR 1)

E> (set-similarities (a a 1))
#|Warning: get-chunk called with no current model. |#
#|Warning: Bad similarity setting in (A A 1) |#
(:ERROR)
```

get-base-level/set-base-levels/set-all-base-levels

Syntax:

get-base-level {*chunk-name**} -> ([base-level | **:error**]*)
get-base-level-fct (*chunk-name**) -> ([base-level | **:error**]*)
set-base-levels (*chunk-name level {creation-time}*)* -> ([base-level | **:error**]*)
set-base-levels-fct ((*chunk-name level {creation-time}*)*) -> ([base-level | **:error**]*)
set-all-base-levels *level {creation-time}* -> [**t** | **nil**]

Remote command name:

get-base-level
get-base-level-fct
set-base-levels
set-base-levels-fct
set-all-base-levels

Arguments and Values:

chunk-name ::= the name of a chunk
base-level ::= a number representing the base-level activation of a chunk
level ::= a number which is the setting for the base-level of chunk-name or all chunks in DM
creation-time ::= a number which represents the time at which chunk-name was added to DM

Description:

Get-base-level will return a list of the current base-level activations in the current model for the chunks provided in the same order as they are given. This will result in the base-level being recomputed for those chunks. If a chunk-name given does not name a chunk which is in DM of the current model then the corresponding base-level value will be **:error**. If there is no current model then a warning is printed and **nil** is returned.

Set-base-levels is used to set the base-level activation for chunks in DM of the current model. For each chunk specified, its base-level is set as described below and if a new creation time is specified that is also set for the chunk. The list of current base-level activations is returned for the chunks specified in the same order as they were given. If a chunk-name is invalid, the level is not a number, or the creation time is specified and is not a number then a warning is printed, no change is made to the chunk's parameters and the corresponding base-level returned will be **:error**.

The setting of the chunk's base-level depends on the settings of the :bll and :ol parameters. If :bll is **nil** then the level provided is used directly as the chunk's base-level. If :bll is non-**nil** then the setting

of the :ol parameter determines how the level is used. If :ol is **t** then the level is the number of references for the chunk (n in the optimized learning equation). If :ol is **nil** then the level specifies how many references the chunk has and a history of the chunk is generated which evenly spaces those references between the current time and the chunk's creation time (which will be the new value if provided). If :ol is a number, then the level specifies the number of references for the chunk (the n in the hybrid optimized equation) and a history list is generated which evenly spaces either the value of :ol or level (whichever is lesser) references between the current time and the chunk's creation-time.

The set-all-base-levels command works like the set-base-levels command except that it applies the level and creation-time (if provided) to all chunks in DM of the current model at the time it is called. If it was successful it returns **t**. If there was a problem then a warning is printed and **nil** is returned.

Examples:

```
1> (define-model test-base-levels
       (sgp :esc t :bll nil)
       (add-dm (a isa chunk)
               (b isa chunk)
               (c isa chunk)))

TEST-BASE-LEVELS

2> (get-base-level a b)
(0.0 0.0)

3> (set-all-base-levels 1.5)
T

4> (set-base-levels (c -1))
(-1)

5> (get-base-level a b c)
(1.5 1.5 -1)

1> (define-model test-base-levels-2
      (sgp :esc t :bll .5 :ol t)
      (add-dm (a isa chunk)
              (b isa chunk)
              (c isa chunk)))
TEST-BASE-LEVELS-2

2> (get-base-level-fct '(a b c))
(2.1910133 2.1910133 2.1910133)

3> (set-all-base-levels 4 -1)
T
4> (sdp)
Declarative parameters for chunk C:
 :Activation  2.079
 :Permanent-Noise  0.000
 :Base-Level  2.079
 :Reference-Count  4.000
 :Creation-Time -1.000
Declarative parameters for chunk B:
 :Activation  2.079
 :Permanent-Noise  0.000
 :Base-Level  2.079
 :Reference-Count  4.000
 :Creation-Time -1.000
```

```
Declarative parameters for chunk A:
 :Activation  2.079
 :Permanent-Noise  0.000
 :Base-Level  2.079
 :Reference-Count  4.000
 :Creation-Time -1.000
(C B A)

5> (set-base-levels-fct '((a 2 -10)))
(0.2350018)

6>(get-base-level-fct '(a b))
(0.2350018 2.0794415)

E> (get-base-level bad-name)
(:ERROR)

E> (set-all-base-levels :not-a-number)
#|Warning: Invalid level :NOT-A-NUMBER |#
NIL

E> (set-all-base-levels 1.5 :not-a-number)
#|Warning: Invalid creation-time :NOT-A-NUMBER |#
NIL

E> (set-base-levels (a))
#|Warning: Invalid level in setting (A) |#
(:ERROR)

E> (set-base-levels (a 1.5) (:not-a-chunk 1.5))
#|Warning: :NOT-A-CHUNK does not name a chunk in DM. |#
(1.5 :ERROR)

E> (get-base-level a)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL

E> (set-base-levels (b 3))
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL

E> (set-all-base-levels 10)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL
```

clear-dm

Syntax:

clear-dm -> [**t** | **nil**]

Remote command name:

clear-dm

Arguments and Values:

Description:

The clear-dm command can be used to remove all chunks from the declarative memory of the current model. It is not recommended for general use, but there may be rare situations where it would be needed. The command returns **t** if the current model's DM was cleared and **nil** if there was no current model or some other problem was encountered. It will always print a warning that states either that all chunks were cleared or that a problem occurred.

Examples:

```
> (clear-dm)
#|Warning: All the chunks cleared from DM. |#
T

E> (clear-dm)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module found |#
NIL
```

reset-declarative-finsts

Syntax:

reset-declarative-finsts -> **nil**

Remote command name:

reset-declarative-finsts

Arguments and Values:

Description:

The reset-declarative-finsts command can be used to remove all of the finst markers from the declarative module of the current model. It takes no parameters and always returns **nil**. If there is no current model then it will print a warning.

This command is not recommended for typical modeling use because the ":recently-retrieved reset" request parameter setting can be used in a request to accomplish the same thing in a more model-driven manner. However, sometimes it may be necessary or more convenient to do that through the code accompanying the model.

Examples:

```
> (reset-declarative-finsts)
NIL

E> (reset-declarative-finsts)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative module found - cannot reset the finsts. |#
NIL
```

merge-dm

Arguments and Values:

merge-dm [chunk-description* | chunk-name*] -> (chunk*)
merge-dm-fct (chunk-description* | chunk-name*) -> (chunk*)

Remote command name:

merge-dm ' [chunk-description* | chunk-name*] **'**
merge-dm-fct ' (chunk-description* | chunk-name*) **'**

Arguments and Values:

chunk-description ::= ({*chunk-name*}{[*doc-string* **isa** *chunk-type* | **isa** *chunk-type*]} {*slot value*}*)
chunk-name ::= the name of the chunk to create
doc-string ::= a string that will be the documentation for the chunk
chunk-type ::= a name of a chunk-type in the model
slot ::= a name of a slot for the chunk
value ::= a value which will be the contents of the correspondingly named slot for this chunk
chunk ::= the name of a chunk that was created

Description:

The merge-dm command functions exactly like the add-dm command to create new chunks for the model. However, unlike add-dm, merge-dm will merge those chunks into the current model's declarative memory in the same way they would be merged if they had been cleared from a buffer. Thus, if any of the chunks created by merge-dm are equal using the equal-chunks test with a chunk already in declarative memory that existing declarative memory chunk is strengthened with a new reference at the current time and those two chunks are merged. If a chunk created by merge-dm is not equal to an existing chunk in the current model's declarative memory then that new chunk is added to declarative memory as if it had been created using add-dm.

If there are dependencies among the chunks created with merge-dm then those chunks will be merged into declarative memory in an order that allows for proper merging of all chunks if such an order exists. If there are dependencies and no safe order exists a warning will be displayed to indicate that and the chunks will be merged into declarative memory in the order that they are provided. Merge-dm returns a list of the names of the chunks that were created in the order in which they were merged into declarative memory (first chunk returned was the first merged).

If the syntax is incorrect or any of the components are an invalid list describing a chunk then a warning is displayed and no chunk is created for that chunk description, but all valid chunks defined will still be created.

If there is no current model or no chunks are created and **nil** is returned.

Examples:

These examples assume that base-level learning is enabled so that there is a strengthening of activations when additional references to a chunk occur.

```
1> (chunk-type node slot1 slot2)
NODE

2> (add-dm (a slot1 b slot2 c)
           (b slot1 10)
           (c slot2 20))
(A B C)

3> (sdp)
Declarative parameters for chunk C:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Reference-Count  1.000
 :Creation-Time  0.000
Declarative parameters for chunk B:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Reference-Count  1.000
 :Creation-Time  0.000
Declarative parameters for chunk A:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Reference-Count  1.000
 :Creation-Time  0.000
(C B A)

4> (merge-dm (d slot1 e slot2 f)
             (e slot1 10)
             (f slot2 20)
             (x slot1 30))
(E F D X)

5> (sdp)
Declarative parameters for chunk C:
 :Activation  2.884
 :Permanent-Noise  0.000
 :Base-Level  2.884
 :Reference-Count  2.000
 :Creation-Time  0.000
Declarative parameters for chunk X:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Reference-Count  1.000
 :Creation-Time  0.000
Declarative parameters for chunk B:
 :Activation  2.884
 :Permanent-Noise  0.000
 :Base-Level  2.884
 :Reference-Count  2.000
 :Creation-Time  0.000
Declarative parameters for chunk A:
 :Activation  2.884
 :Permanent-Noise  0.000
 :Base-Level  2.884
 :Reference-Count  2.000
 :Creation-Time  0.000
(C X B A)

6> (merge-dm-fct '((y)))
```

```
(Y)

7E> (merge-dm (g slot1 h)
              (h slot2 g))
#|Warning: Chunks in call to merge-dm have circular references. |#
#|Warning:   Because of that there is no safe order for merging and they will be merged in
the order provided. |#
(G H)

E> (merge-dm (isa bad-type-name))
#|Warning: Invalid chunk definition: (ISA BAD-TYPE-NAME) chunk-type specified does not
exist. |#
NIL

E> (merge-dm (a))
#|Warning: get-module called with no current model. |#
#|Warning: Could not create chunks because no declarative module was found |#
NIL
```

print-activation-trace

Syntax:

print-activation-trace *time* {*time-in-ms*} -> **nil**

Remote command name:

print-activation-trace

Arguments and Values:

time ::= a number which is the time of a start-retrieval event
time-in-ms ::= a generalized boolean indicating the units for time

Description:

The print-activation-trace command works in conjunction with the retrieval-history to allow one to print the activation trace information for retrieval requests that occurred during a model run after the model has stopped. If the retrieval-history stream is being recorded, then this command will print out the activation trace for the retrieval request which started at the time provided, measured in milliseconds if the time-in-ms parameter is true or not provided or seconds if the time-in-ms parameter is specified as **nil**, from the current model as it would have appeared in the model trace if the :act parameter had been set, except that this trace information will be printed to the command trace instead of the model trace. If the retrieval-history is not being recorded, the time provided does not correspond to the time of a start-retrieval event, or there is no current model then a warning will be printed instead of an activation trace.

Examples:

These examples assume that the fan experiment and model from unit 5 of the ACT-R tutorial have been loaded.

```
1> (record-history "retrieval-history")
T

2> (fan-sentence "hippie" "park" t 'person)
...
     1.444   ------                 Stopped because no events left to process
(1.354 T)

3> (print-activation-trace 485)
Chunk PARK matches
Chunk IN does not match
Chunk STORE does not match
Chunk LAWYER does not match
Chunk FIREMAN does not match
Chunk BANK does not match
Chunk DEBUTANTE does not match
Chunk CAVE does not match
Chunk CAPTAIN does not match
Chunk CHURCH does not match
Chunk HIPPIE does not match
Chunk GIANT does not match
Chunk FOREST does not match
Chunk EARL does not match
Chunk DUNGEON does not match
Chunk CASTLE does not match
Chunk BEACH does not match
Chunk GUARD does not match
Computing activation for chunk PARK
Computing base-level
User provided chunk base-level: 10.0
Total base-level: 10.0
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK0-0
    sources of activation are: (HIPPIE)
    Spreading activation  0.0 from source HIPPIE level  1.0 times Sji 0.0
Total spreading activation: 0.0
Adding transient noise 0.0
Adding permanent noise 0.0
Chunk PARK has an activation of: 10.0
Chunk PARK with activation 10.0 is the best
NIL

4> (print-activation-trace 0.235 nil)
Chunk HIPPIE matches
Chunk IN does not match
Chunk STORE does not match
Chunk LAWYER does not match
Chunk FIREMAN does not match
Chunk BANK does not match
Chunk DEBUTANTE does not match
Chunk CAVE does not match
Chunk CAPTAIN does not match
Chunk CHURCH does not match
Chunk PARK does not match
Chunk GIANT does not match
Chunk FOREST does not match
Chunk EARL does not match
Chunk DUNGEON does not match
Chunk CASTLE does not match
Chunk BEACH does not match
Chunk GUARD does not match
Computing activation for chunk HIPPIE
Computing base-level
User provided chunk base-level: 10.0
Total base-level: 10.0
Computing activation spreading from buffers
Total spreading activation: 0.0
```

```
Adding transient noise 0.0
Adding permanent noise 0.0
Chunk HIPPIE has an activation of: 10.0
Chunk HIPPIE with activation 10.0 is the best
NIL


5E> (print-activation-trace 0.050)
#|Warning: No activation trace information available for time 0.05 |#
NIL

E> (print-activation-trace 0.0)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative module available for reporting activation trace. |#
NIL
```

print-chunk-activation-trace

Syntax:

print-chunk-activation-trace *chunk-name time* {*time-in-ms*} ->
[**nil |** total base-level spreading similarity noise]
print-chunk-activation-trace-fct *chunk-name time* {*time-in-ms*} ->
[**nil |** total base-level spreading similarity noise]

Remote command name:

print-chunk-activation-trace

Arguments and Values:

chunk-name ::= the name of a chunk in the model's declarative memory
time ::= a number which is the time of a start-retrieval event
time-in-ms ::= a generalized boolean indicating the units for time
total ::= a number which is the total activation the chunk had for the retrieval
base-level ::= a number which is the total value of the base-level component of the chunk's activation
spreading ::= a number which is the total spreading activation component of the chunk's activation or **nil** if spreading activation is not enabled
similarity ::= a number which is the total partial matching component of the chunk's activation or **nil** if partial matching is not enabled
noise ::= a number which is the total amount of noise added to the chunk's activation

Description:

The print-chunk-activation-trace command works in conjunction with the retrieval-history to allow one to print the activation trace information for the retrieval requests that occurred during a model run after the model has stopped. If the retrieval-history stream is being recorded, then this command will print out the activation trace for the specified chunk at the time provided, measured in milliseconds if the time-in-ms parameter is true or seconds if it is **nil** or not specified, from the current model in the current meta-process similar to how it would have appeared in the model trace if the :act parameter had been set, except that this trace information will be printed to the command output instead of the model output. If the retrieval-history is not being recorded, the time provided

does not correspond to the time of a start-retrieval event, or there is no current model or meta-process then a warning will be printed instead of an activation trace. If the provided chunk-name doesn't name a chunk or wasn't an element in declarative memory then the output will indicate it doesn't have any activation information to display.

If there was chunk activation information displayed then this command will return five values. The first value will be the total activation for the chunk. The remaining four values are the primary components of that activation value: base-level activation, spreading activation, partial matching penalty, and noise. The spreading activation and partial matching penalty values will be **nil** if the corresponding mechanism is not enabled for the model. If there is no chunk activation information displayed then the return value of the command is **nil**.

Examples:

These examples assume that the fan experiment and model from unit 5 of the ACT-R tutorial has been loaded.

```
1> (record-history "retrieval-history")
T

2> (fan-sentence "hippie" "park" t 'person)
  ...
     1.444   ------                 Stopped because no events left to process
(1.354 T)

3> (print-chunk-activation-trace park 485)
Computing activation for chunk PARK
Computing base-level
User provided chunk base-level: 10.0
Total base-level: 10.0
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK0-0
    sources of activation are: (HIPPIE)
    Spreading activation  0.0 from source HIPPIE level  1.0 times Sji 0.0
Total spreading activation: 0.0
Adding transient noise 0.0
Adding permanent noise 0.0
Chunk PARK has an activation of: 10.0
10.0
10
0.0
NIL
0.0

4> (print-chunk-activation-trace-fct 'p1 .585 nil)
Computing activation for chunk P1
Computing base-level
Starting with blc: 0.0
Total base-level: 0.0
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK0-0
    sources of activation are: (PARK HIPPIE)
    Spreading activation  0.10685283 from source PARK level  0.5 times Sji 0.21370566
    Spreading activation  0.10685283 from source HIPPIE level  0.5 times Sji 0.21370566
Total spreading activation: 0.21370566
Adding transient noise 0.0
Adding permanent noise 0.0
Chunk P1 has an activation of: 0.21370566
0.21370566
```

```
0.0
0.21370566
NIL
0.0

5> (print-chunk-activation-trace-fct 'p5 0.585 nil)
Chunk P5 did not match the request.
NIL

6> (print-chunk-activation-trace-fct 'park 0.585 nil)
Chunk PARK was not considered.
NIL

7E> (print-chunk-activation-trace park 0.0)
#|Warning: No activation trace information available for time 0.0 |#
NIL

E> (print-chunk-activation-trace chunk 0.0)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative module available for reporting activation trace. |#
NIL
```

saved-activation-history

Syntax:

saved-activation-history -> (activation-history*)

Remote command name:

saved-activation-history

Arguments and Values:

activation-history ::= (time chunk-name*)
time ::= the time of a retrieval request for which a history has been saved in milliseconds
chunk-name ::= the name of a chunk for which activation information was stored at time

Description:

The saved-activation-history command returns a list which indicates what retrieval information has been saved in the retrieval-history stream from the current model. The same information is available from the retrieval-times processor for the retrieval-history and that is recommended over this command, but this command may be more convenient since it does not return the data as a JSON string. This command will return a list of lists where each sub-list consists of a time in milliseconds and the chunks which were attempted to be retrieved at that time for which the activation information has been recorded. There will be a separate sub-list for each time for which activation details are recorded and those lists will be in order based on the times (lowest time first). If there is no retrieval history recorded or no current model then a warning will be printed and the return value will be **nil**.

Examples:

This example assume that the fan experiment and model from unit 5 of the ACT-R tutorial has been loaded.

```
1> (record-history "retrieval-history")
T

2> (fan-sentence "hippie" "park" t 'person)
...
     1.444   ------                 Stopped because no events left to process
(1.354 T)


3> (saved-activation-history)
((235 HIPPIE) (485 PARK) (585 P3 P2 P1))

E> (saved-activation-history)
#|Warning: No activation trace information available |#
NIL

E> (saved-activation-history)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative module available for reporting activation trace. |#
NIL
```

whynot-dm

Syntax:

whynot-dm *chunk-name** -> (matching-chunk*)
whynot-dm-fct (*chunk-name**) -> (matching-chunk*)

Remote command name:

whynot-dm

Arguments and Values:

chunk-name ::= the name of a chunk in the current model
matching-chunk ::= the name of a chunk which matched the last retrieval request

Description:

The whynot-dm command can be used to determine which chunks in the current model's declarative memory matched the last retrieval request which the declarative module has received and to indicate reasons why a chunk did not get retrieved. If there has been a retrieval request made to the declarative module then the whynot-dm command will output information to the command trace to show the information related to that request. It will display the time at which the most recent request occurred along with the request's specification. Then, for each of the chunk names passed to it (or all chunks in the model's declarative memory if no names are provided) it will print out the chunk, its appropriate parameters if subsymbolic computations are enabled, and then whether the chunk matched that request or not.

It returns a list of all the chunks which did match that request at the time it was made (regardless of whether they were passed into whynot-dm for display). The list is sorted by the chunks' activations at the time of the request (highest activation first), and if there was a chunk retrieved it will be the first element of the list.

If there is no current model then a warning is printed and **nil** is returned. If an invalid chunk-name is provided it will indicate that in the output.

Examples:

This example assumes the count model from unit 1 of the tutorial has been loaded.

```
1> (reset)
T

2> (whynot-dm)
No retrieval request has been made.
NIL

3> (run .1)
     ...
     0.050   DECLARATIVE            start-retrieval
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
     0.100   DECLARATIVE            RETRIEVED-CHUNK TWO
     ...
     0.100   ------                 Stopped because time limit reached
0.1
20
NIL

4> (whynot-dm)
Retrieval request made at time 0.050:
    NUMBER TWO

FIRST-GOAL
   START  TWO
   END  FOUR

Declarative parameters for chunk FIRST-GOAL:
 :Activation  0.000
 :Permanent-Noise  0.000
 :Base-Level  0.000

FIRST-GOAL did not match the request

FIVE
   NUMBER  FIVE

Declarative parameters for chunk FIVE:
 :Activation  0.000
 :Permanent-Noise  0.000
 :Base-Level  0.000

FIVE did not match the request

FOUR
   NUMBER  FOUR
   NEXT  FIVE

Declarative parameters for chunk FOUR:
 :Activation  0.000
 :Permanent-Noise  0.000
 :Base-Level  0.000

FOUR did not match the request

THREE
   NUMBER  THREE
   NEXT  FOUR
```

```
Declarative parameters for chunk THREE:
 :Activation  0.000
 :Permanent-Noise  0.000
 :Base-Level  0.000

THREE did not match the request

TWO
   NUMBER  TWO
   NEXT  THREE

Declarative parameters for chunk TWO:
 :Activation  0.000
 :Permanent-Noise  0.000
 :Base-Level  0.000
 :Last-Retrieval-Activation  0.000
 :Last-Retrieval-Time  0.050

TWO matched the request
TWO was the chunk chosen to be retrieved

ONE
   NUMBER  ONE
   NEXT  TWO

Declarative parameters for chunk ONE:
 :Activation  0.000
 :Permanent-Noise  0.000
 :Base-Level  0.000

ONE did not match the request
(TWO)

5> (whynot-dm one)
Retrieval request made at time 0.050:
    NUMBER TWO

ONE
   NUMBER  ONE
   NEXT  TWO

Declarative parameters for chunk ONE:
 :Activation  0.000
 :Permanent-Noise  0.000
 :Base-Level  0.000

ONE did not match the request
(TWO)

6> (whynot-dm-fct (list 'two))
Retrieval request made at time 0.050:
    NUMBER TWO

TWO
   NUMBER  TWO
   NEXT  THREE

Declarative parameters for chunk TWO:
 :Activation  0.000
 :Permanent-Noise  0.000
 :Base-Level  0.000
 :Last-Retrieval-Activation  0.000
 :Last-Retrieval-Time  0.050

TWO matched the request
TWO was the chunk chosen to be retrieved
```

```
(TWO)

7> (whynot-dm goal-chunk0)
Retrieval request made at time 0.050:
    NUMBER TWO

Chunk GOAL-CHUNK0 is not in the model's declarative memory.
(TWO)

8E> (whynot-dm :bad-name)
Retrieval request made at time 0.05:
    FIRST 2

:BAD-NAME does not name a chunk in the current model.
(C)

E> (whynot-dm)
#|Warning: Whynot-dm called with no current model. |#
NIL
```

simulate-retrieval-request

Syntax:

simulate-retrieval-request *specification* -> (matching-chunk*)
simulate-retrieval-request-fct (*specification*) -> (matching-chunk*)
simulate-retrieval-request-plus-seed-fct (*specification*) -> (matching-chunk*) seed

Remote command name:

simulate-retrieval-request ‘ *specification* ‘
simulate-retrieval-request-fct ‘ (*specification*) ‘
simulate-retrieval-request-plus-seed-fct ‘ (*specification*) ‘

Arguments and Values:

specification ::= [chunk-name | {**isa** chunk-type }{{modifier} slot value}*]
chunk-name ::= the name of a chunk in the current model
chunk-type ::= the name of a chunk-type in the current model
modifier ::= [**=** | **-** | **<** | **>** | **<=** | **>=**]
slot ::= [possible-slot | request-param]
possible-slot ::= the name of a valid slot in chunk-type or any valid slot if no chunk-type provided
request-param ::= a keyword which is a valid retrieval buffer request parameter
value ::= any value
matching-chunk ::= the name of a chunk in DM which matched specification
seed ::= the value of the :seed parameter in the model after the retrieval process was simulated

Description:

The simulate-retrieval-request command can be used to simulate the results of making a request to the retrieval buffer under the current model conditions. If there is a current model then the specification provided is used to create a chunk-spec which is used to simulate a request to the retrieval buffer. That request will perform the matching and activation calculations based on the

current buffer contents for spreading activation and report the results of whether chunks match the request or not and show the activation for those which do similar to the low detail activation trace.

The simulated request does not perform many of the side effects which occur with a normal retrieval request. The simulated request does not trigger calls to the functions set with the :retrieval-request-hook, :retrieval-set-hook, or :retrieved-chunk-hook parameters. The results of the simulated request are not recorded for use with why-not-dm and are not recorded in the retrieval-history stream. The activations computed will include noise, but the model's :seed parameter will be restored to the value it had prior to those computations. It does however set the activation parameter of the chunks that are matched which can be accessed using the command chunk-activation (see extending chunks for information on using chunk parameters).

It returns a list of all the chunks which match the request specified sorted by the chunks' activations (highest activation first) with any chunk which would have been retrieved as the first element of the list. However, just because there is a first element in the list does not mean that it would necessarily be retrieved because it may have an activation below the current retrieval threshold.

The simulate-retrieval-request-plus-seed-fct function returns the value of the :seed parameter after the retrieval process completes as its second value. That is done so that one can use this mechanism to implement a second buffer that accesses the model's declarative memory and update the random state appropriately.

If there is no current model then a warning is printed and **nil** is returned. If an invalid specification is provided it will indicate that in the output and return **nil**.

Examples:

These examples assume the grouped model from unit 5 of the tutorial has been loaded.

```
> (simulate-retrieval-request)
Chunk LIST has the current best activation 0.13675894
Chunk FIRST has activation -0.36428827
Chunk SECOND has activation -0.2693139
Chunk THIRD is now the current best with activation 0.15103722
Chunk FOURTH has activation 0.069821134
Chunk GROUP1 has activation 0.14088637
Chunk GROUP2 has activation 0.05243059
Chunk GROUP3 has activation -0.31867743
Chunk ITEM1 has activation -0.010031511
Chunk ITEM2 has activation 0.11004096
Chunk ITEM3 has activation -0.087834366
Chunk ITEM4 has activation -0.27916592
Chunk ITEM5 is now the current best with activation 0.21117316
Chunk ITEM6 has activation -0.2579252
Chunk ITEM7 has activation 0.18635121
Chunk ITEM8 has activation 0.09208258
Chunk ITEM9 has activation -0.2433808
Chunk GOAL has activation -0.044656888
Chunk ITEM5 with activation 0.21117316 is the best
(ITEM5 ITEM7 THIRD GROUP1 LIST ITEM2 ITEM8 FOURTH GROUP2 ITEM1 ...)

> (simulate-retrieval-request isa item - name nil)
Chunk ITEM1 has the current best activation 0.13675894
Chunk ITEM2 has activation -0.36428827
Chunk ITEM3 has activation -0.2693139
Chunk ITEM4 is now the current best with activation 0.15103722
```

```
Chunk ITEM5 has activation 0.069821134
Chunk ITEM6 has activation 0.14088637
Chunk ITEM7 has activation 0.05243059
Chunk ITEM8 has activation -0.31867743
Chunk ITEM9 has activation -0.010031511
Chunk ITEM4 with activation 0.15103722 is the best
(ITEM4 ITEM6 ITEM1 ITEM5 ITEM7 ITEM9 ITEM3 ITEM8 ITEM2)

> (simulate-retrieval-request-fct '(position third))
Chunk GROUP1 has the current best activation -0.8632411
Chunk GROUP2 has activation -0.8642883
Chunk GROUP3 is now the current best with activation -0.2693139
Chunk ITEM1 has activation -0.8489628
Chunk ITEM2 has activation -0.43017888
Chunk ITEM3 is now the current best with activation 0.14088637
Chunk ITEM4 has activation -0.94756943
Chunk ITEM5 has activation -0.8186774
Chunk ITEM6 has activation -0.010031511
Chunk ITEM7 has activation -0.88995904
Chunk ITEM8 has activation -0.58783436
Chunk ITEM9 has activation -0.27916592
Chunk ITEM3 with activation 0.14088637 is the best
(ITEM3 ITEM6 GROUP3 ITEM9 ITEM2 ITEM8 ITEM5 ITEM1 GROUP1 GROUP2 ...)

> (simulate-retrieval-request group1)
Chunk GROUP1 has the current best activation 0.13675894
Chunk GROUP2 has activation -1.8642883
Chunk GROUP3 has activation -2.2693138
Chunk GROUP1 with activation 0.13675894 is the best
(GROUP1 GROUP2 GROUP3)

> (simulate-retrieval-request-plus-seed-fct '(name "1"))
Chunk ITEM1 has the current best activation 0.13675894
Chunk ITEM2 has activation -1.3642883
Chunk ITEM3 has activation -1.2693139
Chunk ITEM4 has activation -0.8489628
Chunk ITEM5 has activation -0.9301789
Chunk ITEM6 has activation -0.85911363
Chunk ITEM7 has activation -0.94756943
Chunk ITEM8 has activation -1.3186774
Chunk ITEM9 has activation -1.0100315
Chunk ITEM1 with activation 0.13675894 is the best
(ITEM1 ITEM4 ITEM6 ITEM5 ITEM7 ITEM9 ITEM3 ITEM8 ITEM2)
(77093543977 39822)

E> (simulate-retrieval-request-fct '(isa list))
#|Warning: Element after isa in define-chunk-spec isn't a chunk-type. (ISA LIST) |#
#|Warning: Invalid request specification passed to simulate-retrieval-request. |#
NIL

E> (simulate-retrieval-request)
#|Warning: get-module called with no current model. |#
#|Warning: No declarative memory module available.  Simulate-retrieval-request cannot
perform the request. |#
NIL
```

add-dm-chunks

Syntax:

add-dm-chunks existing-chunk-name* -> (existing-chunk-name*)
add-dm-chunks-fct (existing-chunk-name*) -> (existing-chunk-name*)

Remote command name:

add-dm-chunks
add-dm-chunks-fct

Arguments and Values:

existing-chunk-name ::= the name of a chunk that already exists

Description:

The add-dm-chunks command can be used to add a chunk which already exists to the current model's declarative memory. For each of the names provided, if it names an existing chunk and that chunk is not already in the model's declarative memory it is added to declarative memory in the same way that add-dm adds chunks which it creates.

It returns a list of the chunks which were added to the model's declarative memory. If there is no current model then a warning is displayed and **nil** is returned.

Examples:

```
1> (add-dm a b)
(A B)

2> (define-chunks c d)
(C D)

3> (dm)
B

A

(B A)

4> (add-dm-chunks a c)
(C)

5> (add-dm-chunks-fct '(b d))
(D)

6> (dm)
D

C

B

A

(D C B A)

E> (add-dm-chunks a b)
#|Warning: get-module called with no current model. |#
#|Warning: Could not add chunks to DM because no declarative module was found |#
NIL
```

merge-dm-chunks

Syntax:

merge-dm-chunks existing-chunk-name* -> (existing-chunk-name*)
merge-dm-chunks-fct (existing-chunk-name*) -> (existing-chunk-name*)

Remote command name:

merge-dm-chunks
merge-dm-chunks-fct

Arguments and Values:

existing-chunk-name ::= the name of a chunk that already exists

Description:

The merge-dm-chunks command can be used to merge a chunk which already exists into the current model's declarative memory. For each of the names provided, if it names an existing chunk that is not already in declarative memory then it is merged into declarative memory in the same way that merge-dm merges chunks which it creates.

It returns a list of the chunks which were merged into the model's declarative memory. If there is no current model then a warning is displayed and **nil** is returned.

It would seem like this should allow a chunk to be merged repeatedly into declarative memory to strengthen that chunk, but since the merge-chunks command will not merge a chunk with itself that is not allowed. Instead, one would have to use merge-dm with the description of the chunk which could be created with chunk-spec-to-chunk-def and chunk-name-to-chunk-spec:

```
(merge-dm-fct (list (chunk-spec-to-chunk-def (chunk-name-to-chunk-spec 'd))))
```

Examples:

```
1> (add-dm (a value 1) (b value 2))
(A B)

2> (define-chunks (c value 1) (d value 3))
(C D)

3> (merge-dm-chunks b c)
(C)

4> (sdp)
Declarative parameters for chunk B:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
Declarative parameters for chunk A:
 :Activation  2.884
 :Permanent-Noise  0.000
 :Base-Level  2.884
```

```
 :Creation-Time 0.000
 :Reference-Count  2
(B A)

5> (merge-dm-chunks-fct '(a d))
(D)

6> (sdp)
Declarative parameters for chunk D:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
Declarative parameters for chunk B:
 :Activation  2.191
 :Permanent-Noise  0.000
 :Base-Level  2.191
 :Creation-Time 0.000
 :Reference-Count  1
Declarative parameters for chunk A:
 :Activation  2.884
 :Permanent-Noise  0.000
 :Base-Level  2.884
 :Creation-Time 0.000
 :Reference-Count  2
(D B A)

E> (merge-dm-chunks a)
#|Warning: get-module called with no current model. |#
#|Warning: Could not merge chunks to DM because no declarative module was found |#
NIL
```

Perceptual & Motor modules

The perceptual and motor modules provide a model with a way to interact with a world. The provided perceptual modules allow the model to attend to visual and aural stimuli and the given motor modules provide the model with hands and a voice. The perceptual and motor modules provided with ACT-R are essentially updated versions of the modules which comprised those same components in the ACT-R/PM system. ACT-R/PM was developed by Mike Byrne as a combination of ACT-R, the Visual Interface for ACT-R created by Mike Matessa, and the EPIC cognitive architecture created by David Kieras and David Meyer. Providing a model access to an external world was an important development in the advancement of ACT-R modeling, and that integration lead to many of the changes that came about with the introduction of ACT-R 5 (which eventually replaced ACT-R/PM).

Unlike the cognitive modules, the perceptual and motor modules each primarily work with chunks that are created using the slots of specific chunk-types that the modules define, and the requests which they respond to are more rigidly specified descriptions of actions. The chunk-types a module defines and any initial chunks which it creates will be listed with each module's description.

These modules also have more complicated internal states than the basic state free and state busy which can be queried for all modules. Each of these modules has three separate internal systems: preparation, processor, and execution. Each of those systems can be queried individually for being busy or free. Different requests to these modules may require the use of different internal systems and thus may not require that all internal states be free before being allowed to progress. This is particularly useful in the motor module to request an action before the previous has completed. How the modules respond to the queries and how that affects the requests which can be made to them vary from module to module.

Before describing the perceptual and motor modules themselves, first some information about how those modules interact with the world will be described.

Devices

In previous versions of ACT-R the perceptual and motor modules interacted with the world through a single interface called a device. A model could only be associated with a single device at any time and that device had to provide a set of specific methods for interacting with the perceptual and motor modules. That approach however does not extend well to the distributed system design of this version of ACT-R, and thus the entire notion of a device has been overhauled.

Now, instead of a single device providing a specific set of methods for the perceptual and motor modules, the modules themselves have been redesigned to provide more user access without the need for a device. There is however still the ability to create devices, but now a device does not require any particular methods nor does it have to be associated with all of the perceptual and motor modules simultaneously. In fact, any module may provide an 'interface' to which a device (or possibly multiple devices) can be connected and different modules may have different devices installed at the same time. Effectively, now a device is just a general mechanism for extending the operation of the system.

The basic representation for the device in the older ACT-R software was one where the model was sitting in front of a computer monitor, with its hands on a keyboard or mouse, and speaking into a microphone. A similar set of capabilities are included with the current version, but those are now represented as separate devices, and those devices will be described with the appropriate modules.

There was also a set of tools provided with the older software which allowed one to create simple GUI tasks for a model based on the device mechanism (called the AGI – ACT-R GUI Interface). The AGI is still available, but now is not tied directly to any specific Lisp GUI libraries. It only provides a virtual system, but includes an API for connecting that virtual system to a real UI. The ACT-R Environment uses that API to create a visible UI which can be interacted with by a person or model, as was done through a custom device for the previous versions of ACT-R. Details on the AGI and the ACT-R Environment are available in their own manuals.

Information on creating devices and interfaces for modules are covered later in the manual. Here we will describe the device module which provides the commands for working with devices as well as some parameters for controlling the details for the basic model interface of interacting with a computer.

Device Module

The device module provides the commands for installing and uninstalling devices, for finding out which modules provide interfaces for devices, and which devices are currently installed. It also maintains parameters that control the details of the devices which provide a basic computer interface for a model.

The module is named :device and will be available when any of the motor, vision, or speech modules are available.

Parameters

:cursor-fitts-coeff

This parameter is the b coefficient in the Fitts's Law equation for aimed movements which is used when the model moves the mouse or other cursor devices. The default value is .1 and it can be set to any positive value.

:default-target-width

This is the width of targets with undefined widths when computing the Fitts's law computation for ply and move-cursor actions, when a zero or negative width is provided for any Fitts's law computation, and when an approach width for a visual feature cannot be computed. No units are assumed and this value is used explicitly. Therefore, it is in the same units as the distance provided for Fitts's law computations. The default value is 1.0.

:key-closure-time

This parameter specifies the amount of time in seconds that passes between when a key starts to be depressed and when the switch closes and signals the key is down. It is a representation of the physical devices with which the model interacts. The default value is .01.

:needs-mouse

This parameter controls whether or not the model will be using a mouse device. If it is set to a non-nil value, then when using the AGI tools to build a GUI for the model a mouse device will be installed automatically. If it is set to **nil** then no mouse device will be installed by default, and that is the default value. It can be set to **t**, any string, or any symbol. A string or symbol value is used to indicate a color for the AGI to use when displaying a mouse cursor so that the cursors for different models can be distinguished if being displayed through the visible AGI API.

:pixels-per-inch

This is the number of pixels/inch used for computations of the size of items in terms of degrees of visual angle. The default value is 72 and it can be set to any positive number.

:process-cursor

This parameter controls whether the mouse cursor should be included as a feature for the vision module when using the AGI interface. If it is set to **t,** then a feature for the mouse will be generated automatically. The default value is **nil**.

:stable-loc-names

When using the AGI window device, this parameter determines whether the device sorts the items found in the window before generating the visual features. Setting the parameter to **t**, which is the default value, will force the items to be sorted which means that the same AGI display will result in the same feature names each time it is run on all systems – it will be deterministic. If it is set to **nil** then the items in the interface will not be sorted and the names could vary among runs or across systems. Setting it to **nil** should not affect the model's performance and may improve the time it takes to run the simulation at the potential cost of debugging time needed to compare different model runs.

:viewing-distance

This is the assumed distance between the model's eyes and the display in inches. It is used in determining the size of items in terms of degrees of visual angle. The default is 15 and it can be set to any positive number.

Commands

install-device

Syntax:

install-device *device-list* -> [device-list | **nil**]

Remote command name:

install-device

Arguments and Values:

device-list ::= (interface device {details})
interface ::= a string which names the interface to which the device is being installed
device ::= a string which names the device being installed
details ::= any value which will be passed to the device when installed

Description:

The install-device command takes one parameter which should be a list of two or three items. If the first item in the list names an interface and the second item names a device, then that device is attempted to be installed into that interface for the current model. If a third parameter is provided

then it is passed to the device during the installation. If the device is successfully installed into the interface then the device-list is returned. If any of the parameters are invalid, the given device is already installed for that interface, the device is not successfully installed, or there is no current model then a warning is printed and **nil** is returned.

Examples:

```
> (install-device '("motor" "cursor" "mouse"))
("motor" "cursor" "mouse")

1> (install-device '("motor" "keyboard"))
("motor" "keyboard")

2E> (install-device '("motor" "keyboard"))
#|Warning: The device ("motor" "keyboard") is already installed. No device installed. |#
NIL

E> (install-device '("vision" "keyboard"))
#|Warning: Keyboard does not yet support any features for the vision interface. |#
NIL

E> (install-device '("speech" "keyboard"))
#|Warning: Keyboard device does not provide actions for the "speech" interface. |#
#|Warning: Keyboard does not yet support being used with the speech interface. |#
NIL

E> (install-device '("bad" "keyboard"))
#|Warning: Invalid interface "bad" in call to install-device with ("bad" "keyboard"). No
device installed. |#
NIL

E> (install-device '("motor" "bad"))
#|Warning: Invalid device "bad" in call to install-device with ("motor" "bad"). No device
installed. |#
NIL

E> (install-device '("motor" "keyboard"))
#|Warning: install-device called with no current model. |#
NIL
```

remove-device

Syntax:

remove-device *device-list* -> [**t** | **nil**]

Remote command name:

remove-device

Arguments and Values:

device-list ::= (interface device {details})
interface ::= a string which names the interface to which device was installed
device ::= a string which names the device that was installed
details ::= any value which was passed to the device when installed

Description:

The remove-device command takes one parameter which should be a list of two or three items. If that list of items has been installed as a device in the current model then that device is removed from those which are installed and **t** is returned. If the list is not one which has been installed or there is no current model then a warning is printed and **nil** is returned.

Examples:

```
1> (install-device '("motor" "keyboard"))
("motor" "keyboard")

2> (remove-device '("motor" "keyboard"))
T

3E> (remove-device '("motor" "keyboard"))
#|Warning: Device ("motor" "keyboard") is not currently installed and cannot be removed. |
#
NIL

E> (remove-device '("bad"))
#|Warning: Device ("bad") is not currently installed and cannot be removed. |#
NIL

E> (remove-device '("motor" "keyboard"))
#|Warning: remove-device called with no current model. |#
NIL
```

current-devices

current-devices *interface* -> [(device-list*) | **nil**]

Remote command name:

current-devices

Arguments and Values:

interface ::= a string which names an interface
device-list ::= (interface device {details})
device ::= a string which names a device that was installed
details ::= a value which was passed to the device when installed

Description:

The current-device command takes one parameter which is the name of an interface. It returns a list of device-lists for all of the devices that are installed for that interface in the current model. If there is no current model or the given value does not name an interface then a warning is printed and **nil** is returned.

Examples:

```
1> (install-device '("motor" "cursor" "mouse"))
("motor" "cursor" "mouse")
```

```
2> (current-devices "motor")
(("motor" "cursor" "mouse"))

> (current-devices "vision")
NIL

E> (current-devices "bad")
#|Warning: "bad" does not name a valid interface in call to current-devices. |#
NIL

E> (current-devices "motor")
#|Warning: current-devices called with no current model. |#
NIL
```

defined-devices

defined-devices -> device*

Remote command name:

defined-devices

Arguments and Values:

device ::= a string which names a device

Description:

The defined-devices command takes no parameters and returns a list with the names of all the devices which are currently defined.

Examples:

```
> (defined-devices)
("cursor" "exp-window" "keyboard" "microphone")
```

defined-interfaces

defined-interfaces -> interface*

Remote command name:

defined-interfaces

Arguments and Values:

interface ::= a string which names an interface

Description:

The defined-interfaces command takes no parameters and returns a list with the names of all the interfaces which are currently defined.

Examples:

```
> (defined-interfaces)
("motor" "speech" "vision")
```

notify-device

Syntax:

notify-device *device-list feature* -> [result | **nil**]

Remote command name:

notify-device

Arguments and Values:

device-list ::= a list representing an installed device
feature ::= any value which will be passed to the device's notification command
result ::= any value which is returned by the device's notification command

Description:

The notify-device command takes two parameters. The first should be a list of two or three items which represents an installed device for the current model. The second can be any value. If the current model has the indicated device installed, then the feature value provided will be passed to the notification command for that device (if it has one) and the value returned by that command will be returned. If the device is not installed, there is no current model, or the device does not have a notification command then **nil** will be returned.

What a notification command does with the feature is up to the device and there are no constraints on how that can be used. Some examples of how it is used with the provided devices: the experiment window device of the AGI uses it to allow the user to pass new display details to visible window handlers and the default keyboard device uses it to receive the motor module's finger movements which it uses to determine whether a key press occurs and which key that is if there is a press.

Examples:

```
E> (notify-device nil nil)
#|Warning: notify-device called with no current model. |#
NIL

E> (notify-device nil nil)
#|Warning: Device NIL is not installed when trying to notify with features NIL. |#
NIL
```

Vision module

The vision module provides a model with a visual attention system. That attention system is an abstraction which does not attempt to model what is happening with the eyes. It consists of two subsystems: a "where" system and a "what" system. Those two subsystems work together, but each has its own buffer and accepts its own set of requests.

The name of the module is :vision.

The model's visual world

The vision module "sees" objects that are provided to it directly by the modeler and/or through devices – it does not do any image processing or attempt to create visual features on its own (although people have built extensions which can create the features for the module). Those objects each have a set of features, and all of the features of the objects available to the model are referred to collectively as the visicon (visual icon). The features in the visicon are available to the where system to find the location of an object which results in the creation of a chunk containing some of the information about the corresponding object, like its general categorization, location, and color (the specific details on the information that is available are up to the modeler/device but must include some representation of a location). With that location information, the what system can attend to the object and get a chunk containing a more detailed representation of its information (again the details on the information that is available are up to the modeler/device).

Details on how to create visual features for a model are described in the visicon features section of the manual.

The Where System

The where system takes requests through the visual-location buffer. A request to the visual-location buffer specifies a set of constraints, and the where system searches the visicon to find a feature which matches those constraints and creates a chunk representing the corresponding object's location if one is found. This is often referred to as "finding a location". The constraints are specified as slot-value pairs in a request and should represent visual properties of the feature, the spatial location of the feature, coarse temporal information such as whether it recently became visible, and tests of whether the model has previously attended to that location. This is akin to so-called "pre-attentive" visual processing (Triesman & Gelade, 1980) and supports visual pop-out effects. For example, if the display consists of one green object in a field of blue objects, the time to determine the location of the green object is constant regardless of the number of blue objects. It is also possible to specify the specific information about the feature e.g. find the letter X, which is not information that would be considered pre-attentive. The reason for allowing that is to provide ACT-R modelers with enough flexibility to use the system as they want, and, as with many pieces of the software, it is up to the modeler to decide what is reasonable and justifiable when building a model.

When a visual-location request is made, if there is a feature in the visicon that matches the constraints, then a chunk representing the location of that feature's object is placed in the visual-location buffer. If multiple features meet the constraints, then the newest one (the one with the most recent onset time) will be the one that is chosen. If multiple features meet the constraints and they

have the same onset time, then one of those will be picked randomly. If there are no features which meet the constraints, then the buffer will be left empty, a buffer failure will be signaled, and an error state will also be set.

Finsts

As noted above, one property of the features in the visicon which can be tested is whether the corresponding object has been previously attended by the model. The vision module is able to keep track of a small number of locations to which it has attended. It does so using a set of markers called finsts (fingers of instantiation) which are limited both in number and in duration. When an object is attended by the model a finst is placed upon it. The finst will remain until its duration expires, at which time the object will revert to unattended, or until an attention shift requires a finst and there are none available. If all finsts are in use and a new one is needed then the oldest one which was assigned will be removed (thus forcing that object to revert to unattended) and reused for the newly attended object. The visual finsts work the same as those described for the declarative module, but the two systems are separate with each module having its own set of finsts.

The What System

The what system takes requests through the visual buffer. Its primary use is to attended to objects whose features have been found using the where system. To do that, a request to the what system is made providing a chunk representing the location information from the where system. That will cause the what system to shift visual attention to that location, process the object located there, and place a chunk representing the object into the visual buffer. If there is more than one object at the location specified when the attention shift completes, only one of them will be encoded and placed into the buffer. The vision module chooses among the objects by using the constraints which led to the where system finding that visual location. Thus, if the location to be attended to was found based on a constraint of having the color red, and there are three objects at that location, one of which is red, then the red one will be encoded.

The what system has a rudimentary tolerance for movement. That is, if the location chunk provided to be attended specifies a location, but the object which created that feature has moved slightly such that it is no longer at that indicated location the vision module will still attend to that item if the movement is small. Just how far an object can move and still be encoded is configurable with a parameter, and the default tolerance is 0.5 degrees of visual angle. That means the object can move up to 0.5 degrees of visual angle from the location which was found by the where system and still be processed by the what system.

The basic assumption behind the vision module is that the chunks placed into the visual buffer as a result of an attention operation are episodic representations of the objects in the visual scene. Thus, a chunk with the value "3" represents a memory of the character "3" available via the eyes, not the semantic THREE used in arithmetic—a declarative retrieval would be necessary to make that mapping. Note also that there is no "top-down" influence on the creation of these chunks; top-down effects are assumed to be a result of the system’s processing of these basic visual chunks, not anything that’s done by the vision module. (See Pylyshyn, 1999 for a clear argument about why it should work this way.)

Re-encoding

Once a location has been attended to the model continues to attend to that location until stopped, and if the visual scene changes the module will automatically update the chunk in the visual buffer to reflect any changes which occurred at that location. The where system will be busy while it re-encodes the new object (or lack of one) at the currently attended location. This behavior is sometimes undesirable because visual attention cannot be shifted to a new location while it is busy re-encoding a change at the current location which may make a response to new stimuli slower than desired. If this creates a problem for modeling a task, it is possible to have the vision module stop attending to a location after it has processed the visual chunk. A clear request to the visual buffer can be used to make the vision module stop attending to the visual scene, and then it will no longer re-encode items until a new attention shift is performed.

Scene change

The vision module is sensitive to every change to the visual scene with respect to re-encoding as described above. It is also possible for the model to detect when there has been a change as well, and the modeler can specify how much change is required before the model will "notice" the difference. When there is a change to the visicon the module computes the proportion of the items which have changed. If that value is greater-than or equal to a threshold set with the **:**scene-change-threshold parameter then the module will indicate that there has been a scene change. That signal will only last for a short time (controlled with the :visual-onset-span parameter), and is made available to the model through the scene-change query of the visual buffer.

This is the calculation which computes the proportion of items which have changed:

$$Change = \frac{d + n}{o + n}$$

o: The number of features in the scene prior to the update
d : The number of features which have been deleted or modified from the original scene
n: The number of features which are newly added to the scene by the update

If both o and n are 0 then the change value is also reported as 0 (which could happen if there are no old items and all the new items are added and removed within a single update).

Tracking

The vision module also has a rudimentary ability to track moving objects. The basic pattern is to attend the object, then issue a request to start tracking it. While the module is tracking an object the chunks representing that item in the visual-location and visual buffers will be updated as the object moves, and the where system will remain busy. Tracking will continue until a new request is made of the what system, which could be a clear request to stop attending.

Interface & Devices

The vision module provides an interface called “vision” which can be used to install devices. That interface has very limited functionality associated with it. It will generate an installing-vision-device signal which can be monitored to know when a visual device is installed. The only notification that it will send is the position of the currently attended location if the :show-focus parameter is non-nil. Any number of devices can be connected to it with one exception. There are three devices specified that can be connected.

The “exp-window” device provided by the AGI can be installed for the vision interface to provide the model with visual features for some simple GUI items (text, buttons, lines, and images) which are described in detail in the AGI manual and to display the currently attended location.

A “cursor” device can be installed for the vision interface to provide the model with an object that represents the cursor it is controlling (which presumably is also installed for the motor module so that the model can control it). That object will be updated as the cursor moves. The location chunk for a cursor object will look like this (where the value represents the type of cursor installed):

```
VISUAL-LOCATION0
   KIND  CURSOR
   VALUE  MOUSE
   DISTANCE  1080
   SCREEN-X  0
   SCREEN-Y  0
   SIZE  1.0
```

The object chunk will look like this:

```
CURSOR0-0
   SCREEN-POS  VISUAL-LOCATION0
   VALUE  MOUSE
   CURSOR  T
```

An “object-creator” device can be installed to modify the attended objects, and it is described in detail in the “Creating Visual features” section. Only one object-creator device may be installed for the vision module at a time.

History Stream

visicon-history

The vision module provides one data history stream called visicon-history. When it is enabled it will record the information from the visicon every time it is updated. The data will be recorded based on the time of the update, and the value recorded will be a string with the text as would be output from printed-visicon at that time. The visicon-history data is recorded by a module named :visicon-history.

Parameters

:auto-attend

This parameter controls whether or not a visual-location request results in an automatically generated request to the visual buffer to also move attention to the location which is found. This is designed as a modeling shortcut to allow one to skip productions which make attention shift requests when they

will always follow a visual-location request in the model. It does not affect the timing of the model because there is a 50ms delay before the visual request is sent to compensate for the skipped production's firing time. It is off by default (**nil**) but setting it to **t** will enable that functionality.

:delete-visicon-chunks

This parameter controls what happens to chunks which the vision module creates internally for the visicon when they are no longer needed. The default value is **t** which means that those chunks are deleted and the names uninterned through the purge-chunk command. Setting this parameter to **nil** will prevent those chunks from being deleted. Most models should leave this parameter at the default value, but if one is working to extend or modify the operation of the vision module itself it may be necessary to disable this functionality.

:force-visual-commands

This parameter can be used to force the actions that affect the visicon ([add | delete | delete-all | modify]-visicon-features and proc-display which is the event that performs the updating) to always go through the command interface so that they can be monitored (by default the provided Lisp functions and the AGI bypass the command system for performance purposes). If it is set to **t** then those commands will always happen through a command which can be monitored. If it is set to **nil** then it will not use commands for Lisp and AGI based calls to those functions. The default value is **nil**.

:optimize-visual

This parameter is not currently used by the system. In previous versions of ACT-R it allowed the modeler to control how text is processed by the AGI devices, and it could be set to have each letter that was displayed parsed into multiple sub-letter features from different possible feature sets like those from Gibson's (1968) set and Briggs & Hochevar's (1975) set. This capability will be available again in the future, but might not be associated with this specific parameter because it will likely be part of a more general "processing level" mechanism.

:overstuff-visual-location

This parameter controls whether the module can "stuff" a new chunk into the visual-location buffer when there is already a previously stuffed chunk in the buffer. The default value is **nil** which means that it will not overwrite a previously stuffed chunk, but if it is set to **t** then it will overwrite a chunk which was stuffed into the visual-location buffer with a new one.

:scene-change-threshold

This parameter controls the smallest proportion of change in the visicon which will result in signaling that the scene has changed. It must be set to a number in the range [0.0 – 1.0] and defaults to .25.

:show-focus

This parameter controls whether the position of the vision module's current attention is provided to visual devices that are installed. It may be set to **t**, **nil**, a string, or a symbol. If it is set to a non-nil value then the devices will be notified with a list when attention changes like this: (**"attention"** *x y color*) where x and y are the coordinates of the attended location and color is a string which is the string or symbol set for this parameter or "red" if the parameter is set to t, or a list that only contains the string **"clearattention"** if the model stops attending. The default value is **nil**. The provided exp-window devices will use the notification to draw the attention position using the indicated color (if it is a valid color name).

:tracking-clear

This parameter controls how the module reacts when an object being tracked is no longer found in the visicon. If it is set to **t** (which is the default value) then the module will clear the currently attended location when it stops tracking which will leave the visual buffer empty if it was holding the tracked object chunk. If it is set to **nil** then the currently attended location will be the last tracked location of the object and the re-encoding process will take place if the visual buffer is empty.

:unstuff-visaul-location

This parameter lets the modeler specify whether the vision module removes the chunks which it "stuffs" into the visual-location buffer. The default value is **t** which means that if a stuffed chunk is still in the visual-location buffer and has not be modified after the :visual-onset-span time has passed that chunk will be erased from the buffer by the vision module. If it is set to a number then it works similar to the setting of **t** except that the value of this parameter specifies the time in seconds after which the erasing occurs instead of the :visual-onset-span parameter. If it is set to **nil** then the module will not automatically remove a chunk which has been stuffed into the visual-location.

:visual-attention-latency

This parameter specifies how long a visual attention shift will take measured in seconds. The default value is .085.

:visual-finst-span

This parameter controls how long a finst marker will remain on a feature. It is measured in seconds and defaults to 3.0.

:visual-movement-tolerance

This parameter controls how far an object can move and still being considered the same object by the vision module without being explicitly tracked. It is measured in degrees of visual angle and defaults to 0.5.

:visual-num-finsts

This parameter controls how many finsts are available to the vision module. It can be set to any positive number and defaults to 4.

:visual-onset-span

This parameter specifies how long an item recently added to the visicon will be marked as new and also for how long a scene change notice will be available. It is measured in seconds, and the default value is 0.5.

:visual-encoding-hook

This parameter can be set to a command identifier to adjust the time that it takes for a move-attention request or automatic re-encoding to finish with the encoding-complete action. If a command is set for this parameter it will be called during each move-attention request and automatic re-encoding with four parameters: a list of the coordinates which are currently being attended at the time of the request or **nil** if there is no currently attended location, a list of the coordinates of the new location to attend, the name of the chunk which was used to specify the new location, and the scale value for the attention request. If the hook command returns **nil** then the normal encoding time will apply. If the command returns a number then that is used as a time in seconds for the length of the encoding process (which will be randomized if the :randomize-time parameter is enabled). Any other return value suppresses the completion of the encoding-complete action and the schedule-encoding-complete command must be called to finish the attention shift. Only one command can be set on the hook at a time, and it will print a warning if a command is replaced with a different one.

Visual-location buffer

The visual-location buffer is used to access the where system of the vision module as described above. In addition to taking requests to find locations, the vision module will also place chunks into the visual-location buffer automatically without a model request (a process referred to as "buffer stuffing"). Whenever there is an update to the visual scene, if the visual-location buffer is empty or the :overstuff-visual-location parameter is set to **t** and a previously "stuffed" chunk is in the visual-location buffer, a location chunk for some visual feature may be placed into the visual-location buffer. The feature which gets "stuffed" into the buffer is chosen based on preferences which can be set either by the modeler using the set-visloc-default command or directly by the model with a set-visloc-default request. The default preference is for the left-most unattended item. If the :unstuff-visual-location parameter is not **nil** then the module will also automatically remove a stuffed chunk from the buffer if it is there past the indicated delay time.

The vision module sets the visual-location buffer to **not** be treated with the strict safety mechanism and to always create a new chunk when a chunk is set in the buffer.

Activation spread parameter: :visual-location-activation
Default value: 0.0

Queries

'State busy' will always be **nil.**

‘State free’ will always be **t**.

‘State error’ will be **t** if the last visual-location request failed to find a matching location and it will be **nil** in all other situations. Once it becomes **t** it will remain **t** until a new visual-location request is made or a clear request is made of the *visual* buffer.

The visual-location buffer has an additional query that allows one to check the attended status of the location represented by the chunk currently in the visual-location buffer.

‘Attended t’ will be **t** if there is a chunk in the visual-location buffer and that location currently has a finst on it. Otherwise it will be **nil**.

‘Attended nil’ will be **t** if there is a chunk in the visual-location buffer, that location does not currently have a finst on it, and that location is not the target of a currently ongoing move-attention request to the visual buffer. Otherwise it will be **nil**.

‘Attended new’ will be **t** if there is a chunk in the visual-location buffer, that location does not currently have a finst, and that feature was added to the model’s visicon within the :visual-onset-span. Otherwise it will be **nil**.

‘Attended requested’ will be **t** if there is a chunk in the visual-location buffer, that location does not currently have a finst, that location is the target of a currently ongoing move-attention request to the visual buffer. Otherwise it will be **nil**.

Requests

Find location

{**isa** *location-chunk-type*}
{{modifier} *valid-slot* [*value* | *variable*]}*
{:**nearest** *nearest-spec*}
{**:attended** [***t* | *nil* | *new* | *requested***]}
{**:center** [*vis-loc* | *vis-obj*]}

location-chunk-type ::= the name of a chunk-type
modifier ::= [= | - | > | < | >= | <=]
valid-slot ::= the name of a slot which is valid for location-chunk-type if provided or any chunk if not
value ::= any value, but the symbols **lowest**, **highest** and **current** have special meanings.
variable ::= a name which starts with the character &
nearest-spec ::= [vis-loc | **current** | **current-x** | **current-y** | **current-distance** | **clockwise** | **counterclockwise**]
vis-loc ::= a chunk which represents a visual location
vis-obj ::= a chunk which represents a visual object

A find-location request to the visual-location buffer is an attempt to find an item in the visicon. All of the items in the visicon are compared against the specification provided in the request and if there is an item which matches that specification a chunk describing that item is placed into the visual-

location buffer. The specification given describes the properties which the item must have in order to match. If a property is not specified then its value is not considered for the matching.

Any of the slots may be specified using any of the modifiers (-, <, >, <=, or >=) in much the same way one specifies a retrieval request. Each of the slots may be specified any number of times. In addition, there are some special tests which one can use that will be described below. All of the constraints specified will be used to find a location in the visicon to be placed into the visual-location buffer. If there is no location in the visicon which satisfies all of the constraints then the visual-location buffer will indicate an error state and set the visual-location buffer's failure flag.

When the slot being tested holds a number it is also possible to use the slot modifiers <, <=, >, and >= along with specifying the value. If the value being tested or the value specified is not a number, then those tests will result in warnings and are not considered in the matching.

You can use the values **lowest** and **highest** in the specification of any slot which has a numeric value. Of the features which match the other constraints the one with the numerically lowest or highest value for that slot will then be the one found. There is one note about using **lowest** and **highest** when more than one slot is specified in that way. First, all of the non-relative values are used to determine the set of items to be tested for relative values. Then the relative tests are performed one at a time in the order provided to reduce the matching set.

It is also possible to use the special value **current** in a slot of the request. That means the value of the slot must be the same as the value for the location of the currently attended object (the one attention was last shifted to with a move-attention request to the visual buffer). If the model does not have a currently attended object (it has not yet attended to anything or has cleared its attention) then the tests with a value of **current** are ignored.

An additional component of the find location requests is the ability to use variables to compare the particular values within a feature to each other in the same way that the LHS tests of a production use variables to match chunks. If a value for a slot in a find location request starts with the character **&** then it is considered to be a variable in the request. The request variables can be combined with the modifiers and any of the other values allowed to be used in the requests.

The :nearest request parameter can be used to find the items closest to the currently attended location in some dimension or closest to some other location. If there are constraints other than :nearest specified then they are all tested first. The nearest of the locations that matches all of the other constraints is the one that will be placed into the buffer. There are several options available for using the :nearest request parameter. To find the location of the object nearest to the currently attended location (computed as the straight line distance based on the screen-x, screen-y, and distance values of the feature by default) we can again use the value **current**. Alternatively, one can specify any location chunk for the nearest test, and the location of the object nearest to that location will be the one returned. It is also possible to find the locations of objects nearest to the current object along a particular axis by specifying **current-x**, **current-y**, or **current-distance**. Finally, one can request locations which are nearest in angular distance relative to an arbitrary center point using either **clockwise** or **counterclockwise** as the nearest specification. The center point used for the calculation is the location specified using the :center request parameter (or the location of the object if a visual object is provided as the :center). If no :center is specified in the request then the most recent center specified by the set-visual-center-point command is used, or the default center point of 0,0 is used if set-visual-center-point has not been called.

If the :attended request parameter is specified, that is used as a test of the locations attended status: :attended **t** means that the item is currently marked with a finst, :attended **nil** means that it is not currently marked with a finst and not the target of an ongoing move-attention request, :attended **new** means that it is not currently marked with a finst and it has recently been added to the visicon (within the time specified by the :visual-onset-span parameter), and :attended **requested** means that it is not currently marked with a finst and it was the location that was specified as the target of a visual buffer move-attention request which has not yet completed.

If there is more than one item which is found as a match, then the one which has been added to the visicon most recently will be the one chosen, and if there is more than one with the same recent onset time, then a random one of those will be chosen.

This request takes no time to return the resulting chunk and will show up with the following events when successful:

```
0.050   VISION                Find-location
0.050   VISION                SET-BUFFER-CHUNK VISUAL-LOCATION LOC1
```

When no location in the visicon matches the request a failure will be indicated in the trace with a find-loc-failure event:

```
0.755   VISION                FIND-LOC-FAILURE
```

When the :auto-attend parameter is set to **t** a move attention request will follow all successful find location requests. The move-attention event will occur 50ms after the find-location event and the vision module will be busy during the entire time from the find-location request until the attention shift is completed (the automatically attending event will only show in the high detail trace level):

```
0.050   VISION                Find-location
0.050   VISION                SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0
0.050   VISION                automatically attending VISUAL-LOCATION1-0
...
0.100   VISION                Move-attention VISUAL-LOCATION1-0
0.185   VISION                Encoding-complete VISUAL-LOCATION1-0 NIL
```

Set-visloc-default

{**isa** *set-visloc-default-type*}
set-visloc-default t
{{*modifier*} *valid-slot* [*value* | *variable*]}*
{:**nearest** *nearest-spec*}
{**:attended** [***t*** **|** ***nil*** **|** ***new*** **|** ***requested***]}
{**:center** [*vis-loc* | *vis-obj*]}

set-visloc-default-type ::= the name of a chunk-type
modifier ::= [= | - | > | < | >= | <=]
valid-slot ::= the name of a slot which is valid for the set-visloc-default-type if provided or any chunk otherwise
value ::= any value, but the symbols **lowest**, **highest** and **current** have special meanings.
variable ::= a name which starts with the character &

nearest-spec ::= [vis-loc | **current** | **current-x** | **current-y** | **current-distance** | **clockwise** |
counterclockwise]
vis-loc ::= a chunk which has represents a visual location
vis-obj ::= a chunk which represents a visual object

A set-visloc-default request allows the model to change the constraints that are used when determining which (if any) chunk from the visicon will be stuffed into the visual-location buffer when the screen is updated. It works the same as the set-visloc-default command described below.

The slot values provided can be specified in the same way that they can for a find location request. The only difference is that this request requires the slot set-visloc-default be specified with a value of **t** to distinguish it from a normal find location request.

This request does not directly place a chunk into the visual-location buffer. It works essentially as a delayed request – at each future visicon update this specification will be used to determine if a chunk should be placed into the visual-location buffer. However, it does initiate an immediate check of the visicon using the new specification which could result in a chunk being placed into the buffer at the time of the request.

It will generate an event in the trace which looks like this:

```
0.850   VISION      Set-visloc-default
```

If a chunk is stuffed into the buffer either immediately due to this request or upon a future screen change the trace showing that setting of the chunk in the buffer will indicate that it was unrequested:

```
0.850   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 NIL
```

Visual buffer

The visual buffer is used to access the what system of the vision module as described above. It takes requests to attend to locations, track features, or to stop attending to items, and it will hold a chunk representing a visual object in response to requests.

Activation spread parameter: :visual-activation
Default value: 0.0

Queries

'State busy' will be **t** between the time any visual request is started and the time it completes. It will also be **t** between when an unrequested re-encoding starts and it completes. It will be **nil** otherwise.

'State free' will be **nil** between the time any visual request is started and the time it completes. It will also be **nil** between when an unrequested re-encoding starts and it completes. It will be **t** otherwise.

'State error' will be **t** if the last visual request failed or **nil** otherwise. It will not change from **t** to **nil** until a successful request is completed -- any of the available visual requests will reset the error state to **nil** if completed.

'Scene-change t' will be **t** if there has been a detected scene change which has not been explicitly cleared within the past :visual-onset-span seconds. Otherwise it will be **nil**.

'Scene-change nil' will be **t** if there has not been a detected scene change within the past :visual-onset-span seconds or such a scene change has been explicitly cleared. Otherwise it will be **nil**.

'Scene-change-value *value*' will be **t** if *value* is a number and the last scene change had a proportion of change which is greater than or equal to value. Otherwise it will be **nil**. This query is intended primarily as a debugging aid so that a modeler can see the last change value via the buffer-status command, but there may be circumstances where it would be useful to test that directly within a model.

The visual buffer can be used to query the internal states of the vision module, but this is generally not needed since there is no benefit to doing so since the requests cannot be "pipelined" by checking for particular subsystems being free.

'Preparation busy' will be **t** during the execution of a clear request and it will be **nil** otherwise.

'Preparation free' will be **nil** during the execution of a clear request and it will be **t** otherwise.

'Processor busy' will be **t** between the time a move-attention request is started and the time it completes and it will be **nil** otherwise.

'Processor free' will be **nil** between the time a move-attention request is started and the time it completes and it will be **t** otherwise.

'Execution busy' will be **t** between the time of a move-attention or start-tracking request and its completion as well as during an unreqeusted re-encoding. It will be **nil** otherwise.

'Execution free' will be **nil** between the time of a move-attention or start-tracking request and its completion as well as during an unreqeusted re-encoding. It will be **t** otherwise.

'Last-command *command*' The query will be **t** if *command* is a symbol which is the name of the last request received by the vision module (through either the visual-location or visual buffer) or the symbol **none**, otherwise it will be **nil**. The visual-location requests are named find-location and set-visloc-default, and the visual requests are named move-attention, start-tracking, clear-scene-change, and assign-finst. If there has not been a request, or a clear request has occurred then the last command will be recorded as the symbol **none**.

Requests

move-attention

cmd move-attention
screen-pos *location*

{**scale** *level*}

The move-attention request moves the vision module's attention to the item at the location given, which must be a chunk specifying a visual location (it must have the x and y position slots which are screen-x and screen-y by default). If there is an item within the movement tolerance of that location, then a chunk which represents that item is placed into the visual buffer after the attention shift time passes (unless the :visual-encoding-hook parameter is set in which case the time to finish the encoding may be generated by an external source). If there is no item there, then the buffer is left empty and the error state of the visual buffer is set and a buffer failure is indicated.

The scale value is currently unused. In older versions of ACT-R it was possible for the vision module to attempt to coalesce separate text items provided by the AGI device into words or phrases, but that capability is not currently provided. A more general use of scale is being developed which will provide more flexibility to the modeler in creating the visicon, but that is not yet available.

A move-attention request results in the following events being displayed in the trace showing the move-attention event with the location to which attention was shifted and the scale used (shown as NIL here because no scale was specified in that request), the encoding-complete occurring after the :visual-attention-latency time passes (in this case the default .085 seconds) also showing the location and scale from the request, and then the buffer being set to the chunk that encodes the visual information:

```
0.100   VISION                Move-attention LOC1-0 NIL
...
0.185   VISION                Encoding-complete LOC1-0 NIL
0.185   VISION                SET-BUFFER-CHUNK VISUAL TEXT1
```

If no item is found, then the same first two events will be shown, but there will be no setting of a chunk in the buffer and instead an event will show that no object was found:

```
0.185   VISION                No visual-object found
```

and the state error query will report **t** and the visual buffer's failure flag will be set.

There may also be maintenance events generated which have no trace output that have an action of unlock-device when the move-attention request comes from a production because the vision module delays processing any visual updates that occur while the production is firing to avoid any inconsistencies in the information – no visicon updates are processed between the selection of a production and its firing if that production has a request to the visual buffer.

If a move-attention request is received while the module is currently handling another request, then a warning is printed and the current request is ignored:

```
#|Warning: Attention shift requested at 0.8 while one was already in progress. |#
```

The timing of the encoding-complete event for this request uses the randomize-time command. Therefore, if the :randomize-time parameter is set to a non-**nil** value the timing on that event will be randomized accordingly.

start-tracking

cmd start-tracking

The start-tracking request will make the vision module continue to "track" an item in the visicon as it moves and/or changes over time until the tracking is terminated. If there is an item currently attended by the vision module, then the start-tracking request will keep the vision module's attention focused on that item. Both the visual-location and visual buffers will be updated with changes to that item and if the buffers are empty new chunks will be placed into them representing any changes. The execution state will be busy while the model is tracking. This will show up in the trace as a start-tracking event and there will be subsequent set-buffer-chunk and mod-buffer chunk events to update the visual-location and visual buffers as necessary (note that the setting is marked as requested **nil** because the chunks are not a direct result of the request):

```
0.185   VISION                Start-tracking
...
0.185   VISION                SET-BUFFER-CHUNK VISUAL-LOCATION LOC3 NIL
0.185   VISION                SET-BUFFER-CHUNK VISUAL TEXT1 NIL
...
0.700   VISION                MOD-BUFFER-CHUNK VISUAL-LOCATION
0.700   VISION                MOD-BUFFER-CHUNK VISUAL
...
1.000   VISION                SET-BUFFER-CHUNK VISUAL-LOCATION LOC11 NIL
1.000   VISION                SET-BUFFER-CHUNK VISUAL TEXT5 NIL
```

If a request to start-tracking is made when there is no currently attended item a warning will be displayed and the module will not become busy:

```
#|Warning: Request to track object but nothing is currently being attended. |#
```

There is one minor issue which may be important in the model when using tracking. For the visual-location buffer to be updated it must either be empty when the start-tracking request is made, it must contain the visual-location chunk which was used when the object was first attended, or it must contain the chunk which matches the screen-pos slot of the chunk in the visual buffer. However, buffer stuffing may place a different chunk into that buffer between the attention shift and the starting of tracking. Thus, if one wants to make sure that both buffers will be updated with tracking information there should also be a -visual-location> action in the production which makes the start-tracking request to clear the buffer or an =visual-location> action to keep the current chunk (assuming the current chunk matches the object to be tracked).

If the tracked object no longer appears in the visicon then the module will stop updating the buffers. If the :tracking-clear parameter is set to **t** then the module will not attempt to re-encode a new visual object, but if :tracking-clear is set to **nil** then the re-encoding will occur at the last location of the object being tracked.

clear

[cmd clear | **clear t**]

A clear request can be used to make the vision module stop attending to any currently attended object which will stop the re-encoding from occurring until a new item is attended. A clear request will also stop the tracking of an item, clear the error flags if set for either of the vision module's buffers, and

clear the change scene notice if one is set. A clear request will make the preparation state busy for 50ms.

Here are the events which will show for a clear request.

```
1.455   VISION                CLEAR
...
1.505   VISION                CHANGE-STATE LAST NONE PREP FREE
```

Note, that after the clear request is done the last-command recorded by the module will be none and not clear – the clear effectively clears the history of its own request as well.

It will also generate a visual-clear signal which can be monitored.

clear-scene-change

cmd clear-scene-change

A clear-scene-change request can be used to clear any pending scene change notice from the module. It will not affect any other operation of the module. A clear-scene-change request will take no time and does not make any of the module's stages busy.

Here is the event which will show in the trace for a clear-scene-change request.

```
0.485   VISION                CLEAR-SCENE-CHANGE
```

assign-finst

cmd assign-finst
*[**object** obj | **location** loc]*

The assign-finst request can be used to explicitly tag a visual item as having been attended with a finst. The item can be specified using one of the chunks previously returned by the vision module through either buffer. If it is an object chunk returned through the visual buffer then it must be specified using the object slot, and if it is a location chunk from the visual-location buffer it must be specified using the location slot. It takes no time to process the request and the module will not be marked as busy. An event like one of these will be shown in the trace indicating which slot was used to assign the finst:

```
0.100   VISION                assign-finst LOCATION VISUAL-LOCATION0-0-0
0.235   VISION                assign-finst OBJECT TEXT0-0
```

If the chunk provided represents an item in the current visicon then that item will have a finst placed on it in the same way as if it had been explicitly attended. If the item does not represent a feature in the visicon then a warning is printed and no action is performed:

```
#|Warning: X does not name an object or feature in the current visicon. No finst created.|#
```

This request does not affect the status of any of the module's queries other than last-command.

clear-all-finsts

cmd clear-all-finsts

A clear-all-finsts request can be used to clear all of the finsts from the vision module. It will take no time and does not make any of the module's stages busy.

Here is the event which will show in the trace for a clear-all-finsts request.

```
0.485   VISION                CLEAR-ALL-FINSTS
```

Chunks & Chunk-types

The vision module creates two general chunk types which may be used as the basis for visual features and objects:

```
(chunk-type visual-location screen-x screen-y distance kind color value height width size)
(chunk-type visual-object screen-pos value status color height width)
```

Those chunk-types are used to create the following chunk-types which represent the objects available from the AGI (some of which are created outside of the vision module, but which are listed here for reference):

```
(chunk-type (text (:include visual-object)) (text t))
(chunk-type (oval (:include visual-object)) (oval t))
(chunk-type (line (:include visual-object)) (line t) end1-x end1-y end2-x end2-y)
(chunk-type (image (:include visual-object)) (image t))
(chunk-type (cursor (:include visual-object)) (cursor t))
```

It also creates these types for the requests which it accepts:

```
(chunk-type (set-visloc-default (:include visual-location)) (set-visloc-default t) type)

(chunk-type vision-command cmd)
(chunk-type (move-attention (:include vision-command)) (cmd move-attention) screen-pos scale)
(chunk-type (start-tracking (:include vision-command)) (cmd start-tracking))
(chunk-type (assign-finst (:include vision-command)) (cmd assign-finst) object location)
(chunk-type (clear-scene-change (:include vision-command)) (cmd clear-scene-change))
(chunk-type (clear-all-finsts (:include vision-command)) (cmd clear-all-finsts))
```

It creates many chunks which are used in the specification of requests, in the creation of visual objects, and for the names of the requests if they are not already chunks. All of these chunks are marked as immutable if created by the vision module:

```
(define-chunks
 (lowest name lowest)
 (highest name highest)
 (current name current)
 (current-x name current-x)
 (current-distance name current-distance)
 (current-y name current-y)
 (clockwise name clockwise)
 (counterclockwise name counterclockwise)
```

```
 (external name external)
 (internal name internal)
 (text name text)
 (box name box)
 (line name line)
 (oval name oval)
 (char-primitive name char-primitive)
 (new name new)
 (find-location name find-location)
 (move-attention isa move-attention)
 (assign-finst isa assign-finst)
 (start-tracking isa start-tracking)
 (clear-scene-change isa clear-scene-change)
 (set-visloc-default isa set-visloc-default)
 (clear-all-finsts isa clear-all-finsts)
 (cursor)(mouse)(joystick1)(joystick2))
```

The module also defines a chunk-type and a set of chunks to name colors if chunks with those names do not exist, and it marks the chunks it creates as immutable:

```
(chunk-type color color)

(define-chunks
 (black color black)
 (red color red)
 (blue color blue)
 (green color green)
 (white color white)
 (magenta color magenta)
 (yellow color yellow)
 (cyan color cyan)
 (dark-green color dark-green)
 (dark-red color dark-red)
 (dark-cyan color dark-cyan)
 (dark-blue color dark-blue)
 (dark-magenta color dark-magenta)
 (dark-yellow color dark-yellow)
 (light-gray color light-gray)
 (dark-gray color dark-gray)
 (gray color gray)
 (pink color pink)
 (light-blue color light-blue)
 (purple color purple)
 (brown color brown))
```

Commands & Signals

visicon-update

Signal:

visicon-update

Description:

The visicon-update signal is generated after every update to the visicon.

visual-clear

Signal:

visual-clear

Description:

The visual-clear signal is generated whenever a clear request is processed by the vision module.

installing-vision-device

Signal:

installing-vision-device device

Arguments and Values:

device ::= the device list of the device that is installed.

Description:

The installing-vision-device signal is generated whenever a new device is installed for the “vision” interface. It will have one parameter which is the device list of that device.

print-visicon

Syntax:

print-visicon -> **nil**

Remote command name:

print-visicon

Description:

The print-visicon command will print out a description of the features which are currently in the visicon of the current model to the command trace. Each feature will be printed on a separate line showing all of the values which may be specified in a visual-location request to find the item. All features will show the Name which represents the name of the chunk which will be copied into the visual-location buffer when the feature is found or stuffed, Att (attended) indicating whether or not it currently has a finst or is the target of an ongoing move-attention request, Loc which represents the x, y, and z position of the item (in the screen-x, screen-y, and distance slots by default), and Size which represents the approximate area covered by the item in degrees of visual angle squared. Any other attributes which were specified for the feature will be displayed in other columns, and it is not

necessary for every feature to have all of the attributes. It will always return **nil**. If there is no current model it will print out a warning instead of the visicon.

Examples:

This example represents the result after running the extras/vision-module/multi-window example task.

```
> (print-visicon)
Name              Att  Loc             Kind    Value  Size        Text  Color  Width  Height  Cursor
----------------  ---  --------------  ------  -----  ----------  ----  -----  -----  ------  ------
VISUAL-LOCATION2  NEW  (  0   0 1080)  CURSOR  MOUSE  1.0                                      T
VISUAL-LOCATION0  NEW  ( 15  16 1080)  TEXT    "a"    0.19999999  T     RED    7      10
VISUAL-LOCATION1  NEW  (215 216 1080)  TEXT    "a"    0.19999999  T     BLUE   7      10

NIL

E> (print-visicon)
#|Warning: get-module called with no current model. |#
NIL
```

printed-visicon

Syntax:

printed-visicon -> visicon-string

Remote command name:

printed-visicon

Arguments and Values:

visicon-string ::= a string which contains the visicon information

Description:

The printed-visicon command is exactly like the print-visicon command above, except that instead of printing the visicon to the command trace it returns a string containing the output. If there is no current model a warning will be output and the string will contain a warning instead of the visicon.

Examples:

This example represents the result after running the extras/vision-module/multi-window example task.

```
> (printed-visicon)
"Name              Att  Loc             Kind    Value  Size        Text  Color  Width  Height  Cursor
----------------  ---  --------------  ------  -----  ----------  ----  -----  -----  ------  ------
VISUAL-LOCATION2  NEW  (  0   0 1080)  CURSOR  MOUSE  1.0                                      T
VISUAL-LOCATION0  NEW  ( 15  16 1080)  TEXT    "a"    0.19999999  T     RED    7      10
VISUAL-LOCATION1  NEW  (215 216 1080)  TEXT    "a"    0.19999999  T     BLUE   7      10
```

```
"

E> (printed-visicon)
#|Warning: get-module called with no current model. |#
"#|Warning: No vision module found. |#"
```

remove-visual-finsts

Syntax:

remove-visual-finsts {*set-new* {*restuff*}} -> **nil**

Remote command name:

remove-visual-finsts

Arguments and Values:

set-new ::= a generalized boolean which specifies whether to set all visual features to the new state
restuff ::= a generalized boolean which specifies whether to check for stuffing of the visual-location buffer after removing the finsts

Description:

The remove-visual-finsts command is used to have the vision module of the current model remove all of the finsts from the visual features in the visicon. If the set-new parameter is non-**nil** then the features will all be marked as attended new and have their onset times changed to the current time. If the set-new parameter is **nil** (the default value if not provided) then the features will be either attended **new** or attended **nil** based on their original onset relative to the current time. Those which have not been on the display longer than the module's visual-onset-span time will be marked as attended **new** and the others will be marked as attended **nil**. If the restuff parameter is non-**nil**, then it will trigger the where system to possibly stuff the visual-location buffer after resetting the finsts. If the restuff parameter is **nil** (the default value if not provided) then it will not attempt to stuff the visual-location buffer. The command always returns **nil**. If there is no current model a warning is printed.

This command is not recommended as a plausible mechanism of the vision module, but may be useful in creating some experimental situations which would require reprocessing the whole display otherwise.

Examples:

This example was generated after running the task in examples/vision-module/dynamic-object-creation and the first step of advancing the clock is done to make sure the items are not attended new by default.

```
1> (run-example)
     ...
     0.370   PROCEDURAL             CONFLICT-RESOLUTION
     0.370   ------                 Stopped because no events left to process
0.37
56
```

```
NIL

2> (run-full-time 1)
     1.370   ------                 Stopped because time limit reached
1.0
1
NIL

3> (print-visicon)
Name    Att  Loc            Size
------  ---  -------------  ----
CHUNK0  T    ( 10 20 1080)  1.0
CHUNK1  T    (100 20 1080)  1.0

NIL

4> (remove-visual-finsts)
NIL

5> (print-visicon)
Name    Att  Loc            Size
------  ---  -------------  ----
CHUNK0  NIL  ( 10 20 1080)  1.0
CHUNK1  NIL  (100 20 1080)  1.0

NIL

6> (remove-visual-finsts t)
NIL

7> (print-visicon)
Name    Att  Loc            Size
------  ---  -------------  ----
CHUNK0  NEW  ( 10 20 1080)  1.0
CHUNK1  NEW  (100 20 1080)  1.0

NIL

8> (buffer-chunk visual-location)
VISUAL-LOCATION: NIL
(NIL)

9> (remove-visual-finsts nil t)
NIL

10> (run .01)
     1.370   VISION                 SET-BUFFER-CHUNK VISUAL-LOCATION CHUNK0 NIL
     1.370   PROCEDURAL             CONFLICT-RESOLUTION
     1.380   ------                 Stopped because time limit reached
0.01
7
NIL

11> (print-visicon)
Name    Att  Loc            Size
------  ---  -------------  ----
CHUNK0  NEW  ( 10 20 1080)  1.0
CHUNK1  NEW  (100 20 1080)  1.0

NIL

E> (remove-visual-finsts)
#|Warning: get-module called with no current model. |#
#|Warning: No vision module found.  Cannot remove the visual finsts. |#
NIL
```

set-visloc-default

Syntax:

set-visloc-default {**isa** chunk-type} {{modifier} slot [value | variable]}*
{:**nearest** nearest-loc}
{**:attended** [**t | nil | new | requested**]}
{**:center** [loc | obj]} -> [**t** | **nil**]
set-visloc-default-fct ({**isa** chunk-type} {{modifier} slot [value | variable]}*
{:**nearest** nearest-loc}
{**:attended** [**t | nil | new | requested**]}
{**:center** [loc | obj]}) -> [**t** | **nil**]

Remote command name:

set-visloc-default

Arguments and Values:

chunk-type ::= a symbol which names a chunk-type
modifier ::= [= | **-** | > | < | >= | <=]
slot ::= the name of a slot which must be valid for chunk-type if it is specified
value ::= any value
variable ::= a name which starts with the character &
nearest-loc ::= [vis-loc | **current** | **current-x** | **current-y** | **current-distance** | **clockwise** | **counterclockwise**]
vis-loc ::= a chunk which represents a visual location

Description:

Set-visloc-default is used to set the conditions which are tested in the visicon to determine if a chunk should be stuffed into the visual-location buffer for the current model. The specification is the same as for a find location request to the visual-location buffer. That specification is used to create a chunk-spec which is used with find-matching-chunks to test the visicon chunks at each screen update using "&" as the variable-char and then filtering the results based on any of the request parameters and/or relative slot tests (lowest or highest) which are included in the specification.

The default specification is given by:

```
(set-visloc-default screen-x lowest :attended new)
```

The command returns **t** if a new specification is set. If the specification is not valid then no change is made and **nil** is returned. If there is no current model then it prints a warning and returns **nil**.

Examples:

```
> (set-visloc-default isa visual-location screen-x lowest :attended new)
T

> (set-visloc-default-fct '(isa visual-location color blue :nearest current))
```

```
T

E> (set-visloc-default isa bad-type)
#|Warning: Element after isa in define-chunk-spec isn't a chunk-type. (ISA BAD-TYPE) |#
#|Warning: Invalid chunk specification.  Default not changed. |#
NIL

E> (set-visloc-default)
#|Warning: No current model.  Cannot set visloc defaults. |#
NIL
```

add-word-characters

Syntax:

add-word-characters *char** -> [word-char-list | **nil**]

Remote command name:

add-word-characters

Arguments and Values:

char ::= a character to be added to those used in the construction of words and can be specified as a Lisp character, Lisp symbol, or a single element string
word-char-list ::= a list of all the characters which have been specified with add-word-characters. In Lisp the elements will be characters but for the remote command they will be single element strings.

Description:

The add-word-characters command can be used to adjust how the text items are divided into word based features by the default text processing mechanisms of the AGI for the current model. By default, text items are broken into separate word features as collections of sequential characters using the Lisp alphanumericp function. A word feature is a sequence of characters that have the same value from alphanumericp. Thus, this text string “one--word” would be broken into three separate visual word features: “one”, “--”, and “word”. This command allows one to specify additional characters to group with the alphanumerics. Thus, if “-” were added using this command that string would instead be processed as a single word feature for the visual representation.

Add-word-characters takes any number of characters to add to those grouped with the alphanumerics. If there is a current model it returns a list of all the additional characters which have been added using this command for that model. If there is no current model a warning is printed and **nil** is returned.

This command does not cause the AGI to reprocess its features. Only those items created after adding new word characters will be processed with those new characters included. Any characters added with this command are removed when the model is reset. Thus, this command should probably be included in the model’s definition.

Examples:

```
1> (install-device (open-exp-window "" nil))
```

```
("vision" "exp-window" "")

2> (add-text-to-exp-window nil "splits.on*all_non-alpha+characters")
("" "TEXT-VDI-623")

3> (run .1)
     0.000   VISION                SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0 NIL
     0.000   VISION                visicon-update
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because time limit reached
0.1
6
NIL

4> (print-visicon)
Name               Att  Loc             Text  Kind  Color  Width  Value         Height  Size
-----------------  ---  --------------  ----  ----  -----  -----  ------------  ------  ----------
VISUAL-LOCATION0   NEW  (322 306 1080)  T     TEXT  BLACK  42     "splits"      10      1.18
VISUAL-LOCATION1   NEW  (347 306 1080)  T     TEXT  BLACK  7      "."           10      0.19999999
VISUAL-LOCATION2   NEW  (357 306 1080)  T     TEXT  BLACK  14     "on"          10      0.39
VISUAL-LOCATION3   NEW  (368 306 1080)  T     TEXT  BLACK  7      "*"           10      0.19999999
VISUAL-LOCATION4   NEW  (381 306 1080)  T     TEXT  BLACK  21     "all"         10      0.59
VISUAL-LOCATION5   NEW  (396 306 1080)  T     TEXT  BLACK  7      "_"           10      0.19999999
VISUAL-LOCATION6   NEW  (409 306 1080)  T     TEXT  BLACK  21     "non"         10      0.59
VISUAL-LOCATION7   NEW  (424 306 1080)  T     TEXT  BLACK  7      "-"           10      0.19999999
VISUAL-LOCATION8   NEW  (445 306 1080)  T     TEXT  BLACK  35     "alpha"       10      0.97999996
VISUAL-LOCATION9   NEW  (466 306 1080)  T     TEXT  BLACK  7      "+"           10      0.19999999
VISUAL-LOCATION10  NEW  (504 306 1080)  T     TEXT  BLACK  70     "characters"  10      1.9699999

NIL

5> (reset)
T

6> (add-word-characters "." #\_ '-)
(#\- #\_ #\.)

7> (install-device (open-exp-window "" nil))
("vision" "exp-window" "")

8> (add-text-to-exp-window nil "splits.on*all_non-alpha+characters")
("" "TEXT-VDI-624")

9> (run .1)
     0.000   VISION                SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0 NIL
     0.000   VISION                visicon-update
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because time limit reached
0.1
6
NIL

10> (print-visicon)
Name               Att  Loc             Text  Kind  Color  Width  Value            Height  Size
-----------------  ---  --------------  ----  ----  -----  -----  ---------------  ------  --------
VISUAL-LOCATION0   NEW  (333 306 1080)  T     TEXT  BLACK  63     "splits.on"      10      1.77
VISUAL-LOCATION1   NEW  (368 306 1080)  T     TEXT  BLACK  7      "*"              10      0.19999
VISUAL-LOCATION2   NEW  (417 306 1080)  T     TEXT  BLACK  91     "all_non-alpha"  10      2.56
VISUAL-LOCATION3   NEW  (466 306 1080)  T     TEXT  BLACK  7      "+"              10      0.19999
VISUAL-LOCATION4   NEW  (504 306 1080)  T     TEXT  BLACK  70     "characters"     10      1.96999

NIL

E> (add-word-characters)
#|Warning: get-module called with no current model. |#
#|Warning: No vision module available could not add new word characters. |#
NIL
```

set-visual-center-point

Syntax:

set-visual-center-point *x y* -> [loc | **nil**]

Remote command name:

set-visual-center-point

Arguments and Values:

x ::= a number indicating the x coordinate of the reference point
y ::= a number indicating the y coordinate of the reference point
loc ::= (x y)

Description:

The set-visual-center-point command is used to specify the center point used for the current model when determining the nearest location for a request that specifies :nearest as **clockwise** or **counterclockwise** and which does not also specify a center with the :center request parameter. The x and y values provided must be numbers and they specify the coordinates of the center to use. The default center point is 0,0 if this command is not used. If x and y are both numbers then that point is used as the center and a list of those values is returned. If either x or y is not a number or if there is no current model then a warning is printed and **nil** is returned.

Examples:

```
> (set-visual-center-point 100 75)
(100 75)

E> (set-visual-center-point 10 :not-a-number)
#|Warning: X and Y values must be numbers for set-visual-center-point. |#
NIL

E> (set-visual-center-point 10 40)
#|Warning: get-module called with no current model. |#
#|Warning: No vision module available so cannot set center point. |#
NIL
```

attend-visual-coordinates

Syntax:

attend-visual-coordinates *x y* {*z*} -> [**t** | **nil**]

Remote command name:

attend-visual-coordinates

Arguments and Values:

x ::= a number indicating the current x position of visual attention
y ::= a number indicating the current y position of visual attention
z ::= a number indicating the current z position of visual attention

Description:

The attend-visual-coordinates command is used to set the current model's location of visual attention. If the two or three values provided are all numbers then the model's visual attention point will be set to those coordinates and **t** will be returned. If no z position is provided the current :viewing-distance value will be used.

If there is no current model, or a non-numeric position is provided then this command will print a warning and return **nil**.

Note, this is not performed as a request by the module and is intended for setting the initial position of visual attention. It should not be used while the model is running or if the model has stopped running while there are any visual actions in progress.

Examples:

Only examples of the warning messages are shown here. For actual examples of using the command see the examples/vision-module directory of the distribution.

```
E> (attend-visual-coordinates 50 50)
#|Warning: get-module called with no current model. |#
#|Warning: No vision module found.  Cannot set visual coordinates. |#
NIL

E> (attend-visual-coordinates "x" 50)
#|Warning: Invalid position value in call to attend-visual-coordinates: "x" 50 NIL |#
NIL
```

schedule-encoding-complete

Syntax:

schedule-encoding-complete *delay* -> **nil**

Remote command name:

schedule-encoding-complete

Arguments and Values:

delay ::= a number indicating the time in seconds after which to execute the encoding-complete action

Description:

The schedule-encoding-complete command can be used when the :visual-encoding-hook parameter is set to a command and that command returns a value which suspended the normal scheduling of the encoding-complete event after a move-attention request. It will schedule that event to occur for the vision module of the current model based on the parameters of the last move-attention request after the provided number of seconds have passed. It always returns **nil**. If there is no current model or there has not been a suspended move-attention request for the current model then a warning is printed and no event is scheduled. If the delay provided is not a non-negative number then a warning is printed and the event will be scheduled with a delay of 0.

Examples:

```
> (schedule-encoding-complete .1)
NIL

E> (schedule-encoding-complete -1)
#|Warning: get-module called with no current model. |#
NIL

E> (schedule-encoding-complete -1)
#|Warning: Invalid delay time passed to schedule-encoding-complete -1. Using 0 instead. |#
NIL

E> (schedule-encoding-complete .1)
#|Warning: Schedule-encoding-complete called but there are no attention parameters available. |#
NIL
```

chunk-to-visual-position

Syntax:

chunk-to-visual-position *chunk* -> [(x,y,z)**, nil**]

Remote command name:

chunk-to-visual-position

Arguments and Values:

chunk ::= the name of a chunk representing a visual location or visual object
x ::= a number indicating the x position of the chunk
y ::= a number indicating the y position of the chunk
z ::= a number indicating the z position of the chunk

Description:

The chunk-to-visual-position command can be used to get the position information from a chunk which represents a visual location or a visual object. If the value provided names a chunk in the current model and that chunk contains slots for a visual location's position then the values of those slots are returned in a list ordered x, y, z. If the value provided names a chunk in the current model, that chunk has a slot named screen-pos, and that slot's value is a chunk with visual location position

slots then the values of those slots are returned in a list ordered x, y, z. For any other situation it will return **nil**.

Examples:

This example assumes the examples/vision-module/new-visicon-features-position-slots example task has been run which results in these visual chunks having been created with custom slots for position information (instead of the defaults of screen-x, screen-y, and distance):

```
CHUNK2-0
   VALUE  T
   SIZE  1.0
   POS-1  50
   POS-2  15
   POS-3  1080

CHUNK3-0
   SCREEN-POS  CHUNK2-0
   VALUE  T

CHUNK1-0
   SIZE  1.0
   X  10
   Y  15
   Z  1080

VISUAL-OBJECT1-0
   SCREEN-POS  CHUNK1-0


> (chunk-to-visual-position 'chunk2-0)
(50 15 1080)

> (chunk-to-visual-position 'chunk4-0)
(50 15 1080)

> (chunk-to-visual-position 'chunk1-0)
(10 15 1080)

> (chunk-to-visual-position 'visual-object1-0)
(10 15 1080)

> (chunk-to-visual-position 'free)
NIL

E> (chunk-to-visual-position 'chunk1-0)
#|Warning: chunk-to-visual-position requires a current model. |#
```

Audio module

The audio module provides a model with rudimentary audio perception abilities and is very similar to the vision module. It has both a what and where system and two buffers which accept requests. It has a store of audio events called the *audicon*, and those are transformed into chunks which the model can use by requesting an attention shift to a particular event.

The module is named :audio and will be available whenever the speech module is used.

Auditory world

The sounds which the model hears are simulated using the commands described later, and there are no devices associated with the audio module. There are commands for generating pure tones, spoken digits, spoken words, and a general command which allows one to specify all of the components of the sound directly. In addition, the model will also hear its own speech which it generates using the speech module.

Sound events occur over time and are not immediately available for processing in the audicon. There are several attributes to a sound event which describe it and control the timing of the model's access to the sound.

- Onset: The time at which the sound began.
- Duration: The amount of time that the sound is present.
- Content delay: The amount of time between a sound's onset and when the content of the sound is accessible to the auditory system. No information can be extracted before this time has passed.
- Recode time: The amount of time (after the content is available) that it takes for the auditory system to construct a representation of the sound.
- Content: The value which will be made available to the model once the sound is attended.
- Kind: The basic description of the type of sound. The given commands create kinds of **tone**, **digit**, **word**, and **speech**.
- Location: An indication of where the sound originated. The built-in options are **external** for sounds generated by the simulated sound commands, **self** for words the model speaks, and **internal** for words the model subvocalizes. Other values may be provided when creating custom sounds with the commands described below.

The sound events are only available in the audicon for a short time before they decay. After a sound event ends and the decay time elapses, the sound event is removed from the audicon.

The Where System

The where system takes requests through the aural-location buffer. A request to the aural-location buffer specifies a set of constraints to test against the detectable events in the audicon. If there is a sound event in the audicon that meets those constraints, then a chunk representing that sound event is placed in the aural-location buffer. If multiple sound events meet the constraints, then one will be picked randomly. If there are no sound events which meet the constraints, then the buffer will be left

empty and the state error query to the aural-location buffer will be true and the buffer's failure flag will be set.

Like the vision and declarative modules, the audio module maintains a set of finsts which mark items that have been attended, and the attended status of an audio event can be a constraint in a request to the aural-location buffer. However, unlike those other modules, because the audicon is already time limited (audio events decay on their own) there is no limit on the number or duration of the auditory finsts.

The What System

The what system takes requests through the aural buffer. Its primary use is to attend to audio events which have been found using the where system. A request to the what system requires a chunk representing an audio event. In response to the request, the what system will shift aural attention to that audio event, process the sound, and place a chunk representing that sound into the aural buffer.

Like the vision module, the assumption behind the aural module is that the sound chunks placed into the aural buffer as a result of an attention operation are episodic representations of the sounds. Thus, a sound chunk with content "3" represents a memory of hearing the number "3" being spoken, not the semantic THREE used in arithmetic—a declarative retrieval would be necessary to make that mapping.

History Stream

audicon-history

The audio module provides one data history stream called audicon-history. When it is enabled it will record the information from the audicon every time it is updated. The data will be recorded based on the time of the update, and the value recorded will be a string with the text as returned from printed-audicon at that time. That history information is recorded by a module named :audicon-history.

Parameters

:audio-ms-times

This parameter is used to indicate the units used for the onset, offset, and duration times in the audio-event chunks of the module. If it is set to **t** then they will be in milliseconds, and if it is **nil** then they will be in seconds. The default is **nil**.

:aural-encoding-hook

This parameter can be set to a command identifier to adjust the time that it takes for an attend-sound request to the aural buffer to finish. If a command is set for this parameter it will be called during each attend-sound request with two parameters: the name of the chunk provided as the event in the request and a boolean which indicates whether the request found a matching sound to attend (**t**) or not (**nil**). If the hook command returns **nil** then the normal encoding time will apply. If the command returns a number then that is used as a time in seconds for the length of the encoding process (which will be randomized if the :randomize-time parameter is enabled). Any other return value suppresses

the completion of the action and the schedule-audio-encoding-complete command must be called to finish the aural attention shift. Only one command can be set on the hook at a time, and it will print a warning if a command is replaced with a different one.

:aural-loc-hook

This parameter can be used to adjust the aural-location request and aural-location buffer stuffing actions. It can be used to add a delay to the timing of the action, to force a particular matching chunk to be chosen (when there are multiple matching chunks), or to force a failure to find a chunk. It can be set to a command identifier. Only one hook command can be set at a time, and if a different command is set it will print a warning indicating the change. When it is set, that command will be passed three values: the list of audio-event chunks which match the request, the chunk-spec-id of the request, and a generalized boolean indicating whether this is for the stuffing of the buffer (**t**) or a request to the module (**nil**). If the command returns a number, that number will be used as the delay time (in seconds) before the buffer is set with the result. If the command returns a list of two items, the first of which is a number and the second of which is either an item from the list of matching chunks or **nil** then that will use the number as the delay time (in seconds) and the specified chunk will be the one placed into the buffer, or a find-sound-failure will be generated if the value is **nil**. All other return values will result in the default operation and print a warning to indicate an invalid return value. Therefore, if a command is set and one still wants to get default behavior the command must return 0 (no delay on the action).

:digit-detect-delay

This parameter controls the content delay time given to digit sounds created with the new-digit-sound command. It is measured in seconds. It can be set to any non-negative value and the default is 0.3.

:digit-duration

This parameter controls the duration given to digit sounds created with the new-digit-sound command in seconds. It can be set to any non-negative number and the default is 0.6.

:digit-recode-delay

This parameter controls the recode time given to digit sounds created with the new-digit-sound command in seconds. It is also the time that it takes for a failure to encode to occur when an audio event is no longer available. It can be set to any non-negative number and the default is 0.5.

:overstuff-aural-location

This parameter controls whether the module can “stuff” a new chunk into the buffer when there is already a previously stuffed chunk in the buffer. The default value is **nil** which means that it will not overwrite a previously stuffed chunk when new information becomes available, but if it is set to **t** then it may overwrite a chunk which was stuffed into the aural-location buffer when new auditory information is available.

:sound-decay-time

This parameter controls how long sound events will stay in the audicon measured in seconds. It can be set to any non-negative number and the default is 3.0.

:tone-detect-delay

This parameter controls the content delay time given to tone sounds created with the new-tone-sound command in seconds. It can be set to any non-negative number and the default is 0.05.

:tone-recode-delay

This parameter controls the recode time given to tone sounds created with the new-tone-sound command in seconds. It can be set to any non-negative number and the default is 0.285.

:unstuff-aural-location

This parameter lets the modeler specify whether the audio module removes the chunks which it "stuffs" into the aural-location buffer. The default value is **nil** which means that the module will not automatically remove a chunk which has been stuffed into the aural-location buffer. If it is set to **t** then if a stuffed chunk is still in the aural-location buffer and has not be modified after the :sound-decay-time time has passed that chunk will be erased from the buffer by the audio module. If it is set to a number then it works similar to the setting of **t** except that the value of this parameter specifies the time in seconds after which the erasing occurs instead of the :sound-decay-time parameter.

Aural-location buffer

The aural-location buffer is used to access the where system of the audio module as described above. In addition to taking requests to find sounds, the audio module will also place chunks into the aural-location buffer automatically without a model request (a process referred to as "buffer stuffing"). Whenever there is a new sound available to the model, if the aural-location buffer is empty or the :overstuff-aural-location parameter is **t** and there is a previously stuffed chunk in the aural-location buffer, an audio-event chunk of a feature from the audicon may be placed into the aural-location buffer. The feature which gets "stuffed" into the buffer is chosen based on preferences which can be set by the modeler using the set-audloc-default command or by the model with a set-audloc-default request. The default preference is for any unattended item in the audicon to be stuffed into the buffer. If the :unstuff-aural-location parameter is not **nil** then the module will also automatically remove a stuffed chunk from the buffer if it is there past the indicated delay time.

The audio module sets the aural-location buffer to always create a new chunk as a copy when the buffer is set.

Activation spread parameter: :aural-location-activation
Default value: 0.0

Queries

‘State busy’ will always be **nil.**

‘State free’ will always be **t**.

‘State error’ will be **t** if the last aural-location request failed to find a matching audio-event and it will be **nil** in all other situations. Once it becomes **t** it will remain **t** until a new aural-location request is made or the explicit clear request is made of the aural buffer.

The aural-location buffer has two additional queries that allows one to check the attended and finished status of the audio-event represented by the chunk in the aural-location buffer.

‘Attended t’ will be **t** if there is a chunk in the aural-location buffer and that audio-event currently has a finst on it. Otherwise it will be **nil**.

‘Attended nil’ will be **t** if there is a chunk in the aural-location buffer, that location does not currently have a finst on it, and that location is not the target of a currently ongoing attend sound request to the aural buffer. Otherwise it will be **nil**.

‘Attended requested’ will be **t** if there is a chunk in the aural-location buffer, that location does not currently have a finst on it, and that location is the target of a currently ongoing attend sound request to the aural buffer. Otherwise it will be **nil**.

‘Finished t’ will be **t** if there is a chunk in the aural-location buffer and that audio-event has finished playing (its offset time has been reached or passed). Otherwise it will be **nil**.

‘Finished nil’ will be **t** if there is a chunk in the aural-location buffer and that audio-event has not finished playing (its offset time has not been reached yet). Otherwise it will be **nil**.

Requests

find-sound

{**isa** *audio-event-chunk-type*}
{{modifier} *valid-slot* [*value* | *variable*]}*
{**:attended** [***t*** **|** ***nil*** **|** ***requested***]}
{**:finished** [***t*** **|** ***nil***]}

audio-event-chunk-type ::= a symbol which names a chunk-type used for audio event features
modifier ::= [= | - | > | < | >= | <=]
valid-slot ::= the name of a slot which is valid for the audio-event-chunk-type if provided or any chunk otherwise
value ::= any value, but the symbols **lowest** and **highest** have special meanings
variable ::= a name which starts with the character &

A find-sound request is an attempt to find an audio event in the audicon. All of the items in the audicon are compared against the values provided in the request and if there is an item which is detectable and matches that specification an audio-event chunk describing that item is placed into the aural-location buffer. The specification given describes the properties which the item must have in order to match. If a property is not specified then its value is not considered for the matching

Any of the slots may be specified using any of the modifiers (-, <, >, <=, or >=) in much the same way one specifies a retrieval request. Each of the slots may be specified any number of times. In addition, there are some special tests which one can use that will be described below. All of the constraints specified will be used to find an audio event in the audicon to be placed into the aural-location buffer. If there is no audio event in the audicon which satisfies all of the constraints then the aural-location buffer will indicate an error state and its failure flag will be set.

When the slot being tested holds a number it is also possible to use the slot modifiers <, <=, >, and >= along with specifying the value. If the value being tested or the value specified is not a number, then those tests will result in warnings and are not considered in the matching.

You can use the values **lowest** and **highest** in the specification of any slot which has a numeric value. Of the features which match the other constraints the one with the numerically lowest or highest value for that slot will then be the one found. There is one note about using **lowest** and **highest** when more than one slot is specified in that way. First, all of the non-relative values are used to determine the set of items to be tested for relative values. Then the relative tests are performed one at a time in the order provided to reduce the matching set.

An additional component of the find-sound requests is the ability to use variables to compare the particular values within a feature to each other in the same way that the LHS tests of a production use variables to match chunks. If a value for a slot in a find-sound request starts with the character **&** then it is considered to be a variable in the request. The request variables can be combined with the modifiers and any of the other values allowed to be used in the requests.

If the attended value is specified, that is used as a test with the auditory finsts where :attended **t** means that the item is currently marked with a finst (has been attended), :attended **nil** means that it is not marked (has not been attended) and is not the target of an attend sound request to the aural buffer which is still ongoing, and :attended **requested** means that it is not currently marked with a finst and it is the target of an attend sound request to the aural buffer which is still ongoing.

The finished value can be used to test whether or not the sound is still 'playing' or not. That is determined by the offset time of the sound. If the current time is greater-than or equal to the offset time of the sound then it is considered to be finished, but if the current time is less-than the offset time of the sound it is not finished.

If there is more than one item which is found as a match then a random one of those will be chosen. This request takes no time to return the resulting chunk and will show up with the following events when successful:

```
0.100   AUDIO                   FIND-SOUND
0.100   AUDIO                   SET-BUFFER-CHUNK AURAL-LOCATION AUDIO-EVENT0
```

If no sound event which matches the request is found then the buffer will be left empty and the state error query of the buffer will be true. That will result in a find-sound-failure event showing up in the trace:

```
0.050   AUDIO                   find-sound-failure
```

The aural-location buffer may be set to a chunk even without a request being made. If the aural-location buffer is empty and a new sound event becomes detectable an audio-event chunk which represents it may be stuffed into the aural-location buffer. This is the event which will be generated in the trace indicating a chunk being set without being requested:

```
0.060   AUDIO               SET-BUFFER-CHUNK AURAL-LOCATION AUDIO-EVENT0 NIL
```

If a sound event which is not yet finished is placed into the aural-location buffer it will not have values for its offset or duration slots since the sound is still playing. If that audio event is attended with a request to the aural buffer and remains in the aural-location buffer until the sound is completed then those slots will be updated to contain the appropriate values with an event that will look like this in the trace:

```
0.500   AUDIO                   AUDIO-EVENT-ENDED AUDIO-EVENT0
```

set-audloc-default

{**isa** *audio-default-chunk-type*}
set-audloc-default t
{{modifier} *valid-slot* [*value* | *variable*]}*
{**:attended** [***t*** **|** ***nil*** **|** ***requested***]}
{**:finished** [***t*** **|** ***nil***]}

audio-default-chunk-type ::= a symbol which names a chunk-type used for audio event features
modifier ::= [= | - | > | < | >= | <=]
valid-slot ::= the name of a slot which is valid for the audio-default-chunk-type if provided or any chunk otherwise
value ::= any value, but the symbols **lowest** and **highest** have special meanings
variable ::= a name which starts with the character &

A set-audloc-default request allows the model to change the constraints that are used when determining which (if any) chunk from the audicon will be stuffed into the aural-location buffer when an audio event becomes detectable. It works the same as the set-audloc-default command.

The slot values provided can be specified in the same way that they can for a find-sound request with the only difference being that this request requires the slot set-audloc-default be specified with a value of **t** which is what distinguishes it from a normal find-sound request.

This request does not directly place a chunk into the aural-location buffer. It works essentially as a delayed request – each time a new audio event becomes detectable this specification will be used to determine if a chunk should be placed into the aural-location buffer.

It will generate an event in the trace which looks like this:

```
0.050   AUDIO                   SET-AUDLOC-DEFAULT
```

Aural buffer

The aural buffer is used to access the what system of the audio module as described above. It takes requests to attend to audio events. It attends to the event and creates a chunk to encode it which is placed into the aural buffer.

Activation spread parameter: :aural-activation
Default value: 0.0

Queries

‘State busy’ will be **t** between the time any aural request is started and the time it completes. It will be **nil** otherwise.

‘State free’ will be **nil** between the time any aural request is started and the time it completes. It will be **t** otherwise.

‘State error’ will be **t** if the last aural request failed or **nil** otherwise. It will not change from **t** to **nil** until a successful request is completed – either an attend sound or a clear request will reset it.

The aural buffer can be used to query the internal states of the audio module, but this is generally not needed since there is no benefit to doing so since the requests cannot be “pipelined” by checking for particular subsystems being free.

‘Preparation busy’ will be **t** during the time of a clear request and its completion and during an attend sound request if the sound is not yet available (the detect time has not passed since its entry into the audicon) and it will be **nil** otherwise.

‘Preparation free’ will be **nil** during the time of a clear request and its completion and during an attend sound request if the sound is not yet available (the detect time has not passed since its entry into the audicon) and it will be **t** otherwise.

‘Processor busy’ will always be **nil**.

‘Processor free’ will always be **t**.

‘Execution busy’ will be **t** between the start and end of an attend sound request. It will be **nil** otherwise.

‘Execution free’ will be **nil** between the start and end of an attend sound request. It will be **t** otherwise.

'Last-command *command*' *command* should be a symbol which corresponds to one of the audio module's requests for either buffer, or the symbol none. The query will be **t** if that is the name of the last request received by the audio module otherwise it will be **nil**. Note that it is requests to the module in general which are tested, not just requests to the aural buffer. The possible command value are find-sound, set-audloc-default, sound, or none (representing that there has been no requests made since the module was last cleared).

Requests

clear

[cmd clear | **clear t**]

A clear request can be sent to clear the error flags of both of the audio module's buffers. A clear request will make the preparation state busy for 50ms. These events will show in the trace for a clear request to the aural buffer:

```
0.485   AUDIO                   CLEAR
...
0.535   AUDIO                   CHANGE-STATE LAST NONE PREP FREE
```

Note, that after the clear request completes the last-command recorded by the module will be none and not clear – a clear request effectively clears the history of its own request as well.

attend sound

event *audio-event*

audio-event ::= a chunk which represents an audio event usually provided by the aural-location buffer

An attend sound request moves the audio module's attention to the sound event provided. If that sound event is still available in the audicon then it will be marked as attended and a chunk which represents that sound will be placed into the aural buffer after the sound event's recode time has passed. The resulting chunk will be constructed from the features of the audio event and any additional features specified when it was created. Its kind slot will have the same value as the audio-event that was used to attend to it. Its content slot will be set with the details of the sound. Its event slot will be the name of the original sound event chunk from the audicon, and any additional slots specified when creating the sound action will also be set.

This results in the following events being displayed in the trace showing the attention shift event with the audio-event listed, the audio-encoding-complete occurring after the sound event's recode time passes (in this case the default .285 seconds for a tone sound), and then the buffer being set to the sound chunk that encodes the visual information:

```
0.150   AUDIO                 ATTEND-SOUND AUDIO-EVENT0
...
0.435   AUDIO                 AUDIO-ENCODING-COMPLETE AUDIO-EVENT0
0.435   AUDIO                 SET-BUFFER-CHUNK AURAL TONE0
```

If there is no corresponding sound available in the audicon, then the buffer is left empty, the error state is set to **t**, and the buffer's failure flag is set. This event will show that no object was found after taking the amount of time required to recode a digit (the time to fail is always the same regardless of the type of sound the event represents):

```
0.585   AUDIO                 ATTEND-SOUND AUDIO-EVENT0-1
...
1.085   AUDIO                 attend-sound-failure
```

If a sound request is received while the module is currently handling another sound request, then a warning is printed and the newer request is ignored:

```
#|Warning: Auditory attention shift requested at 0.6 while one was already in progress. |#
```

The timing of the audio-encoding-complete and attend-sound-failure events for this request use the randomize-time command. Thus, if the :randomize-time parameter is set to non-nil the timing on those events will be randomized accordingly.

Chunks & Chunk-types

The audio module creates chunk-types which are used for creating and requesting audio event and attended sound chunks, and also a type for making a set-audloc-default request:

```
(chunk-type audio-event onset offset duration pitch kind location id)
(chunk-type (set-audloc-default (:include audio-event)) (set-audloc-default t))
(chunk-type sound kind content event)
```

It creates several chunks which are used in the specification of requests, in the creation of audio events, the creation of sound chunks, and for the names of the requests if they are not already chunks. All of these chunks are marked as immutable if created by the audio module:

```
(define-chunks
  (digit isa chunk)
  (speech isa chunk)
  (tone isa chunk)
  (word isa chunk)
  (highest isa chunk)
  (lowest isa chunk)
  (sound isa chunk)
  (find-sound isa chunk)
  (set-audloc-default isa chunk)
  (internal isa chunk)
  (external isa chunk)
  (self isa chunk)
  (high isa chunk)
  (middle isa chunk)
  (low isa chunk))
```

Commands & Signals

new-sound

Signal:

new-sound

Description:

The new-sound signal is generated at the onset time of every sound which is generated by one of the sound creation commands below.

new-digit-sound/new-tone-sound/new-other-sound/new-word-sound

Syntax:

new-digit-sound *digit* {*onset* {*time-in-ms*]} -> [**t** | **nil**]
new-tone-sound *freq duration* {*onset* {*time-in-ms*}} -> [**t** | **nil**]
new-word-sound *word* {*onset* {*location* {*time-in-ms*}}} -> [**t** | **nil**]
new-other-sound *content duration delay recode* {*onset* {*location* {*kind* {*time-in-ms* {*feature**]}}}}} -> [**t** | **nil**]

Remote command names:

new-digit-sound
new-tone-sound
new-word-sound *word* {*onset* {'*location*' {*time-in-ms*}}
new-other-sound '*content*' *duration delay recode* {*onset* {'*location*' {'*kind*' {*time-in-ms* {'*feature*'*]}}}}}

Arguments and Values:

digit ::= a number representing the digit to be heard
onset ::= a number which is the time at which the sound will begin in seconds or milliseconds
time-in-ms ::= a generalized boolean which indicates the units used for all of the provided times
freq ::= a number representing the frequency of the tone to be heard
duration ::= a number which is the amount of time between the onset and when the sound stops in seconds or milliseconds
word ::= a string which is the word (or words) which will be heard
location ::= any value which will be the audio event's location slot value
content ::= any value which is the content for the attended sound chunk
delay ::= a number which is the content delay for the sound in seconds or milliseconds
recode ::= a number which is the recode time for the sound in seconds or milliseconds
kind ::= a value which will be used as the value for the kind slot of both chunks
feature ::= ([**:evt** | **:sound** | **:both**] slot value)
slot ::= a symbol which will be used as a slot name in the chunk indicated by the feature
value::= a value which will be used as the value for the corresponding slot

Description:

The new-*-sound commands are used to create new sound events for the audicon of the current model. A newly created audio event will be placed into the audicon at the onset time of the sound event with the other properties of that audio event being set based on which command was used to create it. If the time-in-ms parameter is specified as non-nil then all provided times are measured in milliseconds, and if it is not provided or **nil** the provided times will be measured in seconds. Here is how those values are set based on the command:

new-digit-sound

Onset: as provided or the current time if not provided
Duration: set using randomize-time on the value of :digit-duration
Content delay: set using randomize-time on the value of :digit-detect-delay
Recode time: the value of :digit-recode-delay
Content: the provided digit
Kind: **digit**
Location: **external**

new-tone-sound

Onset: as provided or the current time if not provided
Duration: as provided
Content delay: set set using randomize-time on the value of :tone-detect-delay
Recode time: the value of :tone-recode-delay
Content: the provided frequency
Kind: **tone**
Location: **external**

new-word-sound

Onset: as provided or the current time if not provided
Duration: computed using the get-articulation-time command of the speech module
Content delay: set using randomize-time on the value of :digit-detect-delay
Recode time: the maximum between the duration/2 and the duration - .15 seconds
Content: the provided string
Kind: **word**
Location: as provided, or **external** if not provided

new-other-sound

Onset: as provided or the current time if not provided
Duration: as provided
Content delay: as provided
Recode time: as provided
Content: as provided
Kind: as provided, or **speech** if not provided
Location: as provided, or **external** if not provided
Other slots: the event and/or sound chunk will have additional slots set as provided

Each new sound will generate a maintenance event which will not be shown in the trace. It will have an action of stuff-sound-buffer and no parameters. It will occur at the time the sound event becomes detectable, and this is where the testing is done to determine whether or not a new sound should be stuffed into the aural-location buffer.

Each new sound will also generate a new-sound signal at its onset time.

If a sound is successfully created and added to the audicon of the model then **t** is returned. If there is no current model or an invalid parameter is provided a warning will be displayed and **nil** will be returned.

Examples:

```
> (new-tone-sound 400 .75)
T

> (new-tone-sound 400 .5 1000 t)
T

> (new-digit-sound 6 1.0)
T

> (new-word-sound "Hello" .25 'left)
T

> (new-other-sound 'new-content .5 .2 .15 (mp-time) 'external 'other nil '(:both value t)
                   '(:evt volume large))
T

E> (new-tone-sound 100 .5 'not-a-time)
#|Warning: Onset must be a number.  No new tone sound created. |#
NIL

E> (new-tone-sound 'high .2)
#|Warning: Freq must be a number.  No new tone sound created. |#
NIL

E> (new-digit-sound 3)
#|Warning: No current model found.  Cannot create a new sound. |#
NIL
```

new-ongoing-sound/end-ongoing-sound

Syntax:

new-ongoing-sound *content delay recode* {*onset* {*location* {*kind* {*time-in-ms* {*feature**]}}}}} -> [id | **nil**]
end-ongoing-sound *id* -> [**t** | **nil**]

Remote command names:

new-ongoing-sound '*content*' *delay recode* {*onset* {'*location*' {'*kind*' {*time-in-ms* {'*feature*'*]}}}}}
end-ongoing-sound

Arguments and Values:

onset ::= a number which is the time at which the sound will begin in seconds or milliseconds
time-in-ms ::= a generalized boolean which indicates the units used for all of the provided times
location ::= any value which will be the audio event's location slot value
content ::= any value which is the content for the attended sound chunk
delay ::= a number which is the content delay for the sound in seconds or milliseconds
recode ::= a number which is the recode time for the sound in seconds or milliseconds
kind ::= a value which will be used as the value for the kind slot of both chunks
id ::= a value used as a reference for the ongoing sound
feature ::= ([**:evt** | **:sound** | **:both**] slot value)
slot ::= a symbol which will be used as a slot name in the chunk indicated by the feature
value::= a value which will be used as the value for the corresponding slot

Description:

The new-ongoing-sound command is very similar to the new-other-sound command for creating an arbitrary sound for the current model. The difference is that the sound does not have a predetermined end time. The sound will only stop when the end-ongoing sound command is called. A newly created sound event will be placed into the audicon at the onset time of the audio event with the other properties of that audio event being set as described below. If the time-in-ms parameter is specified as non-nil then all provided times are measured in milliseconds, and if it is not provided or **nil** the provided times will be measured in seconds. Here is how those values are set based on the command:

Onset: as provided or the current time if not provided
Content delay: as provided
Recode time: as provided
Content: as provided
Kind: as provided, or **speech** if not provided
Location: as provided, or **external** if not provided
Other slots: the event and/or sound chunk will have additional slots set as provided

Each new sound will generate a maintenance event which will not be shown in the trace. It will have an action of stuff-sound-buffer and no parameters. It will occur at the time the sound event becomes detectable, and this is where the testing is done to determine whether or not a new sound should be stuffed into the aural-location buffer.

Each new sound will also generate a new-sound signal at its onset time.

If a sound is successfully created and added to the audicon of the model then an id value is returned. If there is no current model or an invalid parameter is provided a warning will be displayed and **nil** will be returned.

The end-ongoing-sound command requires one parameter which is the id of a sound created with the new-ongoing-sound command in the current model. It will end that sound at the current time. If the id matches a current ongoing sound then it will return **t** if it does not match a current ongoing sound or there is no current model then it will return **nil**.

Examples:

```
1> (new-ongoing-sound "value" .2 .15)
1
```

```
2> (end-ongoing-sound 1)
T

3E> (end-ongoing-sound 1)
```

print-audicon

Syntax:

print-audicon -> **nil**

Remote command names:

print-audicon

Description:

The print-audicon command will print out a description of the features which are currently in the audicon of the current model to the command trace. Each feature will be printed on a separate line showing several of the default characteristics of the sound event. It will always return **nil**. If there is no current model then it will print out a warning instead.

Examples:

```
1> (new-tone-sound 400 .5)
T

2> (new-word-sound "Hi" 1.0 'external)
T

3> (new-ongoing-sound "mmm" .2 .4 .7)
1

4> (print-audicon)
Sound event  Att Detectable  Kind     Content     location  onset     offset  Sound ID
-----------  --- ----------  -------- ----------  --------  -----     ------  --------
AUDIO-EVENT0 NIL NIL         TONE     400         EXTERNAL    0.0        0.5  TONE0
NIL

5> (run-full-time 1.0)
1.0
15
NIL

6> (print-audicon)
Sound event  Att Detectable  Kind     Content     location  onset     offset  Sound ID
-----------  --- ----------  -------- ----------  --------  -----     ------  --------
AUDIO-EVENT0 NIL T           TONE     400         EXTERNAL    0.0        0.5  TONE0
AUDIO-EVENT2 NIL T           SPEECH   "mmm"       EXTERNAL    0.7    ongoing  SOUND0
AUDIO-EVENT1 NIL NIL         WORD     "Hi"        EXTERNAL    1.0       1.15  WORD0
NIL

E> (print-audicon)
#|Warning: get-module called with no current model. |#
#|Warning: No audio module found |#
NIL
```

printed-audicon

Syntax:

printed-audicon -> audicon-string

Remote command name:

printed-audicon

Arguments and Values:

audicon-string ::= a string which contains the audicon information

Description:

The printed-audicon command is exactly like the print-audicon command above, except that instead of printing the audicon to the command trace it returns a string containing the output. If there is no current model a warning will be output and the string will contain a warning instead of the audicon.

Examples:

```
1> (new-tone-sound 100 .5)
T

2> (run-full-time 1)
1.0
10
NIL

3> (printed-audicon)
"Sound event  Att Detectable  Kind     Content     location  onset     offset  Sound ID
-----------  --- ----------  -------- ----------  --------  -----     ------  --------
AUDIO-EVENT0 NIL T           TONE     100         EXTERNAL    0.0       0.5  TONE0"

4> (printed-audicon)
#|Warning: get-module called with no current model. |#
"#|Warning: No audio module found|#"
```

set-audloc-default

Syntax:

set-audloc-default {**isa** chunk-type} {{modifier} slot [value | variable]}*
{**:attended** [**t | nil | requested**]} {**:finished** [**t | nil**]} -> [**t** | **nil**]
set-audloc-default-fct ({**isa** chunk-type} {{modifier} slot [value | variable]}*
{**:attended** [**t | nil | requested**]} {**:finished** [**t | nil**]}) -> [**t** | **nil**]

Remote command name:

set-audloc-default ' {**isa** chunk-type} {{modifier} slot [value | variable]}*
{**:attended** [**t | nil | requested**]} {**:finished** [**t | nil**]} '

Arguments and Values:

chunk-type ::= the name of a chunk-type
modifier ::= [= | - | > | < | >= | <=]
slot ::= the name of a slot which must be valid for chunk-type if it is specified
value ::= any value
variable ::= a name which starts with the character &

Description:

The set-audloc-default command is used to set the specification used when testing the items in the audicon to determine if an audio event chunk should be stuffed into the aural-location buffer for the current model. The parameters provided are used to create a chunk-spec that will be tested against the set of chunks in the audicon using find-matching-chunks after it has been filtered for attended and/or finished items. The default specification is set with:

```
(set-audloc-default :attended nil)
```

The command returns **t** if a new specification is set. If there is no current model then it prints a warning and returns **nil**. If the parameters provided do not properly represent a valid chunk-spec then no changes are made to the current default spec and **nil** is returned.

Examples:

```
> (set-audloc-default isa audio-event onset lowest kind tone)
T

> (set-audloc-default-fct (list '- 'location 'self))
T

E> (set-audloc-default isa sound slot)
#|Warning: Chunks extended with slot SLOT during a chunk-spec definition. |#
#|Warning: Invalid specs in call to define-chunk-spec - not enough arguments |#
#|Warning: Invalid chunk specification.  Default audloc not changed. |#
NIL

E> (set-audloc-default :attended t :attended nil)
#|Warning: The :attended and :finished specification for set-audloc-default can only be
specified at most once. |#
#|Warning: Audloc defaults not changed. |#
NIL

E> (set-audloc-default)
#|Warning: No current model.  Cannot set audloc defaults. |#
NIL
```

schedule-audio-encoding-complete

Syntax:

schedule-audio-encoding-complete *delay* -> **nil**

Remote command name:

schedule-audio-encoding-complete

Arguments and Values:

delay ::= a number indicating the time in seconds before finishing the current aural attention shift

Description:

The schedule-audio-encoding-complete command can be used when the :aural-encoding-hook parameter is set to a command and that command returns a value which suspended the normal scheduling of the completion of the attention shift in response to an attend sound request. It will schedule the completion event (either audio-encoding-complete if successful or attend-sound-failure if not) to occur for the audio module of the current model based on the last attend sound request after the provided number of seconds have passed. It always returns **nil**. If there is no current model or there has not been a suspended attend sound request for the current model then a warning is printed and no event is scheduled. If the delay provided is not a non-negative number then a warning is printed and the event will be scheduled with a delay of 0.

Examples:

```
> (schedule-audio-encoding-complete .1)
NIL

E> (schedule-audio-encoding-complete .1)
#|Warning: Schedule-audio-encoding-complete called but there is no pending attend-sound
action. |#
NIL

E> (schedule-audio-encoding-complete .1)
#|Warning: get-module called with no current model. |#
NIL

E> (schedule-encoding-complete -1)
#|Warning: Invalid delay time passed to schedule-encoding-complete -1. Using 0 instead. |#
NIL
```

Motor module

The motor module functions as a model's hands. It is conceptually based on EPIC's Manual Motor Processor (Kieras & Meyer, 1996) and is quite similar in many respects. It provides a model with the ability to operate virtual keyboard and mouse devices by default, but it is possible to extend the actions and devices with which the model can interact. It has one buffer through which it accepts requests and it does not generate any chunks in response. There is currently no learning mechanism built into the motor module.

The name of the module is :motor.

Physical world

The model's hands are represented as existing in a horizontal plane in front of the model (like a desktop) on which devices can be placed, and at any time each hand will be associated with at most one device. Because a keyboard was the first device created for a model to use, that plane is represented as a grid of square cells 3/4" (~19mm) on a side (the standard key spacing for full size computer keyboards) with the origin located where the upper left key of a keyboard (typically the Esc key) would be located for normal use. Each of the model's fingers will be located in a cell of that space, and the position of the model's hands are considered to be the same as the position of the corresponding index finger. The default positions for the hands are the left hand fingers in cells 1,4 through 4,4 with the thumb at 5,6 and the right hand fingers in cells 7,4 through 10,4 with the thumb at 6,6 (which corresponds to the home row positions for touch typing if the provided keyboard device is installed).

Operation

In general, movement requests require specification of a movement type, called a style (which is specified by the cmd slot of the request) and one or more parameters, such as the hand or finger that is to make the movement. The motor module includes several movement styles based on EPIC's Motor Processor. They are:

- Punch. This is a simple downstroke followed by an upstroke of a finger (pressing a key or button located directly beneath the finger).
- Peck. This is a directed movement of a finger to a location followed by a keystroke, all as one continuous movement.
- Peck-recoil. Same as "peck" above, but the finger moves back to the location at which it started its movement.
- Ply. Moving a device to a given location in space or to control the position of an associated object e.g. the cursor on the screen by using the mouse.
- Hand-ply. Moves a hand to a new location in space e.g. from the keyboard to the mouse.

Those movement styles can be executed directly through requests, but typically one will use higher level actions provided by a device that are built upon those low level styles.

The motor module does not place any chunks into its buffer in response to requests. The buffer should always be empty, and it is the state of the module that is important to the model. As described

above for all the perceptual and motor modules, the motor module has three internal states: preparation, processor, and execution. When a request is received by the motor module, it goes through three phases: preparation, initiation, and execution each of which depends upon a different combination of those internal states being available.

In the preparation phase, it builds a list of "features" which guide the actual movement, and it requires the use of the preparation and processor states of the module. The amount of time that preparation takes depends on the number of features that need to be prepared - the more that need to be prepared, the longer it takes. The number of features that need to be prepared depends upon two things: the complexity of the movement to be made and the difference between that movement and the previous movement (the motor module maintains a history of the last set of features that it prepared). On one end of the scale, the motor module is simply repeating the previous movement, then all the relevant features will already be prepared and do not require preparation. On the other end, a request could specify a movement that requires five features (the most for any of the included styles) which do not overlap with the features in the motor module's history, in which case all five features would need to be prepared. The movement features are organized into a hierarchy, such that a change to a feature higher in the hierarchy requires preparing all features below it again regardless of whether they match a previously prepared feature. The movement style is at the top of the hierarchy, and therefore if the movement style changes all of the features required for the movement must be prepared. The hand feature is below the style, and all actions will involve a style and hand. Below the hand is the finger feature (if needed), and then any other features for an action are considered equal and at the bottom of the hierarchy.

When feature preparation is complete, the motor module makes the specified movement. The first 50ms (by default) of the movement is the initiation. During this interval, the processor and execution states are required. Once the initiation phase begins it is not possible for the model to stop the action from completing, but until that happens it is possible for the model to terminate the action (either while it is still being prepared or while it is waiting for a prior execution to finish).

The execution phase requires only the execution state of the module. The amount of time that the movement takes to execute depends on the style and features of the action. Simple styles, like punch, have a fixed execution time, but the more complex styles will have a longer execution time based on the movement necessary which is determined by Fitts's Law.

Fitts's Law

$$T = b * \log_2(D/W + 0.5)$$

T := the time of the movement in seconds
b := a scale parameter dependent on the type of action
D := the distance to the target
W := the width of the target along the direction of motion

Each state of the module may only be engaged for a single action at a time. If a request is made that requires a state that is already engaged then the motor module is said to be "jammed." When the module is jammed it will output a warning to indicate when the jamming occurred like this:

```
#|Warning: Module :MOTOR jammed at time 0.68 |#
```

When the module jams it will ignore the request that caused the jam and continue with the action that was already occurring. To avoid jamming, as with all modules, one must query the state of the module before making a request. The standard query for state free will avoid jamming the module because that is only true when all of the internal states of the module are not busy. However, it is possible to issue motor requests faster than that because the preparation and execution of an action use different internal states and the module can be preparing one action while it is executing another, and it will internally delay the execution of the second action if necessary to wait for the execution state to become free. Therefore one can have the model perform actions closer together by testing for the appropriate internal state being free, and a query for preparation free instead of state free can often be used instead to start preparing the second action as soon as possible. However, there are two situations in which one may need to be careful when attempting to chain actions together like that. The first situation occurs because the processor state is used by both preparation and execution of an action. Therefore, technically one should query that both preparation and processor are free before starting the next action, but because the default initiation time is the same as the default production firing time the preparation free test in a production is usually sufficient since the processor will be free by the time the production fires if the preparation free query is successful. If however one has enabled the noise for the timing of production firings and/or motor actions or changed the timing for either such that a production can take less time than the initiation phase of an action, then both preparation free and processor free queries would be required because it would not be guaranteed that the processor would become free while the production is firing. The other situation occurs when the preparation of the features for the second action depend upon the execution of the first action. That happens if the actions are both movements of the same hand/finger since the features to prepare for the movement depend upon the current position of the item. If the movement has not yet completed its move to a new position then the features for the second move may be determined from the wrong starting point and result in an incorrect set of features. The motor actions described in this manual properly account for that and will compute the features based on the final position after the completion of an ongoing action, but if one is using new or custom movement actions, that may not be the case and it would be safest to use a state free test to ensure that both preparation and execution are available.

Another option for quickly performing actions is to have the module prepare features without executing them. If all of the features for an action are prepared in advance then an execute request can be made to perform that action. Alternatively, one can prepare just a subset of the features needed so that when the action is performed it has a lower preparation cost (which could be useful in the case of a decision task where the model knows it will be punching a finger on the right hand, but doesn't know which one – it could prepare the style and hand features in advance and then only need to prepare the specific finger when known).

Interface & Devices

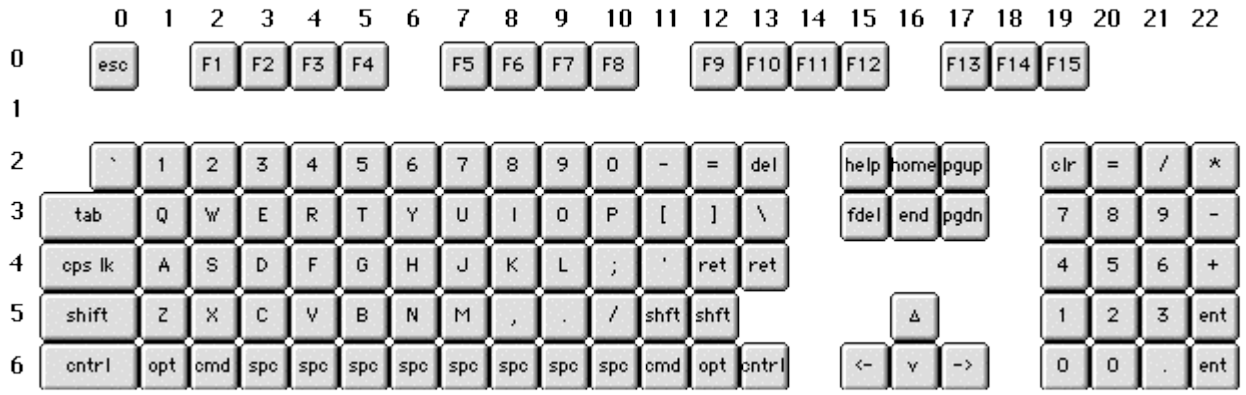
The motor module has an interface called "motor" which can be used to install any number of devices. When a hand is using a device that device will be notified with the details of any actions which that hand performs, which could be the default action styles or extended actions which have been created.

There are two devices included for use with the motor module: a keyboard device called "keyboard" and a device for moving the virtual mouse cursor using a few different input devices (mouse, first

order joystick, and second order joystick) which is called “cursor”. None of those devices are installed by default, but if the “exp-window” device of the AGI is installed for the vision interface it will automatically install a keyboard device and a mouse cursor device for the motor interface if they are not already installed.

Keyboard

This is the layout of the keyboard device for the model:



The device extends the actions which the model can perform to include those for moving the hands to the keyboard, moving the hands on the keyboard, and a command for touch typing keys by name. The requests for those actions and associated modeler commands will be described with the default motor module requests and commands.

There are no details necessary when installing a keyboard device, and only one keyboard device should be installed for the motor interface at a time (technically one could install more than one by providing different details which will be ignored, but that is not recommended).

When the keyboard is notified that a motor action has occurred which will press a key it will generate an output-key signal with two parameters. The first parameter is the name of the model which performed the action and the second is the name of the key which was pressed. That signal can be monitored to detect and record a model's keyboard responses.

Cursor

The cursor device controls a virtual cursor and multiple virtual cursors (each of which is independent of the others) may be installed. There are three provided types of cursor input devices: a mouse, a first order joystick, and a second order joystick. The particular input device is specified as the details of the cursor device being installed and the values for those are “mouse”, “joystick1”, and “joystick2” respectively. All three input devices are located to the right of the default keyboard position at fixed coordinates: 28,2, 28,0, and 28,4 respectively (a simplifying assumption that ignores any movement that is made with the device).

The cursor device extends the actions which the model can perform to include those for moving the virtual cursor to a visual location or visual object, moving the right hand to a cursor device, and clicking the primary mouse cursor button with the index finger. The requests for those actions and associated modeler commands will be described with the default motor module requests and commands.

When a cursor is notified that a model's motor action has occurred which affects the cursor it will generate a signal. There are three signals that are generated for the model actions with a cursor. The first is "move-cursor" which includes three parameters which are the name of the model, the details of the cursor device i.e. the name of which cursor it is, and a list of three values which are the x, y, and z coordinates to which the virtual cursor has been moved. The other two signals relate to the pressing of buttons on the cursor. All of the cursors assume that there is a button below each finger that activates when the finger strikes it, and that will generate a signal. For the mouse cursor a "click-mouse" signal is generated which is passed three parameters: the name of the model, a list of three values which indicate the x, y, and z coordinates of the virtual cursor at the time of the click, and the name of the finger which performed the click. For all other cursors, a "click-cursor" signal is generated which is passed four parameters: the name of the model, the name of the cursor, a list with the x, y, and z coordinates of the cursor when the click occurred, and the name of the finger which performed the click. The cursor also generates the "move-cursor" signal when the cursor is moved explicitly using the command set-cursor-position, and it will generate a signal called "delete-cursor" whenever a cursor device is uninstalled which will be passed two parameters: the name of the model and the details of the device being uninstalled.

Parameters

:cursor-noise

If this is set to **nil** (which is the default) then the cursor movements made by the model will be to the exact location requested. If it is set to **t** then there will be noise added to the location to which the cursor is moved.

:incremental-mouse-moves

When set to **t**, this will update the cursor location approximately every 50 ms when it is in motion. When set to **nil** (which is the default value) it will update the cursor location only at the end of each cursor movement. If it is set to a number then that is considered as a time in seconds between the updates and replaces the time of .05 used when it is set to **t**. The incremental positions are calculated along the line between the old and new points using a minimum jerk velocity profile.

:min-fitts-time

The minimum movement time in seconds required to perform an aimed movement (one for which the Fitts's law timing is applied). The default value is 0.1.

:motor-burst-time

This is the minimum time required for the execution of any motor module movement in seconds. The default is .05.

:motor-feature-prep-time

The time in seconds that it takes to prepare each movement feature. The default is .05.

:motor-initiation-time

This is the length of the initiation time for motor actions in seconds. The default is .05.

:peck-fitts-coeff

The b coefficient in the Fitts's law equation for the timing of peck style movements. The default value is .075.

Manual Buffer

The motor module does not place any chunks into the manual buffer — it is only used for requests.

Almost all of the timing for the requests to the manual buffer (everything except for a clear request) are randomized using randomize-time.

Activation spread parameter: :manual-activation
Default value: 0.0

Queries:

'State busy' will be **t** when any of the internal states of the module (listed below) also report as being busy. Essentially, it will be **t** while there is any request to the manual buffer that has not yet completed. It will be **nil** otherwise.

'State free' will be **t** when all of the internal states of the module (listed below) also report as being free. Essentially, it will be **t** only when all requests to the manual buffer have completed. It will be **nil** otherwise.

'State error' will always be **nil**.

Unlike the perceptual modules, the internal states of the motor module may be useful to track in a model because it is possible to send new requests while the module is partially busy.

'Preparation busy' will be **t** after a request has been received and until it completes the preparation of the features needed for that request which depends on how many features there are and whether or not they overlap with the last features prepared. It will be **nil** otherwise.

‘Preparation free’ will be **nil** after a request has been received and until it completes the preparation of the features needed for that request which depends on how many features there are and whether or not they overlap with the last features prepared. It will be **t** otherwise.

‘Processor busy’ will be **t** while preparation is busy and will continue to be **t** after the features have been prepared until the additional initiation time (set with the :motor-initiation-time parameter) has passed. It will be **nil** otherwise.

‘Processor free’ will be **nil** while preparation is busy and will continue to be **nil** after the features have been prepared until the additional initiation time (set with the :motor-initiation-time parameter) has passed. It will be **t** otherwise.

‘Execution busy’ will be **t** once the preparation of a request’s features has completed and will remain **t** until the time necessary to complete the action has passed. It will be **nil** otherwise.

‘Execution free’ will be **nil** once the preparation of a request’s features has completed and will remain **nil** until the time necessary to complete the action has passed. It will be **t** otherwise.

‘Last-command *command*’ *command* should be a symbol which corresponds to one of the manual buffer’s requests or the symbol none. The query will be **t** if that is the name of the last request received by the manual buffer otherwise it will be **nil**.

Here is a summary indicating the state transitions for a single movement request assuming that the module is entirely free at the start of the request:

Preparation state	**Processor state**	**Execution state**	**When**
FREE	FREE	FREE	Before event arrives
BUSY	BUSY	FREE	When request is received
FREE	BUSY	BUSY	After preparation of movement
FREE	FREE	BUSY	After initiation of movement
FREE	FREE	FREE	When movement is complete

When displaying the events of an action the transition through those stages will indicate the time of the request which corresponds to the action so that if the module is performing multiple actions (because preparation can occur in parallel with execution) it is easier to follow the details of each action.

Requests

clear

[cmd clear | clear t]

A clear request can be sent to clear the history of prepared features. A clear request varies from the other requests in that it will only make the preparation state busy for 50ms and not the processor or execution states. These events will show in the trace for a clear request to the manual buffer:

```
0.050   MOTOR                 CLEAR
...
0.100   MOTOR                 CHANGE-STATE LAST NONE PREP FREE
```

Note, that after the clear request completes the last-command recorded by the module will be none and not clear – the clear has effectively cleared the history of its own request as well.

While this request makes the preparation state busy, unlike other requests it does not require that it be free. That makes it possible to use the clear request to terminate an action which has not yet started its execution.

punch

cmd punch
hand [***left*** | ***right***]
finger [***index*** | ***middle*** | ***ring*** | ***pinkie*** | ***thumb***]

This request will execute a punch action for the specified finger on the specified hand. This will result in sending a punch notification to the device that hand is using (if there is one). That notification contains a list of features like this indicating which hand and where the finger is located:

((**model** model-name) (**style punch**) (**hand** hand) (**loc** (cell-x cell-y))

The time to perform this action is controlled by the initiation and burst times set for the motor module, and the actual execution of the output is controlled by the key closure time. After the initiation time passes the finger starts to move and there is one burst time to complete the downstroke followed by another burst time to complete the upstroke. These are the actions which will be shown in the trace for a punch action indicating the request being received, the preparation of the features completing, the initiation time having passed, the actual striking of a key which is under that finger currently, and the time to finish the execution of the action (returning the finger to a position where it is ready to act again):

```
0.000   MOTOR                 PUNCH HAND LEFT FINGER INDEX
...
0.150   MOTOR                 PREPARATION-COMPLETE 0.0
...
0.200   MOTOR                 INITIATION-COMPLETE 0.0
...
0.210   MOTOR                 MOTOR-ACTION-PERFORMED 0.0
...
0.300   MOTOR                 FINISH-MOVEMENT 0.0
```

If the hand is interacting with a device, then the motor-action-performed event may not occur and a specific action by that device may be shown instead e.g. this result when a keyboard is installed:

```
0.210   KEYBOARD              output-key PRESS-F-MODEL f
```

peck

cmd peck
hand [***left*** | ***right***]
finger [***index*** | ***middle*** | ***ring*** | ***pinkie*** | ***thumb***]
r *distance*
theta *direction*

This request will result in the model making a peck style movement with the indicated finger and hand. This will result in sending a peck notification to the device that hand is using (if there is one). That notification contains a list of features like this indicating which hand, and where the finger will be located as a result of the peck:

((**model** model-name) (**style peck**) (**hand** hand) (**loc** (cell-x cell-y))

That finger will be moved the specified distance and direction from where it currently is and then interact with the device at that location (pressing the key for a keyboard device). The finger will then remain in that location until moved elsewhere. The distance is measured in cell widths as described above. The direction is an angle measured in radians with 0 being movement along the x axis to the right and increasing with clockwise rotation. The time taken to execute this action is controlled by Fitts's law as described above using the :peck-fitts-coeff parameter (currently the key closure time is not used in the timing of the output action as with a punch). These are the events which one will see for such an action showing the progression through the stages of the motor module and performing the action (which may produce an event specific to the device associated with the hand instead of the motor-action-performed event):

```
0.050   MOTOR                 PECK HAND LEFT FINGER INDEX R 1 THETA 0
...
0.300   MOTOR                 PREPARATION-COMPLETE 0.05
...
0.350   MOTOR                 INITIATION-COMPLETE 0.05
...
0.450   MOTOR                 MOTOR-ACTION-PERFORMED 0.05
...
0.500   MOTOR                 FINISH-MOVEMENT 0.05
```

There are no constraints on how far or in which direction a model's finger can move relative to the other fingers. Thus, at this time, the model may be able to make finger movements which would be impossible for a real person to make and it is up to the modeler to consider such issues.

peck-recoil

cmd peck-recoil
hand [***left*** | ***right***]
finger [***index*** | ***middle*** | ***ring*** | ***pinkie*** | ***thumb***]
r *distance*
theta *direction*

A peck-recoil is effectively the same as a peck, except that the finger is returned to where it started after the key has been pressed. This will result in sending a peck-recoil notification to the device that hand is using (if there is one). That notification contains a list of features like this indicating which hand, and where the finger will strike as a result of the peck-recoil:

((**model** model-name) (**style peck-recoil**) (**hand** hand) (**loc** (cell-x cell-y))

These are the events which one will see for such an action showing the progression through the stages of the motor module and performing the action (which may produce an event specific to the device associated with the hand instead of the motor-action-performed event):

```
0.050   MOTOR                   PECK-RECOIL HAND LEFT FINGER INDEX R 1 THETA 0
...
0.300   MOTOR                   PREPARATION-COMPLETE 0.05
...
0.350   MOTOR                   INITIATION-COMPLETE 0.05
...
0.450   MOTOR                   MOTOR-ACTION-PERFORMED 0.05
...
0.600   MOTOR                   FINISH-MOVEMENT 0.05
```

There are no constraints on how far or in which direction a model's finger can move relative to the other fingers. Thus, at this time, the model may be able to make finger movements which would be impossible for a real person to make and it is up to the modeler to consider such issues.

press-key

cmd press-key
key *key*

The press-key request is essentially a programming convenience for modeling typing provided by the keyboard device. It assumes that the model's hands are in the home position or that the right hand is on the keypad and translates the specified key into either a punch or a peck-recoil request as needed to press that key with the appropriate finger from the home position. The key can be specified using either a symbol or string that specifies the name of a key on the keyboard. The names for keys on the default keyboard fall into the following categories:

- Alpha-numeric keys (a-z and 0-9) can be specified with a single character.
- Punctuation keys should be provided in strings or specified with a name (space, backquote, tab, comma, period, semicolon, slash, hyphen, quote, left-bracket, right-bracket, or backslash) to avoid potential syntax problems.
- The function keys are named f1 – f15.
- The other keys in the primary key section are named: escape, equal, delete, caps-lock, return (or newline), left-shift (or shift), right-shift, left-control (or control), left-option (or option), left-command (or command), right-command, right-option, and right-control.
- The keys on the keypad area are named: clear, keypad-=, keypad-/, keypad-*, keypad-7, keypad-8, keypad-9, keypad-minus, keypad-4, keypad-5, keypad-6, keypad-plus, keypad-1, keypad-2, keypad-3, keypad-0, keypad-period, and enter.

This request does not represent an ACT-R theory of typing. It only provides a convenience for modeling a moderately skilled touch typist. An ideal theory of typing would be based on a model learning how to type. The model would have to look at the keyboard to determine where each key is, then acquire chunks that encode which keys map to which locations, through practice it would learn specific productions that handle these, and would also involve learning in the motor system itself.

Here are the events which will show in the trace for a press-key request indicating the key that was specified, the progression through the stages of the action, and showing the keyboard response indicating the model name and key:

```
     0.050   MOTOR                  PRESS-KEY KEY F
     ...
     0.200   MOTOR                  PREPARATION-COMPLETE 0.05
     ...
     0.250   MOTOR                  INITIATION-COMPLETE 0.05
     ...
     0.260   KEYBOARD               output-key PRESS-KEY-MODEL f
     ...
     0.350   MOTOR                  FINISH-MOVEMENT 0.05
```

If the model's hands are using the keyboard device but are not in the appropriate location for the request (either the home row or the keypad depending on the key), then the model will strike the wrong key since the action is generated based on the key, not the current hand positions.

If an invalid key is specified then a warning is printed and no action is taken:

```
     0.050   MOTOR                  PRESS-KEY BAD-KEY
#|Warning: No press-key mapping available for key "BAD-KEY". |#
```

If the keyboard device is not installed for the model or its hands are not interacting with that device then a warning is printed and no action is taken:

```
     0.050   MOTOR                  PRESS-KEY KEY R
#|Warning: No keyboard device installed for motor module.  Press-key action ignored. |#
```

or

```
     0.050   MOTOR                  PRESS-KEY KEY K
#|Warning: The RIGHT hand in a press-key action is not on the keyboard.  Press-key action
ignored. |#
```

If the hand and fingers are not at the home position on the keyboard device then a warning is printed but the corresponding action is still performed which may result in an incorrect press:

```
     0.050   MOTOR                  PRESS-KEY KEY R
#|Warning: Hand not at home position for press-key action. |#
     ...
     0.450   KEYBOARD               output-key PRESS-KEY-MODEL i
```

move-cursor

cmd move-cursor
[**object** *object* | **loc** *location*]
{**hand** [**left** | **right**]}

This request will result in a ply style movement of the model's hand if it is currently interacting with a cursor device. That ply will move the cursor device associated with the indicated hand (the right hand is the default if not provided) to the specified object (which must be a chunk which represents a visual object) or location (which must be a chunk which represents a visual location) taking time

based on Fitts's Law. Note that the actual location of the cursor device itself does not change, only the position of the cursor which it is controlling.

If the :cursor-noise parameter is **nil** then the cursor will be positioned exactly at the coordinates provided by the location or object provided. If :cursor-noise is **t** then a very simplified noise component is added to the target point to determine where the cursor is moved. An offset distance is computed using the effective width of the target – it's width along the vector of approach as used in the Fitts's Law calculation. The offset is computed using the act-r-noise command with an s value that results in it being on the object (along the approach vector) 96% of the time. That offset is applied in a random direction from the target chosen from a uniform distribution.

Here are the events which show for a move-cursor action showing the module progressing through the internal states and a mouse cursor device indicating the final position of the cursor:

```
0.050   MOTOR                 MOVE-CURSOR LOC X
...
0.250   MOTOR                 PREPARATION-COMPLETE 0.05
...
0.300   MOTOR                 INITIATION-COMPLETE 0.05
...
0.466   MOUSE                 move-cursor FOO mouse (30 40 1080)
...
0.516   MOTOR                 FINISH-MOVEMENT 0.05
```

The number shown after the events is the time of the request which corresponds to the action. That is shown so that when the module is performing multiple actions it is easier to follow the details of each action.

If the :incremental-mouse-moves parameter is specified as **t**, then there may be multiple smaller mouse movements leading up to the final position which are spaced approximately 50 ms apart:

```
0.050   MOTOR                 MOVE-CURSOR LOC X
...

0.250   MOTOR                 PREPARATION-COMPLETE 0.05
...
0.300   MOTOR                 INITIATION-COMPLETE 0.05
...
0.300   MOUSE                 move-cursor FOO mouse (2 3 1080)
...
0.350   MOUSE                 move-cursor FOO mouse (13 18 1080)
...
0.400   MOUSE                 move-cursor FOO mouse (25 33 1080)
...
0.466   MOUSE                 move-cursor FOO mouse (30 40 1080)
...
0.516   MOTOR                 FINISH-MOVEMENT 0.05
```

If the model's hand is not on a cursor device a warning is printed and no action is taken:

```
#|Warning: Hand is not on a cursor device in request to move-cursor. |#
```

The move-cursor action assumes movement in only the x,y plane. If a movement includes a change in the z dimension a warning will be printed to indicate that. It will still move the cursor to the

indicated position, but the timing will based on a movement that only occurred in two dimensions i.e. it ignores the z distance traveled and the target width is only measured along the x,y plane:

```
     0.050   MOTOR                  MOVE-CURSOR LOC X
#|Warning: Move-cursor request has different z coordinates for start (0 0 1080) and target
(30 40 10) locations, but motor module assumes a cursor moves in only two dimensions. |#
     ...
     0.250   MOTOR                  PREPARATION-COMPLETE 0.05
     ...
     0.300   MOTOR                  INITIATION-COMPLETE 0.05
     ...
     0.466   MOUSE                  move-cursor FOO mouse (30 40 10)
     ...
     0.516   MOTOR                  FINISH-MOVEMENT 0.05
```

If the target position is the same as the current cursor position then a warning is printed and no action is performed:

```
     0.050   MOTOR                  MOVE-CURSOR LOC X
#|Warning: Move-cursor action aborted because cursor is at requested target X |#
```

click-mouse

cmd click-mouse

If the model's right hand is located on a virtual mouse cursor, then this request will result in a punch action by the right index finger pressing the primary mouse button. These are the events which one will see for such an action showing the progression through the stages of the motor module and the indication from the mouse cursor that a press occurred which indicates the name of the model, the location of the mouse cursor, and which finger (although there are not separate requests for other mouse buttons a punch action on any finger while the hand is on the mouse will generate a click-mouse event for that finger):

```
     0.050   MOTOR                  CLICK-MOUSE
     ...
     0.200   MOTOR                  PREPARATION-COMPLETE 0.05
     ...
     0.250   MOTOR                  INITIATION-COMPLETE 0.05
     ...
     0.260   MOUSE                  click-mouse FOO (0 0 1080) INDEX
     ...
     0.350   MOTOR                  FINISH-MOVEMENT 0.05
```

If the model's right hand is not on the virtual mouse then a warning will be printed and no action taken:

```
#|Warning: CLICK-MOUSE requested when hand not at mouse! |#
```

hand-to-mouse

cmd hand-to-mouse

The hand-to-mouse request will move the model's right hand from where ever it is to the default location for the virtual mouse cursor using a hand-ply style movement (the default location for the

mouse device is at (28 2) and it has an effective width of 4). These are the events which will show the action progressing through the stages of a motor action along with the final movement indicating the distance and direction the right hand moved:

```
0.050   MOTOR                   HAND-TO-MOUSE
...
0.250   MOTOR                   PREPARATION-COMPLETE 0.05
...
0.300   MOTOR                   INITIATION-COMPLETE 0.05
...
0.553   MOTOR                   MOVE-A-HAND RIGHT 21.095022 -0.094951704
...
0.603   MOTOR                   FINISH-MOVEMENT 0.05
```

If the model's hand is already on the virtual mouse it will acknowledge the request, but no actions are taken, the module does not become busy, and a warning is printed:

```
    0.050   MOTOR                   HAND-TO-MOUSE
#|Warning: HAND-TO-MOUSE requested but hand already is (or will be) at the mouse device. |
#
```

hand-to-joystick1

cmd hand-to-joystick1

The hand-to-joystick1 request will move the model's right hand from where ever it is to the default location for the virtual first order joystick cursor using a hand-ply style movement (the default location for the joystick1 device is at (28 0) and it has an effective width of 4). These are the events which will show the action progressing through the stages of a motor action along with the final movement indicating the distance and direction the right hand moved:

```
0.050   MOTOR                   HAND-TO-JOYSTICK1
...
0.250   MOTOR                   PREPARATION-COMPLETE 0.05
...
0.300   MOTOR                   INITIATION-COMPLETE 0.05
...
0.555   MOTOR                   MOVE-A-HAND RIGHT 21.377558 -0.1882215
...
0.605   MOTOR                   FINISH-MOVEMENT 0.05
```

If the model's hand is already on the virtual joystick1 it will acknowledge the request, but no actions are taken, the module does not become busy, and a warning is printed:

```
    0.050   MOTOR                   HAND-TO-JOYSTICK1
#|Warning: HAND-TO-JOYSTICK1 requested but hand already is (or will be) at the joystick1
device. |#
```

hand-to-joystick2

cmd hand-to-joystick2

The hand-to-joystick2 request will move the model's right hand from where ever it is to the default location for the virtual second order joystick cursor using a hand-ply style movement (the default location for the joystick1 device is at (28 4) and it has an effective width of 4). These are the events which will show the action progressing through the stages of a motor action along with the final movement indicating the distance and direction the right hand moved:

```
0.050   MOTOR                   HAND-TO-JOYSTICK2
...
0.250   MOTOR                   PREPARATION-COMPLETE 0.05
...
0.300   MOTOR                   INITIATION-COMPLETE 0.05
...
0.552   MOTOR                   MOVE-A-HAND RIGHT 21.0 0.0
...
0.602   MOTOR                   FINISH-MOVEMENT 0.05
```

If the model's hand is already on the virtual joystick2 it will acknowledge the request, but no actions are taken, the module does not become busy, and a warning is printed:

```
    0.050   MOTOR                   HAND-TO-JOYSTICK2
#|Warning: HAND-TO-JOYSTICK2 requested but hand already is (or will be) at the joystick2
device. |#
```

hand-to-home

cmd hand-to-home

The hand-to-home request will move the model's right hand from where ever it is to the home position on the virtual keyboard using a hand-ply style movement (the target location for the home position is (7 4) with a width of 4) and position all of the fingers over the appropriate keys. These are the events which will show the action progressing through the stages of a motor action along with the final movement indicating the distance and direction the hand moved:

```
0.050   MOTOR                   HAND-TO-HOME
  ...
0.250   MOTOR                   PREPARATION-COMPLETE 0.05
...
0.300   MOTOR                   INITIATION-COMPLETE 0.05
...
0.553   MOTOR                   MOVE-A-HAND RIGHT 21.095022 3.0466409
...
0.603   MOTOR                   FINISH-MOVEMENT 0.05
```

If the model's hand is already at the home position it will acknowledge the request, but no actions are taken, the module does not become busy, and a warning is printed:

```
    0.000   MOTOR                   HAND-TO-HOME
#|Warning: HAND-TO-HOME requested but hand already is (or will be) at the home position. |
#
```

hand-to-keypad

cmd hand-to-keypad

The hand-to-keypad request will move the model's right hand from where ever it is to the keypad on the virtual keyboard using a hand-ply style movement (the target location for the keypad position is (19 4)) and position the fingers over the keys 4, 5, 6, and enter with the thumb over 0. These are the events which will show the action progressing through the stages of a motor action along with the final movement indicating the distance and direction the hand moved:

```
    0.050   MOTOR                  HAND-TO-KEYPAD
    ...
    0.250   MOTOR                  PREPARATION-COMPLETE 0.05
    ...
    0.300   MOTOR                  INITIATION-COMPLETE 0.05
    ...
    0.481   MOTOR                  MOVE-A-HAND RIGHT 12.0 0.0
    ...
    0.531   MOTOR                  FINISH-MOVEMENT 0.05
```

If the model's hand is already at the keypad position it will acknowledge the request, but no actions are taken, the module does not become busy, and a warning is printed:

```
    0.050   MOTOR                  HAND-TO-KEYPAD
#|Warning: HAND-TO-KEYPAD requested but hand already is (or will be) at the keypad
position. |#
```

point-hand-at-key

cmd point-hand-at-key
hand [**left** | **right**]
to-key *key*
{**offsets** [**standard** | **(***finger-offset****)**]}

key ::= either a symbol or string that specifies the key to which the hand should move
finger-offset ::= (*finger-name x y*)
finger-name ::= [**index | middle | ring | pinkie | thumb**]
x ::= an integer indicating the x coordinate offset for the finger from the position of the hand
y ::= an integer indicating the y coordinate offset for the finger from the position of the hand

This request will move the hand on the virtual keyboard causing all of the fingers to be re-positioned using a hand-ply style movement. The hand will be positioned at the coordinate of the specified key for the installed keyboard device. If the offsets slot is not specified then the fingers will have the same offset from the hand position as they had before it was moved (any previous peck actions will still be reflected in the new positions). If the offsets value is specified as standard then the index finger of the specified hand will be positioned over the indicated key and the other fingers will be positioned on the keys in the same relative positions as they would be on the home row. If specific finger offsets are provided then those fingers will be over the keys at the specified offset from the position of the hand and fingers not specified will have the same offset they did before the move.

The key can be specified using either a symbol or string that specifies the name of a key as the target location for the hand in the same way they are named for a press-key request.

Here are the events which will show in the trace for a point-hand-at-key request indicating the hand and key that were specified, the progression through the stages of the action, and indicating the distance and direction the hand was moved:

```
    0.050   MOTOR                  POINT-HAND-AT-KEY HAND LEFT TO-KEY t
    ...
    0.250   MOTOR                  PREPARATION-COMPLETE 0.05
    ...
    0.300   MOTOR                  INITIATION-COMPLETE 0.05
    ...
    0.400   MOTOR                  MOVE-A-HAND LEFT 1.4142135 -0.7853982
    ...
    0.450   MOTOR                  FINISH-MOVEMENT 0.05
```

If the model's hand is already at the indicated key position it will acknowledge the request, but no actions are taken, the module does not become busy, and a warning is printed:

```
    0.450   MOTOR                  POINT-HAND-AT-KEY HAND LEFT TO-KEY t
#|Warning: POINT-HAND-AT-KEY requested but hand already is (or will be) at the requested
key position. |#
```

If an invalid key is specified or no keyboard device is installed then a warning is printed and no action is taken:

```
    0.050   MOTOR                  POINT-HAND-AT-KEY HAND LEFT TO-KEY BAD-KEY
#|Warning: No key mapping available for key "BAD-KEY". Point-hand-at-key action ignored. |#
```

or

```
#|Warning: No keyboard device installed for motor module.  Point-hand-at-key action
ignored. |#
```

prepare

cmd prepare
style [*punch* | *peck* | *peck-recoil* | *ply* | *hand-ply*]
{**hand** [***left*** | ***right***] }
{**finger** [***index*** | ***middle*** | ***ring*** | ***pinkie*** | ***thumb***] }
{**r** *distance*}
{**theta** *direction*}

The prepare request can be used to have the motor module prepare but not immediately execute a set of features. Those features are stored the same way that the features for a previously executed action are, and thus will decrease the preparation time of a subsequent action which shares those features. Using the execute request it is also possible to perform the action specified by the history of features, so a prepare could be used to set up an action which one may execute later. For instance, if you know the next motor action is going to be a punch of the right index finger, but you're not sure when, you can prepare the movement in advance and then execute it later.

You must specify a style to prepare, and then you may specify any of the parameters that are relevant for that style.

Here is the trace showing a preparation for a ply style action (movement of the left index finger two cells to the right) which shows that only the preparation step occurs for a prepare request:

```
0.050   MOTOR                   PREPARE PLY HAND LEFT FINGER INDEX R 2 THETA 0
...
0.300   MOTOR                   PREPARATION-COMPLETE 0.05
```

If that is followed by an execute action there is no preparation step at that time, and the previously prepared action is executed. Here is a continuation of that trace showing an execute request occurring next:

```
0.350   MOTOR                   EXECUTE
...
0.400   MOTOR                   INITIATION-COMPLETE 0.05
...
0.500   MOTOR                   MOVE-A-FINGER LEFT INDEX 2 0
...
0.550   MOTOR                   FINISH-MOVEMENT 0.05
```

execute

cmd execute

The execute request causes the model to execute the last movement which was prepared. That will either be a movement which was specified by an explicit prepare request or the last action which was requested. Because all of the features are already prepared there is no preparation step required as shown in the sequence of events (in this case the last prepared features were for a punch with the left index finger using the keyboard device):

```
0.350   MOTOR                   EXECUTE
...
0.400   MOTOR                   INITIATION-COMPLETE 0.05
...
0.410   KEYBOARD                output-key FOO f
...
0.500   MOTOR                   FINISH-MOVEMENT 0.05
```

If there are no currently prepared features then the execute request prints a warning and no action is taken:

```
0.000   MOTOR                   EXECUTE
#|Warning: Motor Module has no movement to EXECUTE. |#
```

Chunks & Chunk-types

The motor module and the provided devices create chunk-types for each of the requests they make available with the same name as the request and having a cmd slot with a default value set to a chunk which also has that same name and is defined using that same chunk-type. Here are the chunk-type definitions that are executed by the motor module:

```
(chunk-type motor-command (cmd "motor action"))
(chunk-type (punch (:include motor-command)) (cmd punch) hand finger)
```

```
(chunk-type (click-mouse (:include motor-command)) (cmd click-mouse))
(chunk-type (peck (:include motor-command)) (cmd peck) hand finger r theta)
(chunk-type (peck-recoil (:include motor-command)) (cmd peck-recoil) hand finger r theta)
(chunk-type (press-key (:include motor-command)) (cmd press-key) key)
(chunk-type (move-cursor (:include motor-command)) (cmd move-cursor) hand object loc)
(chunk-type (hand-to-mouse (:include motor-command)) (cmd hand-to-mouse))
(chunk-type (hand-to-joystick1 (:include motor-command)) (cmd hand-to-joystick1))
(chunk-type (hand-to-joystick2 (:include motor-command)) (cmd hand-to-joystick2))
(chunk-type (hand-to-home (:include motor-command)) (cmd hand-to-home))
(chunk-type (hand-to-keypad (:include motor-command)) (cmd hand-to-keypad))
(chunk-type (point-hand-at-key (:include motor-command)) (cmd point-hand-at-key)
            hand to-key offsets)
(chunk-type (prepare (:include motor-command)) (cmd prepare) style hand finger r theta)
(chunk-type (execute (:include motor-command)) (cmd execute))
```

These are the chunks which are created if not already defined. These chunks are marked as immutable if defined by the motor module:

```
(define-chunks
  (punch isa punch)
  (click-mouse isa click-mouse)
  (peck isa peck)
  (peck-recoil isa peck-recoil)
  (press-key isa press-key)
  (move-cursor isa move-cursor)
  (hand-to-mouse isa hand-to-mouse)
  (hand-to-joystick1 isa hand-to-joystick1)
  (hand-to-joystick2 isa hand-to-joystick2)
  (hand-to-home isa hand-to-home)
  (hand-to-keypad isa hand-to-keypad)
  (point-hand-at-key isa point-hand-at-key)
  (prepare isa prepare)
  (execute isa execute)
  (left name left)
  (right name right)
  (index name index)
  (middle name middle)
  (ring name ring)
  (pinkie name pinkie)
  (thumb name thumb))
```

Commands

start-hand-at-mouse

Syntax:

start-hand-at-mouse -> [**t** | **nil**]

Remote command name:

start-hand-at-mouse

Description:

The start-hand-at-mouse command is used to position the right hand of the current model on the virtual mouse device instead of at the default location. It should be called before running the model, and typically it would be placed into the model definition. It is not intended for moving the model's

hand, only specifying its initial location. If the model's hand is successfully placed on the mouse, then **t** is returned. If there is no current model then no change is made, a warning is printed, and **nil** is returned. If there is not a mouse cursor device installed, then one will be installed automatically and a warning will be printed to indicate that and **t** will be returned.

Examples:

```
> (start-hand-at-mouse)
T

E> (start-hand-at-mouse)
#|Warning: No current model.  Cannot set hand at mouse. |#
NIL

E> (start-hand-at-mouse)
#|Warning: Installing a default mouse because of start-hand-at-mouse. |#
T
```

start-hand-at-joystick1

Syntax:

start-hand-at-joystick1 -> [**t** | **nil**]

Remote command name:

start-hand-at-joystick1

Description:

The start-hand-at-joystick1 command is used to position the right hand of the current model on the virtual first order joystick cursor device instead of at the default location. It should be called before running the model, and typically it would be placed into the model definition. It is not intended for moving the model's hand, only specifying its initial location. If the model's hand is successfully placed on the joystick cursor, then **t** is returned. If there is no current model then no change is made, a warning is printed, and **nil** is returned. If there is not a joystick1 cursor device installed, then one will be installed automatically and a warning will be printed to indicate that and **t** will be returned.

Examples:

```
> (start-hand-at- joystick1)
T

E> (start-hand-at-joystick1)
#|Warning: No current model.  Cannot set hand at joystick1. |#
NIL

E> (start-hand-at-joystick1)
#|Warning: Installing a default joystick1 because of start-hand-at-joystick1. |#
T
```

start-hand-at-joystick2

Syntax:

start-hand-at-joystick2 -> [**t** | **nil**]

Remote command name:

start-hand-at-joystick2

Description:

The start-hand-at-joystick2 command is used to position the right hand of the current model on the virtual second order joystick cursor device instead of at the default location. It should be called before running the model, and typically it would be placed into the model definition. It is not intended for moving the model's hand, only specifying its initial location. If the model's hand is successfully placed on the joystick cursor, then **t** is returned. If there is no current model then no change is made, a warning is printed, and **nil** is returned. If there is not a joystick2 cursor device installed, then one will be installed automatically and a warning will be printed to indicate that and **t** will be returned.

Examples:

```
> (start-hand-at- joystick2)
T

E> (start-hand-at-joystick2)
#|Warning: No current model.  Cannot set hand at joystick2. |#
NIL

E> (start-hand-at-joystick2)
#|Warning: Installing a default joystick2 because of start-hand-at-joystick2. |#
T
```

start-hand-at-keypad

Syntax:

start-hand-at-keypad -> [**t** | **nil**]

Remote command name:

start-hand-at-keypad

Description:

The start-hand-at-keypad command is used to position the right hand of the current model on the virtual keyboard's keypad with the fingers over the 4, 5, 6, and enter keys and the thumb over 0. It should be called before running the model, and generally it would be placed into the model definition. It is not intended for moving the model's hand, only specifying its initial location. If the model's hand is successfully placed on the keypad, then **t** is returned. If there is no current model, then no change is made, a warning is printed, and **nil** is returned. If there is no keyboard device installed then one will be installed automatically, a warning will be printed to indicate that, and **t** will be returned.

Examples:

```
> (start-hand-at-keypad)
T

E> (start-hand-at-keypad)
#|Warning: No current model.  Cannot set hand at keypad. |#
NIL

E> (start-hand-at-keypad )
#|Warning: Keyboard device installed automatically by start-hand-at-keypad |#
T
```

start-hand-at-key

Syntax:

start-hand-at-key *hand key* -> [**t** | **nil**]

Remote command name:

start-hand-at-key

Arguments and Values:

hand ::= [**left | right]**
key ::= the name of a key on the keyboard device

Description:

The start-hand-at-key command is used to position a hand of the current model on the virtual keyboard over a specified key instead of the default home row position. It should be called before running the model, and generally it would be placed into the model definition. It is not intended for moving the model's hand, only specifying its initial location. If the model's hand is successfully placed over the indicated key, then **t** is returned. If there is no current model or an invalid key name is provided, then no change is made, a warning is printed, and **nil** is returned. If there is no keyboard device installed then one will be installed automatically, a warning will be printed to indicate that, and **t** will be returned.

Examples:

```
> (start-hand-at-key 'right 'return)
T

E> (start-hand-at-key 'left "a")
#|Warning: No current model.  Cannot start hand at key. |#
NIL

E> (start-hand-at-key 'right "bad-key")
#|Warning: Invalid key "bad-key" in start-hand-at-key. |#
NIL

E> (start-hand-at-key 'left "a")
#|Warning: Keyboard device installed automatically by start-hand-at-key. |#
T
```

set-hand-location

Syntax:

set-hand-location *hand x y* {*device*} -> [**t** | **nil**]
set-hand-location-fct *hand xy-loc* {*device*} -> [**t** | **nil**]

Arguments and Values:

hand ::= [**left | right]**
x ::= a number specifying the x coordinate of the cell for the specified hand's position
y ::= a number specifying the y coordinate of the cell for the specified hand's position
xy-loc ::= a list of two numbers specifying the starting x and y coordinates respectively of the cell for the specified hand's position
device ::= a device list indicating the device which that hand is currently using

Description:

The set-hand-location command can be used to set the position of the specified hand of the current model and indicate which device it is using. It should not be called while the model is running to avoid conflicts with any model generated hand movements, but can be called before running the model or when it is stopped. The x and y coordinates specify the cell over which the specified hand and its index finger are placed, and the other fingers will be located relative to that location as they would for a hand on the home row of a keyboard (each finger in a separate cell of the same row offset one column in the appropriate direction for the hand and the thumb being two rows below the index finger and one column away in the opposite direction from the other fingers). If the position of the hand is set for the model then **t** is returned. If there is no current model or the position or device provided is invalid then no change is made, a warning is printed, and **nil** is returned.

Examples:

```
> (set-hand-location left 0 0)
T

> (set-hand-location-fct 'right '(10 4))
T

> (set-hand-location right 3 3 ("motor" "keyboard"))
T

E> (set-hand-location right a b)
#|Warning: Invalid location (A B) provided to set-hand-location-fct. |#
NIL

E> (set-hand-location-fct 'right '(10 4) '("bad" "device"))
#|Warning: Invalid device ("bad" "device") given to set-hand-location-fct. |#
NIL

E> (set-hand-location left 0 0)
#|Warning: No current model.  Cannot set hand location. |#
NIL
```

set-cursor-position

Syntax:

set-cursor-position *x y* { z {*cursor-name*}} -> [xyz-loc | **nil**]
set-cursor-position-fct *new-loc* {*cursor-name*} -> [xyz-loc | **nil**]

Remote command names:

set-cursor-position
set-cursor-position-fct

Arguments and Values:

x ::= a number specifying the x coordinate for the cursor
y ::= a number specifying the y coordinate for the cursor
z ::= a number specifying the z coordinate for the cursor

new-loc ::= a list of two or three values representing a new location for the cursor
cursor-name ::= a string naming an installed cursor device which defaults to “mouse”
xyz-loc ::= a list of three values representing the current location of the cursor

Description:

The set-cursor-position command can be used to set the position of an installed cursor device for the current model. If a z coordinate is not provided or provided as a non-numeric value, then it will get a default value based on the :viewing-distance and :pixels-per-inch parameters of the model. It should not be called while the model is running to avoid conflicts with any model generated cursor movements, but can be called before running the model or when it is stopped. If the named cursor is installed and its position is updated then a list with the current cursor coordinates is returned. If there is no current model, the named cursor is not installed for the motor interface, or an invalid value is provided then no change is made, a warning is printed, and **nil** is returned.

Examples:

```
> (set-cursor-position 1 1)
 (1 1 1080)

> (set-cursor-position-fct '(10 10))
(10 10 1080)

> (set-cursor-position 1 1 200)
(1 1 200)

> (set-cursor-position 30 30 200 "mouse")
(30 30 200)

> (set-cursor-position 30 30 nil "mouse")
(30 30 1080)

E> (set-cursor-position 10 20)
#|Warning: No current model.  Cannot set cursor position. |#
NIL

E> (set-cursor-position 0 0)
```

```
#|Warning: No cursor device named "mouse" is currently installed for the motor interface.
|#
NIL

E> (set-cursor-position-fct 'invalid)
#|Warning: Location for set-cursor-position-fct must be a list of two values but INVALID
provided. |#
NIL
```

extend-manual-requests

Syntax:

extend-manual-requests *chunk-type-def request-function* -> [**t** | **nil**]
extend-manual-requests-fct *chunk-type-def request-function* -> [**t** | **nil**]

Arguments and Values:

chunk-type-def ::= a list with a valid definition for a new chunk-type
request-function ::= a symbol which is the name of a function to call to handle the new request

Description:

The extend-manual-requests command allows one to add new requests to those which are accepted by the manual buffer. Extend-manual-requests only needs to be called once for each new request being added, and it does not have to occur within the context of a model. The chunk-type-def parameter must be a list which is valid for passing to chunk-type-fct. That chunk-type definition will have an additional slot called cmd specified with a default value that matches the name of the chunk-type from the definition and then be passed to chunk-type-fct. If that chunk-type name is not also defined as a chunk then one will be defined using that same name as the chunk-type and it will be marked as immutable. Thus, if one were to provide this chunk-type-def value:

```
(new-motor-action hand finger pressure)
```

This chunk-type would be defined:

```
(chunk-type new-motor-action hand finger pressure (cmd new-motor-action))
```

and this chunk would be created and marked as immutable:

```
(define-chunks (new-motor-action isa new-motor-action))
```

When a request to the manual buffer is made with the cmd slot specifying the chunk-type-name indicated then the function specified by request-function will be called with the current model's motor module as the first parameter and the chunk-spec of the request as the second parameter. There are no restrictions on what the new request may do, nor are there any default operations performed – it is entirely up to the extension to handle all scheduling of events as necessary to change the state of the motor module and perform the actions necessary. [Note however, that the internal representation of the motor module and its state is not currently part of the API and thus there is no documentation on how to use it directly in that manner at this time. Also, because the motor module itself is passed to the request function it cannot be passed to an external command. Both of those issues will be addressed in the future to make this more accessible and usable.]

Once a new request has been added it cannot be overwritten by a new request with the same name. However, it can be removed using the remove-manual-request command and then be defined again.

If chunk-type-def is not a valid list, request-function does not name a currently defined function or the chunk-type being specified is already used for an extension then extend-manual-requests will print a warning, no new request extension will be made, and **nil** will be returned.

If successfully created, the new request will be available to all models which are subsequently defined and **t** will be returned.

The recommended use of this command is to place a file which has the necessary request function and any support code needed along with a call to extend-manual-requests into one of the directories for which the files are loaded automatically. That way the request function is compiled with the rest of the sources and is made available to all models right from the start. If it is called while there are models already defined the new request will not be available to those models.

Most of the default requests which the motor module accepts are created using extend-manual-requests.

Examples:

These examples assume that there are functions named handle-right-click and handle-hold already defined.

```
> (extend-manual-requests (right-click) handle-right-click)
T

1> (extend-manual-requests-fct '((hold-key (:include motor-command)) key) 'handle-hold)
T

2E> (extend-manual-requests-fct '((hold-key (:include motor-command) key)) 'handle-hold)
#|Warning: Request HOLD-KEY is already an extension of the manual buffer.  To redefine you
must remove it first with remove-manual-request. |#
NIL

E> (extend-manual-requests bad-type handle-right-click)
#|Warning: Invalid chunk-type specification BAD-TYPE.  Manual requests not extended. |#
NIL

E> (extend-manual-requests-fct '(chord finger1 finger2) 'not-a-function)
#|Warning: NOT-A-FUNCTION does not name a function.  Manual requests not extended. |#
NIL
```

remove-manual-request

Syntax:

remove-manual-request *chunk-type-name* -> [**t** | **nil**]
remove-manual-request-fct *chunk-type-name* -> [**t** | **nil**]

Arguments and Values:

chunk-type-name ::= a symbol which is the name of a chunk-type used to extend the manual requests

Description:

Remove-manual-request is used to remove a request that has been added to the manual buffer through the use of extend-manual-requests. The chunk-type-name parameter should be the name of a chunk-type which was defined with a call to extend-manual-requests. The request of that chunk-type will be removed from the set of requests that the manual buffer will process for all models and that chunk-type will no longer be defined in any new models (its definition will still remain in any existing models until they are reset).

If chunk-type-name does name an extended request, then after removing the request this command will return **t**. If chunk-type-name is not the name of a previously extended request then a warning will be printed and **nil** will be returned.

This command is typically only needed when one is developing some extensions to the manual module and needs to change some of the requests under development. It is not recommended for use in other situations.

Examples:

These examples assume that there are functions named handle-right-click and handle-hold already defined.

```
1> (extend-manual-requests (right-click) handle-right-click)
T

2> (extend-manual-requests-fct '((hold-key (:include motor-command)) key) 'handle-hold)
T

3> (remove-manual-request-fct 'right-click)
T

4> (remove-manual-request hold-key)
T

5E> (remove-manual-request hold-key)
#|Warning: HOLD-KEY is not a previously extended request for the manual module. |#
NIL

E> (remove-manual-request-fct 'bad-chunk-name)
#|Warning: BAD-CHUNK-NAME is not a previously extended request for the manual module. |#
NIL
```

Speech module

The speech module gives a model a rudimentary ability to speak. This system is not designed to provide a sophisticated simulation of human speech production, but to allow a model to speak words and short phrases for simulating verbal responses in experiments and for subvocalizing text internally. The module has one buffer, vocal, and works in much the same way as the motor module.

The name of the module is :speech.

The vocal world

The model's speech output is fairly limited. When it speaks or subvocalizes it will hear its own words through the audio module. The speak actions (and possibly subvocalize actions) are also detectable through the installation of a device for the "speech" interface, described below.

Operation

Like the motor module, the speech module takes requests that specify a style of action and the appropriate attributes for that style. There are only two styles available for the speech module:

- Speak to produce normal speech output.
- Subvocalize to produce internal speech – the model speaking to itself with no external output.

The only attribute for each of those styles is a string of text to speak.

The speech module does not place any chunks into its buffer in response to the requests. The vocal buffer should always be empty, and it is the state of the module that is most important to the model in this case. As described above for all the perceptual and motor modules, the speech module has three internal states: preparation, processor, and execution. How a request progresses through those states is described in detail below.

An important thing to note is that while the vocal buffer does not receive a chunk in response to a speech action the aural-location buffer might. Because the model hears its own speech acts the automatic buffer stuffing of the aural-location buffer may occur as a result of a vocal request.

When a request is received by the speech module, it goes through three phases: preparation, initiation, and execution. The amount of time that speech output preparation takes depends on the history of previous speech acts. The speech module records the last string which it has output. If there is no previous string which has been spoken, then the module requires the preparation of three features (which by default take 50ms each). If there is a previously spoken string, then there are no features to prepare if the same string is being output again or two features if it is not the same string.

After preparation is complete, the speech module makes the specified vocal output. The first 50ms of that output is initiation. During this interval, the preparation state becomes free and the processor and execution states become busy. After initiation ends, the processor state becomes free. It is at that time that speech output is made available to the device and the auditory system. Note that the typical detection delay and recoding times still apply for the encoding of sounds as described in the audio

module, but speech output though subvocalizing has a separate parameter for the detection delay and a recoding time of 0 seconds. The amount of time that the speech takes to finish after initiation depends on the articulation time of the string which defaults to .15 seconds per assumed syllable, but can be changed in various ways (see the get-articulation-time command below for details).

The speech module can only prepare one output at a time. If the speech module is in the process of preparing output and another request is received, the later request will be ignored and the speech module is said to be "jammed." When the module is jammed it will output a warning indicating when the jamming occurred like this:

```
#|Warning: Module :SPEECH jammed at time 0.1 |#
```

The way to avoid jamming, as with all modules, is to test the state of the module before making a request. Testing that state free is true will avoid jamming the module, but it is possible to issue speech requests faster than that – because the state will not be free until the previous output has been completed. Instead, one usually only needs to test that the preparation state is free to be able to issue a new request to the speech module, but a more conservative approach would be to test the processor state because it is still busy during the initiation time of the last output request.

Interface & Devices

The speech module has an interface called “speech” which can be used to install a single device. If a device is installed for the speech interface then it will be notified at the start and end of every speech output. It will also be notified at installation time with a list containing only the item check-subvocalize. If the device responds to that notification with a non-nil result then the device will also be notified at the start and end of subvocalize actions, otherwise it will not be notified for subvocalize actions. The features provided to the device will be described with the requests that generate them.

Microphone

There is one device provided for use with the speech interface called “microphone”. If a microphone device is installed for the speech interface (which will happen automatically for the experiment window devices of the AGI) it will respond to the start of speech output by generating an “output-speech” signal at that time which has two parameters: the name of the model which spoke and the string of the text that is being spoken. Installing a microphone device and monitoring the output-speech signal is the recommended way to detect and record a model’s speech output.

Parameters

:char-per-syllable

This parameter controls how the model breaks a text string into syllables and is measured in a number of characters (see get-articulation-time for how it applies). It can be set to any positive number and defaults to 3.

:subvocalize-detect-delay

This parameter sets the detect delay timing for the sound events generated by a subvocalize action (see the audio module for details on the detect delay). It is measured in seconds and can be set to any non-negative value. It defaults to .3 (which is the same value that normal text has).

:syllable-rate

This parameter controls the time it takes the model to articulate each syllable in a text string and is measured in seconds (see get-articulation-time below for how it applies). It can be set to any non-negative number and defaults to 0.15.

Vocal buffer

The speech module does not place any chunks into the vocal buffer. The preparation timing for the actions will be set using the randomize-time function, but all other action times will be fixed regardless of the :randomize-time parameter setting.

Activation spread parameter: :vocal-activation
Default value: 0.0

Queries

'State busy' will be **t** when any of the internal states of the module (listed below) also report as being busy. Essentially, it will be **t** while there is any request to the vocal buffer that has not yet completed. It will be **nil** otherwise.

'State free' will be **t** when all of the internal states of the module (listed below) also report as being free. Essentially, it will be **t** only when all requests to the vocal buffer have completed. It will be **nil** otherwise.

'State error' will always be **nil**.

Unlike the perceptual modules, the internal states of the speech module may be useful to track in a model because it is possible to send new requests while the module is partially busy. Only the preparation stage of the module needs to be free to avoid jamming. For each request that is received the module will progress through three stages as described above: preparation, initiation, and execution.

'Preparation busy' will be **t** after a request has been received and until it completes the preparation of the features needed for that request which depends on how many features there are and whether or not they overlap with the last features prepared. It will be **nil** otherwise.

'Preparation free' will be **nil** after a request has been received and until it completes the preparation of the features needed for that request which depends on how many features there are and whether or not they overlap with the last features prepared. It will be **t** otherwise.

‘Processor busy’ will be **t** while preparation is busy and will continue to be **t** after the features have been prepared until the additional initiation time (fixed at .05 seconds) has passed. It will be **nil** otherwise.

‘Processor free’ will be **nil** while preparation is busy and will continue to be **nil** after the features have been prepared until the additional initiation time (fixed at .05 seconds) has passed. It will be **t** otherwise.

‘Execution busy’ will be **t** once the preparation of a request’s features has completed and will remain **t** until the time necessary to complete the action has passed. It will be **nil** otherwise.

‘Execution free’ will be **nil** once the preparation of a request’s features has completed and will remain **nil** until the time necessary to complete the action has passed. It will be **t** otherwise.

‘Last-command *command*’ *command* should be a symbol which corresponds to one of the vocal buffer’s requests or the symbol none. The query will be **t** if that is the name of the last request received by the vocal buffer otherwise it will be **nil**.

Here is a summary indicating the state transitions for a single vocal request assuming that the module is entirely free at the start of the request:

Preparation state	**Processor state**	**Execution state**	**When**
FREE	FREE	FREE	Before event arrives
BUSY	BUSY	FREE	When event is received
FREE	BUSY	BUSY	After preparation time
FREE	FREE	BUSY	After initiation (.05 seconds)
FREE	FREE	FREE	When speech completes (articulation time)

Requests

clear

[cmd clear | **clear t**]

A clear request can be sent to clear the history of the last string vocalized. A clear request will make the preparation state busy for 50ms. These events will show in the trace for a clear request to the vocal buffer:

```
0.050   SPEECH                CLEAR
...
0.100   SPEECH                CHANGE-STATE LAST NONE PREP FREE
```

Note, that after the clear request completes the last-command recorded by the module will be none and not clear – the clear request has effectively cleared the history of its own request as well.

While this request makes the preparation state busy, unlike other requests it does not require that it be free. That makes it possible to use the clear request to terminate an action which has not yet started its execution.

speak

cmd speak
string *text*

A speak request causes the model to generate vocal output. The output that is made is the string specified by text. That speech output is made available to the model's audio module as a word sound with a location of self. That may trigger buffer stuffing of the aural-location buffer. It will also generate two notifications for an installed device. The first notification occurs when the initiation phase ends and execution begins. That notification will be a list of three elements:

(**start speak** *text*)

where text is the string that is being spoken. The second notification will occur when the execution phase ends and will also be a list of three elements:

(**end speak** *text*)

Here are the events which will show in the trace for a speak request showing the text that is to be output and the progression through the stages of the action:

```
0.050   SPEECH                 SPEAK TEXT hello
...
0.200   SPEECH                 PREPARATION-COMPLETE
...
0.250   SPEECH                 INITIATION-COMPLETE
...
0.250   SPEECH                 SPEAK hello
...
0.500   SPEECH                 FINISH-MOVEMENT
```

If a microphone device is installed then instead of the speak event an output-speech event will show in the trace indicating the current model and the text spoken:

```
0.250   MICROPHONE             output-speech SPEECH-TEST hello
```

If an invalid text value is given then this warning will show in the trace and no action will be taken by the module:

```
#|Warning: String slot in a speak request must be a string. |#
```

subvocalize

cmd subvocalize
string *text*

A subvocalize request causes the current model to generate internal speech (the model is talking to itself). That speech output is made available to the model's audio module as a word sound with a location of internal. That may trigger buffer stuffing of the aural-location buffer. It will also generate two notifications for an installed device if that device responded with a non-nil value to the check-

subvocalize notification when it was installed. The first notification occurs when the initiation phase ends and execution begins. That notification will be a list of three elements:

(**start subvocalize** *text*)

where text is the string that is being subvocalized. The second notification will occur when the execution phase ends and will also be a list of three elements:

(**end subvocalize** *text*)

Here are the events which will show in the trace for a subvocalize request showing the text that is to be subvocalized and the progression through the stages of the action:

```
0.050   SPEECH                SUBVOCALIZE TEXT hello
...
0.200   SPEECH                PREPARATION-COMPLETE
...
0.250   SPEECH                INITIATION-COMPLETE
...
0.500   SPEECH                FINISH-MOVEMENT
```

If an invalid text value is given then this warning will show in the trace and no action will be taken by the module:

```
#|Warning: String slot in a subvocalize request must be a string. |#
```

Chunks & Chunk-types

The speech module creates a chunk-type for each of the requests it accepts with the same name as the request and which has a cmd slot with a default value set to a chunk which also has that same name and is defined using that same chunk-type. Here are the chunk-type definitions that are executed by the speech module:

```
(chunk-type speech-command (cmd "speech command"))
(chunk-type (speak (:include speech-command)) (cmd speak) string speak)
(chunk-type (subvocalize (:include speech-command)) (cmd subvocalize) string subvocalize)
```

These are the chunks which are created if not already defined. These chunks are marked as immutable if defined by the speech module:

```
(define-chunks
  (speak isa speak)
  (subvocalize isa subvocalize)
  (internal name internal)
  (self name self))
```

Commands

get-articulation-time/register-articulation-time

Syntax:

get-articulation-time *string* {*time-in-ms*} -> [time | **nil**]

register-articulation-time *string time* {*time-in-ms*} -> [time | **nil**]

Remote command names:

get-articulation-time
register-articulation-time

Arguments and Values:

string ::= a string for which a specific articulation time is required (case insensitive)
time-in-ms ::= a generalized boolean indicating the units to use for the time
time ::= a non-negative number indicating the time that it takes to articulate the string

Description:

These commands are used to get the articulation time for a text string and to set an explicit time to articulate a string in the current model. That time will be used by the audio module as the duration of such a string if it is heard by the model and will be the length of time that the model requires to speak such a string using the speech module.

Register-articulation-time sets the articulation time for the provided string in the current model. If the optional parameter is provided as non-nil then the units for the time given will be milliseconds otherwise they will be seconds. If such a value is set then time is returned. If there is no current model or one of the parameters is invalid, then a warning is printed and **nil** is returned.

Get-articulation-time returns the time it takes to articulate a string of text for the current model. That time will be either the explicit time that was set using register-articulation-time if one was set, or computed based on the length of the string and the values of the parameters :syllable-rate and :char-per-syllable using this equation:

$$AT = Max(r * L / c, r)$$

AT := articulation time for the string
r := value of the :syllable-rate parameter
L := the length of the string
c := value of the :char-per-syllable parameter

The max guarantees that the minimum time for an utterance is the syllable-rate value.

If the optional parameter time-in-ms is provided as non-nil then the return value will be measured in milliseconds, otherwise it will be measured in seconds.

If the string is invalid or there is no current model then a warning is printed and **nil** is returned instead.

Examples:

```
1> (sgp :char-per-syllable :syllable-rate)
:CHAR-PER-SYLLABLE 3 (default 3) : Characters per syllable.
```

```
:SYLLABLE-RATE 0.15 (default 0.15) : Seconds per syllable.
(3 0.15)

2> (get-articulation-time "Hello")
0.25

3> (get-articulation-time "Hello" t)
250

4> (get-articulation-time "Goodbye")
0.35

5> (get-articulation-time "A")
0.15

6> (register-articulation-time "Hello" 185 t)
185

7> (get-articulation-time "Hello")
0.185

E> (register-articulation-time "Hello" .25)
#|Warning: No current model.  Cannot set articulation time. |#
NIL

E> (get-articulation-time "Hello")
#|Warning: No current model.  Cannot get articulation time. |#
NIL

E> (get-articulation-time 'hello)
#|Warning: Must specify a string for which to get the articulation time. |#
NIL

E> (register-articulation-time 'hello .2)
#|Warning: Must specify a string for which the articulation time is to be set. |#
NIL

E> (register-articulation-time "Hello" -1)
#|Warning: Articulation time must be a non-negative number. |#
NIL

E> (get-articulation-time "Hello" t)
#|Warning: No current model.  Cannot get articulation time. |#
NIL

E> (register-articulation-time "Hello" .185)
#|Warning: No current model.  Cannot set articulation time. |#
NIL
```

Temporal Module

The temporal module provides a model with a means of determining time intervals and is based on research by Taatgen, van Rijn, & Anderson (2007). It does so by providing a timer which counts the number of "ticks" which have passed since the timer was started.

The name of the module is temporal.

Temporal Ticks

The ticks counted by the temporal module have lengths which are noisy and also increase in duration as time progresses. Thus it is more accurate for timing shorter intervals than longer ones. The current tick count is available to the model via a chunk in the temporal buffer which has a slot called ticks. Once the timer is started the module will continue to update the ticks slot of the chunk in the buffer with the current count automatically. The timer can be explicitly reset to start a new count or stopped by the model at any time, and if the chunk is removed from the buffer it will implicitly stop the count from incrementing.

The tick lengths are generated based on the following equations for the nth tick (the tick count is equal to n, and the first tick happens at t_1):

$$t_0 = start + \varepsilon_1$$

$$t_n = a \cdot t_{n-1} + \varepsilon_2$$

start := value of the :time-master-start-increment parameter (default 0.011 seconds)
a := value of the :time-mult parameter (default 1.1)
b := value of the :time-noise parameter (default 0.015)
ε_1 := noise generated with the act-r-noise command with an s of b * 5 * start
ε_2 := noise generated with the act-r-noise command with an s of b * a * t_{n-1}

Parameters

:record-ticks

This parameter controls whether or not the time incrementing event generates an action which the buffer trace module will detect. If it is set to **t** then there will be an extra event in the trace for each clock increment which will be associated with activity in the temporal buffer. It can be set to **t** or **nil** and the default value is **t**.

:time-master-start-increment

This parameter controls the length of the 0^{th} tick in seconds. It can be set to any positive number and defaults to 0.011.

:time-mult

This parameter sets the multiplier for increasing the tick length. It can be set to any positive number and defaults to 1.1.

:time-noise

This parameter scales the s value of the noise added to the tick lengths. It can be set to any positive number and defaults to 0.015.

Temporal buffer

The temporal module sets the temporal buffer to **not** be strict harvested and **not** subject to strict safety.

Activation spread parameter: :temporal-activation
Default value: 0.0

Queries

The temporal buffer only responds to the default queries and like the goal module is always available and never in an error state.

'State busy' will always be **nil**.

'State free' will always be **t**.

'State error' will always be **nil**.

Requests

time

ticks *value*

A time request requires that the ticks slot be specified with any value (which will be ignored). A time request will reset the internal tick counter to 0, put a chunk into the temporal buffer with a ticks slot value of 0, and start the timer which will increment the value in the ticks slot of that chunk as described above. This event will happen at the time of the request indicating the creation of the new chunk:

```
0.050   TEMPORAL              SET-BUFFER-CHUNK-FROM-SPEC TEMPORAL
```

The updating of the timer will happen at the appropriate times in the future and will generate multiple events in the trace for each update. If the :record-ticks parameter is set to **t** then there will be three events for each timer update:

```
0.063   TEMPORAL               Incrementing time ticks to 1
0.063   TEMPORAL               MODULE-MOD-REQUEST TEMPORAL
0.063   TEMPORAL               MOD-BUFFER-CHUNK TEMPORAL
```

whereas if :record-ticks is set to **nil** there will only be two events for each update:

```
0.063   TEMPORAL               Incrementing time ticks to 1
0.063   TEMPORAL               MOD-BUFFER-CHUNK TEMPORAL
```

clear

[cmd clear | clear t]

The clear request will stop the temporal counter if it is incrementing. This is often done in a model when a time estimation finishes i.e. the ticks count is no longer needed. Stopping the counter will eliminate the incrementing and modification events from being scheduled. The reason one may want to stop the counter is because as long as those events are being scheduled there will be events in the queue to keep the model running and the procedural module will continue to attempt conflict resolution when those events occur. Typically, that will just be wasted effort by the software if the model is not intended to be doing anything during that time, thus it can improve the software performance without affecting the model's operation. It may also be useful if one is recording the temporal module's activity for comparison to BOLD or other neurophysiological data because otherwise the module will show continuous activity instead of only during a meaningful time estimation period. The clear action will occur at the time of the request and will generate an event like this in the trace:

```
15.559   TEMPORAL               Clear
```

Note: clearing the chunk from the temporal buffer will have the same effect as issuing an explicit clear request to the temporal module because that will also stop the incrementing, but it will not result in the event being generated by the temporal module if that is important for buffer tracing purposes.

Modification requests

Technically, the temporal module allows modification requests because they are used internally to update the ticks count when the :record-ticks parameter is set to t. However, that capability is not intended for general use and modification requests should not be made to the temporal buffer.

Chunks & Chunk-types

The temporal module defines one chunk-type and no chunks:

```
(chunk-type time (ticks 0))
```

Commands

The temporal module provides no user commands. All of its operation is controlled through the requests that it accepts.

Advanced Topics

The previous sections of the manual have covered the basic operation of the system and the operation of most of the modules that are provided. That is the information which should be of general use to those using ACT-R to build models. However, there are other capabilities which one can use in the system in addition to being able to extend the system itself. The following sections will describe more of the low level subsystems that are available for working with ACT-R and will cover more advanced topics in using the system like running multiple models, defining new modules for the model to use, and adjusting how the model operates in real-time mode. These sections will assume that one has a good grasp of the concepts from the earlier sections.

One note about the advanced topics is that the purpose is to describe the facilities that the system makes available. Because the system is available as source code it is entirely possible for the user to modify or change the definition of the system itself. That is not the sort of thing that will be covered in this, or any, section of the reference manual.

Extending Possible Chunk Slots

As has been mentioned in other places in the manual it is possible for a model to add new slots to chunks as it runs. The mechanism which does that is also available to the user for use in new modules or other extensions of the system. In ACT-R 6.0 this was referred to as extending the chunk-types, but now that chunks no longer have a specific type the mechanism is more appropriately referred to as extending the possible slots of chunks.

Extending the possible chunk slots creates a new possible slot name for use in chunks. It will happen automatically when chunks or productions are defined which specify names for slots which do not currently exist. In those situations a warning will be displayed to indicate that the extension has occurred. It will also happen through dynamic chunk modifications which use slot names that are not currently valid, and when that happens there will be an event in the trace to indicate the extension occurred. It is also possible to explicitly extend the set of possible slot names in code to avoid the warnings which would occur for defining chunks or productions that use new slot names

Commands

extend-possible-slots

Syntax:

extend-possible-slots *new-slot* {*warn?*} -> [new-slot | **nil**]

Remote command names:

extend-possible-slots

Arguments and Values:

new-slot ::= the name of a slot to add to chunks
warn? ::= a generalized boolean which indicates whether or not to print a warning for an existing slot

Description:

The extend-possible-slots command is used to add a new slot name for use in chunks. It requires one parameter which should be non-nil name which starts with an alphanumeric character and names the new slot to add for chunks. A second optional parameter may be provided and if it is non-nil then a warning will be output if the new slot name specified already names a valid slot in chunks (it is **t** by default). If the new slot name provided is a valid name and not already the name of a possible slot for chunks then it is added to the possible slot names for the current model and that slot name is returned.

If the slot name is not valid or there is no current model then a warning is printed and **nil** is returned.

Examples:

```
1> (extend-possible-slots 'new-slot-name)
```

```
NEW-SLOT-NAME

2E> (extend-possible-slots 'new-slot-name)
#|Warning: NEW-SLOT-NAME already names a possible slot for chunks. |#
NIL

3> (extend-possible-slots 'new-slot-name nil)
NIL

E> (extend-possible-slots nil)
#|Warning: Nil is not a valid slot name when trying to extend slots. |#
NIL

E> (extend-possible-slots '&bad-slot-name)
#|Warning: &BAD-SLOT-NAME cannot be used as a slot name because it does not start with an
alphanumeric character. |#
NIL

E> (extend-possible-slots 'new-slot-name)
#|Warning: Chunk-type info not available so the slot NEW-SLOT-NAME cannot be added. |#
NIL
```

Chunk-Specs

A chunk-spec is an internal representation for the specification of a chunk (*chunk-spec*ification). Chunk-specs consist of a set of constraints for the slots of a chunk along with specifications for request parameters. An individual slot or request parameter specification in a chunk-spec is referred to as a slot-spec. Chunk-specs can be used for a variety of purposes and are a key component in the communication between modules. They were used implicitly in several of the commands of the modules described above and occasionally showed up in the text of a warning message. The best example of chunk-specs shown in the modules is in the commands for defining productions. The LHS buffer tests and RHS module requests are both direct applications of chunk-specs. That also describes the two primary uses of chunk-specs: testing (or finding) whether chunks match a specification and making a request to a module.

The description of a slot in a chunk-spec can use modifiers and variables in much the same way that the production pattern matching does. The same modifiers used in productions are available in a chunk-spec: =,-,<,>,<=, and >= for specifying slots. The default behavior is the same as used in productions: = means that the slots must be equal, - means they must differ, and the inequality tests are only valid for numbers. However, one is not restricted to only that usage. How each of those modifiers is used to match or find a chunk with a chunk-spec can be controlled individually in the commands which do so. An example where one might want to change that would be to allow using the inequality tests among a set of qualitative sizes like {tiny, small, normal, big, gigantic}. Names starting with an '=' character are considered as variables for both the slot name and for the slot value positions of a slot-spec by default when using the provided matching commands, but that character can also be changed for those commands and one can also implement their own matching mechanisms using chunk-specs which do not need to use that convention (note however that when creating a chunk-spec only the '=' character is considered a variable and thus any other name specified in the slot name position must be valid for slot names).

Unlike a slot's specification, the specification for a request parameter cannot include a modifier other than =. Variables however may still be used for the values in a request parameter specification. The request parameter specifications are ignored by the provided commands for matching chunks to a chunk-spec, and their purpose is determined entirely by the code that uses the chunk-spec.

The most common place where one will need to use chunk-specs is when developing a new module. All requests to the module will be encoded as chunk-specs. Thus any module which accepts requests will have to process chunk-specs. If the module also holds a set of chunks internally for some purpose, like the vision module does for the features of the visual scene, then one may also find the matching and search commands which are available with chunk-specs to be useful.

Because the semantics of the modifiers and the specification of a variable in a chunk-spec are configurable, a chunk-spec does not really have any particular meaning on its own. Without knowing the context in which the chunk-spec will be used it is impossible to know what it represents. Thus any particular chunk-spec is effectively meaningless outside of the context in which it is created and used.

The internal representation of a chunk-spec is not part of the API for the system therefore one should only operate on them using the provided commands. It is not possible to pass an internal chunk-spec

directly through the remote interface, but there are commands which will convert a chunk-spec to an id value which can be used anywhere a chunk-spec can (as long as that id is still valid). The remote versions of the commands will always return a chunk-spec id. The only difference between using an internal chunk-spec and a chunk-spec id is that when using a chunk-spec id one should release it when done using it for efficiency reasons, and once it is released it will no longer be a reference to a valid chunk-spec.

Commands

define-chunk-spec

Syntax:

define-chunk-spec *specification* -> [chunk-spec | **nil**] {(extended*)}
define-chunk-spec-fct *(specification)* {*extend*} {*warn*} -> [chunk-spec | **nil**] {(extended*)}

Remote command names:

define-chunk-spec ' *specification* '
define-chunk-spec-fct ' *(specification)* ' {*extend*} {*warn*}

Arguments and Values:

specification ::= [chunk-name | {**isa** chunk-type} [{modifier} slot value | {**=**} request-param value]*]
extend ::= a generalized boolean indicating whether to extend the possible slots for invalid slot names
warn ::= a generalized boolean indicating whether to print a warning if possible slots are extended
chunk-name ::= the name of a chunk in the current model
chunk-type ::= the name of a chunk-type in the current model
modifier ::= [**=** | **-** | **<** | **>** | **<=** | **>=**]
slot ::= the name of a valid slot for the chunk-type specified, the name of a slot valid for any chunk if no chunk-type provided and extend is **nil**, a variable, any name which can represent a slot if extend is true
request-param ::= a keyword (name beginning with a colon) naming a valid request-parameter
variable ::= a name which begins with the = character
value ::= any value (a name which has a first character of = is considered to be a variable)
chunk-spec ::= an internal chunk-spec (Lisp calls) or a chunk-spec id (remote calls)
extended ::= the name of a slot that was passed to extend-possible-slots

Description:

The define-chunk-spec command is used to create a chunk-spec. There are two ways to define a chunk-spec. If a chunk-name is given as the only parameter then a chunk-spec will be created that matches that chunk exactly. It will include a slot-spec for each slot in that chunk with the = modifier and the current value of that slot in the chunk. Alternatively, an optional chunk-type may be provided and then any number of slot-specs and request parameters may be specified for the chunk-spec.

The two optional parameters for the function allow one to indicate whether the set of possible slots should be extended automatically with newly named slots in the definition of the chunk-spec and

whether warnings are displayed when that occurs. If the extend parameter is provided as true (which is the default value) then any slots which are specified that are not variables and not currently possible slot names will be extended using the extend-possible-slots command. If the warn parameter is provided, then that is passed as the warn? parameter to extend-possible-slots when a new slot needs to be added for the chunk-spec. The default value of the warn parameter is **t** if not provided.

The define-chunk-spec macro does not accept the optional parameters for extending and warning. When define-chunk-spec is used the default of **t** is used for each of the optional parameters.

A slot specified using a variable (a symbol which begins with an "=" character) is not tested as a possible slot and will not result in extending the possible slots through the definition of the chunk-spec.

If the syntax of the specification is valid and all of the components are valid two values are returned. The first is a chunk-spec (or chunk-spec id) and the second is a list of all the slot names which were passed to extend-possible-slots.

If the syntax is incorrect, any of the components are invalid, or there is not a current model then a warning is displayed and a single value of **nil** is returned.

As indicated in the general description of a chunk-spec, the chunk-spec representation itself is not part of the API. Thus the specific return value of this command should not be used directly and is only intended to be passed to other chunk-spec processing commands, and if it is a remote call the chunk-spec id should be released when no longer needed.

Examples:

```
1> (chunk-type goal value state)
GOAL

2> (define-chunks (g isa goal value 2 state start))
(G)
```

The following three chunk-spec calls all result in the same chunk-spec being returned:

```
3> (define-chunk-spec g)
#S(ACT-R-CHUNK-SPEC ...)
NIL

4> (define-chunk-spec-fct '(isa goal = value 2 = state start))
#S(ACT-R-CHUNK-SPEC ...)
NIL

5> (define-chunk-spec value 2 state start)
#S(ACT-R-CHUNK-SPEC ...)
NIL
```

The purpose of the next chunk-spec is ambiguous without knowing a context in which it will be used because the @ may be used to represent a variable, or perhaps the symbol @value has a particular meaning where it will be used:

```
1> (chunk-type compare val1 val2)
COMPARE

2> (define-chunk-spec-fct '(isa compare val1 @value <= val2 @value - val2 10))
```

```
#S(ACT-R-CHUNK-SPEC ...)
NIL

> (define-chunk-spec-fct '(new-slot1 start value true))
#|Warning: Chunks extended with slot NEW-SLOT1 during a chunk-spec definition. |#
#S(ACT-R-CHUNK-SPEC ...)
(NEW-SLOT1)

> (define-chunk-spec-fct '(new-slot1 start value true) t nil)
#S(ACT-R-CHUNK-SPEC ...)
(NEW-SLOT1)

> (define-chunk-spec =variable-slot =variable-value)
#S(ACT-R-CHUNK-SPEC ...)
NIL

E> (define-chunk-spec-fct '(new-slot1 start value true) nil)
#|Warning: Invalid slot-name NEW-SLOT1 in call to define-chunk-spec. |#
NIL

E> (define-chunk-spec not-a-chunk)
#|Warning: define-chunk-spec's 1 parameter doesn't name a chunk: (NOT-A-CHUNK) |#
NIL

E> (define-chunk-spec isa bad-name)
#|Warning: Element after isa in define-chunk-spec isn't a chunk-type. (ISA BAD-NAME) |#
NIL

E> (define-chunk-spec)
#|Warning: define-chunk-spec-fct called with no current model. |#
NIL
```

chunk-spec-to-id

Syntax:

chunk-spec-to-id *chunk-spec* -> [id | **nil**]

Arguments and Values:

chunk-spec ::= a chunk-spec which was returned from define-chunk-spec
id ::= a chunk-spec id which can be passed through the remote interface

Description:

The chunk-spec-to-id command is used to generate a chunk-spec id for a chunk spec which can be passed to commands through the remote interface. If a valid chunk-spec is provided then a unique id value is returned which can be used to reference that chunk-spec. [Currently, that id will be an integer, but that might change in the future.] If the value passed in is not a valid chunk-spec then **nil** is returned instead.

When an id returned from this command is no longer needed it should be released for efficiency reasons.

Examples:

```
> (chunk-spec-to-id (define-chunk-spec isa text))
1

E> (chunk-spec-to-id "not-a-chunk-spec")
NIL
```

release-chunk-spec-id

Syntax:

release-chunk-spec-id *id* -> result

Remote command name:

release-chunk-spec-id

Arguments and Values:

id ::= a chunk-spec id returned from a remote call to define-chunk-spec or chunk-spec-to-id
result ::= a generalized boolean which will be true if the id was valid and released otherwise **nil**

Description:

The release-chunk-spec-id command is used to free up the memory resources used for a chunk-spec and its mapping to an id when that chunk-spec is no longer needed. If the id provided is a valid chunk-spec id then that chunk-spec will be removed from the mapping table and can be garbage collected (assuming that there are not any other internal references to it), that id will no longer refer to a valid chunk-spec, and a true value will be returned. If the id provided is not valid then **nil** will be returned.

Examples:

```
1> (chunk-spec-to-id (define-chunk-spec isa chunk))
4

2> (release-chunk-spec-id 4)
T

3> (release-chunk-spec-id 4)
NIL
```

chunk-name-to-chunk-spec

Syntax:

chunk-name-to-chunk-spec *name* -> [chunk-spec | **nil**]

Remote command name:

chunk-name-to-chunk-spec

Arguments and Values:

name ::= the name of a chunk in the current model
chunk-spec ::= an internal chunk-spec (Lisp calls) or a chunk-spec id (remote calls)

Description:

The chunk-name-to-chunk-spec command is a function which works the same as define-chunk-spec does when provided a chunk name as its only parameter. A chunk-spec will be created that matches that chunk exactly. It will include a slot-spec for each slot in that chunk with the = modifier and the current value of that slot in the chunk. Chunk-name-to-chunk-spec can be used as a short-cut to calling define-chunk-spec-fct with a list of a chunk name.

If the chunk-name provided names a chunk in the current model then a chunk-spec which matches that chunk is returned. If the parameter provided does not name a chunk in the current model or there is no current model then a warning will be displayed and **nil** is returned.

Examples:

```
> (chunk-name-to-chunk-spec 'free)
#S(ACT-R-CHUNK-SPEC ...)

E> (chunk-name-to-chunk-spec :not-a-chunk)
#|Warning: Chunk-name-to-chunk-spec called with a non-chunk :NOT-A-CHUNK. |#
NIL

E> (chunk-name-to-chunk-spec 'free)
#|Warning: get-chunk called with no current model. |#
#|Warning: Chunk-name-to-chunk-spec called with a non-chunk FREE. |#
NIL
```

pprint-chunk-spec

Syntax:

pprint-chunk-spec *chunk-spec* -> **nil**

Remote command name:

pprint-chunk-spec

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id

Description:

The pprint-chunk-spec command can be used to print a chunk-spec to the model's command output trace. If the chunk-spec provided is valid then a description of that chunk-spec will be output on the model's command output trace. Each slot-spec will be output on a separate line. The = modifiers

will not be printed in the output, but all other modifiers will be. If the provided parameter is not a valid chunk-spec, then no output will be performed. If there is no current model then a warning will be printed and no output will occur. The command will always return **nil**.

Examples:

```
1> (chunk-type test slot1 slot2 value)
TEST

2> (defvar *s1* (define-chunk-spec slot1 true - slot2 nil <= slot1 =value :attended new))
*S1*

3> (pprint-chunk-spec *s1*)
    SLOT1 TRUE
 -  SLOT2 NIL
 <= SLOT1 =VALUE
    :ATTENDED NEW
NIL

E> (pprint-chunk-spec :not-a-spec)
NIL

E> (pprint-chunk-spec *s1*)
#|Warning: Pprint-chunk-spec called with no current model. |#
NIL
```

printed-chunk-spec

Syntax:

printed-chunk-spec *chunk-spec* {*flat*} -> [output | **nil**]

Remote command name:

printed-chunk-spec

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id
flat ::= a generalized boolean which indicates whether the result should contain newlines
output ::= a string containing the printed chunk-spec representation

Description:

The printed-chunk-spec command is very similar to the pprint-chunk-spec command except that instead of printing the representation to the command trace it will be returned in a string. If the optional parameter is provided as a non-nil value then the string will not add newline characters between the slot specs. If the provided parameter is not a valid chunk-spec then it will return **nil**, and if there is no current model a warning will be printed and it will return **nil**.

Examples:

```
1> (chunk-type test slot1 slot2 value)
TEST
```

```
2> (defvar *s1* (define-chunk-spec slot1 true - slot2 nil <= slot1 =value :attended new))
*S1*

3> (printed-chunk-spec *s1*)
"    SLOT1 TRUE
 -  SLOT2 NIL
 <= SLOT1 =VALUE
    :ATTENDED NEW
"

4> (printed-chunk-spec *s1* t)
"SLOT1 TRUE - SLOT2 NIL <= SLOT1 =VALUE :ATTENDED NEW"

E> (printed-chunk-spec :not-a-spec)
NIL

E> (printed-chunk-spec *s1*)
#|Warning: Printed-chunk-spec called with no current model. |#
NIL
```

match-chunk-spec-p

Syntax:

match-chunk-spec-p *chunk-name chunk-spec* {**:=test** *test-fn*} {**:-test** *test-fn*} {**:<=test** *test-fn*} {**:>=test** *test-fn*} {**:>test** *test-fn*} {**:<test** *test-fn*} {**:variable-char** *var*} -> result

Remote command name:

match-chunk-spec-p *chunk-name chunk-spec* { < **=test** *test-fn*, **-test** *test-fn*, **<test** *test-fn*, **<=test** *test-fn*, **>test** *test-fn*, **>=test** *test-fn*, **variable-char** *var* > }

Arguments and Values:

chunk-name ::= the name of a chunk in the current model
chunk-spec ::= a valid chunk-spec or chunk-spec id
test-fn ::= a command identifier which must take two parameters and return a generalized boolean
var ::= a Lisp character or string containing one character
result ::= a generalized boolean indicating whether or not the match was a success

Description:

The match-chunk-spec-p command is used to determine if a chunk matches a chunk-spec. If it matches, then a true value is returned and if it does not match **nil** is returned.

A chunk matches the chunk-spec if every slot specified in the chunk-spec with a non-**nil** value exists in that chunk, every slot specified in the chunk-spec with a **nil** value does not exist in that chunk, and the test of every slot in the specification with the corresponding slot value in the chunk results in a true value. Any request parameters which are a part of the chunk-spec are ignored for the purposes of matching the chunk with this command. To test the slot values, the command which corresponds to the modifier on that slot in the chunk-spec will be called with the chunk's slot's value as the first parameter and the chunk-spec's slot-spec value as the second parameter unless the slot value specified is a variable. If the slot-spec's value is a variable, then the value bound to that variable (as described next) will be passed to the testing command. If a slot name is specified as a variable that test will be performed on the slot named by the value to which that variable is bound.

If there are any variables in the chunk-spec they are first tested for consistency and to determine their bindings before performing the slot tests. Each variable in the chunk-spec must appear as a value in at least one slot-spec which uses the = modifier. If there is a variable which does not meet that requirement the match fails. If more than one slot-spec using the = modifier contains the same variable as a value, then all slots where the = test is used with that variable as a value must have the same value (using the function for the = test) or the match will fail. If those conditions are true, then the value in that slot(s) will be bound to the variable for the remainder of the slot tests in the chunk-spec. If a variable is bound in a slot which is named with a variable then that slot name variable will be bound before the slot value can be bound. Unlike productions the specification of variablized slot names is not restricted to a single level of indirection, but if there are dependencies among the variablized slot names such that there is no valid order in which to bind the slots the matching fails.

If there is not a variable-character provided then the default character of '=' is used to denote variables in the chunk-spec.

If no test commands are specified then the default chunk matching functions are used. Those functions work as follows:

- The = test is chunk-slot-equal
- The – test is the negation of using chunk-slot-equal
- All of the inequality tests are true if
  - Both values are numbers and
  - The specified inequality holds between them with the chunk's slot value being the left of the items in the test and the chunk-spec's slot value the right.

If chunk-name, chunk-spec or one of the testing commands is invalid or there is no current model then a warning is displayed and **nil** is returned.

Examples:

```
1> (chunk-type test slot1 slot2 slot3)
TEST

2> (define-chunks (tiny) (small) (medium) (large)
                  (slot1) (slot2)
                  (a isa test slot1 10 slot2 5)
                  (b isa test slot1 large slot2 small)
                  (c isa test slot1 medium slot2 small slot3 tiny)
                  (d isa test slot1 10 slot2 slot1)
                  (e isa test slot1 10 slot2 slot1 slot3 slot2))
(TINY SMALL MEDIUM LARGE SLOT1 SLOT2 A B C D E)

3> (defun smaller-size (x y)
     (let ((valid '(tiny small medium large huge)))
       (and (find x valid)
            (find y valid)
            (< (position x valid) (position y valid)))))
SMALLER-SIZE

4> (match-chunk-spec-p 'a (define-chunk-spec - slot1 7 >= slot2 1))
T

5> (match-chunk-spec-p 'a (define-chunk-spec slot1 4))
NIL
```

```
6> (match-chunk-spec-p 'a (define-chunk-spec slot1 =v < slot2 =v))
T

7> (match-chunk-spec-p 'a (define-chunk-spec slot1 10 :attended t))
T

8> (match-chunk-spec-p 'a (define-chunk-spec slot3 nil))
T

9> (match-chunk-spec-p 'c (define-chunk-spec slot3 nil))
NIL

10> (match-chunk-spec-p 'b (define-chunk-spec slot1 =v < slot2 =v))
NIL

11> (match-chunk-spec-p 'b (define-chunk-spec slot1 =v < slot2 =v) :<test 'smaller-size)
T

12> (match-chunk-spec-p 'b (define-chunk-spec slot1 $v < slot2 $v) :<test 'smaller-size)
NIL

13> (match-chunk-spec-p 'b (define-chunk-spec slot1 $v < slot2 $v) :<test 'smaller-size
                        :variable-char #\$)
T

14> (match-chunk-spec-p 'd (define-chunk-spec =slot 10 =slot2 =slot slot3 =slot2))
NIL

15> (match-chunk-spec-p 'e (define-chunk-spec =slot 10 =slot2 =slot slot3 =slot2))
T

E> (match-chunk-spec-p 'bad-chunk (define-chunk-spec))
#|Warning: BAD-CHUNK does not name a chunk in call to match-chunk-spec-p. |#
NIL

E> (match-chunk-spec-p 'a 'not-a-chunk-spec)
#|Warning: NOT-A-CHUNK-SPEC is not a valid chunk-spec or chunk-spec id in call to match-
chunk-spec-p. |#
NIL

E> (match-chunk-spec-p 'a (define-chunk-spec slot1 10) :=test 'not-a-function)
#|Warning: Error #<UNDEFINED-FUNCTION @ #x2283eb5a> encountered in matching chunk A. |#
NIL

E> (match-chunk-spec-p 'a (define-chunk-spec isa chunk) :variable-char 3)
#|Warning: 3 is not a valid variable character in call to match-chunk-spec-p. |#
NIL

E> (match-chunk-spec-p nil nil)
#|Warning: Match-chunk-spec-p called with no current model. |#
NIL
```

find-matching-chunks

Syntax:

find-matching-chunks *chunk-spec* {**:chunks** [**:all** | (*chunk**)]} {**:=test** *test-fn*} {**:-test** *test-fn*} {**:<=test** *test-fn*} {**:>=test** *test-fn*} {**:>test** *test-fn*} {**:<test** *test-fn*} {**:variable-char** *var*} -> result

Remote command name:

find-matching-chunks *chunk-spec* { [(*chunk**) | **"all"**] { (< **=test** *test-fn*, **-test** *test-fn*, **<test** *test-fn*, **<=test** *test-fn*, **>test** *test-fn*, **>=test** *test-fn*, **variable-char** *var* >) }}

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id
chunk ::= a symbol which should name a chunk in the current model
test-fn ::= a command identifier which must take two parameters and return a generalized boolean
var ::= a Lisp character or string containing one character
result ::= (chunk*)

Description:

The find-matching-chunks command tests each chunk provided in the list of chunks provided or all chunks in the current model if it is omitted or specified as :all (or "all" for remote calls), against the chunk-spec provided. It returns the list of chunk names which match the chunk-spec using the same matching as described in match-chunk-spec-p which includes the possibility of specifying alternate testing commands and a variable character other than the default of "=".

If the chunks list contains items which do not name chunks, then for each such item a warning will be printed and that item will be ignored, but the matching will still occur for the valid chunks.

If chunk-spec, chunks, or a testing command is invalid or there is no current model then a warning is displayed and **nil** is returned.

Examples:

```
1> (chunk-type test slot1 slot2 slot3)
TEST

2> (define-chunks (tiny) (small) (medium) (large)
                  (slot1) (slot2)
                  (a isa test slot1 10 slot2 5)
                  (b isa test slot1 large slot2 small)
                  (c isa test slot1 medium slot2 small slot3 tiny)
                  (d isa test slot1 10 slot2 slot1)
                  (e isa test slot1 10 slot2 slot1 slot3 slot2))
(TINY SMALL MEDIUM LARGE SLOT1 SLOT2 A B C D E)

3> (defun smaller-size (x y)
     (let ((valid '(tiny small medium large huge)))
       (and (find x valid)
            (find y valid)
            (< (position x valid) (position y valid)))))
SMALLER-SIZE

4> (find-matching-chunks (define-chunk-spec - slot1 nil))
(A C E B D)

5> (find-matching-chunks (define-chunk-spec - slot1 nil) :chunks '(a b free busy))
(B A)

6> (find-matching-chunks (define-chunk-spec < slot1 large) :<test 'smaller-size)
(C)

7E> (find-matching-chunks (define-chunk-spec < slot1 large) :<test 'bad-function-name)
```

```
#|Warning: Function BAD-NAME passed to dispatch-apply is not a local function or valid remote command string |#
#|Warning: Function BAD-NAME passed to dispatch-apply is not a local function or valid remote command string |#
#|Warning: Function BAD-NAME passed to dispatch-apply is not a local function or valid remote command string |#
#|Warning: Function BAD-NAME passed to dispatch-apply is not a local function or valid remote command string |#
#|Warning: Function BAD-NAME passed to dispatch-apply is not a local function or valid remote command string |#
NIL

E> (find-matching-chunks :not-a-chunk-spec)
#|Warning: :NOT-A-CHUNK-SPEC is not a valid chunk-spec or chunk-spec id in call to find-matching-chunks. |#
NIL

E> (find-matching-chunks (define-chunk-spec) :chunks '(not-a-chunk))
#|Warning: NOT-A-CHUNK does not name a chunk in call to match-chunk-spec-p. |#
NIL

E> (find-matching-chunks (define-chunk-spec) :chunks 'not-a-list)
#|Warning: NOT-A-LIST is not a valid value for the :chunks keyword parameter to find-matching-chunks. |#
NIL

E> (find-matching-chunks :not-a-chunk-spec)
#|Warning: Find-matching-chunks called with no current model. |#
NIL
```

chunk-spec-slots

Syntax:

chunk-spec-slots *chunk-spec* -> (slot*)

Remote command name:

chunk-spec-slots

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id
slot ::= the name of a slot or request parameter specified in chunk-spec

Description:

The chunk-spec-slots command returns a list of the names of the slots and request parameters that are used in the provided chunk-spec. Each slot will occur only once in the return list no matter how many times it may be tested in chunk-spec, and the list is in no particular order. That list will include any variables which are used in the slot name position.

If chunk-spec is not a valid chunk-spec or chunk-spec-id then a warning is printed and **nil** is returned.

Examples:

```
> (chunk-spec-slots (define-chunk-spec))
NIL

> (chunk-spec-slots (define-chunk-spec color blue size =x))
(COLOR SIZE)

> (chunk-spec-slots (define-chunk-spec - color red - color green))
(COLOR)
```

```
> (chunk-spec-slots (define-chunk-spec :attended t =slot t))
(:ATTENDED =SLOT)

E> (chunk-spec-slots 'not-a-spec)
#|Warning: Chunk-spec-slots called with something other than a chunk-spec or chunk-spec-id |#
NIL
```

slot-in-chunk-spec-p

Syntax:

slot-in-chunk-spec-p *chunk-spec slot* -> result

Remote command name:

slot-in-chunk-spec-p

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id
slot ::= the name of a slot, variable, or request parameter
result ::= a generalized boolean indicating whether slot was found in chunk-spec

Description:

The slot-in-chunk-spec-p command tests whether the given slot occurs in some slot-spec of the chunk-spec provided. It returns a non-**nil** value if that slot is specified in chunk-spec and **nil** if it is not.

If chunk-spec is not a valid chunk-spec or valid chunk-spec id or if slot does not name a valid slot for chunks, a valid request parameter, or a variable then a warning is printed and **nil** is returned.

Examples:

```
> (slot-in-chunk-spec-p (define-chunk-spec size 10) 'color)
NIL

> (slot-in-chunk-spec-p (define-chunk-spec color blue size =x) 'color)
T

> (slot-in-chunk-spec-p (define-chunk-spec slot1 10 =x 20 slot2 =x) '=x)
T

E> (slot-in-chunk-spec-p 'not-a-spec nil)
#|Warning: Slot-in-chunk-spec-p called with something other than a chunk-spec or chunk-spec-id |#
NIL

E> (slot-in-chunk-spec-p (define-chunk-spec screen-x 10) 'not-slot)
#|Warning: NOT-SLOT does not name a valid slot in the current model. |#
NIL
```

chunk-spec-slot-spec

Syntax:

chunk-spec-slot-spec *chunk-spec* {*slot*} -> (spec-list*)

Remote command name:

chunk-spec-slot-spec *chunk-spec* {*slot*} -> ' (spec-list*) '

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id
slot ::= the name of a slot, variable, or request parameter to find in chunk-spec
spec-list ::= (modifier slot-name value)
slot-name ::= the name of a slot, variable, or request parameter
modifier ::= [**=** | **-** | **<** | **>** | **<=** | **>=**]
value ::= any value

Description:

The chunk-spec-slot-spec command is used to get the slot specifications from a chunk-spec. It returns a list of specification lists. A specification list is a list of three elements. The first item in a specification list is the modifier for the slot-spec, the second element is the slot name in the slot-spec (which could be a variable or request parameter), and the third element is the value in the slot-spec. If no slot is specified, then a specification list is returned for each slot-spec in the chunk-spec and the specification lists will be in the same order as the slot-specs were provided when the chunk-spec was defined.

If a slot is specified, then only the specification lists which reference that slot are returned, again in the order that they were provided when the chunk-spec was defined. If a slot is specified for chunk-spec-slot-spec and there are no slot-specs in the chunk-spec which use that slot then **nil** will be returned.

If chunk-spec is not a valid chunk-spec then a warning is printed and **nil** is returned.

Examples:

```
1> (defvar *test-spec* (define-chunk-spec < screen-x 10
                                          > screen-x 0
                                          screen-x =var
                                          color blue
                                          - screen-y =var
                                          :attended t))

*TEST-SPEC*

2> (chunk-spec-slot-spec *test-spec*)
((< SCREEN-X 10) (> SCREEN-X 0) (= SCREEN-X =VAR) (= COLOR BLUE) (- SCREEN-Y =VAR)
 (= :ATTENDED T))

3> (chunk-spec-slot-spec *test-spec* 'color)
((= COLOR BLUE))

4> (chunk-spec-slot-spec *test-spec* 'screen-x)
((< SCREEN-X 10) (> SCREEN-X 0) (= SCREEN-X =VAR))
```

```
5> (chunk-spec-slot-spec *test-spec* :attended)
((= :ATTENDED T))

6> (chunk-spec-slot-spec *test-spec* 'size)
NIL

E> (chunk-spec-slot-spec 'not-a-spec)
#|Warning: Chunk-spec-slot-spec was not passed a valid chunk-spec or chunk-spec id |#
NIL
```

slot-spec-modifier/slot-spec-slot/slot-spec-value

Syntax:

slot-spec-modifier *slot-spec-list* -> modifier
slot-spec-slot *slot-spec-list* -> slot
slot-spec-value *slot-spec-list* -> value

Remote command name:

slot-spec-modifier
slot-spec-slot
slot-spec-value

Arguments and Values:

slot-spec-list ::= a three element list describing a slot-spec as returned by chunk-spec-slot-spec
modifier ::= [**=** | **-** | **<** | **>** | **<=** | **>=**]
slot ::= the name of the slot, request parameter, or variable in the slot name position of slot-spec-list
value ::= the value from the value position of slot-spec-list

Description:

The slot-spec-* commands can be used to access the corresponding components of a slot-spec list as returned by chunk-spec-slot-spec. They are not really necessary since a slot-spec list is just a three element list, but it can be cleaner in code to see an accessor name than a generic index function like first, second, third, or something like nth.

If the slot-spec-list isn't a three element list then all of these will print a warning and return **nil**. [There is currently no way to distinguish an actual slot-spec-value of **nil** from one returned because of an invalid list other than the warning message, but if the slot-spec-list comes from one of the other commands it should always be valid.]

Examples:

```
1> (setf *spec-list* (first (chunk-spec-slot-spec (define-chunk-spec color blue))))
(= COLOR BLUE)

2> (slot-spec-modifier *spec-list*)
=

3> (slot-spec-slot *spec-list*)
COLOR

4> (slot-spec-value *spec-list*)
```

```
BLUE

E> (slot-spec-modifier nil)
#|Warning: Invalid slot-spec list NIL passed to slot-spec-modifier. |#
NIL

E> (slot-spec-slot nil)
#|Warning: Invalid slot-spec list NIL passed to slot-spec-slot. |#
NIL

E> (slot-spec-value nil)
#|Warning: Invalid slot-spec list NIL passed to slot-spec-value. |#
NIL
```

chunk-spec-variable-p

Syntax:

chunk-spec-variable-p *value* {*var*} -> result

Remote command name:

chunk-spec-variable-p

Arguments and Values:

value ::= any value
var ::= a character (Lisp command) or one character string (remote)
result ::= a generalized boolean

Description:

The chunk-spec-variable-p command can be used to determine if a value would be considered as a variable in a chunk-spec. If the value is a name with length greater than one and the first character of the name is the same as var (or '**=**' if var is not specified) then a true value is returned otherwise **nil** is returned.

Examples:

```
> (chunk-spec-variable-p 'value)
NIL

> (chunk-spec-variable-p '=value)
T

> (chunk-spec-variable-p '@value #\@)
T

> (chunk-spec-variable-p '=value #\@)
NIL

> (chunk-spec-variable-p "=value")
NIL
```

chunk-spec-to-chunk-def

Syntax:

chunk-spec-to-chunk-def *chunk-spec* -> [chunk-def | **nil**]

Remote command name:

chunk-spec-to-chunk-def *chunk-spec* -> [' chunk-def ' | **nil**]

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id
chunk-def ::= a chunk definition list which is valid for passing to define-chunks

Description:

The chunk-spec-to-chunk-def command can be used to convert a chunk-spec into a list which can be passed to define-chunks for creating a chunk. To be able to create a chunk definition the chunk-spec must meet the following conditions:

- It must specify each slot no more than once
- It must not have any modifiers other than =
- There must not be any variables in the specification

Any request parameters in the chunk-spec are ignored unless they contain variables, in which case they fall under the third case above. If chunk-spec is a valid chunk-spec and meets the three criteria shown then this command returns a list which contains a definition for a chunk based on the slot-specs in the chunk-spec. If chunk-spec is not a valid chunk-spec or one or more of the three conditions specified above is not true then a warning is printed and **nil** is returned. Note that although **nil** would be a valid return value for a chunk-spec that has no slots, instead such a situation will return the list (isa chunk) to provide a non-**nil** value upon success.

The primary use of this command is by modules like goal and imaginal which create new chunks based on requests.

Examples:

```
> (chunk-spec-to-chunk-def (define-chunk-spec))
(ISA CHUNK)

> (chunk-spec-to-chunk-def (define-chunk-spec color blue = size 10))
(COLOR BLUE SIZE 10)

> (chunk-spec-to-chunk-def (define-chunk-spec color blue :attended t))
(COLOR BLUE)

E> (chunk-spec-to-chunk-def (define-chunk-spec - color blue))
#|Warning: Chunk-spec may only use the = modifier in a call to chunk-spec-to-chunk-def. |#
NIL

E> (chunk-spec-to-chunk-def (define-chunk-spec color blue color red))
#|Warning: Chunk-spec may only specify a slot once in a call to chunk-spec-to-chunk-def. |#
```

```
NIL

E> (chunk-spec-to-chunk-def (define-chunk-spec color blue :attended =val))
#|Warning: Chunk-spec has variables in the values in a call to chunk-spec-to-chunk-def. |#
NIL

E> (chunk-spec-to-chunk-def (define-chunk-spec =slot value))
#|Warning: Chunk-spec has variablized slots in a call to chunk-spec-to-chunk-def. |#
NIL

E> (chunk-spec-to-chunk-def 'not-a-chunk-spec)
#|Warning: Chunk-spec-to-chunk-def called with something other than a chunk-spec. |#
NIL
```

verify-single-explicit-value

Syntax:

verify-single-explicit-value *chunk-spec slot-name module-name cmd* { *var* } -> [value | **nil**] [**t** | **nil**]

Remote command name:

verify-single-explicit-value *chunk-spec slot-name module-name cmd* { *var* } -> [' value ' | **nil**] [**t** | **nil**]

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id
slot-name ::= the name of a slot or request parameter
module-name ::= a name of a module to display in the warning
cmd ::= a value to display as a command in a warning
var ::= a character or string of a character to consider as the variable indicator
value ::= the value from the specified slot of the chunk-spec

Description:

The verify-single-explicit-value command can be used to get the value of a particular slot or request parameter slot-spec in a chunk-spec while also testing for the following conditions:

- the slot occurs exactly once in the chunk-spec
- it uses the = modifier
- it has a non-variable value based on the var character specified or '=' if var is not provided

If any of those conditions are violated then a warning is printed using the module-name and cmd value provided to create the warning message. After printing the warning message it returns two **nil** values.

If all of those conditions are satisfied then the function will return the value of that slot in the chunk-spec as its first return value and **t** as its second return value to indicate success since **nil** could be the value of the slot in the chunk-spec.

This command is used by several of the provided modules in processing their requests and may be of use to those implementing new modules.

Examples:

```
1> (setf *test-spec* (define-chunk-spec color blue - size 10 :attended =x value 3 value 4
                                        name &x))
#S(ACT-R-CHUNK-SPEC ...)

2> (verify-single-explicit-value *test-spec* 'color 'test-module 'test-command)
BLUE
T

3E> (verify-single-explicit-value *test-spec* 'size 'test-module 'test-command)
#|Warning: TEST-COMMAND command to TEST-MODULE module requires a value for the SIZE slot. |#
NIL
NIL

4E> (verify-single-explicit-value *test-spec* 'value 'test-module 'test-command)
#|Warning: VALUE slot may only be specified once in a TEST-COMMAND command to the TEST-
MODULE module. |#
NIL
NIL

5E> (verify-single-explicit-value *test-spec* :attended 'test-module 'test-command)
#|Warning: ATTENDED slot must be explicit - not a variable in a TEST-COMMAND command to
the TEST-MODULE module. |#
NIL
NIL

6> (verify-single-explicit-value *test-spec* :attended 'test-module 'test-command #\&)
=X
T

7> (verify-single-explicit-value *test-spec* 'name 'test-module 'test-command)
&X
T

8E> (verify-single-explicit-value *test-spec* 'name 'test-module 'test-command #\&)
#|Warning: NAME slot must be explicit - not a variable in a TEST-COMMAND command to the
TEST-MODULE module. |#
NIL
NIL

9E> (verify-single-explicit-value 'not-a-spec 'name 'test-module 'test-command #\&)
#|Warning: NOT-A-SPEC is not a chunk-spec in TEST-COMMAND command to the TEST-MODULE
module. |#
NIL
NIL
```

test-for-clear-request

Syntax:

test-for-clear-request *chunk-spec* -> result

Remote command name:

test-for-clear-request

Arguments and Values:

chunk-spec ::= a valid chunk-spec or chunk-spec id

result ::= a generalized boolean indicating whether the chunk-spec indicates a typical clear request

Description:

The test-for-clear-request command can be used to determine if a chunk-spec has the format of the "clear" requests handled by many modules. It will return true if it is passed a chunk-spec that has only one slot-spec in it and that slot-spec is either: "**= cmd clear**" or "**= clear** *true*" where *true* is any non-**nil** value. Otherwise it will return **nil**.

This command is used by several of the provided modules in processing their requests and may be of use to those implementing new modules.

Examples:

```
> (test-for-clear-request (define-chunk-spec clear t))
T

> (test-for-clear-request (define-chunk-spec cmd clear))
T

> (test-for-clear-request (define-chunk-spec isa clear))
T

> (test-for-clear-request (define-chunk-spec clear nil))
NIL

> (test-for-clear-request (define-chunk-spec - cmd clear))
NIL

> (test-for-clear-request (define-chunk-spec clear t cmd clear))
NIL

> (test-for-clear-request 'not-a-chunk-spec)
NIL
```

chunk-difference-to-chunk-spec

Syntax:

chunk-difference-to-chunk-spec *chunk1 chunk2* -> [chunk-spec | **nil**]

Remote command name:

chunk-difference-to-chunk-spec

Arguments and Values:

chunk1 ::= the name of a chunk
chunk2 ::= the name of a chunk
chunk-spec ::= a chunk-spec (internal) or chunk-spec id (remote)

Description:

The chunk-difference-to-chunk-spec command can be used to create a chunk-spec that contains the modifications necessary to convert chunk2 into chunk1. That chunk-spec could be passed to mod-buffer-chunk to perform the modifications if chunk2 were in the desired buffer. If chunk1 and chunk2 are the names of chunks in the current model then a chunk-spec is created which has all of the slots from chunk1 as would be created from chunk-name-to-chunk-spec for that chunk and also includes slot-specs for each of the slots of chunk2 which must be removed specified with **nil**.

If either chunk1 or chunk2 is not the name of a chunk in the current model or there is no current model then warnings will be displayed and **nil** will be returned.

Examples:

```
1> (define-chunks (a value 1 color blue) (b value 3 color blue size 5))
(A B)

2> (chunk-difference-to-chunk-spec 'a 'b)
#S(ACT-R-CHUNK-SPEC ...)

3> (pprint-chunk-spec *)
    SIZE NIL
    COLOR BLUE
    VALUE 1
NIL

E> (chunk-difference-to-chunk-spec :bad :names)
#|Warning: Chunk-difference-to-chunk-spec called with :BAD and :NAMES which are not both
chunks. |#
NIL

E> (chunk-difference-to-chunk-spec 'a 'b)
#|Warning: get-chunk called with no current model. |#
#|Warning: get-chunk called with no current model. |#
#|Warning: Chunk-difference-to-chunk-spec called with A and B which are not both chunks. |#
NIL
```

Using Buffers

In the earlier section on buffers their role in the system was described and the commands which a modeler may use to inspect and query the buffers were presented. This section is going to describe the commands that allow one to manipulate the chunk in a buffer and to use the buffer to interact with modules directly. These commands are generally used when one is creating a new module, but may also be useful for other purposes.

There are several things which one can do with a buffer. They are: read the chunk that it holds, test if the buffer is empty, query the state of the buffer and its module, request an action of the buffer's module, modify the chunk in the buffer, clear the chunk from the buffer, place a new chunk into the buffer, overwrite the chunk in the buffer, and set the failure flag of the buffer. The commands for performing those actions will be detailed below. Creation of buffers is not described in this section because buffers are only created when modules are defined – buffers only exist in conjunction with a module. Thus buffer creation will be described in the section on creating modules.

Any buffer may be accessed for any of the operations at any time. With the provided modules, only the procedural module directly accesses the buffers belonging to other modules, but there is nothing that prevents other module-to-module communication or interaction. Modules receive the requests sent to them regardless of where they come from or how they are created. However most modules only accept one request at a time and the procedural module's requests from productions are delayed relative to their testing of a module's state i.e. a production queries the module to determine if it is free to accept requests but does not send a request until 50ms later (by default). So, if you plan on using the buffers for requests between modules you may want to take care with how the productions in any models which operate in that situation also issue requests.

Also, while it is possible to write to any buffer at any time, generally only the owning module should be storing chunks into its buffer. Often the module responds to a request by placing a chunk into the buffer, and thus if one were to arbitrarily write a chunk into the buffer while it was processing a request it could lead to problems in a model which made a request and was expecting a particular result. Again, the procedural module's productions are the primary source of requests and are typically written to expect a result consistent with the request. Thus, if you write a module or other code which modifies buffers explicitly, care should be taken when using that in conjunction with the normal production processing of a model.

For many of these commands there are two versions. One which performs an immediate action and one which schedules the action to occur as an event. In general, the scheduled versions of the requests and modifications are preferable to the non-scheduled ones because they will then be recorded in the trace and thus be detectable by other things and also be ordered appropriately. However, sometimes it may be necessary to use the immediate version, and in particular, the reading and testing functions often need to be done immediately because the current result is what is important.

In addition to the commands for using the buffers, there are also some additional commands described below for accessing other buffer information. One allows one to find the name of the buffer's owning module. This may be useful when implementing tracing tools or other event monitoring utilities which might have access to only the buffer names. Another allows one to find the value of the buffer's activation spread parameter without knowing the name of the parameter the

module has made available for that purpose. That may be useful when developing alternative equations for the spreading activation calculation or for creating tools for monitoring and tracking the activation calculations. There is also a command that allows one to get the value of a slot in a buffer's chunk directly instead of having to first get the name of the chunk and then using the chunk-slot-value command.

Commands

buffer-read

Syntax:

buffer-read *buffer* -> [chunk-name | **nil**]
schedule-buffer-read *buffer time-delta* {**:module** *module*} {**:priority** *priority*}
{**:output** *output*} {**:time-in-ms** *time-units*} -> [event-id | **nil**]
buffer-read-report *buffer* {**:module** *module*} -> [chunk-name | **nil**]

Remote command name:

buffer-read

Arguments and Values:

buffer ::= the name of a buffer
chunk-name ::= the name of a chunk which is in the buffer
time-delta ::= a number indicating when to schedule the event
module ::= a symbol which will be used as the module of the event in the trace
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
output ::= [**t** | **high** | **medium** | **low** | **nil**]
time-units ::= a generalized boolean indicating whether time-delta is in seconds or milliseconds
(default is **nil** which means seconds)
event-id ::= an integer which can be used to reference the event created

Description:

The buffer-read commands are used to read the name of the chunk which is currently in the named buffer of the current model.

For buffer-read, the name of the chunk is returned directly. If the buffer is empty the return value is **nil.** If the buffer named is invalid or there is no current model then a warning is printed and **nil** is returned.

Schedule-buffer-read is used to record a buffer reference in the trace of the model. It schedules an event to occur as if the following was executed:

```
(schedule-event-relative time-delta 'buffer-read-action
                         :time-in-ms time-units
                         :module module
```

```
                        :priority priority
                        :params (list buffer)
                        :output output)
```

The default values for the parameters are **:none** for module, 0 for priority, and **t** for output if not provided. The buffer-read-action function essentially does nothing and is only there to record a reference for the trace. It returns the event that is scheduled. If any of the parameters are not valid or there is no current model or current meta-process then a warning is printed, **nil** is returned and nothing is scheduled.

Buffer-read-report is used to read a buffer's chunk and have a record of the buffer-read recorded in the trace of the model. It is essentially a combination of buffer-read and schedule-buffer-read. It schedules an event to occur as if the following were executed:

```
(schedule-event-relative time-delta 'buffer-read-action
                         :module module
                         :priority :max
                         :params (list buffer)
                         :output t)
```

The name of the chunk currently in the named buffer is returned. If the buffer is empty then **nil** is returned. If the buffer named is invalid or there is no current model then a warning is printed and **nil** is returned.

As noted in the general description of buffers, some buffers may reuse a single chunk instead of creating new copies every time. Thus, the return value from this command may always be the same for some buffers, even though it represents a different chunk being in the buffer. Also worth noting is that this command does not provide any guarantee as to the chunk that is returned remaining in the buffer – if the model is running then many things can happen to change the buffer and it's also possible for code running in another connected system to also manipulate the buffer at any time. Thus, one should be careful about how the name which is returned from this command is used.

Examples:

This example assumes that the model starts with no chunk in the goal buffer and has the :trace-detail parameter set to **high**.

```
1> (buffer-read 'goal)
NIL

2> (goal-focus free)
FREE

3> (run .1)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FREE NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   ------                  Stopped because no events left to process
0.0
4
NIL

4> (buffer-read 'goal)
GOAL-CHUNK0

5> (schedule-buffer-read 'goal .2)
```

```
6

6> (mp-show-queue)
Events in the queue:
     0.200   NONE                  BUFFER-READ-ACTION GOAL
     0.200   PROCEDURAL            CONFLICT-RESOLUTION
2

7> (run .2)
     0.200   NONE                  BUFFER-READ-ACTION GOAL
     0.200   PROCEDURAL            CONFLICT-RESOLUTION
     0.200   ------                Stopped because time limit reached
0.2
2
NIL

8> (buffer-read-report 'goal :module 'test-module)
GOAL-CHUNK0

9> (mp-show-queue)
Events in the queue:
     0.200   TEST-MODULE           BUFFER-READ-ACTION GOAL
     0.200   PROCEDURAL            CONFLICT-RESOLUTION
2

E> (buffer-read 'bad-name)
#|Warning: Buffer-read called with an invalid buffer name BAD-NAME |#
NIL

E> (schedule-buffer-read 'bad-name .1)
#|Warning: schedule-buffer-read called with an invalid buffer name BAD-NAME |#
NIL

E> (schedule-buffer-read 'goal 'bad-time)
#|Warning: schedule-buffer-read called with a non-number time-delta: BAD-TIME |#
NIL

E> (schedule-buffer-read 'goal '.1 :priority 'bad)
#|Warning: schedule-buffer-read called with an invalid priority BAD |#
NIL

E> (buffer-read-report 'bad-name)
#|Warning: buffer-read-report called with an invalid buffer name BAD-NAME |#
NIL

E> (buffer-read 'goal)
#|Warning: buffer-read called with no current model. |#
NIL
```

query-buffer

Syntax:

query-buffer *buffer queries* -> [**t** | **nil**]
schedule-query-buffer *buffer queries time-delta* {**:module** *module*} {**:priority** *priority*}
{**:output** *output*} {**:time-in-ms** *time-units*} -> [event-id | **nil**]

Arguments and Values:

buffer ::= the name of a buffer
queries ::= [query-list | query-spec]

query-list ::= ({{mod } query value}*)
query-spec ::= an ACT-R chunk-spec or chunk-spec id which contains valid query information
mod ::= [**=** | **-**]
query ::= a query to test
value ::= a value to test for with the associated query
time-delta ::= a number indicating when to schedule the event
module ::= a name which will be used as the module of the event and in the trace
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
output ::= [**t** | **high** | **medium** | **low** | **nil**]
time-units ::= a generalized boolean indicating whether time-delta is in seconds or milliseconds
(default is **nil** which means seconds)
event-id ::= an integer which can be used to reference the event created

Description:

The query-buffer commands are used to query the state of the buffer and/or its module in the current model. The query provided may be specified either as a list of query items, a chunk-spec containing slot-specs that are valid queries, or a chunk-spec id of a valid query chunk-spec. A query list must contain two or three items per query and may contain any number of queries. Within a single query the optional item is a modifier to use which can be either = or –, with = being a test that the query is true and – being a test that it is false. The default is = if not provided. The next item in the query is the name of the query and that is followed by the value to be tested for that query. A valid chunk-spec for a query would be one that was created with a specification as described for the query list.

For query-buffer each of the queries specified is tested from left to right and if they all return true then query-buffer returns **t**. If any query fails, then **nil** is returned without making any more queries. If the buffer named is invalid, any of the queries are not valid for the buffer or module, or there is no current model then a warning is printed and **nil** is returned.

Schedule-query-buffer is used to record buffer querying in the trace of the model. It schedules an event to occur as if the following was executed:

```
(schedule-event-relative time-delta 'query-buffer-action
                         :time-in-ms time-units
                         :module module
                         :priority priority
                         :params (list buffer queries)
                         :output output
                         :details (format nil "query-buffer-action ~a" buffer))
```

The default values for the parameters are **:none** for module, 0 for priority, and **t** for output if not provided. The query-buffer-action function essentially does nothing and is only there to record a reference for the trace. It returns the event-id of the scheduled event. If any of the parameters are not valid or there is no current model then a warning is printed, **nil** is returned and nothing is scheduled.

Examples:

This example assumes that the model starts with no chunk in the goal and buffer and has the :trace-detail parameter set to **high**.

```
1> (query-buffer 'goal '(state free))
T

2> (query-buffer 'goal '(= buffer empty error nil))
T

3> (query-buffer 'goal (define-chunk-spec - buffer full error nil))
T

4> (query-buffer 'goal nil)
T

5> (query-buffer 'goal '(state busy))
NIL

6> (schedule-query-buffer 'goal '(buffer empty) .1)
7

7> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL #S(CENTRAL-PARAMETERS ...)
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   NONE                  QUERY-BUFFER-ACTION GOAL
3

8> (run .1)
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   NONE                  QUERY-BUFFER-ACTION GOAL
     0.100   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because time limit reached
0.1
4
NIL

E> (query-buffer 'bad-name nil)
#|Warning: query-buffer called with an invalid buffer name BAD-NAME |#
NIL

E> (query-buffer 'goal '(bad-query free))
#|Warning: Invalid query name BAD-QUERY in call to define-query-spec. |#
#|Warning: Invalid query-buffer of buffer GOAL with queries-list-or-spec (BAD-QUERY FREE)
|#
NIL

E> (schedule-query-buffer 'bad-name nil .1)
#|Warning: schedule-query-buffer called with an invalid buffer name BAD-NAME |#
NIL

E> (query-buffer 'goal '(< state free))
#|Warning: Query specs only allow = or - modifiers. |#
#|Warning: Invalid query-buffer of buffer GOAL with queries-list-or-spec (< STATE FREE) |#
NIL

E> (schedule-query-buffer 'goal (define-chunk-spec < state free) .1)
#|Warning: schedule-query-buffer called with an invalid query specification
  #S(ACT-R-CHUNK-SPEC ...))) |#
NIL

E> (schedule-query-buffer 'goal nil nil)
#|Warning: schedule-query-buffer called with non-number time-delta: NIL |#
NIL

E> (schedule-query-buffer 'goal nil 1.0 :priority 'bad)
#|Warning: schedule-query-buffer called with an invalid priority BAD |#
NIL

E> (query-buffer 'goal nil)
```

```
#|Warning: query-buffer called with no current model. |#
NIL
```

clear-buffer

Syntax:

clear-buffer *buffer* -> [chunk-name | **nil**]
schedule-clear-buffer *buffer time-delta* {**:module** *module*} {**:priority** *priority*}
{**:output** *output*} {**:time-in-ms** *time-units*} -> [event | **nil**]

Remote command name:

clear-buffer

Arguments and Values:

buffer ::= the name of a buffer
chunk-name ::= the name of the chunk which is in the buffer
time-delta ::= a number indicating when to schedule the event
module ::= a name which will be used to as the module of the event and in the trace
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
output ::= [**t** | **high** | **medium** | **low** | **nil**]
time-units ::= a generalized boolean indicating whether time-delta is in seconds or milliseconds
(default is **nil** which means seconds)
Event-id ::= an integer which can be used to reference the event created

Description:

The clear-buffer commands are used to clear any chunk which may be in a buffer which will leave the buffer empty, and it will also clear the buffer's failure flag if it is set. Any module which is monitoring for buffer clearing will be notified that the chunk has been cleared – in particular the declarative module will merge the cleared chunk into the model's declarative memory.

For clear-buffer, the buffer is cleared immediately and the name of the chunk which is in the buffer currently is returned. If the buffer is empty the return value is **nil.** If the buffer named is invalid or there is no current model then a warning is printed and **nil** is returned.

Schedule-clear-buffer is used to schedule the clearing of the buffer such that it occurs during the running of the model. It schedules an event to occur as if the following was executed:

```
(schedule-event-relative time-delta 'clear-buffer
                         :time-in-ms time-units
                         :module module
                         :priority priority
                         :params (list buffer)
                         :output output)
```

The default values for the parameters are **:none** for module, 0 for priority, and **low** for output if not provided. It returns the event that is scheduled. If any of the parameters are not valid or there is no current model then a warning is printed, **nil** is returned and nothing is scheduled.

Because the buffer may be reusing the same chunk for all actions one should be careful about what is done with the name that is returned – that same chunk may be used again in the buffer, and the chunk-not-storable command can be used to test that if necessary.

Examples:

This example assumes that the model starts with no chunk in the goal buffer.

```
1> (clear-buffer 'goal)
NIL

2> (goal-focus free)
FREE

3> (run 1)
     0.000   GOAL                    SET-BUFFER-CHUNK GOAL FREE NIL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.000   ------                  Stopped because no events left to process
0.0
4
NIL

4> (clear-buffer 'goal)
GOAL-CHUNK0

5> (buffer-read 'goal)
NIL

6> (goal-focus free)
FREE

7> (schedule-clear-buffer 'goal .2 :module 'example)
4

8> (run 1)
     0.200   EXAMPLE                 CLEAR-BUFFER GOAL
     0.200   PROCEDURAL              CONFLICT-RESOLUTION
     0.200   ------                  Stopped because no events left to process
0.2
2
NIL

9> (buffer-read 'goal)
NIL

E> (clear-buffer 'bad-name)
#|Warning: clear-buffer called with an invalid buffer name BAD-NAME |#
NIL

E> (schedule-clear-buffer 'bad-name .1)
#|Warning: schedule-clear-buffer called with an invalid buffer name BAD-NAME |#
NIL

E> (schedule-clear-buffer 'goal nil)
#|Warning: schedule-clear-buffer called with a non-number time-delta: NIL |#
NIL

E> (clear-buffer 'goal)
```

```
#|Warning: clear-buffer called with no current model. |#
NIL
```

set-buffer-chunk

Syntax:

set-buffer-chunk *buffer chunk-description* {*requested*} -> [buffer-chunk-name | **nil**]
schedule-set-buffer-chunk *buffer chunk-description time-delta* {**:module** *module*} {**:priority** *priority*}
{**:output** *output*} {**:requested** *requested*} {**:time-in-ms** *time-units*} -> [event-id | **nil**]

Remote command name:

set-buffer-chunk
schedule-set-buffer-chunk *buffer chunk-description time-delta* { < **module** *module*, **priority** *priority*,
time-in-ms *time-units*, **requested** *requested*, **output** *output* > }

Arguments and Values:

buffer ::= the name of a buffer
chunk-description::= [chunk-name | chunk-list | chunk-spec **]**
chunk-name ::= the name of a chunk
chunk-list ::= **(**{slot-name slot-value}***)**
chunk-spec ::= a chunk-spec or chunk-spec id which contains a valid description for a chunk
requested ::= a generalized boolean
buffer-chunk-name ::= the name of the chunk in the buffer
time-delta ::= a number indicating when to schedule the event
module ::= a name which will be used to as the module of the event and in the trace
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
output ::= [**t** | **high** | **medium** | **low** | **nil**]
time-units ::= a generalized boolean indicating whether time-delta is in seconds or milliseconds
(default is **nil** which means seconds)
event-id ::= an integer which can be used to reference the event created

Description:

The set-buffer-chunk commands are used to copy a chunk into a buffer. That chunk can be specified by name or the description of a chunk can be provided (either as a list of slot-value pairs or a chunk-spec) to create the copy. It will copy the chunk specified or the description of a chunk to a chunk in the buffer. That may result in a new chunk being created, or reusing a previous chunk for the buffer if the buffer does not require copies. Before it copies the information into the buffer, it will first clear the buffer. Thus, any chunk which may be there will be cleared as described for the clear-buffer command. The buffer clearing is not scheduled, thus there will not be an event in the trace to indicate explicitly that the buffer was cleared.

For set-buffer-chunk, the buffer is cleared and then set immediately with the information and the name of the chunk which is then in the buffer is returned. If either the buffer or the chunk information is invalid or there is no current model then a warning is printed and **nil** is returned.

The optional requested parameter specifies whether the buffer will indicate that the chunk was requested or not. If requested is specified as **t**, any other true value, or not provided at all, then the setting of the chunk is to be interpreted as being the result of a request to a module and the query of that buffer for "buffer requested" will be true. If the requested parameter is specified as **nil**, which should be done when the setting of the chunk is not the result of a module request, then the "buffer requested" query for the buffer will be **nil** and the "buffer unrequested" query will be true. An example of when the requested value should be **nil** is the buffer stuffing which the visual-location buffer performs when there is a screen change. That does not happen because of an explicit request to the module, and thus if a chunk is placed into the buffer it should be marked accordingly.

Schedule-set-buffer-chunk is used to schedule the setting of the buffer such that it occurs during the running of the model. It schedules an event to occur as if the following was executed:

```
(schedule-event-relative time-delta 'set-buffer-chunk
                         :time-in-ms time-units
                         :module module
                         :priority priority
                         :params (if requested
                                     (list buffer-name chunk-description)
                                   (list buffer-name chunk-name requested))
                         :output output
                         :details <setting-description>)
```

The default values for the parameters are **:none** for module, 0 for priority, **t** for requested, and **low** for output if not provided. The setting-description depends upon whether a chunk-name or one of the descriptive forms was provided. If it is a name then it will be "set-buffer-chunk" followed by the buffer name, the chunk-name, and if not requested, that will be followed by **nil**. If it is a description of a chunk, then it will be "set-buffer-chunk-from-spec" followed by the buffer name, and then if not requested **nil**.

It returns the event that is scheduled. If any of the parameters are not valid or there is no current model then a warning is printed, **nil** is returned and nothing is scheduled.

Examples:

```
1> (define-chunks (a) (b color b))
(A B)

2> (dm)
NIL

3> (set-buffer-chunk 'goal 'a)
GOAL-CHUNK0

4> (buffer-chunk goal)
GOAL: GOAL-CHUNK0 [A]
GOAL-CHUNK0

(GOAL-CHUNK0)

5> (dm)
NIL

6> (schedule-set-buffer-chunk 'goal 'b .1)
4
```

```
7> (run 1)
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   NONE                  SET-BUFFER-CHUNK GOAL B
     0.100   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because no events left to process
0.1
4
NIL

8> (dm)
GOAL-CHUNK0-0

(GOAL-CHUNK0-0)

9> (buffer-chunk goal)
GOAL: GOAL-CHUNK0 [B]
GOAL-CHUNK0
   COLOR  B

(GOAL-CHUNK0)

10> (query-buffer 'goal '(buffer requested))
T

11> (set-buffer-chunk 'goal '(value 3) nil)
GOAL-CHUNK0

12> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   VALUE  3

(GOAL-CHUNK0)

13> (dm)

GOAL-CHUNK0-1
   COLOR  B

GOAL-CHUNK0-0

(GOAL-CHUNK0-1 GOAL-CHUNK0-0)

14> (query-buffer 'goal '(buffer requested))
NIL

15> (query-buffer 'goal '(buffer unrequested))
T

16> (schedule-set-buffer-chunk 'goal (define-chunk-spec color red) 0 :requested nil)
6

17> (run .1)
     0.100   NONE                  SET-BUFFER-CHUNK-FROM-SPEC GOAL  NIL
     0.100   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because no events left to process
0.0
2
NIL

18> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   COLOR  RED

(GOAL-CHUNK0)
```

```
E> (set-buffer-chunk 'bad-name 'a)
#|Warning: set-buffer-chunk called with an invalid buffer name BAD-NAME |#
NIL

E> (set-buffer-chunk 'goal 'bad-name)
#|Warning: set-buffer-chunk called with an invalid chunk name or chunk-spec BAD-NAME |#
NIL

E>(set-buffer-chunk 'goal '(bad-description value odd-slot))
#|Warning: define-chunk-spec's 1 parameter doesn't name a chunk: (BAD-DESCRIPTION) |#
#|Warning: set-buffer-chunk called with an invalid chunk name or chunk-spec (BAD-
DESCRIPTION) |#
NIL

E> (schedule-set-buffer-chunk 'goal 'b nil)
#|Warning: schedule-set-buffer-chunk called with time-delta that is not a number: NIL |#
NIL

E> (set-buffer-chunk 'goal 'a)
#|Warning: set-buffer-chunk called with no current model. |#
NIL
```

overwrite-buffer-chunk

Syntax:

overwrite-buffer-chunk *buffer chunk-description* {*requested*} -> [buffer-chunk-name | **nil**]
schedule-overwrite-buffer-chunk *buffer chunk-description time-delta* {**:module** *module*} {**:priority** *priority*} {**:output** *output*} {**:requested** *requested*} {**:time-in-ms** *time-units*} -> [event-id | **nil**]

Remote command name:

overwrite-buffer-chunk
schedule-overwrite-buffer-chunk *buffer chunk-description time-delta* { < **module** *module*, **priority** *priority*, **time-in-ms** *time-units*, **requested** *requested*, **output** *output* > }

Arguments and Values:

buffer ::= the name of a buffer
chunk-description::= [chunk-name | chunk-list | chunk-spec **]**
chunk-name ::= the name of a chunk
chunk-list ::= **(**{slot-name slot-value}***)**
chunk-spec ::= a chunk-spec or chunk-spec id which contains a valid description for a chunk
requested ::= a generalized boolean
buffer-chunk-name ::= the name of the chunk in the buffer
time-delta ::= a number indicating when to schedule the event
module ::= the name of the module to use for the event and in the trace
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
output ::= [**t** | **high** | **medium** | **low** | **nil**]
time-units ::= a generalized boolean indicating whether time-delta is in seconds or milliseconds
(default is **nil** which means seconds)
event-id ::= an integer which can be used to reference the event created

Description:

The overwrite-buffer-chunk commands are used to copy a chunk into a buffer like set-buffer-chunk. That chunk can be specified by name or the description of a chunk can be provided (either as a list of slot-value pairs or a chunk-spec) to create the copy. It will copy the chunk specified or the description of a chunk to a chunk in the buffer. That may result in a new chunk being created, or reusing a previous chunk for the buffer if the buffer does not require copies. The difference between overwrite-buffer-chunk and set-buffer-chunk is that the overwrite operation does not clear the buffer first. Thus, if there is a chunk in the buffer when the overwrite-buffer-chunk command is issued there will be no clearing of that chunk and no modules will be notified that it has been cleared. One specific consequence of that is that the previous chunk in the buffer, if there was one, will not be collected by the declarative module and added to the model's declarative memory.

Typically, one will use set-buffer-chunk when building a module or otherwise working with the buffers. However, there are rare situations where the model or a module may want to destructively erase a chunk which is in a buffer with this command.

The requested parameter specifies whether the buffer will indicate that the chunk was requested or not. If requested is specified as **t** or any other true value, then the overwritting of the chunk is to be interpreted as being the result of a request to a module and the query of that buffer for "buffer requested" will be true. If the requested keyword parameter is specified as **nil** or not provided, which should be done when the setting of the chunk is not the result of a module request, then the "buffer requested" query for the buffer will be **nil** and the "buffer unrequested" query will be true.

For overwrite-buffer-chunk, the buffer is set immediately with the information and the name of the chunk which is then in the buffer is returned. If either the buffer or chunk description is invalid or there is no current model then a warning is printed and **nil** is returned.

Schedule-overwrite-buffer-chunk is used to schedule the setting of the buffer such that it occurs during the running of the model. It schedules an event to occur essentially as if the following was executed:

```
(schedule-event-relative time-delta 'overwrite-buffer-chunk
                         :time-in-ms time-units
                         :module module
                         :priority priority
                         :params (list buffer-name chunk-description requested)
                         :output output
                         :details <overwrite-description>)
```

The default values for the parameters are **:none** for module, 0 for priority, **nil** for requested, and **low** for output if not provided. The overwrite-description depends upon whether a chunk-name or one of the descriptive forms was provided. If it is a name then it will be "overwrite-buffer-chunk" followed by the buffer name, the chunk-name, and if not requested, that will be followed by **nil**. If it is a description of a chunk, then it will be "overwrite-buffer-chunk-from-spec" followed by the buffer name, and then if not requested **nil**.

It returns the event that is scheduled. If any of the parameters are not valid or there is no current model then a warning is printed, **nil** is returned and nothing is scheduled.

Examples:

```
1> (define-chunks (a) (b color b))
(A B)

2> (dm)
NIL

3> (overwrite-buffer-chunk 'goal 'a)
GOAL-CHUNK0

4> (buffer-chunk goal)
GOAL: GOAL-CHUNK0 [A]
GOAL-CHUNK0

(GOAL-CHUNK0)

5> (dm)
NIL

6> (schedule-overwrite-buffer-chunk 'goal 'b .1)
3

7> (run 1)
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   NONE                  OVERWRITE-BUFFER-CHUNK GOAL B NIL
     0.100   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because no events left to process
0.1
4
NIL

8> (dm)
NIL

9> (buffer-chunk goal)
GOAL: GOAL-CHUNK0 [B]
GOAL-CHUNK0
   COLOR  B

(GOAL-CHUNK0)

10> (query-buffer 'goal '(buffer requested))
NIL

11> (overwrite-buffer-chunk 'goal '(color blue) :requested t)
GOAL-CHUNK0

12> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   COLOR  BLUE

(GOAL-CHUNK0)

13> (query-buffer 'goal '(buffer requested))
T

E> (overwrite-buffer-chunk 'bad-name 'a)
#|Warning: overwrite-buffer-chunk called with an invalid buffer name BAD-NAME |#
NIL

E> (overwrite-buffer-chunk 'goal 'bad-name)
#|Warning: overwrite-buffer-chunk called with an invalid chunk name BAD-NAME |#
NIL
```

```
E> (overwrite-buffer-chunk 'goal '(bad-description))
#|Warning: define-chunk-spec's 1 parameter doesn't name a chunk: (BAD-DESCRIPTION) |#
#|Warning: overwrite-buffer-chunk called with an invalid chunk name or chunk-spec (BAD-
DESCRIPTION) |#
NIL

E> (schedule-overwrite-buffer-chunk 'goal 'a nil)
#|Warning: schedule-overwrite-buffer-chunk called with a non-number time-delta: NIL |#
NIL

E> (overwrite-buffer-chunk 'goal 'a)
#|Warning: overwrite-buffer-chunk called with no current model. |#
NIL
```

mod-buffer-chunk

Syntax:

mod-buffer-chunk *buffer modifications* -> [chunk-name | **nil**]
schedule-mod-buffer-chunk *buffer modifications time-delta* {**:module** *module*} {**:priority** *priority*}
{**:output** *output*} {**:time-in-ms** *time-units*} -> [event-id | **nil**]

Remote command name:

mod-buffer-chunk
schedule-mod-buffer-chunk *buffer modifications time-delta* { < **module** *module*, **priority** *priority*,
time-in-ms *time-units*, **output** *output* > }

Arguments and Values:

buffer ::= the name of a buffer
chunk-name ::= the name of the chunk in the buffer
modifications ::= [mod-list | mod-spec]
mod-list ::= **(**{slot-name slot-value}***)**
mod-spec ::= an ACT-R chunk-spec or chunk-spec id which contains valid modification information
slot-name ::= the name of a slot of the chunk in the named buffer
slot-value ::= a value to set for the corresponding slot-name of the chunk in the named buffer
time-delta ::= a number indicating when to schedule the event
module ::= a name which will be used as the module of the event and in the trace
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
output ::= [**t** | **high** | **medium** | **low** | **nil**]
time-units ::= a generalized boolean indicating whether time-delta is in seconds or milliseconds
(default is **nil** which means seconds)
event-id ::= an integer which can be used to reference the event created

Description:

The mod-buffer-chunk commands are used to make modifications to the chunk which is in a buffer. It works similar to the mod-chunk command, but there are a few differences between mod-chunk and mod-buffer-chunk. The first is that instead of providing the name of a chunk, a buffer is named and

the chunk which is in that buffer is the one which is modified. Another is that in addition to providing a list of slot-value pairs to specify the modifications to make mod-buffer-chunk will also accept a chunk-spec with slot-specs that indicate the modifications to make (such a chunk-spec must only use the modifier = in the slot-specs). Finally, if a slot specified in the modification is not currently a possible slot it will be added to the possible slots using the extend-possible-slots command before the modifications are performed.

If there is a chunk in the buffer which is named and the modifications provided are valid then those modifications are made to that chunk. To be valid, the modifications may only specify each slot once. If any value specified for a slot in the modification is a symbol and not the name of a chunk in the current model then it is created as a new chunk with no slots and a warning is displayed before the modification is made.

For mod-buffer-chunk, if there is not a chunk in the named buffer, the modifications provided are not valid, or there is no current model then a warning is displayed, no changes are made, and **nil** is returned.

If there is a chunk in the buffer and the modifications are valid, then the chunk is modified and the name of that chunk is returned.

Schedule-mod-buffer-chunk is used to schedule the modifications to the chunk in the buffer such that it occurs during the running of the model. It schedules an event to occur as if the following was executed:

```
(schedule-event-relative time-delta 'mod-buffer-chunk
                         :time-in-ms time-units
                         :module module
                         :priority priority
                         :params (list buffer modifications)
                         :details (format nil "~s ~s" 'mod-buffer-chunk buffer-name)
                         :output output)
```

The default values for the parameters are **:none** for module, 0 for priority, and **low** for output if not provided. It returns the event that is scheduled. If any of the parameters are not valid or there is no current model then a warning is printed, **nil** is returned and nothing is scheduled.

When schedule-mod-buffer-chunk is called with a slot that is not currently a possible slot name the extension will be performed immediately at the time it is called and not at the scheduled time for the modification.

Examples:

```
1> (define-chunks a)
(A)

2> (set-buffer-chunk 'goal 'a)
GOAL-CHUNK0

3> (buffer-chunk goal)
GOAL: GOAL-CHUNK0 [A]
GOAL-CHUNK0

(GOAL-CHUNK0)
```

```
4> (mod-buffer-chunk 'goal '(color blue))
GOAL-CHUNK0

5> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   COLOR  BLUE

(GOAL-CHUNK0)

6> (schedule-mod-buffer-chunk 'goal (define-chunk-spec size 10) .1)
3

7> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   NONE                  MOD-BUFFER-CHUNK GOAL
3

8> (run .1)
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   NONE                  MOD-BUFFER-CHUNK GOAL
     0.100   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because time limit reached
0.1
4
NIL

9> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   COLOR  BLUE
   SIZE  10

(GOAL-CHUNK0)

10E> (mod-buffer-chunk 'goal '(size 11 new-slot new-chunk))
#|Warning: Chunks extended with slot NEW-SLOT during a chunk-spec definition. |#
#|Warning: Creating chunk NEW-CHUNK with no slots |#
GOAL-CHUNK0

11> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   COLOR  BLUE
   SIZE  11
   NEW-SLOT  NEW-CHUNK

(GOAL-CHUNK0)

12E> (schedule-mod-buffer-chunk 'goal '(new-new-slot t color nil) .1)
#|Warning: Chunks extended with slot NEW-NEW-SLOT during a chunk-spec definition. |#
6

13> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   COLOR  BLUE
   SIZE  11
   NEW-SLOT  NEW-CHUNK

(GOAL-CHUNK0)

14> (run .1)
     0.200   NONE                  MOD-BUFFER-CHUNK GOAL
```

```
     0.200   PROCEDURAL             CONFLICT-RESOLUTION
     0.200   ------                 Stopped because time limit reached
0.1
2
NIL

15> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   SIZE  11
   NEW-SLOT  NEW-CHUNK
   NEW-NEW-SLOT  T

(GOAL-CHUNK0)

E> (mod-buffer-chunk 'not-a-buffer nil)
#|Warning: mod-buffer-chunk called with an invalid buffer name NOT-A-BUFFER |#
NIL

E> (mod-buffer-chunk 'goal '(color blue color red))
#|Warning: mod-buffer-chunk called with an invalid modification (COLOR BLUE COLOR RED) |#
NIL

E> (schedule-mod-buffer-chunk 'goal '(color blue) nil)
#|Warning: schedule-mod-buffer-chunk called with non-number time-delta: NIL |#
NIL

E> (mod-buffer-chunk 'goal nil)
#|Warning: mod-buffer-chunk called with no current model. |#
NIL
```

set-buffer-failure

Syntax:

set-buffer-failure *buffer* {**:requested** *requested*} {**:ignore-if-full** *if-full*} -> [**t** | **nil**]

Remote command name:

set-buffer-failure *buffer* { < **requested** *requested*, **ignore-if-full** *if-full* > }

Arguments and Values:

buffer ::= a symbol which should name a buffer
requested ::= a generalized boolean
if-full ::= a generalized boolean

Description:

The set-buffer-failure command is used to set the failure flag in a buffer. A buffer's failure flag will remain set until the buffer is cleared. If the flag is successfully set then the function returns **t**.

If buffer does not name a buffer in the current model, or there is no current model then a warning is printed and **nil** is returned.

The requested keyword parameter specifies whether the buffer will indicate that the failure was requested or not. If requested is specified as **t** (which is the default) or any other true value, then the setting of the failure flag is to be interpreted as being the result of a request to a module having failed and the query of that buffer for "buffer requested" will be true. If the requested keyword parameter is specified as **nil**, then the "buffer requested" query for the buffer will be **nil** and the "buffer unrequested" query will be true.

The failure flag cannot be set when there is currently a chunk in the specified buffer. The ignore-if-full parameter specifies what to do if there is a chunk in the buffer when set-buffer-failure is called. If the parameter is specified as **nil** (the default value) then it will print a warning and return **nil** if there is a chunk in the buffer. If the parameter is true then no warning will be displayed and **nil** will be returned.

Examples:

```
1> (buffer-status goal)
GOAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
(GOAL)

2> (set-buffer-failure 'goal)
T

3> (buffer-status goal)
GOAL:
  buffer empty          : NIL
  buffer full           : NIL
  buffer failure        : T
  buffer requested      : T
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
(GOAL)

4> (clear-buffer 'goal)
NIL

5> (buffer-status goal)
GOAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
(GOAL)

6> (set-buffer-failure 'goal :requested nil)
T
```

```
7> (buffer-status goal)
GOAL:
  buffer empty          : NIL
  buffer full           : NIL
  buffer failure        : T
  buffer requested      : NIL
  buffer unrequested    : T
  state free            : T
  state busy            : NIL
  state error           : NIL
(GOAL)

8> (set-buffer-chunk 'goal 'red)
RED-0

9> (buffer-status goal)
GOAL:
  buffer empty          : NIL
  buffer full           : T
  buffer failure        : NIL
  buffer requested      : T
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
(GOAL)

10E> (set-buffer-failure 'goal)
#|Warning: cannot set the failure flag when there is a chunk in the GOAL buffer |#
NIL

11> (set-buffer-failure 'goal :ignore-if-full t)
NIL

12> (buffer-status goal)
GOAL:
  buffer empty          : NIL
  buffer full           : T
  buffer failure        : NIL
  buffer requested      : T
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
(GOAL)

E> (set-buffer-failure 'not-a-buffer)
#|Warning: set-buffer-failure called with an invalid buffer name NOT-A-BUFFER |#
NIL

E> (set-buffer-failure 'goal)
#|Warning: set-buffer-failure called with no current model. |#
NIL
```

module-request

Syntax:

module-request *buffer chunk-spec*-> [**t** | **nil**]
schedule-module-request *buffer chunk-spec time-delta* {**:module** *module*} {**:priority** *priority*}
{**:output** *output*} {**:details** *details*} {**:time-in-ms** *time-units*}
-> [event-id | **nil**]

Remote command name:

module-request
schedule-module-request *buffer chunk-spec time-delta* { < **module** *module*, **priority** *priority*,
output *output,* **details** *details*, **time-in-ms** *time-units* > }

Arguments and Values:

buffer ::= the name of a buffer
chunk-spec ::= an ACT-R chunk-spec or chunk-spec-id
time-delta ::= a number indicating when to schedule the event
module ::= a name which will be used as the module of the event and in the trace
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
output ::= [**t** | **high** | **medium** | **low** | **nil**]
details ::= a string to display in the trace when the request occurs
time-units ::= a generalized boolean indicating whether time-delta is in seconds or milliseconds
event-id ::= an integer which can be used to reference the event created

Description:

The module-request commands are used to send a request to a module through its buffer. This is the only recommended way to interact with a module to make requests.

If the buffer name is valid and a valid chunk-spec is provided, then that chunk-spec will be sent to the buffer's module as a request. Note that the command does not implicitly clear the buffer as occurs for requests from the productions of a model. If the buffer should be cleared that must be done explicitly in conjunction with the request.

For module-request, if the buffer name and chunk-spec are valid and the named buffer's module accepts requests then a value of **t** is returned. If the buffer name is invalid, an invalid chunk-spec is provided, the buffer's module does not accept requests, or there is no current model then a warning is displayed and **nil** is returned.

The only test performed upon the chunk-spec to determine if it is valid (assuming that it is a chunk-spec) is to verify that any request parameters provided are valid for the buffer to which it is being sent. Any other processing of the request for validity is up to the module which receives the request.

When using module-request, even though the request itself is not scheduled the actions performed by the module in response to that request should be (at least if the module is written according to the recommended guidelines). Thus, it is likely that no changes will occur until the model is run.

It is recommended that all requests be scheduled using schedule-module-request.

Schedule-module-request is used to schedule the sending of the request to the buffer's module such that it occurs during the running of the model. It schedules an event to occur as if the following was executed:

```
(schedule-event-relative time-delta 'module-request
```

```
                        :time-in-ms time-units
                        :module module
                        :priority priority
                        :params (list buffer chunk-spec)
                        :details (if (stringp details)
                                     details
                                   (format nil "~s ~s" 'module-request buffer-name))
                        :output output)
```

The default values for the parameters are **:none** for module, 0 for priority, **medium** for output, and **nil** for details. It returns the event that is scheduled. If any of the parameters are not valid or there is no current model then a warning is printed, **nil** is returned and nothing is scheduled. Note that for schedule-module-request the test whether the module accepts requests is not performed until the event occurs. Thus any warning about that will not occur until the model is run.

Examples:

These examples assume that there is a module called dummy with a buffer called dummy which does not accept requests.

```
1> (buffer-chunk goal)
GOAL: NIL
(NIL)

2> (module-request 'goal (define-chunk-spec value free))
T

3> (buffer-chunk goal)
GOAL: NIL
(NIL)

4> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   GOAL                  SET-BUFFER-CHUNK-FROM-SPEC GOAL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION3

5> (run .001)
     0.000   GOAL                  SET-BUFFER-CHUNK-FROM-SPEC GOAL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   ------                Stopped because no events left to process
0.0
5
NIL

6> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   VALUE  FREE

(GOAL-CHUNK0)

7> (schedule-module-request 'goal (define-chunk-spec value busy) .1)
5

8> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   VALUE  FREE

(GOAL-CHUNK0)
```

```
9> (mp-show-queue)
Events in the queue:
     0.100   NONE                  MODULE-REQUEST GOAL
     0.100   PROCEDURAL            CONFLICT-RESOLUTION
2

10> (run .1)
     0.100   NONE                  MODULE-REQUEST GOAL
     0.100   GOAL                  SET-BUFFER-CHUNK-FROM-SPEC GOAL
     0.100   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because time limit reached
0.1
3
NIL

11> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   VALUE  BUSY

(GOAL-CHUNK0)

E> (module-request 'dummy (define-chunk-spec))
#|Warning: Module DUMMY does not handle requests. |#
NIL

1> (schedule-module-request 'dummy (define-chunk-spec) 0)
8

2E> (run .1)
     0.100   NONE                  MODULE-REQUEST DUMMY
#|Warning: Module DUMMY does not handle requests. |#
     0.100   PROCEDURAL            CONFLICT-RESOLUTION
     0.100   ------                Stopped because no events left to process
0.0
2
NIL

E> (module-request 'not-a-buffer (define-chunk-spec))
#|Warning: module-request called with an invalid buffer name NOT-A-BUFFER |#
NIL

E> (module-request 'goal 'not-a-chunk-spec)
#|Warning: module-request called with an invalid chunk-spec NOT-A-CHUNK-SPEC |#
NIL

E> (schedule-module-request 'goal (define-chunk-spec) nil)
#|Warning: schedule-module-request called with a non-number time-delta: NIL |#
NIL

E> (module-request 'goal *spec*)
#|Warning: module-request called with no current model. |#
NIL
```

module-mod-request

Syntax:

module-mod-request *buffer modifications* -> [**t** | **nil**]
schedule-module-mod-request *buffer modifications time-delta* {**:module** *module*} {**:priority** *priority*}
{**:output** *output*} {**:time-in-ms** *time-units*}
-> [event-id | **nil**]

Remote command name:

module-mod-request
schedule-module-mod-request *buffer modifications time-delta* { < **module** *module*, **priority** *priority*,
output *output*, **time-in-ms** *time-units* > }

Arguments and Values:

buffer ::= the name of a buffer
modifications ::= [mod-list | mod-spec]
mod-list ::= **(**{slot-name slot-value }***)**
mod-spec ::= a chunk-spec which contains valid modification information
slot-name ::= the name of a slot of the chunk in the named buffer
slot-value ::= a value to set for the corresponding slot-name of the chunk in the named buffer
time-delta ::= a number indicating when to schedule the event
module ::= a name which will be used to as the module of the event and in the trace
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
output ::= [**t** | **high** | **medium** | **low** | **nil**]
time-units ::= a generalized boolean indicating whether time-delta is in seconds or milliseconds
event-id ::= an integer which can be used to reference the event created

Description:

The module-mod-request commands are used to send a modification request to a module through its buffer. This is the only recommended way to interact with a module to make modification requests. A modification request requires that there be a chunk in the specified buffer at the time these commands are issued.

For module-mod-request, if the buffer name is valid, the modifications are valid, there is a chunk in the specified buffer, and the named buffer's module accepts modification requests then a value of **t** is returned. If the buffer name is invalid, an invalid modification is provided, the buffer is empty, the buffer's module does not accept modification requests, or there is no current model then a warning is displayed and **nil** is returned.

The modifications may be specified as a list of slot-value pairs or a chunk-spec with slot-specs that indicate the modifications to make (such a chunk-spec must only use the modifier = in the slot-specs and may contain request parameters valid for the specified buffer). If a slot specified in a modification list is not currently a possible slot it will be added to the possible slots using the extend-possible-slots command at the time the module-mod-request function is called. There is no test performed by module-request to determine if the modification list provided is acceptable to the module prior to sending it other than the test for valid request parameters. All processing of that nature is done by the module once it has received the modification request.

When using module-mod-request, even though the request itself is not scheduled the actions performed by the module in response to the request should be (at least if the module is written according to the recommended guidelines). Thus, it is likely that no changes will occur until the model is run.

It is recommended that all modification requests be scheduled using schedule-module-mod-request.

Schedule-module-mod-request is used to schedule the sending of the modification request to the buffer's module such that it occurs during the running of the model. It schedules an event to occur as if the following was executed:

```
(schedule-event-relative time-delta 'module-mod-request
                         :time-in-ms time-units
                         :module module
                         :priority priority
                         :params (list buffer modifications)
                         :details (format nil "~s ~s" 'module-mod-request buffer-name)
                         :output output)
```

The default values for the parameters are **:none** for module, 0 for priority, and **medium** for output if not provided. It returns the event that is scheduled. If any of the parameters are not valid or there is no current model then a warning is printed, **nil** is returned and nothing is scheduled. Note that for schedule-module-mod-request the test whether the module accepts modification requests is not performed until the event occurs. Thus the warning will not occur until the model is run.

Examples:

These examples assume that there is a module called dummy with a buffer called dummy which does not accept modification requests.

```
1> (set-buffer-chunk 'goal 'free)
FREE-0

2> (buffer-chunk goal)
GOAL: GOAL-CHUNK0 [FREE]
GOAL-CHUNK0
   NAME  FREE

(GOAL-CHUNK0)

3> (module-mod-request 'goal '(value t))
T

4> (buffer-chunk goal)
GOAL: GOAL-CHUNK0 [FREE]
GOAL-CHUNK0
   NAME  FREE

(GOAL-CHUNK0)

5> (mp-show-queue)
Events in the queue:
     0.000   NONE                  CHECK-FOR-ESC-NIL
     0.000   GOAL                  MOD-BUFFER-CHUNK GOAL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
3

6> (run .01)
     0.000   GOAL                  MOD-BUFFER-CHUNK GOAL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   ------                Stopped because no events left to process
0.0
3
NIL
```

```
7> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   NAME  FREE
   VALUE  T

(GOAL-CHUNK0)

8> (schedule-module-mod-request 'goal (define-chunk-spec name busy) 0)
5

9> (mp-show-queue)
Events in the queue:
     0.000   NONE                  MODULE-MOD-REQUEST GOAL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
2

10> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   NAME  FREE
   VALUE  T

(GOAL-CHUNK0)

11> (run .1)
     0.000   NONE                  MODULE-MOD-REQUEST GOAL
     0.000   GOAL                  MOD-BUFFER-CHUNK GOAL
     0.000   PROCEDURAL            CONFLICT-RESOLUTION
     0.000   ------                Stopped because no events left to process
0.0
3
NIL

12> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   NAME  BUSY
   VALUE  T

(GOAL-CHUNK0)

1E> (module-mod-request 'dummy nil)
#|Warning: module-mod-request called with no chunk in buffer DUMMY |#
NIL

2> (set-buffer-chunk 'dummy 'busy)
DUMMY-CHUNK0

3E> (module-mod-request 'dummy nil)
#|Warning: Module DUMMY does not support buffer modification requests. |#
NIL

E> (module-mod-request 'not-a-buffer nil)
#|Warning: module-mod-request called with an invalid buffer name NOT-A-BUFFER |#
NIL

E> (module-mod-request 'goal 'bad-modification)
#|Warning: module-mod-request called with an invalid modification BAD-MODIFICATION |#
NIL

E> (module-mod-request 'goal '(new-slot t))
#|Warning: Chunks extended with slot NEW-SLOT during a chunk-spec definition. |#
T

E> (schedule-module-mod-request 'goal nil nil)
#|Warning: schedule-module-mod-request called with a non-number time-delta: NIL |#
```

```
NIL

E> (module-mod-request 'goal nil)
#|Warning: module-mod-request called with no current model. |#
NIL
```

buffer-spread

Syntax:

buffer-spread *buffer* -> [spread-value | **nil**]

Remote command name:

buffer-spread

Arguments and Values:

buffer ::= the name of a buffer
spread-value ::= a number indicating the buffer spreading parameter value for the buffer

Description:

For the spreading activation calculation in declarative memory each buffer has associated with it a value for the amount of activation it can spread. Each module may specify a particular name for that parameter for each buffer which it owns. This command allows one to get the value of that parameter for any buffer without knowing the specific name of the parameter which the module assigned for it.

If the buffer name given is the name of a buffer in the current model, then the value of that buffer's activation spread parameter will be returned. If the buffer name is invalid or there is no current model then a warning will be printed and **nil** will be returned.

This command is not likely to be used by the typical modeler or module developer, but it may be useful when investigating alternative equations for implementing the spreading activation and is used internally by the declarative module.

The values are recorded by a module named buffer-params, and that module will be available whenever the declarative module is used.

Examples:

```
1> (sgp :ga 1.5 :imaginal-activation 2.0)
(1.5 2.0)

2> (buffer-spread 'goal)
1.5

3> (buffer-spread 'imaginal)
2.0

4> (buffer-spread 'retrieval)
0
```

```
E> (buffer-spread 'bad)
#|Warning: buffer-spread called with an invalid buffer name bad |#
nil

E> (buffer-spread 'goal)
#|Warning: buffer-spread called with no current model. |#
nil
```

buffers-module-name

Syntax:

buffers-module-name *buffer* -> [name | **nil**]

Remote command name:

buffers-module-name

Arguments and Values:

buffer ::= the name of a buffer
name ::= the name of the module that owns the buffer specified

Description:

The buffers-module-name command can be used to find the name of a module when you know the name of a buffer. If the buffer name given names a valid buffer in the current model then the name of the module which owns that buffer is returned. If the buffer name is not valid or there is no current model then **nil** is returned.

This command will typically be used if one is building general tools for tracing events or otherwise producing code which will be monitoring the model's event stream and need to determine module names from buffer actions.

Examples:

```
> (buffers-module-name 'goal)
goal

> (buffers-module-name 'visual-location)
:vision

E> (buffers-module-name 'bad)
#|Warning: invalid buffer name bad |#
NIL

E> (buffers-module-name 'goal)
#|Warning: buffers-module-name called with no current model. |#
NIL
```

buffer-slot-value

Syntax:

buffer-slot-value *buffer slot ->* [value | **nil**]

Remote command name:

buffer-slot-value

Arguments and Values:

buffer ::= the name of a buffer
slot ::= the name of a slot
value ::= the value of slot in the chunk in the buffer

Description:

The buffer-slot-value command can be used to get the value of a slot from the chunk in a buffer of the current model. It is a short-cut so that one does not have to first use buffer-read to get the name of the chunk and then use chunk-slot-value to get the value of a slot from that chunk. If buffer names a valid buffer in the current model then buffer-slot-value will return the value of the specified slot from the chunk in that buffer. If the buffer is empty, then it will return **nil**. If the buffer name is not valid or there is no current model then **nil** is returned and a warning is output.

Examples:

```
1> (set-buffer-chunk 'goal 'blue)
GOAL-CHUNK0

2> (buffer-chunk goal)
GOAL: GOAL-CHUNK0 [BLUE]
GOAL-CHUNK0
   COLOR  BLUE

(GOAL-CHUNK0)

3> (buffer-slot-value 'goal 'color)
BLUE

4> (buffer-slot-value 'goal 'value)
NIL

5> (buffer-chunk imaginal)
IMAGINAL: NIL
(NIL)

6> (buffer-slot-value 'imaginal 'value)
NIL

E> (buffer-slot-value 'not-a-buffer 'color)
#|Warning: Buffer-slot-value called with an invalid buffer name NOT-A-BUFFER |#
NIL

E> (buffer-slot-value 'goal 'color)
#|Warning: buffer-slot-value called with no current model. |#
NIL
```

Extending Chunks

Sometimes it may be convenient to associate supporting information with chunks i.e. information which is not appropriate to encode within the chunk using the slots. This is often useful when creating a new module. As noted in the general description of chunks, each chunk has associated with it a set of parameters which can be used to hold such information. This section will describe how to add and use new chunk parameters.

The command to add a new parameter to chunks is called extend-chunks and will be described in detail below. Here the general concepts and support for chunk parameters will be described.

The first thing to note is that extending chunks is a system wide operation. Once the parameter is added all chunks in all models will have such a parameter available. Thus, extending chunks is a one-time operation. It is recommended that chunk parameters be added when there are no models defined and thus no preexisting chunks. If there are chunks defined when a new parameter is added, then an attempt to access that new parameter value in one of those existing chunks will have unpredictable consequences and could result in errors. The recommended way to add a new parameter is to place the extend-chunks call at the top-level in a file that is loaded automatically by ACT-R at initial load time. That will ensure that the functions for setting and accessing the parameter value are compiled with the rest of the code and that there will be no problems or warnings with attempts to redefine that parameter. There is no mechanism provided for removing a chunk parameter once it has been added and redefinition of an existing chunk parameter is not allowed.

Adding a new chunk parameter causes two internal functions to be created to get the parameter and to set the value of the parameter, and two commands are created to access those functions. The accessor function and command will both have the name **chunk**-*param* where param is the name of the parameter which was added. Thus, if you were to add a parameter named foo to chunks the accessor function for that parameter would be **chunk-foo** and the command would be "**chunk-foo**". The accessor takes one parameter which should be the name of a chunk in the current model and it will return the current value of that parameter for that chunk. To change the parameter internally (in the Lisp running ACT-R) you can use setf in conjunction with the accessor. Thus, assuming one has added a parameter called foo this shows how one could get and set the value of that parameter for a chunk named free:

```
1> (chunk-foo 'free)
NIL

2> (setf (chunk-foo 'free) 10)
10

3> (chunk-foo 'free)
10
```

The command for setting the value will be called "**set-chunk**-*param*" and it takes two parameters. The first of which is the name of a chunk and the second of which is the new value for that parameter of the chunk.

The functions and commands will test that there is a current model and that the chunk name is valid and will print warnings and return **nil** if there is a problem:

```
E> (chunk-foo 'bad-name)
#|Warning: Chunk BAD-NAME does not exist in attempt to access CHUNK-FOO. |#
NIL

E> (chunk-foo 'free)
#|Warning: get-chunk called with no current model. |#
#|Warning: Chunk FREE does not exist in attempt to access CHUNK-FOO. |#
NIL
```

After adding a parameter, it will be shown when the pprint-chunks-plus command is called and will display the current value just like all of the other chunk parameters which are currently defined:

```
> (pprint-chunks-plus free)
FREE
  ISA CHUNK

  --chunk parameters--
   FOO  10
   FAN-LIST  (FREE)
   ACTIVATION  0
   ...
```

When creating a parameter for the chunks it is also possible to control how that parameter is treated under the following conditions:

- How it is initially set when a chunk is created
- How it is set in the copy when a chunk is copied
- How it is set when two chunks are merged

The details of how to specify those controls when creating a chunk parameter and examples of their use are provided with the details of the extend-chunks command. How they apply to the operation of the system will be described here.

There are two possible ways one can specify the initial value for the parameter. If neither is used, then the initial value for the parameter when a chunk is created will be **nil**. The first option is to specify a default value. The parameter will be set to that value for each new chunk created. The other method for setting the initial value is to provide a command identifier to set the value. If a default value command is provided, then that will be called to get the initial value for the parameter. It will be called with one parameter, which will be the name of the chunk in which the default value is being set. The return value will be the initial setting of that chunk parameter. The parameters for a chunk will be initialized in no particular order, and thus the initialization function should not rely on any other parameters of the chunk having been set. Also, the initialization will not happen until the first time that the chunk's parameter value is requested. Thus, it may not be called for every chunk and may not be called until well after the initial creation time of the chunk.

When a chunk is copied using the copy-chunks command the settings of the parameters for the new copy are determined as follows. By default, the parameter will be set in the same manner as the initial value for a newly created chunk i.e. either **nil**, the specified default value, or the result of calling the default value command. However, it is possible to instead specify a command identifier to indicate a command to use to set the value for the copy. The copy command will be passed one parameter and its return value will be the setting for the parameter in the copied chunk. There are two options available for specifying a command to set a parameter value in a copied chunk and the difference between them is what value is passed to the command. One option is to set the "copy"

command which will be passed the current value of the parameter from the chunk which is being copied. The other option is to set the "copy from chunk" command which will be passed the name of the chunk which is being copied. Only one of the copying mechanisms can be used, and if both are specified then the "copy" command will be the one that gets used. If one wants to have the copied chunk's parameter set the same as the original chunk's parameter specifying the copy command as the Lisp function identity is recommended.

When two chunks are merged using the merge-chunks command (which will happen automatically when the declarative module collects chunks cleared from the buffers) the values of the parameters for the merged chunk after the merging are set by default to the values that existed for the primary chunk (the first one in the call to merge-chunks) prior to the merge. That can be overridden by providing a command identifier to indicate the command to merge the parameters. There are two possible options for specifying a merging command. If a "merge" command is provided then when two chunks are merged it will be called with the names of the chunks being merged as its only two parameters. They will be passed to the merge command in the same order as they were given to merge-chunks, and the return value of that call will be the setting of that parameter in the merged chunk. Alternatively, a "merge by value" command can be provided. That command will be passed the values of the parameter from the two chunks in the same order as the chunks were given to merge-chunks. The return value of calling that command will be the setting of that parameter in the merged chunk. If both merging commands are provided the "merge by value" commands return value will be the one set for the parameter in the merged chunk.

Commands

extend-chunks

Syntax:

extend-chunks *parameter-name* {**:default-value** *value*} {**:default-function** *def-fn*}
{**:copy-function** *copy-fn*} {**:copy-from-chunk-function** *copy-from-fn*}
{**:merge-function** *merge*} **:merge-value-function** *merge-value-fn*} ->
[accessor | **:duplicate-parameter** | **nil**]

Remote command name:

extend-chunks *parameter-name* { < **default-value '***value***', default-function '***def-fn***',**
copy-function '*copy-fn***', copy-from-chunk-function '***copy-from-fn***',**
merge-function '*merge*', **merge-value-function** '*merge-value-fn*' >}

Arguments and Values:

parameter-name ::= the name of the new parameter for the chunk
value ::= any value
def-fn ::= a command identifier which takes one parameter
copy-fn ::= a command identifier which takes one parameter
copy-from-fn ::= a command identifier which takes one parameter
merge ::= [*merge-fn* | **:second** | **:second-if**]
merge-fn ::= a command identifier which takes two parameters
merge-value-fn ::= a command identifier which takes two parameters
accessor ::= the name of the accessor function for the new parameter

Description:

The extend-chunks command is used to add a new parameter to chunks. If chunks do not already have a parameter by that name, then an accessor called chunk-*parameter-name* (where *parameter-name* is the parameter-name symbol provided) will be created which takes one parameter which should always be a chunk name. That accessor can be used to get the corresponding parameter of a chunk or used with setf or a remote setting command to change the value of that parameter for the chunk.

The initial value for the new parameter when a chunk is created will be **nil** unless either the default-value or default-function keyword parameter is provided. If a default-value is specified then that will be set as the value of the parameter for a newly created chunk. If a default-function command is specified, then that will be called with the name of the chunk as its only parameter and the return value of that call will be used as the initial value. If both a default-value and default-function are given, then the default-function will be used.

When a copy of a chunk is being made the parameter value for the new copy of the chunk will be set to the default value as determined above unless either a copy-function command or a copy-from-chunk-function command is provided. If one of those is provided, then the new chunk will have its value set to the value returned from calling that item. The difference between the copying mechanisms is that the copy-function command is called with the current parameter value of the chunk which is being copied and the copy-from-chunk-function command gets called with the name of the chunk which is being copied. If both are specified then the copy-from-chunk-function command will be used.

When two chunks are merged the value of a parameter will be the value from the first chunk unless either the merge-function or merge-value-function value is provided. If a merge-function command is provided as a non-keyword value, then when two chunks are being merged that command will be called with the names of those chunks in the order which they were merged and the value it returns will be the setting for the parameter in the merged chunk. If the merge-function is specified with the keyword :second, then the value of the parameter in the merged chunk will be the value from the second of the chunks being merged (or the default value if that chunk did not have a value set), and if it is the keyword :second-if then it will be the value of the second chunk only if that value has been set and is non-**nil** otherwise it will be the value from the first chunk. If the merge-value-function is provided then that command will be called with the current values of the parameter in the order the chunks are being merged and the return value of that call will be the value for the merged chunk.

If a new parameter is created, then the name of the accessor is returned.

If a parameter by that name already exists, then a warning will be printed and the keyword **:duplicate-parameter** will be returned.

If parameter-name is not valid a warning is printed and **nil** is returned.

If there is already a function with the same name as the accessor or the update function created then a warning will be printed to indicate that and those functions will be redefined for the chunk parameter. In some cases, that warning may appear if a file containing an extend-chunks call is compiled and then loaded. In those circumstances the warning can typically be safely ignored, and if one wants to

eliminate the warning then the extend-chunks command can be called between calls to the functions suppress-extension-warnings and unsuppress-extension-warnings to prevent the output of the warnings:

```
(suppress-extension-warnings)
(extend-chunks ...)
(unsuppress-extension-warnings)
```

The use of the warning suppression function is only recommended for use when an extend-chunks call occurs at the top level of a file and one is certain the parameter name's redefinition of the function(s) is not a problem.

Important Note: when creating external commands for the copy or merge operations you will not be able to access the values of any parameters in the corresponding chunk(s) from inside of those commands (a call to a parameter accessor will just hang forever). If you need the values of the parameters you will have to use the copy-from-chunk-function or merge-value-function to get the value directly.

Examples:

```
1> (defun count-copies (n) (1+ n))
COUNT-COPIES

2> (defun merge-use-second (a b) b)
MERGE-USE-SECOND

3> (defun start-with-name (x) (string x))
START-WITH-NAME

4> (extend-chunks simple)
CHUNK-SIMPLE

5> (extend-chunks counter :default-value 0 :copy-function count-copies)
CHUNK-COUNTER

6> (extend-chunks merge-demo :default-function start-with-name
                             :merge-function merge-use-second)
CHUNK-MERGE-DEMO

7> (define-chunks (a))
(A)

8> (pprint-chunks-plus a)
A

  --chunk parameters--
   MERGE-DEMO  "A"
   COUNTER  0
   SIMPLE  NIL
   ...

(A)

9> (copy-chunk a)
A-0

10> (pprint-chunks-plus a-0)
A-0

  --chunk parameters--
   MERGE-DEMO  "A-0"
```

```
   COUNTER  1
   SIMPLE  NIL
   ...

(A-0)

11> (merge-chunks a a-0)
A

12> (pprint-chunks-plus a)
A

  --chunk parameters--
   MERGE-DEMO  A-0
   COUNTER  0
   SIMPLE  NIL
   ...

(A)

13E> (extend-chunks simple)
#|Warning: Parameter SIMPLE already defined for chunks. |#
:DUPLICATE-PARAMETER

1> (defun chunk-dummy ())
CHUNK-DUMMY

2E> (extend-chunks dummy)
#|Warning: Function CHUNK-DUMMY already exists and is being redefined. |#
CHUNK-DUMMY

E> (extend-chunks "not a symbol")
#|Warning: "not a symbol" is not a valid symbol for specifying a chunk parameter. |#
NIL
```

Defining New Modules

The primary means of extending the system, both in terms of extending the cognitive capabilities of models and extending the software system itself, is through adding new modules. This section will describe the mechanism for defining a new module and detail how it interacts with the system.

To create a new module one uses the define-module command. A module can only be defined when there are currently no models in the system. The typical way to do that for a Lisp based module is to place the file with the module definition into one of the directories from which all of the .lisp files are loaded automatically at startup. That way the new module will be compiled and loaded with the rest of the ACT-R files. However it is not necessary to do it that way, and one can define modules using the define-module command at any time when there are no models defined.

When a module is defined it must be given a name. That name must be unique among the currently defined modules i.e. only one module with a given name may exist in the system. Once a module is defined it cannot be overwritten with a new definition for a module with the same name. However, one can use the undefine-module command to explicitly remove a module from the system if it is necessary to replace it. Undefining a module can also only happen when there are no models defined.

Once a module is defined every model which gets defined will have its own instance of that module. What constitutes an "instance" is determined by the module's creation command (described in detail below). The recommendation is that a new instance should be created for each model and that there should be no sharing of state between modules in separate models, particularly for the cognitive modules. However, there is nothing which prevents such operation and in some circumstances that may be useful, for example, a module might make one connection to an external simulation and then allow all the models to access that same connection through their own instances of the module.

There are several items which may be specified when defining a module. It is not necessary for a module to specify all of them, and other than a name no others are required. All of these items will be described in the following sections.

Documentation

When the module is defined one should provide a string for the version number of the module and a string containing the description of the module. These strings are displayed when the system is initially loaded and when the mp-print-versions command is called. There are no requirements on what those strings must contain, but the recommendation is to provide some sort of number for the version string and a very brief description of the module for the documentation. If documentation strings are not provided then a warning will be displayed indicating that they should be, but that will not prevent the module from being created.

Buffers

When the model is defined it may have any number of buffers associated with it. This is the only way to add new buffers to the system – they do not exist independently of a module. The buffers for a module will provide the interface for other modules to interact with the new module. The buffers provide the means of making requests and queries to the module, and it may respond to requests or

other actions by placing chunks into its buffers. Note that every module has access to all of the buffers of the system and can place chunks into any of them, but the recommendation is that a module should only manipulate its own buffers. Of the default modules, the only one which does not follow that recommendation is the procedural module where the productions are allowed to manipulate, clear, or place chunks in any buffer.

There are several options which can be given when creating a new buffer. The only required component is a name. Each buffer must be given a name and that name must be unique in the system – there is can only be one buffer with any given name. The other options are described in the following sections. One other consideration for the buffer is whether it must always create new chunks when set or whether it can reuse a single chunk. That is not specified as part of the buffer description. If a buffer must have newly named chunks created every time it is set then that must be indicated by using the buffer-requires-copies command during the primary reset function for the module.

spreading activation weight

The name of the parameter used to set that buffer's weight for the spreading activation calculation and the default value for that parameter may be specified. If they are not specified then the parameter will be named *buffer*-activation where *buffer* is the name of the buffer and the default value for the parameter will be 0.

request parameters

Any request parameters which are to be used with the buffer must be specified when the module is defined. Only those request parameters which are specified when the module is created will be considered valid when making a request to that buffer through the provided module request functions. However, there is no constraint placed on the generation of a chunk-spec since it does not make reference to any buffer at its creation time. Therefore, it is possible for code which doesn't use normal request mechanisms to pass a chunk-spec with invalid request parameters to the handler functions of a module. It is not recommended that one use the request handler functions of a module directly in that fashion, but if those functions are to be used that way they should perform additional tests in verifying the validity of any request parameters in the chunk-spec provided.

queries

Any queries which the module will accept through the buffer, other than the default query of state which all modules must accept, need to be specified when the module is defined. Only those queries which are specified at definition time will be accepted as valid when using the query-buffer command. However, as described with the specification of a buffer's request parameters, if one calls the module's query function directly there is no pretesting of the values and it should not assume that all queries are valid.

query printing

By default, buffer-status will print out the results of querying the buffer's buffer and state queries (those to which every buffer must respond). If the module has other queries that one would like to

show when buffer-status is called that can be done by providing a query printing command to do so. That command should return a string with the text to display after the normal output by buffer-status.

multi-buffer

A buffer may indicate whether or not it is to be treated as a "multi-buffer". A multi-buffer is a construct which allows one to specify a set of chunks which can be used with the buffer that will not be copied when placed into the buffer – they will be placed directly into the buffer. Details on multi-buffers are described in their own section and will not be covered further here.

Parameters

Each module may specify a set of parameters which it will use. Those parameters can be either new parameters which the module will "own" and make available to the system, or existing parameters owned by other modules which it would like to be informed about when they change. Whenever a parameter is changed through the use of the sgp command the module which owns that parameter is given the new value specified in the sgp call. The module is responsible for recording that new value, or whatever value it wants to use based on that value, and then return the current value for the parameter. If any other modules are watching that parameter as non-owners, then they are notified of the new value which the owning module has reported.

In Lisp the parameters are specified using the define-parameter command, and remotely one provides an option list of values. These are the items that can be provided for a parameter in the module.

name

Each parameter must specify the name of the parameter. The name must be a Lisp keyword. If it is the name of a parameter that has already been defined by another module then it is only valid if this definition explicitly claims that it is not the "owner" of that parameter. If it specifies that it is the owner of the parameter, then that name must not already be taken by a parameter of another module.

owner

When defining the parameter it must be specified whether it should be created as a new parameter or one which is to be watched and assumed to already exist. If it is being specified as a new parameter, that is, the specification claims that it is being defined by its owner, then the remaining properties may also be specified for the parameter. If the specification claims to not be the owner of the parameter then only the name of the parameter is relevant.

documentation

A string describing the parameter can be specified. That string will be printed by the sgp command when displaying the details of the parameter.

default-value

The value the parameter will have by default. If no default value is given then the default value will be **nil**.

valid-test

A command identifier may be specified to use when testing the parameter values set by the sgp command. If a valid-test is specified, then that will be passed one value, which is the requested setting from an sgp call. If the test returns a non-**nil** value then the setting is passed on to the module to handle. If the test returns **nil** then a warning is displayed and that parameter setting is not passed to the module.

warning

If a parameter value fails the valid-test the warning which is printed is constructed based on the warning string provided when the parameter is defined. The warning will always be of this form:

```
#|Warning: Parameter param cannot take value val because it must be warn. |#
```

where *param* is the name of the parameter, *val* is the invalid value given and *warn* is the warning string specified when defining the parameter.

Interaction commands

A module interacts with the rest of the system by providing commands to be called at the appropriate times. None of these items are required unless the module also provides one or more buffers or one or more parameters for the system. If the module has a buffer then it must provide a command to handle queries of the buffer, and if it has any parameters then it must provide a command to handle the setting and getting of the parameter values.

Here are the possible situations for which a module may provide commands and the parameters which it will be passed and how the return value is used.

creation

Whenever a new model is defined it will create an instance of each module in the system. To create that instance each module's creation command is called. That command will be passed one parameter which will be the name of the model being defined. The value returned will be saved as the instance of that module in that model. The module's instance should be a data structure capable of holding any parameter values and state information necessary for the module to operate or a unique indicator which the module code will use to locate that model specific information (because the remote calling mechanisms do not provide shared access to items a unique identifier should always be used for a module not defined in Lisp since it would not be possible to manipulate the actual instance held by ACT-R remotely). That instance will be passed to all of the other interface commands which the module provides. If a module does not provide a creation command then its instance will be the value **nil** for the purpose of calling any of its other interface commands.

If the module has any new chunk-types or constant chunks that it needs then those can be defined in the creation function as well instead of having to be redefined at every reset. Any chunks which are defined in the creation function will automatically be marked as immutable.

reset

The module may specify one, two or three commands to call when a model is reset. Those commands will be called with the instance of the module as their only parameter. The three reset commands are called at different times during the resetting of a model and a module may use any or all of them if needed. The primary reset is called before any parameters get reset to their default values. The secondary reset gets called after the default parameters have been set and before any user code is evaluated. The tertiary reset gets called after the user code of the model definition has been evaluated. Most modules are likely only going to need one of the reset commands, and typically only the primary reset is necessary. However, if a module needs to modify the value of another module's parameter at reset time it will have to do so in a secondary or tertiary reset, otherwise any change will be overwritten. Although using the secondary or tertiary reset is necessary to adjust another module's parameter from the default value, it may not be sufficient because other modules may also have secondary or tertiary reset actions which will also adjust or restore that value. In such cases, watching the parameter, by adding it to the module as a parameter which it does not own, will allow for more control and monitoring of the changes. The return value of a module's reset command is not used.

delete

The module may specify a command to be called when the model in which it has been created is deleted. The delete function will be passed the instance of the module in the model being deleted as its only parameter. The instance of the module will not be referenced by the given system code after it has been deleted and thus may be destructively modified, deallocated, or any other explicit cleanup as needed may be performed upon it. To ensure that deleted module instances are not referenced, one should not access any parameters using sgp in a module's delete action. The return value of the module's delete command is not used.

parameters

If the module makes parameters available to the system or is monitoring the parameters of other modules then it must provide a command for setting and getting those parameter values. The module's parameter command will be called with two parameters. The first will be the instance of the module in the current model. The second depends upon whether the module was defined from within the Lisp running ACT-R or externally. If it was defined in Lisp then it will be either the name of a parameter, in which case this is a request for the current value of the parameter which the command should return, or it will be a cons of a parameter name and a new value for that parameter which the module should set. If the module was defined externally then the second parameter will always be a list. If it is a request for the current value that list will contain one item which is the name of the parameter, and if it is a request to set a new value for the parameter the list will have two items which will be the name of the parameter and the new value for it respectively. When a new value is indicated for a parameter, the module should set the parameter as needed based on that value and then return the current value of the parameter (which may or may not be the same as the value which was provided). A module's parameter function will only be called with parameters which the

module has specified when it was defined. For those which it owns it will get both calls for the current value and calls to change the value. If a module does not own the parameter it will only be sent notifications of changes to the parameter and the return value from the function in those cases is ignored.

queries

If the module has one or more buffers, then it must provide a command to handle queries of those buffers. The module's query command will be called whenever the query-buffer command is used. It will be called with four parameters. The first will be the instance of the module in the current model. The second will be the name of the buffer being queried. The third will be one of the valid queries for the module – either state, which all modules must accept, or one of the ones given when the buffer was specified. The fourth parameter will be the value of the query to test. There are no constraints on the values which may be used. Thus, a module should be able to handle any value which is provided, but it does not have to consider them all valid and may display warnings when invalid values are given. Every module with a buffer is expected to respond to queries of state with values of free, busy, or error, but other than those there are no prespecified queries to which a module must respond. The return value of the query function is considered as a generalized boolean. If the query of the given value is true then the module should return a true value and if the query of the given value is not true the function should return **nil**.

requests

If the module has one or more buffers then it may provide a command to handle requests to those buffers, but it is not required that a module with buffers accept requests. If a request command is specified for the module then it will be called whenever the module-request command is called for one of the module's buffers. It will be called with three parameters. The first will be the instance of the module in the current model. The second will be the name of the buffer to which the request was made, and the third will be a chunk-spec (or chunk-spec-id) which represents the request being made. The chunk-spec provided may include any number of slot tests and request parameters, but only those request parameters which are specified with the buffer's definition will be included. Other than that there are no tests performed on the chunk-spec before it is passed to the module. Therefore the module's request command is responsible for testing and verification of whether the request being made is something which the module is able to handle and should signal warnings to indicate invalid or malformed requests. The return value of the request command is ignored.

What a module does in response to a request is entirely up to the module writer – there are no mandatory actions which must occur. It is recommended however that the module should schedule events to handle all of the actions which it performs in response to the request. By doing so, the trace will show those actions, other modules will be able to detect that they have occurred (for instance the procedural module may schedule another conflict-resolution event if there is not one pending), the model debugging tools will allow one to see that the events have been scheduled, and the stepping tools can be used for testing and debugging of the module's actions.

buffer modification requests

If the module has one or more buffers then it may provide a command to handle buffer modification requests, but a module is not required to handle such requests. If a command for buffer modification

requests is provided for the module then it will be called whenever the module-mod-request command is called for one of the module's buffers. The module's buffer modification request command will be called with three parameters. The first will be the instance of the module in the current model. The second will be the name of a buffer to which the request was made, and the third will be a chunk-spec (or chunk-spec-id) of modification information (a chunk-spec that only uses the modifier = in the slot-specs, specifies each slot only once, and may contain request parameters valid for the specified buffer). A buffer modification request will only occur when there is a chunk in the buffer, but the slots specified may or may not exist in that chunk. The return value of the modification request command is ignored.

What a module does in response to a buffer modification request is entirely up to the module writer – there are no mandatory actions which must occur. It is recommended however that the module should schedule events to handle all of the actions which it performs in response to the request. The general purpose of the modification request is to allow the module to perform an action like mod-chunk which has a time cost during which time the module will be busy and unable to handle other requests. However, it does not have to be used that way and may be used to perform other module actions.

notify upon clearing

A module may specify a command to be called when any buffer is cleared. If a module provides a command to be notified when buffers clear it will be called with three parameters after every buffer clearing occurs. The first parameter will be the instance of the module in the current model. The second parameter will be the name of a buffer, and the third parameter will be the name of the chunk which was cleared from the buffer. The module may use that information however it wants, but there are two things to be careful about. One is that it should not modify the chunk which was cleared from the buffer because other modules may also need the information which is in that chunk. The other is that if the name of the chunk is important or the chunk is being stored for later access then the chunk-not-storable command should be used to verify that it is not a chunk that is going to be reused by the buffer. If it is a chunk that will be reused, then the module should make a copy of it for storing/recording purposes. The return value of the notify upon clearing command will be ignored.

notify at the start of a new call to run the system

A module may specify a command to be called whenever one of the system running commands is called. If a module provides a command to be notified when a run starts then that command will be called with one parameter before the first event of the run is executed. That parameter will be the instance of the module in the current model. This notification function is not recommended for the normal operations of a module because it should not depend on how or when the system is run. The intended use of this notification is to allow a module an opportunity to perform some safety or verification tests before the system runs. The return value of this command is ignored.

An example of its use is the procedural module using it to make sure that there is always a conflict-resolution or other appropriate procedural event scheduled or waiting. This avoids a problem that could occur because of an unusual run termination (a Lisp break in the middle of a conflict-resolution action for example) which would leave the procedural module without any events on the queue and thus unable to fire any more productions until it is reset.

An important note is that this command will be called regardless of how the running command was called. Some of the running commands may actually result in multiple start/stop pairs because they can involve multiple calls to running commands internally. Thus, start/stop pairs may not map 1:1 with user calls to run the system.

notify upon a completion of a call to run the system

A module may also specify a command to be called whenever one of the system running commands is finished running the system. If a module provides a command to be notified when a run ends then it will be called with one parameter after the last event of the run is executed. That parameter will be the instance of the module in the current model. Like the run start notification, this is not recommended for the normal operations of a module because it should not depend on how or when the system is run. The intended use of this notification is to allow a module an opportunity to perform some safety or verification tests after the system runs.

As noted with the run start description, this command will be called regardless of how the running command was called. Some of the running commands may actually result in multiple start/stop pairs because they can involve multiple calls to running commands internally. Thus, start/stop pairs may not map 1:1 with user calls to run the system.

warning of an upcoming request

A module may specify a command which will be called to provide the module with a warning of an upcoming request from a production. If a warning command is provided it will be called with three parameters. The first parameter will be the instance of the module. The second will be the name of one of the module's buffers and the third will be the chunk-spec (or chunk-spec-id) of the request. The procedural module will call a module's warning command, if it has one, at production selection time to warn about any requests which will be made when the selected production fires. This is the only time that the warning command will be called – requests from other modules or from explicit requests made by other code will not be preceded by warnings. Having a warning command allows a module to know that a production will be making a request which may be dependent on information which was true at the time the production was selected. The module gets called with the warning at the selection time and thus may suspend pending actions or note the relevant information necessary at that time to use when handling the request. The return value of this command is ignored.

The only module which currently uses a warning command is the vision module. It allows the vision module to suspend the processing of a screen update during a production which will be making a move-attention request so that the visual-location chunk which is used in the production does not get invalidated by a change in the display before the request is handled.

search and offset

Two additional commands can be specified when the module has one or more searchable buffers. How those functions are used is described in the searchable buffers section.

Common Class of Modules – Goal Style

There is a particular type of module which modelers often find useful to create for various situations. That type of module is one which works like the goal and imaginal modules where a request is a direct specification of a chunk to create and be placed into the buffer. Those are referred to as "goal style" modules. There are three Lisp functions which exist to make creating such modules easy (those functions are not currently available remotely). Those functions can be used as the query, request, and modification request functions for creating such a module, and they are the functions goal-style-query, goal-style-request, and goal-style-mod-request respectively.

Using those functions, one can create a new module which acts just like the default goal module and buffer using something like this:

```
(define-module name (name) nil :version "1.0" :documentation "Example"
               :query goal-style-query
               :request goal-style-request
               :buffer-mod goal-style-mod-request)
```

Where *name* is the name you want to give to the module and buffer, which must be the same for the assumptions in the goal-style-* functions.

Those commands do not have to only be used in that manner, and it is possible to call them from other functions. For example, one could specify a different request function when creating the module which performs some error checking or possible restrictions on the requests which can be made to the module before then calling goal-style-request to do the rest of the work.

The file which defines the goal-style components is included in the support directory of the distribution. Therefore it is not loaded automatically when the system loads. So, any file which uses those commands should include this line near the top of the file:

```
(require-compiled "GOAL-STYLE-MODULE")
```

That will ensure that the goal style support code is loaded appropriately. Typically, the main goal module will already have loaded that support, but it is safest to be certain that it has been loaded, especially when creating modules or other code which may be shared with others who may have made other changes to the modules or default system.

Writing Module Code

When writing code to handle the module's operations there are some assumptions which can be made and practices which should be followed. This section will cover those assumptions and recommended practices.

Because the module commands which one provides will always be passed the current model's instance of the module one can assume that there is a current model in handling those calls. However, if one has additional functions which go along with the module that may be called at other times, or without requiring an instance of the module as a parameter, then the use of the get-module command is recommended to get the current model's instance of the module to work with. The get-module command takes one parameter which should be the name of a module and it returns the instance of that module in the current model. If there is no current model then get-module will print a warning and return **nil**.

When a module performs actions in a running model, particularly actions relating to the buffers, it should always schedule those as events instead of directly calling commands which make those changes. When scheduling such events, it should always indicate the module's name when the event is generated. Doing those things makes it much easier to debug a model which uses the module and also makes it easier to integrate new modules from different sources because any unexpected interactions should then be detectable in the model's trace.

If a module needs to reference the values of parameters of other modules then it is recommended that they be specified as non-owned parameters for the module. Those parameters' values should then be recorded in some way in the instance of the module with the module's parameter function even if the module has no parameters of its own. That is recommended for performance reasons because using sgp to get parameter values is a relatively slow process and often also requires suppressing the output which also may have a significant cost to performance relative to the work done by the module.

Any chunk-types and chunks which a module is going to define should be defined in the module's creation command if possible so that they can be automatically restored at reset time, or the primary reset function if there is a dependence upon other information that is not available at creation time. If the module depends on the chunks or chunk-types of other modules it should not reference those items during the creation or primary reset function because there is no guarantee that the other module's corresponding function will be called prior to the current module's (and presumably that's when the other module is defining them).

If the module will be extending chunks or productions with new parameters for its use that should be done at the top level in the module's definition file because extending those items should only occur once. Such calls do not belong in either the creation or reset function for the module.

Module examples

The examples provided below will generally only show the basic syntax of the commands, and will not have "working" module definitions as examples because the necessary support code is outside of the scope of the examples for the reference manual. Also, one often needs a model which uses the module to really have an example that shows the components in operation. In the examples directory of the source code distribution one can find a directory called creating-modules. In that directory are new module definition files which implement demonstration modules along with corresponding models which use the features provided by those modules. The documentation for the modules and how to run the associated models are included in the comments of those files.

Commands

get-module

Syntax:

get-module *name* -> [instance | **nil**] [**t** | **nil**]
get-module-fct *name* -> [instance | **nil**] [**t** | **nil**]

Remote command name:

get-module

Arguments and Values:

name ::= the name of a module
instance ::= the named module's instance in the current model

Description:

The get-module command is used to get the instance of a module in the current model. It returns two values. If there is a module with that name in the system then the first return value is the instance of that module and the second return value will be **t**. If that name does not name a module in the current model or there is no current model then a warning will be printed and both return values will be **nil**. The purpose of the second return value is to indicate that the module instance exists because a module may use **nil** as its instance.

Examples:

```
> (get-module goal)
#S(GOAL-MODULE ...)
T

> (get-module-fct 'imaginal)
#S(IMAGINAL-MODULE ...)
T

E> (get-module foo)
#|Warning: FOO is not the name of a module in the current model. |#
NIL
NIL

E> (get-module-fct 'goal)
#|Warning: get-module called with no current model. |#
NIL
NIL
```

define-buffer

Syntax:

define-buffer *name* {**:param-name** *param*} {**:param-default** *default*} {**:request-params** *request-params*}
{**:queries** *queries*} {**:status-fn** *status*} {**:search** *search*} {**:multi** *multi*} {**:copy** *copy*}
-> buffer-list
define-buffer-fct *name* {**:param-name** *param*} {**:param-default** *default*} {**:request-params** *request-params*}
{**:queries** *queries*} {**:status-fn** *status*} {**:search** *search*} {**:multi** *multi*} {**:copy** *copy*}
-> buffer-list

Arguments and Values:

name ::= a symbol which is the name of the buffer
param ::= a keyword that names the source activation parameter for the buffer
default ::= the default value for the source activation of this buffer
request-params ::= (request-param*)
request-param ::= a keyword indicating a valid request parameter for this buffer

queries ::= (query*)
query ::= a symbol indicating a valid query for this buffer
status ::= a command identifier indicating the command to call for additional buffer-status text
multi ::= a generalized boolean indicating whether this is a regular multi-buffer
search ::= a generalized boolean indicating whether this is a searchable multi-buffer
copy ::= a generalized boolean indicating whether this is a multi-buffer which should copy chunks
buffer-lst ::= (name (p-name p-default) request-params queries status multi-type)
p-name ::= param if it is provided, otherwise the keyword :*name*-activation
p-default ::= default if it is provided, otherwise **nil**
multi-buffer ::= [**:multi** | **:search** | **:multi-copy** | **:search-copy | nil**] depending on the values of multi search and copy

Description:

The define-buffer command can be used to create a buffer definition list for use in a module definition. The value returned from this function has no real use in the system other than as a member of the list of buffers when defining a module. It is recommended that define-buffer be used to create a buffer definition list whenever the buffer uses any of the needed components to make the definition more understandable. If a value is not provided for one of the keyword parameters then a **nil** value will be placed into the definition list for that component, with two exceptions: if the param-name is not provided but a param-default is then the standard default activation name will be used, and both the search and multi values must be **nil** (or not provided) for the multi-buffer specifier to be **nil**.

Define-buffer does not test any of the values for validity and just creates an appropriately formatted list for use in a module definition.

Examples:

```
> (define-buffer test :param-name :test-val)
(TEST (:TEST-VAL NIL) NIL NIL NIL NIL)

> (define-buffer test :multi t :param-default 3)
(TEST (:TEST-ACTIVATION 3) NIL NIL NIL :MULTI)

> (define-buffer-fct 'test :queries (list 'status 'size) :status-fn 'print-my-status)
(TEST NIL NIL (STATUS SIZE) PRINT-MY-STATUS NIL)
```

define-parameter

Syntax:

define-parameter *param-name* {**:owner** *owner*} {**:default-value** *default*} {**:documentation** *docs*}
{**:valid-test** *test*} {**:warning** *warn*} -> [parameter | **nil**]

Arguments and Values:

param-name ::= a keyword for the name of the parameter being defined
owner ::= a generalized boolean indicating whether this definition is specifying the parameter's owner
default ::= a value which will be the default value for the parameter

docs ::= a string describing the parameter
test ::= a command identifier or nil used to test values for this parameter through sgp
warn ::= a string to print when an invalid parameter value is detected
parameter ::= an instance of an ACT-R internal parameter item

Description:

The define-parameter command is used to create a parameter for a module. The value returned from this function has no use in the system other than as a member of the list of parameters when defining a module. A parameter defined through this command will not be available to the system until it is part of a module which owns it.

The only parameter required when calling define-parameter is the name of the parameter which must be a Lisp keyword.

The owner parameter specifies whether the module which uses this parameter definition is to be considered the owner of that parameter. If not provided the default value is **t**.

The default parameter specifies the value the parameter should have as its default when the system is reset. If not provided, then the default value for the parameter will be **nil**. The only restriction on the default value is that it cannot be a Lisp keyword because it is not possible to use sgp to set a single parameter to a keyword value.

The docs parameter should be a string which describes the parameter. That string is printed by sgp when the parameter value is displayed.

The valid test command is called whenever this parameter's value is changed using the sgp command. The command will be passed the new value specified in the sgp call. If the command returns a true value then the new value is considered valid and it is passed on to the owning module's parameter function to set. If the command returns **nil** then a warning is printed and the parameter value is left unchanged. If no test is specified in the definition for the parameter then no testing is performed on the values.

If a valid test command is provided, then when it reports an invalid value the warning which gets printed will look like this:

```
#|Warning: Parameter param-name cannot take value val because it must be warn. |#
```

where *param-name* is the name of the parameter, *val* is the invalid value given and *warn* is the warn string specified when defining the parameter. If no warn string is provided, then it defaults to an empty string.

If any of the parameters passed to define-parameter are invalid then a warning will be displayed and **nil** will be returned.

Examples:

```
> (define-parameter :new :documentation "A new parameter")
#S(ACT-R-PARAMETER ...)

> (define-parameter :count :valid-test 'fixnump :warning "a fixnum")
```

```
#S(ACT-R-PARAMETER ...)

> (define-parameter :bll :owner nil)
#S(ACT-R-PARAMETER ...)

E> (define-parameter 'not-a-keyword)
#|Warning: Parameter name must be a keyword. |#
NIL

E> (define-parameter :new :documentation 'not-a-string)
#|Warning: documentation must be a string. |#
NIL

E> (define-parameter :new :valid-test 'not-a-function)
#|Warning: valid-test must be a function, the name of a function, or nil. |#
NIL

E> (define-parameter :new :default-value :keywords-not-allowed)
#|Warning: default-value cannot be a keyword. |#
NIL

E> (define-parameter :new :warning 'not-a-string)
#|Warning: warning must be a string. |#
NIL
```

define-module

Syntax:

define-module *module-name* (*buffer-def**) (*param**) {**:version** *version*} {**:documentation** *doc-string*}
{**:creation** *create*} {**:reset** *reset*} {**:request** *request*} {**:query** *query*} {**:buffer-mod** *mod*}
{**:params** *params*} {**:delete** *delete*} {**:notify-on-clear** *clear*} {**:warning** *warn*}
{**:run-start** *run-start*} {**:run-end** *run-end*} {**:search** *search*} {**:offset** *offset*} {**:required** *required*}
{**:requires** *requires*}-> [module-name | **nil**]

define-module-fct *module-name* (*buffer-def**) (*param**) {**:version** *version*} {**:documentation** *doc-string*}
{**:creation** *create*} {**:reset** *reset*} {**:request** *request*} {**:query** *query*} {**:buffer-mod** *mod*}
{**:params** *params*} {**:delete** *delete*} {**:notify-on-clear** *clear*} {**:warning** *warn*}
{**:run-start** *run-start*} {**:run-end** *run-end*} {**:search** *search*} {**:offset** *offset*} {**:required** *required*}
{**:requires** *requires*}-> [module-name | **nil**]

Remote command name:

define-module *module-name* (*buffer-def**) (*remote-param**)
{ < **version** *version,* **documentation** *doc-string,* **creation** *create*, **reset** *reset*,
request *request,* **query** *query*, **buffer-mod** *mod*, **params** *params*, **delete** *delete*,
notify-on-clear *clear*, **warning** *warn*, **run-start** *run-start*, **run-end** *run-end*,
search *search*, **offset** *offset,* **required** *required,* **requires** *requires* >}

Arguments and Values:

module-name ::= the name for the module being defined
buffer-def ::= [buffer-name |
(buffer-name {buff-params { (req-param*) { (query-names*) { [print-status | **nil**]
{multi-buffer}}}}})]
buffer-name ::= a name of the buffer being defined

buff-params ::= [pname | (pname pdefault) | (**nil** pdefault) | (pname **nil**) | **nil**]
pname ::= a name for the parameter to create for the buffer's spreading activation value
pdefault ::= a number which will be the default for the buffer's spreading activation value parameter
req-param ::= a name for a request parameter this buffer will accept
query-names ::= a name of a new query which is valid for this buffer
print-status ::= a command identifier of the command to be called for additional buffer-status output
multi-buffer ::= [**:multi** | **:search** | **:multi-copy** | **:search-copy | nil**]
param ::= a parameter item as returned by the define-parameter command
doc-string ::= a string to provide a brief description of the module
create ::= a command identifier of the command to handle the module creation
reset ::= [primary-reset | ([primary-reset | **nil**] { [secondary-reset | **nil**] { [tertiary-reset | **nil**] }})]
primary-reset ::= a command identifier of the command to handle the module's primary reset
secondary-reset ::= a command identifier of the command to handle the module's secondary reset
tertiary-reset ::= a command identifier of the command to handle the module's tertiary reset
request ::= a command identifier of the command to handle module requests
query ::= a command identifier of the command to handle module queries
mod ::= a command identifier of the command to handle module modification requests
params ::= a command identifier of the command to handle the module's parameter
delete ::= a command identifier of the command to handle the deletion of the module
clear ::= a command identifier of the command to call whenever a buffer is cleared
warn ::= a command identifier of the command to be called to warn of a new request to the module
run-start ::= a command identifier of the command to be called when a running command is called
run-end ::= a command identifier of the command to be called when a running command finishes
search ::= a command identifier of the command to be called when searching a multi-buffer
offset ::= a command identifier of the command to be called after a multi-buffer search for preferences
remote-param ::= (param-name {< **owner** *owner,* **valid-test** '*test* '**, default-value** '*default* ', **warning** *warn,*
documentation *docs* > })
param-name ::= the name of the parameter being defined
owner ::= a generalized boolean indicating whether this definition is specifying the parameter's owner
test ::= a command identifier or **nil** used to test the value for this parameter through sgp
default ::= a value which will be the default value for the parameter
warn ::= a string to print when an invalid parameter value is detected
docs ::= a string describing the parameter
version ::= a string providing version information for the module
required ::= [**t** | **nil** | module | (module*)]
requires ::= (existing-module*)
module ::= the name of another module
existing-module ::= the name of another module which has been previously defined

Description:

The define-module command is used to add a new module to the system. A new module may only be added if there are currently no models defined. The first parameter to define-module must be a name for the new module being defined. If there is not already a module defined with that name and all of the remaining parameters provided to describe the module are valid (as described below) then a new module is added to the system and the name of the module is returned. Otherwise, a warning is printed and **nil** is returned.

The second parameter must be a list of the buffer descriptions for the buffers of the module. It may be an empty list, in which case the module has no buffers. If it is not an empty list, then the elements of that list must be either names or lists.

If an element of the buffer definition list is a name, then the module will have a buffer with that name which will be given the default values for its components. If a list is provided then one can specify the other components of the buffer as well. The define-buffer command is recommended for creating a buffer definition list, but is not required. The list may be up to six elements long and the components of the list are as follows:

- The first element must be the name of the buffer.
- The second element specifies the name of the spreading activation parameter to add to the system for this buffer and/or the default value for the buffer's spreading activation parameter.
    - If it is a keyword which is not already the name of a parameter in the system then that name will be used for the parameter and it will have a default value of 0.
    - If it is a list, then the first element of the list is the name of the parameter and the second element is the default value, which should be a number. If the name is specified as **nil** then the default name for the parameter is used.
- The third element is the list of request parameters which the buffer will accept. It must be a list of keywords or **nil**. Only those items specified in this list will be considered as valid request parameters by the module-request command.
- The fourth element is the list of queries which may be made to the module in addition to the standard query for state. It must be a list of names or **nil**. Only those items specified in this list will be considered as valid queries by the query buffer command.
- The fifth element should be a valid command. This command will be called after the buffer-status command has printed the default query information for the buffer. This is typically added when one provides additional queries so that their status may be displayed for the user along with the normal queries using buffer-status.
- The sixth element, if provided, indicates that this should be considered as a multi-buffer and specifies which multi-buffer mechanism to use.

If a module has one or more buffers then it must provide a query command. It is not required to provide a request or modification request command.

The third parameter to define-module must be a list of parameter specifications returned by the define-parameter command in Lisp or a list which is formatted as shown above for a remote-param. If the list of parameters is non-empty then each parameter must have a single owner. If a parameter in the list is specified as being owned by the module then it must not be owned by any other module, and if a parameter in the list is indicated as not being owned then that parameter must be owned by some other module. A module which specifies parameters must also provide a params command to support them.

The version and documentation parameters should be strings and are used to display information about the module when the mp-print-versions command is called. They are not required, but if either is not provided a warning will be displayed before defining the module.

The required and requires parameters are used to provide information about how this module interacts with the use-modules command. If required is set to **t** then the module will be included in all models regardless of the use-modules settings. If required is set to the name of a module or a list

of module names then it will be included if any of those modules are on the list of modules to use (it is required *by* those modules). Requires can be used to set the dependence in the other direction (this module requires another one) – all of the modules specified on the requires list will be included whenever this module is in the list of modules to use. If required is not set, or is set to **nil**, then the module will only be included if it is on the list of modules to use or another module has indicated that it requires this module. There are two things to note about setting these parameters for a module. The first is that requires can only be used to indicate modules that have been previously defined, but required can specify names of modules that have not yet been defined. The other is that currently the use-modules testing does not chain through the dependencies and they are processed in an arbitrary order. Thus, currently, if module A depends on module B, module B depends on module C, and module B specifies that it requires C, it is still necessary for module A to require both B and C because just requiring B may not result in module C being available.

The rest of the keyword parameters are used to specify the commands to call for interfacing the module to the rest of the system. How they interface to the system is described in the interaction commands section. Here the details of the parameters they will be passed and expected return values will be described.

The create command will be passed one parameter. That will be the symbol naming the model in which a new instance of the module is being created. The return value of the module's create function will be the instance used for calling all of the module's other commands from that model.

The module's reset command (or commands) are called with one parameter. That parameter will be the instance of the module in the current model. The return values of the reset commands are ignored by the system.

The request command will be passed three parameters. The first will be the instance of the module in the current model. The second will be a symbol naming one of the module's buffers indicating to which buffer the request was made. The third parameter will be the chunk-spec or chunk-spec-id which describes the request. The return value of the request command is ignored by the system.

The query command will be passed four parameters. The first will be the instance of the module in the current model. The second will be the name of one of the module's buffers indicating which buffer is being queried. The third will be the name of a query being made, and the fourth will be the value being queried. The return value of the query command will be considered as a generalized boolean and should indicate whether the value specified for the query was true or false.

The mod command will be passed three parameters. The first will be the instance of the module in the current model. The second will be the name of one of the module's buffers indicating to which buffer the modification request was made. The third will be a chunk-spec or chunk-spec-id of modification information (a chunk-spec that only uses the modifier = in the slot-specs, specifies each slot only once, and may contain request parameters valid for the specified buffer). The return value of the mod command is ignored by the system.

The params command will be passed two parameters. The first will be the instance of the module in the current model. The second will depend on whether the command is a Lisp function or a command string. If it is a Lisp function then the second will be either the keyword naming one of the module's owned parameters or a cons of a parameter keyword and a value. If just the parameter name is provided then that indicates that the current value for that parameter is being requested and

the return value of the command should be that parameter's current value in the current model. If a cons is provided that is specifying a new value for that parameter. If the command is specified with a string then the second parameter will always be a list. If it is a request for the current parameter value the list will contain one item which is the name of the parameter. To change the current value a list of two items will be provided with the first being the name of the parameter and the second being the new value. If this module owns the parameter being changed then the return value of the params command will be considered the current value of that parameter. If the module does not own the parameter being changed then the return value of the params command is ignored.

The delete command will be passed one parameter. That parameter will be the instance of the module in the model being deleted. The return value of the delete command is ignored by the system.

The clear command will be passed three parameters. The first will be the instance of the module in the current model. The second will be the name of a buffer which is being cleared. The third will be a the name of a chunk which is being cleared from that buffer. The return value of the clear command is ignored by the system.

The warn command will be passed three parameters. The first will be the instance of the module in the current model. The second will be a the name of one of the module's buffers indicating to which buffer the request will be made. The third will be a chunk-spec or chunk-spec-id indicating a request that will be made. The return value of the warn command is ignored by the system.

The run-start command will be passed one parameter. That parameter will be the instance of the module in the current model. The return value of the run-start command is ignored by the system.

The run-end command will be passed one parameter. That parameter will be the instance of the module in the current model. The return value of the run-end command is ignored by the system.

The search command will be passed two parameters. The first will be the instance of the module in the current model. The second will be the name of a multi-buffer of the module. The return value of the search command should be a list of chunks in that buffer's buffer set, in the order they are to be searched or **nil** indicating no order preference.

The offset command will be passed three parameters. The first will be the instance of the module in the current model. The second will be the name of a multi-buffer of the module. The third will be a list of chunk names from the buffer set of that multi-buffer. The return value of the offset command should be a list of numbers representing the offset value for the matching of the chunks in the list provided or **nil** if no offsets are to be used.

Examples:

Examples of modules along with demo models which use them can be found in the examples/creating-modules directory of the distribution. The examples here are only to show the syntax of the command and some of the warnings and errors which may occur.

```
> (define-module foo nil nil)
#|Warning: Modules should always provide a version and documentation string. |#
FOO
```

```
1> (define-module bar nil nil :version "" :documentation "")
BAR

2E> (define-module bar nil nil :version "" :documentation "")
#|Warning: Module BAR already exists and cannot be redefined.  Delete it with undefine-
module first if you want to redefine it. |#
NIL

> (define-module-fct 'foo '(foo-1 (foo-2 (:foo-spread 1.5)))
               (list (define-parameter :foo-value))
               :version "0.3"
               :documentation "example"
               :params 'foo-param-function
               :query 'foo-query-function)

FOO

E> (define-module-fct nil nil nil)
#|Warning: Modules should always provide a version and documentation string. |#
#|Warning: Nil is not a valid module-name. No module defined. |#
NIL

E> (define-module-fct 'bad '(buffer-1) nil)
#|Warning: Modules should always provide a version and documentation string. |#
#|Warning: A module with a buffer must support queries.
Module BAD not defined. |#
NIL

E> (define-module-fct 'bad nil (list 'bad-parameter))
#|Warning: Modules should always provide a version and documentation string. |#
#|Warning: Invalid params-list (BAD-PARAMETER).
Module BAD not defined. |#
NIL

E> (define-module-fct 'bad '(buffer-1 (buffer-2 bad-param-name)) nil :query 'query-fn)
#|Warning: Modules should always provide a version and documentation string. |#
#|Warning: Invalid buffer specification: (BUFFER-2 BAD-PARAM-NAME) |#
#|Warning: Error in module buffer definitions.
Module BAD not defined. |#
NIL

E> (define-module 'bad nil nil)
#|Warning: Modules should always provide a version and documentation string. |#
#|Warning: Cannot create a new module when there are models defined. |#
NIL
```

undefine-module

Syntax:

undefine-module *module-name* -> [**t** | **nil**]
undefine-module-fct *module-name* -> [**t** | **nil**]

Remote command name:

undefine-module

Arguments and Values:

module-name ::= the name of a module

Description:

The undefine-module command is used to remove a module from the system. It takes one required parameter which is the name of the module to remove. If that names a module in the system and there are no models defined then that module, all of its buffers, and all of its parameters are removed from the system and the value **t** will be returned.

If the name does not name a module in the system or there is a model defined then a warning is printed and a value of **nil** is returned.

There are typically two reasons for using this command. The first is when first writing and debugging a module. Often one finds that they need to change something with it and this command is the only way to remove a broken or incomplete module without quitting the system and reloading everything. The other is when one has built a module which is a replacement for an existing module. In that case, the file with a new version of the module undefines the original version of the module before defining the replacement.

Examples:

```
1> (define-module bar nil nil :version "" :documentation "")
BAR

2> (define-module foo nil nil :version "" :documentation "")
FOO

3> (undefine-module bar)
T

4> (undefine-module-fct 'foo)
T

5E> (undefine-module-fct 'foo)
#|Warning: FOO is not the name of a currently defined module. |#
NIL

E> (undefine-module goal)
#|Warning: Cannot delete a module when there are models defined. |#
NIL
```

goal-style-query

Syntax:

goal-style-query *instance buffer slot value* -> [**t** | **nil**]

Arguments and Values:

instance ::= this parameter is ignored
buffer ::= the name of the buffer being queried
slot ::= the slot being queried
value ::= the value of the query

Description:

The goal-style-query command is designed to be used as the query function for a module's definition. It assumes that only the default queries for state will be made. It responds to those queries as follows: a state busy query will always return **nil**, a state free query will always return **t**, and a state error query will always return **nil**. For any other values it will print a warning indicating that the query was invalid and return **nil**.

Examples:

```
> (goal-style-query nil 'goal 'state 'free)
T

> (goal-style-query nil 'goal 'state 'busy)
NIL

> (goal-style-query nil 'goal 'state 'error)
NIL

E> (goal-style-query nil 'goal 'state 'bad)
#|Warning: Unknown state query BAD to GOAL buffer |#
NIL

E> (goal-style-query nil 'goal 'bad-query t)
#|Warning: Unknown query BAD-QUERY T to the GOAL buffer |#
NIL
```

goal-style-request

Syntax:

goal-style-request *instance buffer chunk-spec* {*delay* {*priority*}} -> [event-id | **nil**]

Arguments and Values:

instance ::= this parameter is ignored
buffer ::= the name of the buffer to which the request was made
chunk-spec ::= a chunk-spec or chunk-spec-id of the request
delay ::= a number indicating how many seconds to wait before creating the chunk
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
event-id ::= an integer id for the event which will create the new chunk in the buffer

Description:

The goal-style-request command is designed to be used as the request function for a module's definition, but it may also be called by other functions to handle the creation of a chunk in the buffer and provides optional delay and priority parameters for such use. If the chunk-spec provided is valid for the chunk-spec-to-chunk-def command, then this command uses schedule-set-buffer-chunk command to create a chunk using that chunk definition for the specified buffer after the provided delay time has passed with the indicated priority. If no delay time is provided, then it default to 0 seconds. If the priority is not specified then it defaults to -1000. The id of the event scheduled is returned. If the chunk-spec is invalid then a warning is printed and **nil** is returned.

Examples:

```
1> (goal-style-request nil 'goal (define-chunk-spec isa chunk))
3

2> (goal-style-request nil 'goal (define-chunk-spec isa chunk) .2)
4

3> (with-parameters (:trace-detail high)
     (run .25))
     0.000   GOAL                    SET-BUFFER-CHUNK-FROM-SPEC GOAL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.200   GOAL                    SET-BUFFER-CHUNK-FROM-SPEC GOAL
     0.200   PROCEDURAL              CONFLICT-RESOLUTION
     0.200   ------                  Stopped because no events left to process
0.2
5
NIL

E> (goal-style-request nil 'goal 'bad-spec)
#|Warning: chunk-spec-to-chunk-def called with something other than a chunk-spec. |#
#|Warning: Invalid request made of the GOAL buffer. |#
NIL
```

goal-style-mod-request

Syntax:

goal-style-mod-request *instance buffer mods* {*delay* {*priority*}} -> [event-id | **nil**]

Arguments and Values:

instance ::= this parameter is ignored
buffer ::= the name of the buffer to which the request was made
mods ::= a modification chunk-spec or chunk-spec-id
delay ::= a number indicating how many seconds to wait before modifying the chunk
priority ::= [**:max** | **:min** | priority-val]
priority-val ::= a number indicating the priority to use for the event
event-id ::= the integer id of the scheduled event which will modify the chunk in the buffer

Description:

The goal-style-mod-request command is designed to be used as the buffer modification request function for a module's definition, but it may also be called by other functions to handle the modification of a chunk in the buffer and provides optional delay and priority parameters for such use. This command just calls schedule-mod-buffer-chunk with the buffer, module (same as buffer), chunk-spec, delay, and priority provided. If no delay time is provided, then it default to 0 seconds. If no priority is provided then the default value is 20. The value returned from that call to schedule-mod-buffer-chunk is returned.

Examples:

```
1> (set-buffer-chunk 'goal '(value t))
GOAL-CHUNK0
```

```
2> (goal-style-mod-request nil 'goal (define-chunk-spec value clear))
3

3> (goal-style-mod-request nil 'goal (define-chunk-spec color blue) .5)
4

4> (run .5)
     0.000   GOAL                    MOD-BUFFER-CHUNK GOAL
     0.000   PROCEDURAL              CONFLICT-RESOLUTION
     0.500   GOAL                    MOD-BUFFER-CHUNK GOAL
     0.500   PROCEDURAL              CONFLICT-RESOLUTION
     0.500   ------                  Stopped because time limit reached
0.5
5
NIL

5> (buffer-chunk goal)
GOAL: GOAL-CHUNK0
GOAL-CHUNK0
   VALUE  CLEAR
   COLOR  BLUE

(GOAL-CHUNK0)
```

Multi-buffers

A multi-buffer provides some new possibilities for how a module can use its buffer as well as possibly changing how the procedural module will interact with that buffer. These capabilities are still considered an experimental modification to the system and thus the reason for covering them in a separate section instead of in the other sections. If you use multi-buffers in your own modules please let me know of any problems you encounter or suggestions for improvements which you have.

Multi-buffers were introduced as a general mechanism to allow for the implementation of modules which do things which were not easy to do with the system previously. One such module was the threaded cognition module by Salvucci and Taatgen. Prior to the introduction of the multi-buffers, the implementation of the threaded cognition module required making changes to many of the internal processes of the system. That made that module difficult to maintain since it had to be updated often to stay in line with updates and changes to the main system. Those changes also had the potential to interfere with modules written by other people which could lead to problems integrating new mechanisms. The current design of multi-buffers was sufficient to allow threaded cognition to be implemented as a module without needing to change any of the main system code, and the expectation is that the multi-buffer concept may be useful in other areas as well.

The difference between a multi-buffer and a “normal” buffer is that a module with a multi-buffer may specify a set of chunks which can be placed into that buffer without being copied first. Despite the name, a multi-buffer is still restricted to only holding one chunk at any time. It is that additional set of chunks which accompany the buffer to which the multi prefix refers, but when used as a searchable buffer that chunk may be changed among those in the set automatically by the conflict resolution process thus being treated as if it holds any one of them for production matching purposes. When a chunk which is not in the “buffer set” of a multi-buffer is placed into the multi-buffer, it will work like a normal buffer and copy that chunk first.

Some of the buffer related commands described above work slightly differently when the buffer provided is a multi-buffer. Set-buffer-chunk and overwrite-buffer-chunk do not copy the chunk being placed into a multi-buffer if the chunk is a member of the buffer set for that buffer. When clear-buffer is passed a multi-buffer then the chunk being cleared from the buffer is also removed from the buffer set of that buffer. Finally, the buffer-chunk command will show the buffer set of a multi-buffer when that buffer’s information is displayed. The buffer set will be shown in curly braces after the name of the chunk currently in the buffer if the buffer set is non-empty.

Not every chunk may be added to the buffer set of a multi-buffer. Essentially, only those chunks which are created by the module which created the multi-buffer are valid members of the multi-set. Chunks which are, or could potentially be, referenced by other modules are marked as being invalid as members of a buffer set. In particular, chunks which have been cleared from a buffer and chunks which have been explicitly added into declarative memory cannot be put into a buffer set. Additionally, one may mark a chunk as explicitly unavailable for the buffer set of any multi-buffer by setting the buffer-set-invalid parameter of the chunk to **t** using either setf in Lisp or by calling the set-chunk-buffer-set-invalid command created for the chunk parameter. That may be useful when creating a module which defines chunks that are made available for other uses, but which should not be directly placed into buffers. If a chunk is already in a buffer set when it is marked as invalid then it will remain in that buffer set, but will be copied into the buffer from that point forward.

When working with a multi-buffer a module should be careful to not allow chunks which it wants to remain in the buffer set to be cleared from the buffer. The module should probably use overwrite-buffer-chunk instead of set-buffer-chunk internally to avoid clearing the current chunk first. Similarly, the module may want to turn off strict-harvesting for the multi-buffer to avoid the automatic clearing that the procedural module may perform. Note however that a request to the multi-buffer from a production will still clear the buffer. Thus, care may be required in how a model's productions interact with the multi-buffer if the buffer set is to be maintained.

To create a multi-buffer the module needs to provide a sixth item in the buffer definition list for the buffer in the module definition. A value of :multi will make the buffer a multi-buffer. There are other keyword values which create a searchable buffer described in the section below. If an invalid sixth item is given then a warning will be printed and the module will not be created.

Note that a multi-buffer will be set to always require copies since the names of the chunks in the buffer are assumed to be meaningful.

Commands

There are four additional commands that are used to work with the buffer set of a multi-buffer and one other general buffer command which is useful for multi-buffers. For all of the examples shown in the new commands this module with two multi-buffers, foo and bar, is assumed to exist:

```
(define-module :foo ((foo nil nil nil nil :multi)(bar nil nil nil nil :multi)) nil
               :query goal-style-query :version "" :documentation "")
```

As is this model which creates some initial chunks to use in the examples:

```
(define-model foo (sgp :v t)
  (define-chunks (a) (b) (c))
  (add-dm (d)))
```

store-m-buffer-chunk

Syntax:

store-m-buffer-chunk *buffer chunk* -> [chunk | **nil**]

Arguments and Values:

buffer ::= the name of a multi-buffer
chunk ::= the name of a chunk to add to the buffer set of buffer

Description:

The store-m-buffer-chunk command is used to add a chunk to the buffer set of a multi-buffer. If the buffer name given is the name of a multi-buffer and chunk names a chunk defined in the current model which is not marked as invalid for a buffer set then that chunk will be added to the buffer set of that multi-buffer in the current model and the chunk name will be returned. If the chunk is already

a member of the buffer set then no change to the buffer set is made and the chunk name is still returned.

If there is no current model, buffer does not name a multi-buffer, chunk is not a valid chunk name, or chunk names a chunk which is marked as invalid for a buffer set then there will be a warning printed and the value **nil** will be returned.

Examples:

These examples assume the module and simple example model shown above have been defined.

```
1> (reset)
DEFAULT

2> (buffer-chunk foo bar)
FOO: NIL
BAR: NIL
(NIL NIL)

3> (store-m-buffer-chunk 'foo 'a)
A

4> (store-m-buffer-chunk 'foo 'b)
B

5> (store-m-buffer-chunk 'bar 'b)
B

6> (buffer-chunk foo bar)
FOO: NIL  {A B}
BAR: NIL  {B}
(NIL NIL)

7> (set-buffer-chunk 'foo 'a)
A

8> (buffer-chunk foo)
FOO: A  {A B}
A

(A)

9> (set-buffer-chunk 'foo 'b)
B

10> (buffer-chunk foo)
FOO: B  {B}
B

(B)

11> (setf (chunk-buffer-set-invalid 'b) t)
T

12> (overwrite-buffer-chunk 'foo 'b)
B-0

13> (buffer-chunk foo)
FOO: B-0 [B] {B}
B-0

(B-0)
```

```
E> (store-m-buffer-chunk 'goal 'a)
#|Warning: store-m-buffer-chunk cannot store a chunk in buffer GOAL because it is not a
multi-buffer |#
NIL

E>: (store-m-buffer-chunk 'foo 'd)
#|Warning: store-m-buffer-chunk cannot store D in a buffer set because it has been marked
as invalid for a buffer set most likely because it has been previously cleared from a
buffer |#
NIL
```

get-m-buffer-chunks

Syntax:

get-m-buffer-chunks *buffer* -> (chunk*)

Arguments and Values:

buffer ::= the name of a multi-buffer
chunk ::= the name of a chunk in the buffer set of buffer

Description:

The get-m-buffer-chunks command is used to get the buffer set of a multi-buffer. If the buffer name given is the name of a multi-buffer then a list of the chunks which are in the buffer set of that multi-buffer in the current model will be returned. There is no specification for the ordering of the chunks in the list which is returned, and one should not assume anything about the buffer set based on that ordering.

If there is no current model or buffer does not name a multi-buffer a warning is printed and **nil** will be returned.

Examples:

These examples assume the module and model shown above have been defined.

```
1> (reset)
DEFAULT

2> (store-m-buffer-chunk 'foo 'a)
A

3> (store-m-buffer-chunk 'foo 'c)
C

4> (store-m-buffer-chunk 'bar 'a)
A

5> (store-m-buffer-chunk 'bar 'b)
B

6> (get-m-buffer-chunks 'foo)
(A C)
```

```
7> (get-m-buffer-chunks 'bar)
(A B)

E> (get-m-buffer-chunks 'goal)
#|Warning: get-m-buffer-chunks cannot return a buffer set for buffer GOAL because it is
not a multi-buffer |#
NIL
```

remove-m-buffer-chunk

Syntax:

remove-m-buffer-chunk *buffer chunk* -> [chunk | **nil**]

Arguments and Values:

buffer ::= the name of a multi-buffer
chunk ::= the name of a chunk to remove from the buffer set of buffer

Description:

The remove-m-buffer-chunk command is used to remove a chunk from the buffer set of a multi-buffer. If the buffer name given is the name of a multi-buffer and the chunk names a chunk defined in the current model which is currently in the buffer set of that multi-buffer then that chunk will be removed from that buffer set and the chunk name will be returned. If the chunk is not a member of the buffer set then no change to the buffer set is made and the chunk name is still returned.

If there is no current model, buffer does not name a multi-buffer, or chunk is not a valid chunk name then there will be a warning printed and **nil** will be returned.

Examples:

These examples assume the module and model shown above have been defined.

```
1> (reset)
DEFAULT

2> (store-m-buffer-chunk 'foo 'a)
A

3> (store-m-buffer-chunk 'foo 'c)
C

4> (store-m-buffer-chunk 'bar 'a)
A

5> (store-m-buffer-chunk 'bar 'b)
B

6> (get-m-buffer-chunks 'foo)
(A C)

7> (get-m-buffer-chunks 'bar)
(A B)
```

```
8> (remove-m-buffer-chunk 'foo 'a)
A

9> (remove-m-buffer-chunk 'bar 'b)
B

10> (get-m-buffer-chunks 'foo)
(C)

11> (get-m-buffer-chunks 'bar)
(A)

12> (remove-m-buffer-chunk 'bar 'd)
D

13> (get-m-buffer-chunks 'bar)
(A)

E> (remove-m-buffer-chunk 'goal 'a)
#|Warning: remove-m-buffer-chunk cannot remove a chunk from buffer GOAL because it is not
a multi-buffer |#
NIL

E> (remove-m-buffer-chunk 'bar :not-a-chunk)
#|Warning: remove-m-buffer-chunk cannot remove :NOT-A-CHUNK from the buffer set because it
does not name a chunk |#
NIL
```

remove-all-m-buffer-chunks

Syntax:

remove-all-m-buffer-chunks *buffer* -> [**t** | **nil**]

Arguments and Values:

buffer ::= the name of a multi-buffer

Description:

The remove-all-m-buffer-chunks command is used to remove all of the chunks from the buffer set of a multi-buffer. If the buffer name given is the name of a multi-buffer then the buffer set of that multi-buffer in the current model will be cleared and the value **t** will be returned.

If there is no current model or buffer does not name a multi-buffer then there will be a warning printed and the value **nil** will be returned.

Examples:

These examples assume the module and model shown above have been defined.

```
1> (reset)
DEFAULT

2> (store-m-buffer-chunk 'foo 'a)
A
```

```
3> (store-m-buffer-chunk 'foo 'b)
B

4> (get-m-buffer-chunks 'foo)
(A B)

5> (remove-all-m-buffer-chunks 'foo)
T

6> (get-m-buffer-chunks 'foo)
NIL

E> (remove-all-m-buffer-chunks 'goal)
#|Warning: remove-all-m-buffer-chunks cannot remove a chunk from buffer GOAL because it is
not a multi-buffer |#
NIL
```

erase-buffer

Syntax:

erase-buffer *buffer* -> [chunk | **nil**]

Remote command name:

erase-buffer

Arguments and Values:

buffer ::= the name of a buffer
chunk ::= the name of a chunk

Description:

The erase-buffer command is used to remove a chunk from a buffer without notifying other modules. This can be used with a normal buffer or a multi-buffer. It is similar to clear-buffer except that it skips the notification step. That will prevent the chunk from being collected by declarative memory and thus being marked as invalid for a buffer set. Erase-buffer is to clear-buffer as overwrite-buffer-chunk is to set-buffer-chunk. If the buffer name given is the name of a buffer and there is a chunk in that buffer that chunk will be removed from the buffer and the chunk name will be returned. If the buffer is already empty then **nil** will be returned.

If there is no current model or buffer does not name a buffer then there will be a warning printed and the value **nil** will be returned.

Examples:

These examples assume the module and model shown above have been defined.

```
1> (reset)
DEFAULT

2> (store-m-buffer-chunk 'foo 'a)
A
```

```
3> (store-m-buffer-chunk 'foo 'c)
C

4> (set-buffer-chunk 'foo 'a)
A

5> (set-buffer-chunk 'goal 'a)
GOAL-CHUNK0

6> (buffer-chunk foo goal)
FOO: A  {A C}
A

GOAL: GOAL-CHUNK0 [A]
GOAL-CHUNK0

(A GOAL-CHUNK0)

7> (erase-buffer 'foo)
A

8> (buffer-chunk foo)
FOO: NIL  {A C}
(NIL)

9> (erase-buffer 'goal)
GOAL-CHUNK0

10> (set-buffer-chunk 'foo 'a)
A

11> (buffer-chunk foo)
FOO: A  {A C}
A

(A)

12> (clear-buffer 'foo)
A

13> (set-buffer-chunk 'foo 'a)
A-0

14 (buffer-chunk foo)
FOO: A-0 [A] {C}
A-0

(A-0)

E> (erase-buffer :not-a-buffer)
#|Warning: erase-buffer called with an invalid buffer name :NOT-A-BUFFER |#
NIL
```

Searchable buffers

A searchable buffer is a multi-buffer which the procedural module will treat differently than other buffers. Except for the different treatment from the procedural module, a searchable buffer continues to operate like a multi-buffer as described in the previous section. When the procedural module matches a production's condition against a searchable buffer it does not restrict the matching to only the chunk which is in the buffer. Instead, it will search the buffer set of that buffer to find a chunk which matches. How that search takes place and how the module may influence the search will be detailed in this section.

An important consideration in the development of the searchable buffers was to maintain plausibility. That means avoiding the potential for multiple instantiation issues as well as not allowing the capability to solve NP-hard problems within a single production. The concept that seems to best fit with those constraints is to limit the search such that it is performed in parallel for all searchable buffers within a production and to terminate the search at the first chunk found as a match.

The testing of the conditions for a production thus follows these steps:

- Normal buffer's conditions are tested and variable bindings occur
    - If it is a dynamic production this includes bindings from the variablized slots
- Other conditions which use only those variables (or none) are tested (!eval!, !bind!, queries)
- Each search buffer has its buffer set searched to find a chunk which matches all of the conditions that are currently defined i.e. involve constants or already bound variables
- Bind all of the variables necessary from the search buffer chunks found
- Test all remaining condition

There are a couple of additional details to add to that. One important issue is that if there is more than one search buffer tested within a production this is not guaranteed to find a set of chunks which satisfy all of the conditions in that production because tests among the search buffer chunks is performed after the search has completed – it will not go back and search again to find other chunks if those conditions fail to match.

Another thing to note relates to dynamic productions. Because the variablized slot bindings occur before the search, a variable bound in a search buffer condition cannot be used as a variablized slot. However, a search buffer could test variablized slots that were bound in the normal buffer conditions. This is the result of generalizing the constraint of dynamic testing which only allows one level of indirection since searching a multi-buffer is effectively another level of indirection.

Once the conflict set has been determined the production with the highest utility in the set will be selected and fired. If that production involved one or more search buffers, then the chunk(s) found during the search will be placed into the appropriate buffer(s) at the time it is selected.

During the condition matching processes with a search buffer any references to the buffer name variable of the search buffer will reflect a binding to the name of a chunk in the buffer set. However, once a production is selected that variable will be bound to the actual chunk in the buffer. That only differs if it is a search-copy buffer (as described below) because a new chunk will be created as a copy for the buffer instead of placing the buffer set chunk there directly. The reason for that is

because actions of the production may need to refer to the actual chunk in the buffer. That changing of the variable after the matching may seem like a problem, but it makes the copy and non-copy buffers operate the same for matching purposes if the buffer variable is used in the conditions (probably not something which would typically be done). The alternative would be to actually create a copy of each chunk in the buffer set for the matching of a search-copy buffer, but since that name would be new it wouldn't be very useful to match it in the conditions of a production.

There are two ways for the module which owns the searchable buffer to affect the search and selection process. First, the module may specify the order in which to search the buffer set and possibly exclude some members. The module does that by specifying a function with the :search keyword in the module definition. The search function will be called once during each conflict-resolution event. It will be passed the module instance and the name of a searchable buffer of the module. It should return a list of chunks from the buffer set in the order that they are to be searched. Any chunks in the list returned which are not in the buffer set will be ignored in the search. If no search function is provided for the module then the whole buffer set will be searched in an arbitrary order.

The other thing the module can do is specify a preference for each of the chunks which have matched to offset the utilities of the productions which matched them. To do that the module must specify an offset function with the :offset keyword in the module definition. The offset function will be called once for each matched searchable buffer during each conflict-resolution event in which the conflict set is non-empty. The function will be passed three parameters: the module instance, the name of a search buffer of the module, and a list of the chunks from the buffer set of that buffer which were found as matches in some production. The return value from that function should be a list of numbers of the same length as the list of chunks it was passed where each number will be the offset for the corresponding chunk's matching in a production. Those offset values will be added to the utility of a production which matched that chunk before determining which production to fire. The recommendation for offsets is to return 0 for a preferred chunk and negative values for non-preferred chunks.

To create a searchable buffer for a module one must specify a sixth parameter in the buffer definition similar to how a multi-buffer is specified. For search buffers there are actually two options available. The first is to specify the keyword :search. That will create a multi-buffer which has the search capability described above. The other option is to specify the value :search-copy. That will create a special variation of a multi-buffer. A buffer created with :search-copy will actually have the chunks from the buffer set copied into the buffer like a normal buffer does. Otherwise, the search-copy buffer operates just like a standard searchable buffer. The advantage of using a search-copy buffer is that the chunks in the buffer set are then protected from being unintentionally cleared from the buffer (and thus being removed from the buffer set) through strict harvesting or module requests and they will not be modified since only a copy is made available through the module. This "copied" multi-buffer operation is also available for a normal multi-buffer by specifying a value of :multi-copy when creating it, but such a buffer would act the same as a normal buffer and that option is not recommended.

Multiple Models

In the model section it indicates that it is possible to run more than one model at a time, but it does not cover the details on how to do so. This section will describe how to create and use multiple models and show the commands that are available for working with them.

The first thing to discuss is the notion of the current model. That term was introduced in the model section above and most of the commands described in this manual indicate that they only work with respect to the current model. If more than one model is defined, which one is the current one will typically need to be specified by the user. When a model is initially defined and whenever the model is reset the code provided in the model's definition will be executed with that model set as the current one by the system. When each event is executed the meta-process will set the current model to be the model which generated that event before it performs the event's action. If there is more than one model defined, then after an event's action is complete the meta-process will return to not having a current model. It is possible for the code in an event's action to indicate that a different model is current if necessary, for example to send a notice to some other model.

Because the meta-process maintains the current model automatically based on the events, user defined modules (or other code) which generate events to perform their actions should not need to have any changes made to them to be able to work with multiple models. The only thing that would be important for a module is that if it has any internal state it would need to generate a unique instance for each model when it is created. Thus, as long as the creation function for the module returns a new "instance" (structure, class, vector, key, etc.) for each model and doesn't rely on globally defined module states it should work with multiple models without any modifications. All of the standard modules provided with the system will work as described in this manual whether there is only one model defined or if there are multiple models defined.

When multiple models are defined, any command which runs the system will run all of the models together synchronously from the same event queue. In some previous versions it was possible to also have multiple meta-process which allowed for running models asynchronously, but that is not currently supported in this version.

When working with multiple models one thing to be aware of is that the system does not come with any built in ways for those models to interact. Other than sharing the event queue and clock there is no interaction among the models. Each one has its own set of modules, chunk-types, chunks, and parameters and unless there is some interaction implemented by the user the models will run the same when they are run together as each would run on its own because they are not aware of any other model's existence. In particular, they are not sensitive the other models' events in the queue. Thus, events waiting to be scheduled will not be removed from the waiting queue until an appropriate trigger from the same model occurs.

To create synchronous models all one needs to do is define them. There is no special syntax needed, and the standard define-model command will create each model the same as it would if that were the only model being defined. Some examples of defining multiple synchronous models can be found in the examples/multiple-models directory of the distribution, and the file called "unit-1-together-1-mp.lisp" will be used for some of the examples below. That file contains the definitions for all three of the example models from unit 1 of the tutorial (count, addition, and semantic). Each of the model definitions is just copied from the corresponding tutorial model file. The only difference between

loading that file with all three defined and loading the individual model files is that the individual model files each call clear-all when loaded which results in removing all existing models before defining the model in the file. The combined file only calls clear-all once to remove other models and then defines each of the models one after the other.

After loading that file one can run it just as one would have run any of the individual models by calling the run command. Here is the beginning of the trace of a run of those models:

```
> (run 10)
     0.000  COUNT     GOAL                 SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000  SEMANTIC  GOAL                 SET-BUFFER-CHUNK GOAL G1 NIL
     0.000  ADDITION  GOAL                 SET-BUFFER-CHUNK GOAL SECOND-GOAL NIL
     0.000  COUNT     PROCEDURAL           CONFLICT-RESOLUTION
     0.000  COUNT     PROCEDURAL           PRODUCTION-SELECTED START
     0.000  COUNT     PROCEDURAL           BUFFER-READ-ACTION GOAL
     0.000  SEMANTIC  PROCEDURAL           CONFLICT-RESOLUTION
     0.000  ADDITION  PROCEDURAL           CONFLICT-RESOLUTION
     0.050  COUNT     PROCEDURAL           PRODUCTION-FIRED START
     0.050  COUNT     PROCEDURAL           MOD-BUFFER-CHUNK GOAL
     0.050  COUNT     PROCEDURAL           MODULE-REQUEST RETRIEVAL
     0.050  COUNT     PROCEDURAL           CLEAR-BUFFER RETRIEVAL
     0.050  SEMANTIC  PROCEDURAL           PRODUCTION-FIRED INITIAL-RETRIEVE
     0.050  SEMANTIC  PROCEDURAL           CLEAR-BUFFER RETRIEVAL
     0.050  ADDITION  PROCEDURAL           PRODUCTION-FIRED INITIALIZE-ADDITION
     0.050  ADDITION  PROCEDURAL           CLEAR-BUFFER RETRIEVAL
     ...
```

When there are multiple models running there will be an additional column shown in the trace indicating which model is performing the action. In that trace we see actions from each of the count, semantic, and addition models occurring.

One final thing to note is that for commands called through the dispatcher the current model is always provided as part of the communication and it is possible for a remote command to specify a model other than the one that is "current" in the meta-process when calling a command.

Commands

current-model

Syntax:

current-model -> [name | **nil**]

Remote command name:

current-model

Arguments and Values:

name ::= the name of the current model

Description:

The current-model command can be used to get the name of the current model. If there is a current model then that model's name will be returned. If there is no current model then **nil** will be returned.

This command is likely to be used when one has code which can be called for different models and it's important to know which model is the current one.

Note that while there is a remote version of this command, since the communication protocol already provides the current model it is often not going to be necessary to call it, and also there's no guarantee that the value returned will still be the "current" model in the meta-process if the model is running unless it occurs during the processing of an event since the remote communication is happening in parallel with the model running.

Examples:

```
1> (clear-all)
NIL

2> (current-model)
NIL

3> (define-model m1)
M1

4> (current-model)
M1

5> (define-model m2)
M2

6> (current-model)
NIL

7> (define-model m3 (format t "Current-model is: ~S~%" (current-model)))
Current-model is: M3
M3

8> (current-model)
NIL
```

mp-models

Syntax:

mp-models -> (name*)

Remote command name:

mp-models

Arguments and Values:

name ::= the name of a currently defined model

Description:

The mp-models command can be used to get the names of all of the models currently defined. It returns a list of those names in no particular order.

Examples:

```
1> (clear-all)
NIL

2> (mp-models)
NIL

3> (define-model m1)
M1

4> (mp-models)
(M1)

5> (define-model m2)
M2

6> (mp-models)
(M2 M1)
```

delete-model

Syntax:

delete-model {*name*} -> [**t** | **nil**]
delete-model-fct *name* -> [**t** | **nil**]

Arguments and Values:

name ::= the name of a model

Description:

The delete-model command can be used to remove a currently defined model. When a name is provided and there is a model with that name that model will be completely removed from the meta-process and **t** will be returned. If name does not name a model in the meta-process then a warning will be printed and **nil** will be returned.

If no name is provided to delete-model then the current model will be removed from the meta-process. If there is a current model then that model is removed and **t** will be returned. If no name is provided and there is no current model then a warning will be printed and **nil** will be returned.

One should be careful with using delete-model because it is possible that external commands may still be “using” a model at any point, and the consequences of deleting it out from under it could lead to errors. Currently there is no provided mechanism to determine whether there are pending calls to commands through the dispatcher which were generated for a specific model so one should be certain the state of the system is “safe” before attempting to explicitly delete a model.

Examples:

```
1> (clear-all)
NIL

2> (define-model m1)
M1

3> (delete-model m1)
T

4> (define-model m2)
M2

5> (delete-model)
T

6> (define-model m3)
M3

7> (define-model m4)
M4

8> (define-model m5)
M5

9> (delete-model-fct 'm3)
T

10> (mp-models)
(M4 M5)

11E> (delete-model)
#|Warning: No current model to delete. |#
NIL

E> (delete-model foo)
#|Warning: No model named FOO in current meta-process. |#
NIL
```

with-model

Syntax:

with-model *name form** -> [result | **nil**]
with-model-eval *name form** -> [result | **nil**]
with-model-fct *name* (*form**) -> [result | **nil**]

Arguments and Values:

name ::= the name of a model
form ::= a valid Lisp expression to evaluate
result ::= the value returned from the last form evaluated

Description:

The with-model commands are used to set a model to be the current model and then execute some commands. If the name provided is the name of a currently defined model then that model will be set as the current model before evaluating the forms provided. After those forms have been evaluated the current model will be returned to whichever model was the current one before with-model was called.

The return value from the last form evaluated will be returned by with-model. If the name provided does not name a defined model then a warning will be printed and **nil** will be returned without evaluating any of the forms.

In addition to the usual macro and functional versions of the command there is an additional macro version for with-model – with-model-eval. That command is a hybrid of the functional and macro versions and probably the one which is most likely to be used in code. The difference between with-model and with-model-eval is that with-model-eval will evaluate the expression provided for the name position to determine the name of the model to use.

Examples:

These examples assume that the "unit-1-together-1-mp.cl" example file has been loaded.

```
> (dolist (model (mp-models))
    (format t "Model: ~s~%" model)
    (with-model-eval model
      (goal-focus)))
Model: COUNT
Will be a copy of FIRST-GOAL when the model runs
FIRST-GOAL
   START  2
   END  4

Model: SEMANTIC
Will be a copy of G1 when the model runs
G1
   OBJECT  CANARY
   CATEGORY  BIRD

Model: ADDITION
Will be a copy of SECOND-GOAL when the model runs
SECOND-GOAL
   ARG1  5
   ARG2  2

NIL

1> (run 10)
     0.000  COUNT     GOAL                    SET-BUFFER-CHUNK GOAL FIRST-GOAL NIL
     0.000  SEMANTIC  GOAL                    SET-BUFFER-CHUNK GOAL G1 NIL
     0.000  ADDITION  GOAL                    SET-BUFFER-CHUNK GOAL SECOND-GOAL NIL
     ...
     0.500  -         ------              Stopped because no events left to process
0.5
147
NIL

2> (with-model semantic
     (goal-focus g2))
G2

3> (run 10)
     0.500  SEMANTIC  GOAL                    SET-BUFFER-CHUNK GOAL G2 NIL
     0.500  SEMANTIC  PROCEDURAL              CONFLICT-RESOLUTION
     0.550  SEMANTIC  PROCEDURAL              PRODUCTION-FIRED INITIAL-RETRIEVE
     0.550  SEMANTIC  PROCEDURAL              CLEAR-BUFFER RETRIEVAL
     0.550  SEMANTIC  DECLARATIVE            start-retrieval
     0.550  SEMANTIC  PROCEDURAL              CONFLICT-RESOLUTION
     0.600  SEMANTIC  DECLARATIVE            RETRIEVED-CHUNK P14
     0.600  SEMANTIC  DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL P14
     0.600  SEMANTIC  PROCEDURAL              CONFLICT-RESOLUTION
```

```
     0.650  SEMANTIC  PROCEDURAL            PRODUCTION-FIRED CHAIN-CATEGORY
     0.650  SEMANTIC  PROCEDURAL            CLEAR-BUFFER RETRIEVAL
     0.650  SEMANTIC  DECLARATIVE           start-retrieval
     0.650  SEMANTIC  PROCEDURAL            CONFLICT-RESOLUTION
     0.700  SEMANTIC  DECLARATIVE           RETRIEVED-CHUNK P20
     0.700  SEMANTIC  DECLARATIVE           SET-BUFFER-CHUNK RETRIEVAL P20
     0.700  SEMANTIC  PROCEDURAL            CONFLICT-RESOLUTION
     0.750  SEMANTIC  PROCEDURAL            PRODUCTION-FIRED DIRECT-VERIFY
     0.750  SEMANTIC  PROCEDURAL            CLEAR-BUFFER RETRIEVAL
     0.750  SEMANTIC  PROCEDURAL            CONFLICT-RESOLUTION
     0.750  -         ------                Stopped because no events left to process
0.25
36
NIL

4> (with-model-fct 'count
     '((goal-focus)))
Goal buffer is empty
NIL

E> (with-model foo (goal-focus))
#|Warning: FOO does not name a model in the current meta-process |#
NIL
```

Other multiple model examples

There are two other example models which define multiple synchronous models available in the examples directory. Each will be described briefly here and more details can be found in the comments in those files.

The “examples/multiple-models/multi-model-talking-models.lisp” file defines three very simple models which communicate by speaking. The corresponding “examples/multiple-models/multi-model-talking.lisp” and “examples/multiple-models/multi-model-talking.py” files contain the code which installs the microphone devices and monitors for the output-speech actions to handle that communication when running the models.

The “examples/other/game-of-life.lisp” file uses multiple models along with the AGI to display a set of cells following the rules of Conway’s Game of Life. Each cell is controlled by a separate model which can see how many neighbors it has through a feature in the visicon, and indicates it current state each cycle through a speak action.

Configuring Real Time Operation

When a meta-process is run with the real-time flag set to a non-nil value the system is run in step with an external clock. By default, the clock used is the Lisp get-internal-real-time function, but the user can change that default behavior to specify an alternate clock as well as customize some other features of how the meta-process executes in real time mode. The command mp-real-time-management is the mechanism for changing the operation. Before describing that command, a more complete description of how the meta-process advances the clock in real time mode will be provided.

When a meta-process is not run in real time mode, as described in the running section, the scheduled events drive the clock directly and there is no delay between event executions regardless of the difference in time between them. When the meta-process runs in real time mode the "ACT-R time" is still determined by the events on the queue, but their execution is delayed, if necessary, so as to not run ahead of the real time clock provided. Here is some Lisp pseudo-code that describes the operation of the meta-process running in real time mode:

```
(defun process-real-time-events (real-time-scale)

  (setf act-r-start-time (mp-time))

  (setf starting-real-time (dispatch-apply real-time-function))

  (loop

    (when (run-end-conditions-satisfied) (return))

    (setf meta-p-time
      (min (evt-time (next-event))
           (case real-time-mode
              (absolute
                  (/ (dispatch-apply real-time-function) real-units-per-second))
              (interval
                  (+ act-r-start-time
                     (* real-time-scale
                        (/ (- (dispatch-apply real-time-function) starting-real-time)
                           real-units-per-second)))))))

    (if (<= (evt-time (next-event)) meta-p-time)
        (execute (next-event))
      (dispatch-apply real-time-slack meta-p-time (evt-time (next-event))))))
```

The functions in blue are either not ACT-R commands or not described in this manual, and should be assumed to work as follows:

run-end-conditions-satisfied returns true when any condition(s) specified for the current run have been met.

next-event returns the next event from the event queue.

execute performs all the actions necessary to deal with an event (calling the event hooks, printing the trace, calling the action function, etc.).

dispatch-apply is like the Lisp apply function except that it works for both internal Lisp functions and ACT-R commands provided through the dispatcher (it is described in the remote file found in the docs directory).

The variables in red are items that can be set by the user to control how real time runs.

real-time-scale is the value passed to the run command to indicate it should be in real-time (where a value of t corresponds to 1.0).

real-time-function must be a command that takes no parameters. It should return a number which represents a time, and those numbers should be non-decreasing i.e. time can't move backwards but can stand still. How that time is used depends on the real-time-mode. The default function for this value is the Lisp function **get-internal-real-time**.

real-time-mode There are two options for providing a real time clock: absolute or interval. If it is absolute time mode then the real-time-function returns the current time for the system directly. If it is the interval time mode then the real-time-function is an interval timer used to pace the model -- it is the difference between its starting value and the current value plus the model's starting time that determines the "current" time. The default value is interval.

real-units-per-second is a number which is used to scale the return value from the real-time-function into seconds. The default value is the value of the Lisp variable **internal-time-units-per-second**.

real-time-slack this must be a command which accepts two parameters. It is called whenever the next model event is delayed because the real time has not yet advanced to that event's time. The first parameter it is passed is the current real time (in milliseconds) and the second parameter is the time of the next scheduled event (in milliseconds). The default command just calls bt:thread-yield to allow other threads an opportunity to run since a long wait may loop over this many times, but it could also be used to perform some external communication with a task or provide a cleaner 'wait' action if one knows there are no asynchronous actions which could schedule new events before the one that's waiting.

Dynamic events

Because events can be scheduled asynchronously with the running of the model through the dispatcher it is possible in real-time mode for an event to be scheduled at a time that is earlier than the current next event when that next event is in the future and the system is waiting for time to pass. [Even with that however it is not possible to schedule an event for a time which has already passed. The ACT-R clock will only move forward and any event scheduled with a time that has already passed will be scheduled with the current real-time time instead.] Because some events are scheduled based on when other events occur (the schedule-event-after-* commands) it may be important to have those events sensitive to new events which occur earlier in time even if they have already been scheduled because of an event that was scheduled. That is the purpose of the :dynamic keyword parameter in those scheduling functions. If it is specified as **t** then such an event may be rescheduled for an earlier time if such a triggering event happens, and such events are referred to as dynamic events.

Of the events generated by the standard modules of the system, only the procedural module currently schedules any dynamic events. The conflict-resolution event of the procedural module is dynamic

and will be rescheduled to occur after any newer model events which are generated relative to when it is initially scheduled. That is important so that the model can respond to external actions which occur (typically visual or aural percepts) when they happen instead of having to wait for the next internal action which may have already caused a conflict-resolution to be scheduled in the future (after a retrieval failure for example). That is very likely the only event which needs to be dynamic for most modeling purposes, but if one is creating new modules or tools which are scheduled using the after-* commands it it may be important to set the :dynamic flag for those events if they need to be sensitive to asynchronous events which occur.

One final note is that although dynamic events are described with respect to real-time running, it can also be an issue when running without real-time (when the events are the clock). That can happen if actions are scheduled out of order during an event i.e. if an action that occurs because of an event itself schedules multiple events and those events are not scheduled in chronological order. That can cause a waiting after-* event to be scheduled in response to an event further in the future than newer events that might also trigger it. The dynamic schedule mechanism still applies in that case, and will reschedule things appropriately if they are marked as dynamic.

Commands

mp-real-time-management

Syntax:

mp-real-time-management {**:time-function** *timefct*} {**:units-per-second** *ups*} {**:slack-function** *slackfct*}
{**:mode** [***interval*** **|** ***absolute***] } -> [**t** | **nil**]

Arguments and Values:

timefct ::= a command identifier of the command to use as the real time clock (the real-time-function value)
ups ::= a positive number specifying the number of units in a second for timefct (the real-units-per-second value)
slackfct ::= a command identifier of the command to call when the model has to wait for real time to pass (the real-time-slack value)

Description:

The mp-real-time-management command is used to modify how the meta-process operates when run in real-time mode. It sets the real time controls to the provided values and returns **t**. How those controls affect the operation of the system is described in the Configuring Real Time Operation section above.

If the model is currently running or any of the provided parameters are invalid then no changes will be made, there will be a warning printed, and the value **nil** will be returned.

Examples:

These examples only show the possible warnings.

```
E> (mp-real-time-management :mode 'other)
#|Warning: Mode OTHER not a valid value for mp-real-time-management. Must be absolute or
interval. |#
NIL

E> (mp-real-time-management :time-function nil)
#|Warning: Time-function NIL not a valid function for mp-real-time-management |#
NIL

E> (mp-real-time-management :units-per-second t)
#|Warning: Units-per-second T must be a positive number |#
NIL

E> (mp-real-time-management :slack-function 'not-function)
#|Warning: Slack-function NOT-FUNCTION not a valid function for mp-real-time-management |#
NIL

1> (schedule-event-now 'mp-real-time-management)
3

2E> (run 1)
#|Warning: Mp-real-time-management cannot adjust real-time operation while the model is
running. |#
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.000   ------                 Stopped because no events left to process
0.0
3
NIL
```

Module Activity and Brain Predictions

The activity of the modules in ACT-R (as reported through their buffers) along with a mapping of those modules/buffers onto the brain can be used to make predictions from a model for data from various imaging methods like fMRI, EEG, PET, or MEG. The ACT-R software includes commands for getting a summary of the module activity as well as commands for producing a prediction of a blood-oxygen-level dependent (BOLD) response for comparison to fMRI data.

This section will describe how one can have the system record the module activity and ways to access that data, and the next one will describe the tools which use that data to produce a BOLD response. For information on mappings of modules to brain regions and additional details on predicting the BOLD response there are many papers available from the ACT-R website under the fMRI category, and a good place to start is the paper "A central circuit of the mind".

What counts as buffer activity?

Buffer activity is determined from the buffer-trace data which means only actions which occur as scheduled events will be considered. That covers all the normal actions of the provided modules and their use through the procedural module in a model, but any function calls made outside of the events which directly affect a buffer (for example set-buffer-chunk) will not be counted as buffer activity. Activity starts when one of three things occurs: a request (or modification request) is made to the buffer, a chunk is placed into the buffer, or a "state busy" query of the buffer is true. Once activity has started, the buffer will be considered active until one of three conditions occurs: the "state busy" query returns **nil**, the "state free" query returns true, or a new request (or modification request) is made to the buffer (which ends the current activity and also starts a new one).

Some buffers (in particular the goal buffer) may have activities which are instantaneous i.e. the start and stop times are the same. That activity is still recorded, and how that is treated by the different activity reporting mechanisms will be discussed with each one.

Recording module activity

The data used to determine module activity and produce a model's BOLD response is the buffer-trace history data as described in the buffer trace module section. Therefore one must record that history data along with the buffers for which the information is needed. That can be done directly by recording the "buffer-trace" history, or by recording one of the processors described in this section or the next. Here's an example that records the data for four of the buffers from the included modules:

```
> (record-history "buffer-trace" "goal" "visual" "vocal" "manual")
```

Recording the module activity can be a costly operation over the course of a long model run, so it is recommended that one only record the information that's needed for efficiency purposes.

Getting module activity

There are three history data processors available to convert that buffer-trace data into module activity which provide different ways to report that data. All of these history processors report the activity at the buffer level i.e. if a module has more than one buffer each buffer is tracked separately. If one would like to process the module activity differently it is always possible to use buffer-trace history information directly. Each of the processors also accepts two optional parameters to restrict the times over which the data should be reported. It is important to note that restricting that range for the processor is not necessarily the same as processing a restricted range of the buffer-trace data i.e.

```
(get-history "module-demand-times" nil 3 14)
```

is not likely to be the same as:

```
(process-history-data "module-demand-times" nil nil (3 14))
```

The reason for the discrepancy happens when activity crosses one of the provided time boundaries. With the first approach the start signal would be lost for activity which began before the start time but had a stop time within the range and the stop signal would be lost for activity which began during the range but ended after. However the second approach will be able to accurately report the results for activity which overlaps with the range requested.

For each of the processors there is also a corresponding Lisp command which will get the processed data and then decode the JSON string into Lisp data.

module-demand-times

The module-demand-times processor will convert the buffer-trace history into a list of lists, where each sublist has two elements. The first element of a sublist is the name of a buffer and the second element is a list of two element lists indicating the start and stop time at which that buffer was active:

((buffer-name ((start-time stop-time)*)*)

Example:

```
1> (actr-load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))

4> (get-history-data "module-demand-times")
"[[\"GOAL\",[[0.0,0.0],[2.735,2.735],[5.63,5.63],[8.375,8.375],[10.62,10.62],
[13.965,13.965],[17.31,17.31],[20.555,20.555],[22.9,22.9],[25.145,25.145],[27.99,27.99],
[30.835,30.835],[33.68,33.68],[37.025,37.025],[39.37,39.37],[42.215,42.215],[44.46,44.46],
[47.805,47.805],[50.65,50.65],[53.895,53.895],[56.24,56.24],[58.485,58.485],[61.73,61.73],
[64.075,64.075],[67.32,67.32]]],[\"MANUAL\",[[2.735,3.035],[5.63,5.78],[8.375,8.525],
[10.62,10.87],[13.965,14.215],[17.31,17.46],[20.555,20.805],[22.9,23.05],[25.145,25.395],
[27.99,28.24],[30.835,31.085],[33.68,33.93],[37.025,37.275],[39.37,39.62],[42.215,42.365],
```

```
[44.46,44.71],[47.805,48.055],[50.65,50.8],[53.895,54.145],[56.24,56.39],[58.485,58.635],
[61.73,61.98],[64.075,64.225],[67.32,67.47]]]]"

5> (process-history-data "module-demand-times" nil nil (3 14))
"[[\"GOAL\",[[5.63,5.63],[8.375,8.375],[10.62,10.62],[13.965,13.965]]],[\"MANUAL\",
[[2.735,3.035],[5.63,5.78],[8.375,8.525],[10.62,10.87],[13.965,14.215]]]]"
```

Lisp Command:

module-demand-times {**:start** *start*} {**:end** *end*} -> ((buffer-name ((start-time stop-time)*)*)

Arguments and Values:

start ::= a number indicating the starting time over which activity is to be reported in seconds
end ::= a number indicating the end time over which activity is to be reported in seconds
buffer-name ::= the name of a buffer
start-time ::= a number indicating the starting time for an active period of the buffer
stop-time ::= a number indicating the end time for an active period of the buffer

Description:

The module-demand-times command has two keyword parameters, :start and :end, which can be used to restrict the reported activity to the specified range. If no start time is provided then it starts at time 0, and if no end time is provided it ends at the current model time. It returns a list of lists of buffer activity times for all of the buffers for which the "buffer-trace" history is recorded.

If a start and/or end time is provided then only activities which overlap with that range will be reported. That may include activities which begin before the provided start time and persist past it as well as activities which begin before the provided end time and continue past it.

Examples:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))

4> (module-demand-times)
((GOAL ((0.0 0.0) (2.735 2.735) (5.63 5.63) (8.375 8.375) (10.62 10.62) (13.965 13.965)
(17.31 17.31) (20.555 20.555) (22.9 22.9) (25.145 25.145) ...))
 (MANUAL ((2.735 3.035) (5.63 5.78) (8.375 8.525) (10.62 10.87) (13.965 14.215) (17.31
17.46) (20.555 20.805) (22.9 23.05) (25.145 25.395) (27.99 28.24) ...)))

5> (module-demand-times :start 3 :end 14)
((GOAL ((5.63 5.63) (8.375 8.375) (10.62 10.62) (13.965 13.965))) (MANUAL ((2.735 3.035)
(5.63 5.78) (8.375 8.525) (10.62 10.87) (13.965 14.215))))
```

module-demand-functions

The module-demand-functions processor will convert the buffer-trace history into a list of lists where each sublist consists of the name of a buffer followed by zeros and ones to indicate whether there was any activity by that buffer during a time step. The time steps default to the length of the :bold-inc parameter (which defaults to 2 seconds) but that can be specified as a parameter for the processor. Those steps are determined between a start and end time which default to 0 and current model time, but can also be specified as parameters to the processor. The activity will be reported over n elements where:

$$n = \left\lceil \frac{end - start}{step} \right\rceil$$

Each of those elements, indexed by i, represents the activity recorded for the time (s_i, s_{i+1}) where:

s_0 = start
$s_i = s_{i-1} + step$

If a buffer has any activity within a time segment the corresponding element of the list will be 1 and if it has no activity the value will be 0. Note that if the end time of a buffer activity (as reported by module-demand-times) corresponds with the end time of a segment that will not count as activity occurring at the start of the next segment i.e. if the step size is 2 and a buffer has reported activity of (0.0 . 2.0) that will only count as activity in the first step and not the second.

An activity that takes no time (the start and end times are the same) is still considered activity and will result in a 1 for the step in which it occurs.

There are four optional parameters for the module-demand-functions processor which are the start time, stop time, step length, and output flag respectively. The first three were described above. The output flag is a generalized boolean which indicates whether the table of data should also be sent to the command output trace.

Example:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))

4> (get-history-data "module-demand-functions")
"[[\"GOAL\",1,1,1,0,1,1,1,0,1,0,1,1,1,1,0,1,1,0,1,1,0,1,1,1,0,1,1,0,1,1,1,0,1,1],
[\"MANUAL\",0,1,1,0,1,1,1,1,1,0,1,1,1,1,1,1,1,0,1,1,0,1,1,1,1,1,1,1,1,1,1,0,1,1]]"
```

```
5> (process-history-data "module-demand-functions" nil nil (0 30 2 t))
    time    GOAL  MANUAL
   0.000   1.000   0.000
   2.000   1.000   1.000
   4.000   1.000   1.000
   6.000   0.000   0.000
   8.000   1.000   1.000
  10.000   1.000   1.000
  12.000   1.000   1.000
  14.000   0.000   1.000
  16.000   1.000   1.000
  18.000   0.000   0.000
  20.000   1.000   1.000
  22.000   1.000   1.000
  24.000   1.000   1.000
  26.000   1.000   1.000
  28.000   0.000   1.000

"[[\"GOAL\",1,1,1,0,1,1,1,0,1,0,1,1,1,1,0],[\"MANUAL\",0,1,1,0,1,1,1,1,1,0,1,1,1,1,1]]"
```

Lisp Command:

module-demand-functions {**:start** *start*} {**:end** *end*} {**:step** *step*} {**:output** *output*} -> ((buffer [0 | 1]*)*)

Arguments and Values:

start ::= a number indicating the starting time for which activity is to be reported in seconds
end ::= a number indicating the end time for which activity is to be reported in seconds
step ::= a number indicating the granularity of the activity record to report in seconds
output ::= a generalized boolean indicating whether to print the results to the command trace
buffer ::= the name of a buffer

Description:

The module-demand-functions command has four keyword parameters. :start and :end can be used to restrict the reported activity to the specified range. If no start time is provided then it starts at time 0, and if no end time is provided it ends at the current model time. :step can be specified to indicate the length of the time intervals over which activity is reported, and if not provided defaults to the current value of the :bold-inc parameter. :output indicates whether or not the data should be shown in the command output trace. It returns a list of lists of buffer activity during the requested time in the indicated interval lengths for all of the buffers for which the “buffer-trace” history is recorded.

Examples:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))
```

```
4> (module-demand-functions)
((GOAL 1 1 1 0 1 1 1 0 1 ...) (MANUAL 0 1 1 0 1 1 1 1 1 ...))

5> (module-demand-functions :start 0 :end 30 :step 2 :output t)
    time    GOAL  MANUAL
   0.000   1.000   0.000
   2.000   1.000   1.000
   4.000   1.000   1.000
   6.000   0.000   0.000
   8.000   1.000   1.000
  10.000   1.000   1.000
  12.000   1.000   1.000
  14.000   0.000   1.000
  16.000   1.000   1.000
  18.000   0.000   0.000
  20.000   1.000   1.000
  22.000   1.000   1.000
  24.000   1.000   1.000
  26.000   1.000   1.000
  28.000   0.000   1.000

((GOAL 1 1 1 0 1 1 1 0 1 ...) (MANUAL 0 1 1 0 1 1 1 1 1 ...))
```

module-demand-proportion

The module-demand-proportion processor works the same as module-demand-functions except that instead of zero or one to indicate activity it reports the proportion of the time during the interval when there was activity. If a module activity takes 0 time (the start and end times are the same) it is considered to take 1ms for computing the proportion.

Example:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))

4> (get-history-data "module-demand-proportion")
"[[\"GOAL\",5.0e-4,5.0e-4,5.0e-4,0,5.0e-4,5.0e-4,5.0e-4,0,5.0e-4,0,5.0e-4,5.0e-4,5.0e-
4,5.0e-4,0,5.0e-4,5.0e-4,0,5.0e-4,5.0e-4,0,5.0e-4,5.0e-4,5.0e-4,0,5.0e-4,5.0e-4,0,5.0e-
4,5.0e-4,5.0e-4,0,5.0e-4,5.0e-4],
[\"MANUAL\",0,0.15,0.075,0,0.075,0.125,0.0175,0.1075,0.075,0,0.125,0.075,0.125,0.005,0.12,
0.125,0.125,0,0.125,0.125,0,0.075,0.125,0.0975,0.0275,0.075,0.0525,0.0725,0.075,0.075,0.12
5,0,0.075001955,0.075]]"

5> (process-history-data "module-demand-proportion" nil nil (0 30 2 t))
    time    GOAL  MANUAL
   0.000   0.001   0.000
   2.000   0.001   0.150
   4.000   0.001   0.075
   6.000   0.000   0.000
   8.000   0.001   0.075
  10.000   0.001   0.125
```

```
  12.000   0.001   0.018
  14.000   0.000   0.108
  16.000   0.001   0.075
  18.000   0.000   0.000
  20.000   0.001   0.125
  22.000   0.001   0.075
  24.000   0.001   0.125
  26.000   0.001   0.005
  28.000   0.000   0.120

"[[\"GOAL\",5.0e-4,5.0e-4,5.0e-4,0,5.0e-4,5.0e-4,5.0e-4,0,5.0e-4,0,5.0e-4,5.0e-4,5.0e-
4,5.0e-4,0],
[\"MANUAL\",0,0.15,0.075,0,0.075,0.125,0.0175,0.1075,0.075,0,0.125,0.075,0.125,0.005,0.12]
]"
```

Lisp Command:

module-demand-proportion {**:start** *start*} {**:end** *end*} {**:step** *step*} {**:output** *output*} -> ((buffer prop*)*)

Arguments and Values:

start ::= a number indicating the starting time for which activity is to be reported in seconds
end ::= a number indicating the end time for which activity is to be reported in seconds
step ::= a number indicating the granularity of the activity record to report in seconds
output ::= a generalized boolean indicating whether to print the results to the command trace
buffer ::= the name of a buffer
prop ::= the proportion of time the buffer was busy during a time step

Description:

The module-demand-proportion command works the same as module-demand-functions except that it returns the proportion of time that a buffer was active during a time step instead of a simple zero or one flag. If the start and stop times are the same for an activity it is assumed to be 1ms long for computing the proportion.

Examples:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))

4> (module-demand-proportion)
((GOAL 5.0e-4 5.0e-4 5.0e-4 0 5.0e-4 5.0e-4 5.0e-4 0 5.0e-4 ...) (MANUAL 0 0.15 0.075 0
0.075 0.125 0.0175 0.1075 0.075 ...))

5> (module-demand-proportion :start 0 :end 30 :step 2 :output t)
    time    GOAL  MANUAL
   0.000   0.001   0.000
```

```
   2.000   0.001   0.150
   4.000   0.001   0.075
   6.000   0.000   0.000
   8.000   0.001   0.075
  10.000   0.001   0.125
  12.000   0.001   0.018
  14.000   0.000   0.108
  16.000   0.001   0.075
  18.000   0.000   0.000
  20.000   0.001   0.125
  22.000   0.001   0.075
  24.000   0.001   0.125
  26.000   0.001   0.005
  28.000   0.000   0.120

((GOAL 5.0e-4 5.0e-4 5.0e-4 0 5.0e-4 5.0e-4 5.0e-4 0 5.0e-4 ...) (MANUAL 0 0.15 0.075 0
0.075 0.125 0.0175 0.1075 0.075 ...))
```

BOLD module

The BOLD module provides the modeler with a history stream processor and Lisp command for predicting blood-oxygen-level dependent (BOLD) response values from the activity of the buffers recorded through the buffer-trace history for comparison to or prediction of fMRI data. This section will provide a general description of how that calculation is performed and then describe the parameters for configuring it and the processor and command to generate the data. This description assumes that one has read the previous section on module activity and brain predictions for an understanding of how the buffer activities are determined and that one has some understanding of what the BOLD response in fMRI data represents.

The name of the module is bold.

BOLD response

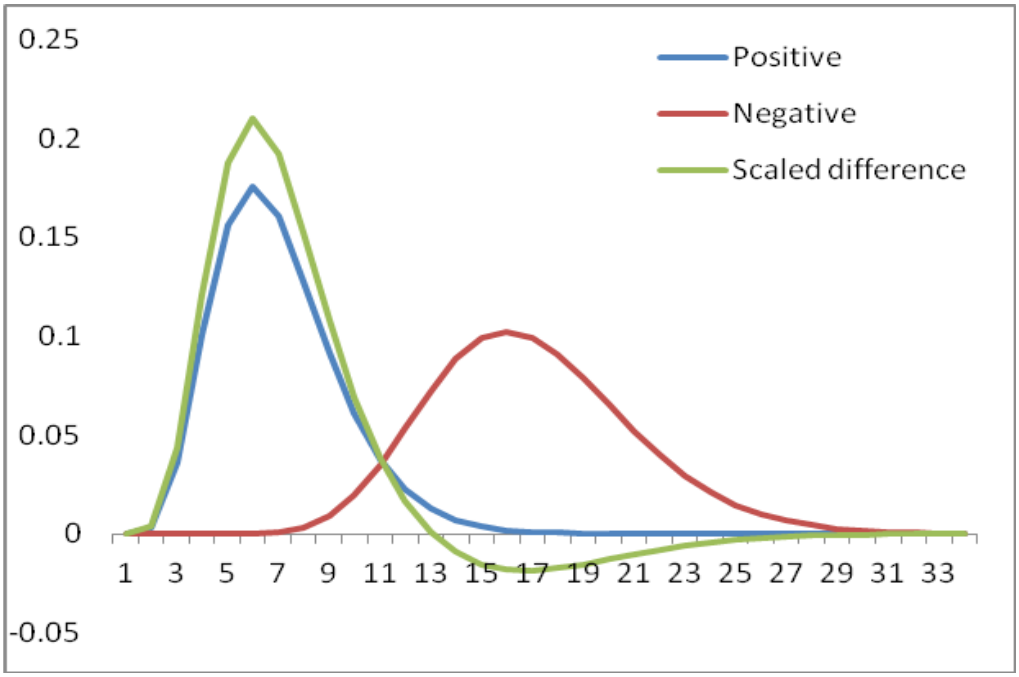
The basic concept used to create the BOLD response prediction for a model is that while a module is active it corresponds to an increased metabolic demand which produces a hemodynamic response that generates a BOLD response. Therefore, to compute the BOLD response for a model run we need two things. The first is the model's buffer activity which we will get from the module-demand-times data. We will use those times to create a demand function for the buffer activity where the value of the function is 1 when the buffer is active and 0 when it is not. We will call this function D(t). The other is a representation of the hemodynamic response. For that we will use a difference of two Gamma probability density functions which is used by many other researchers and also used in the SPM software package (Friston, Ashburner, Kiebel, Nichols, & Penny, 2011).

The Gamma probability density function is described in terms of two parameters, an exponent (or shape), **a** and a scale, **b**:

$$gammapdf(x;a,b) = \frac{x^{a-1}e^{-x/b}}{b^{a}(a-1)!}$$

The default settings for the parameters in the BOLD module use the same exponent and scale parameters for the positive and negative curves as SPM (a=6,b=1 for positive and a=16,b=1 for the negative), but they are combined using a slightly different scaling in the ACT-R representation. How to set the parameters for specifying the positive and negative curves and the parameters to control the scale factors combining them are described below along with how one would change that to match the scaling used in SPM.

Here is what the default functions used by the BOLD module look like:



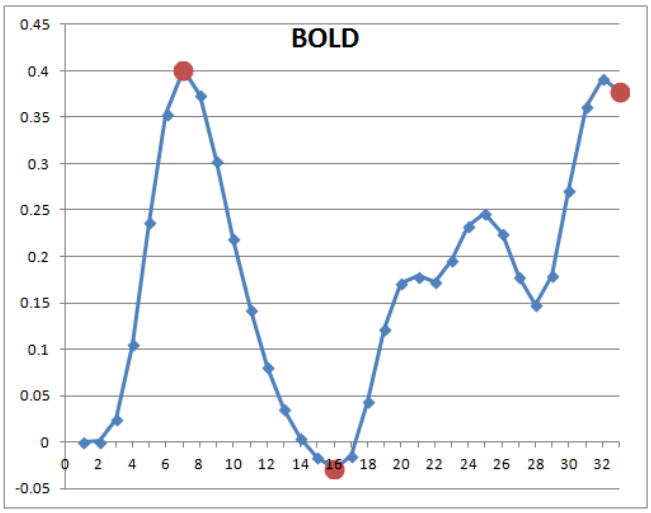
The green curve is the hemodynamic response function we will use and call H(t).

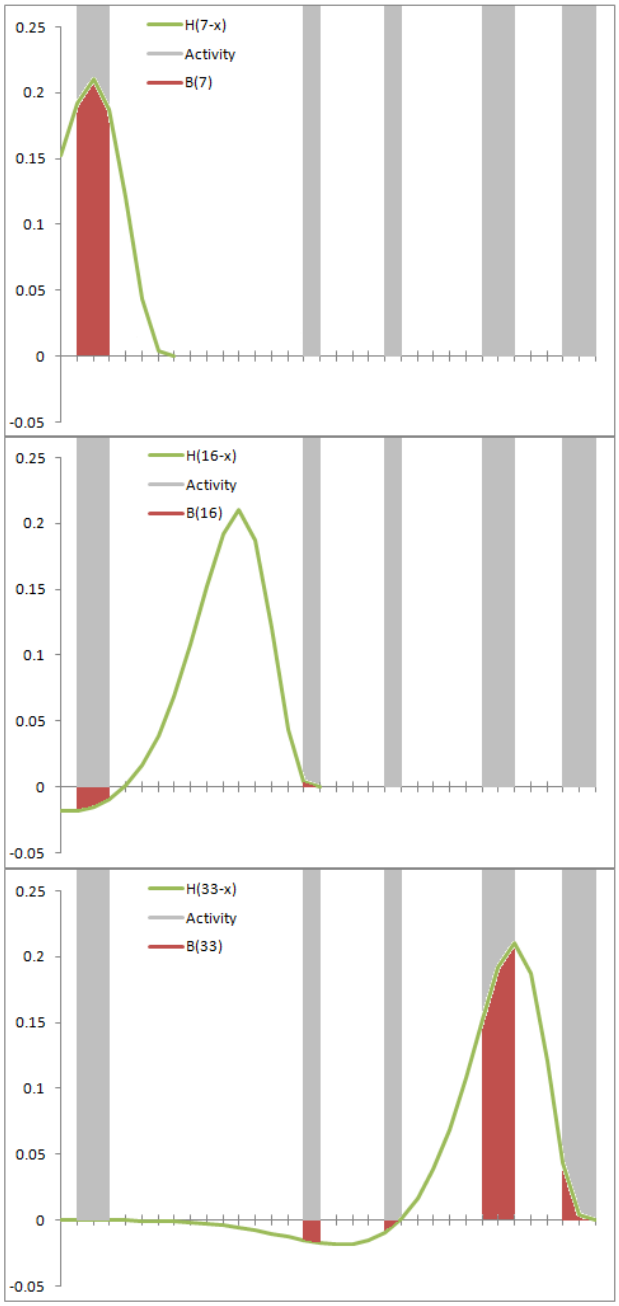
To produce the BOLD response at a given time, B(t), we need to compute the accumulated hemodynamic response over all of the activity of the module up to that time. That can be done using the convolution of the demand function with the hemodynamic response function:

$$B(t) = \int_0^t D(x)H(t-x)dx$$

Because our demand function only has values of 0 or 1 the B(t) value is the area under the reversed and shifted hemodynamic response function in the periods of module activity.

Here's an example showing the BOLD response for a module which has activity during the times 1-3, 15-16, 20-21, 26-28, and 31-33 and how the values were computed for three of those points:





Parameters

:bold-param-mode

This parameter determines how the exponent parameters for the Gamma distributions are set as well as how the scaling is determined for combining the positive and negative curves to generate the hemodynamic response function. It has two possible values: act-r and spm. The default value is act-r. The differences between those modes will be described with the affected parameters.

:bold-exp & :neg-bold-exp

These two parameters are used to set the exponent parameters (the **a** parameters) for the positive and negative Gamma distributions which generate the hemodynamic response function, and the values must be integers. If the :bold-param-mode value is spm then the :bold-exp and :neg-bold-exp values should be set to the **a** values desired, which would be 6 and 16 respectively for the default function. If the :bold-param-mode value is act-r then these parameters must be set to one less than the **a** parameters desired i.e. they would need to be set to 5 and 15 for the default function. Since act-r mode is the default these parameters default values are 5 and 15. However, if one changes :bold-param-mode to spm when both :bold-exp and :neg-bold-exp are set to their default values they will be automatically changed to the corresponding spm values of 6 and 16.

:bold-scale & :neg-bold-scale

These parameters are used to set the scale parameters for the positive and negative Gamma distributions which generate the hemodynamic response function. Their setting does not depend on the :bold-param-mode value and both default to a value of 1.

:bold-positive & :bold-negative

These two parameters are the weights used when combining the positive and negative Gamma distributions to generate the hemodynamic response function. The default values are 6 and 1 respectively.

When :bold-param-mode is set to act-r the weights are used as follows to combine the positive and negative Gamma distributions:

$$H(t) = \left[\frac{bp}{bp - bn}\ positive(t) \right] - \left[\frac{bn}{bp - bn} negative(t) \right]$$

where:

bp = :bold-positive value
bn = :bold-negative value
positive(t) = the positive Gamma distribution
negative(t)= the negative Gamma distribution

With this scaling method a module with a constant activity will have a BOLD value of 1, but the peak BOLD value for a module may exceed a value of 1.

When :bold-param-mode is set to spm the weights are used as follows to combine the positive and negative Gamma distributions:

$$H(t) = \left[\frac{bp}{\max(bp, bn)}\ positive(t) \right] - \left[\frac{bn}{\max(bp, bn)} negative(t) \right]$$

where:

bp = :bold-positive value
bn = :bold-negative value
positive(t) = the positive Gamma distribution
negative(t)= the negative Gamma distribution

This is the scaling used in SPM to generate the default hemodynamic response function.

These parameters can be set to 0 to disable the positive or negative component if desired (note however that if the positive component is disabled in act-r mode the result will be a positive function because the bp – bn value will also be negative).

:bold-settle

This parameter is used to help with the efficiency of computing the BOLD response values. It can be set to a time in seconds beyond which H(t) can be considered as having a value of 0. Only activity which occurs within :bold-settle seconds of the current time is used in computing the BOLD response (essentially the integral is computed from t - :bold-settle to t instead of 0 to t). The default value is 40 (with the other default values H(40) = -.0000052).

:bold-inc

This parameter is used to set the interval, in seconds, at which the BOLD predictions are computed. The default value is 2 seconds.

:point-predict

This parameter is used to specify a list of buffer names for which the corresponding module activities occur instantaneously, but a BOLD prediction is still desired (since the standard calculation will result in values of 0 for instantaneous activity). For the buffers on this list the demand associated with each activity will be treated as an impulse function with an area of 1 occurring at the time of the activity. Thus, the B(t) value will be the sum of the H(x-t) values at the activity times. The default value is a list containing the buffer name goal.

History Processors

There are three history processors which can be used to get the BOLD prediction data from the buffer-trace history. They all use the same process described above for computing the results, but differ in how exactly the data is reported.

bold-prediction

The bold-prediction history processor computes the BOLD prediction as described above for each of the buffers in the current buffer-trace history. It has two optional parameters which can be used to specify a starting and ending time to limit the range over which the predictions are computed, and a third optional parameter which indicates whether the data should be printed to the command trace. It returns a list of lists where the first item in a sublist is the name of a buffer and the rest of the list is the BOLD prediction data for each time step in the range of times requested (which is 0 to current time if none provided): ((buffer bold-value*)*).

Example:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))

4> (get-history-data "bold-prediction")
"[[\"MANUAL\",0.0,7.116422e-7,0.015379674,0.059214685,0.07821559,0.074922346,0.07778276,
0.08459592,0.084080234,0.07669602,0.06397217,0.056394327,0.06966068,0.077085264,0.08674426
4,0.09169287,0.091012,0.09067639,0.0911798,0.08056933,0.082401596,0.09309575,0.08512345,0.
079779565,0.0789257,0.077776566,0.07488024,0.062607914,0.062190473,0.073173605,0.073846556
,0.06338371,0.06570311],
[\"GOAL\",0.0036787947,0.12099249,0.27242562,0.36315846,0.40226096,0.41133723,0.4366023,0.
41118938,0.36133355,0.30863062,0.30381384,0.29339045,0.33684182,0.39727795,0.42140335,0.40
263155,0.3712272,0.35467446,0.3532136,0.31072795,0.32460716,0.36801147,0.37339666,0.403027
53,0.37886032,0.34314317,0.33192348,0.32307497,0.3179245,0.36359704,0.41549307,0.39395335,
0.36075956]]"

5> (process-history-data "bold-prediction" nil nil (4 30))
"[[\"MANUAL\",0.015379674,0.059214685,0.07821559,0.074922346,0.07778276,0.08459592,0.08408
0234,0.07669602,0.06397217,0.056394327,0.06966068,0.077085264,0.086744264],
[\"GOAL\",0.27242562,0.36315846,0.40226096,0.41133723,0.4366023,0.41118938,0.36133355,0.30
863062,0.30381384,0.29339045,0.33684182,0.39727795,0.42140335]]"

6> (process-history-data "bold-prediction" nil nil (4 30 t))
    time    GOAL  MANUAL
   5.000   0.272   0.015
   7.000   0.363   0.059
   9.000   0.402   0.078
  11.000   0.411   0.075
  13.000   0.437   0.078
  15.000   0.411   0.085
  17.000   0.361   0.084
  19.000   0.309   0.077
  21.000   0.304   0.064
  23.000   0.293   0.056
  25.000   0.337   0.070
  27.000   0.397   0.077
  29.000   0.421   0.087

"[[\"MANUAL\",0.015379674,0.059214685,0.07821559,0.074922346,0.07778276,0.08459592,0.08408
0234,0.07669602,0.06397217,0.056394327,0.06966068,0.077085264,0.086744264],
[\"GOAL\",0.27242562,0.36315846,0.40226096,0.41133723,0.4366023,0.41118938,0.36133355,0.30
863062,0.30381384,0.29339045,0.33684182,0.39727795,0.42140335]]"
```

bold-prediction-with-time

The bold-prediction-with-time history processor operates like the bold-prediction processor above except for two small differences. The first is that it does not have an optional parameter for printing the results. The other is that there is an additional list of values as the first sublist in the results. That list starts with the name time and is followed by the values for the mid-points of the time intervals for

which the BOLD predictions in the remaining lists are generated (the same as the first column which is printed in the output for the bold-prediction processor): ((**time** mid-point*)(buffer bold-value*)*).

Example:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))

4> (get-history-data "bold-prediction-with-time")
"[[\"time\",1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31,33,35,37,39,41,43,45,47,49,51,53,55
,57,59,61,63,65,67],
[\"GOAL\",0.0036787947,0.12099249,0.27242562,0.36315846,0.40226096,0.41133723,0.4366023,0.
41118938,0.36133355,0.30863062,0.30381384,0.29339045,0.33684182,0.39727795,0.42140335,0.40
263155,0.3712272,0.35467446,0.3532136,0.31072795,0.32460716,0.36801147,0.37339666,0.403027
53,0.37886032,0.34314317,0.33192348,0.32307497,0.3179245,0.36359704,0.41549307,0.39395335,
0.36075956],[\"MANUAL\",0.0,7.116422e-
7,0.015379674,0.059214685,0.07821559,0.074922346,0.07778276,0.08459592,0.084080234,0.07669
602,0.06397217,0.056394327,0.06966068,0.077085264,0.086744264,0.09169287,0.091012,0.090676
39,0.0911798,0.08056933,0.082401596,0.09309575,0.08512345,0.079779565,0.0789257,0.07777656
6,0.07488024,0.062607914,0.062190473,0.073173605,0.073846556,0.06338371,0.06570311]]"

5> (process-history-data "bold-prediction-with-time" nil nil (4 30))
"[[\"time\",5,7,9,11,13,15,17,19,21,23,25,27,29],
[\"GOAL\",0.27242562,0.36315846,0.40226096,0.41133723,0.4366023,0.41118938,0.36133355,0.30
863062,0.30381384,0.29339045,0.33684182,0.39727795,0.42140335],
[\"MANUAL\",0.015379674,0.059214685,0.07821559,0.074922346,0.07778276,0.08459592,0.0840802
34,0.07669602,0.06397217,0.056394327,0.06966068,0.077085264,0.086744264]]"
```

bold-prediction-with-time-scaled

The bold-prediction-with-time-scaled history processor operates like the bold-prediction-with-time processor above except for one difference. The data for each of the buffers is scaled such that it is in the range [0.0,1.0].

Example:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
```

```
((2.2949998 2.8075 3.32) (8 8 8))


4> (get-history-data "bold-prediction-with-time-scaled")
"[[\"time\",1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31,33,35,37,39,41,43,45,47,49,51,53,55
,57,59,61,63,65,67],
[\"GOAL\",0.0,0.2709802,0.62077206,0.8303538,0.92067575,0.9416408,1.0,0.94129926,0.8261384
4,0.7044012,0.69327503,0.6691983,0.7695656,0.9091656,0.9648923,0.92153174,0.8489916,0.8107
568,0.8073824,0.70924574,0.74130505,0.84156364,0.8540028,0.9224464,0.86662316,0.7841209,0.
7582048,0.73776585,0.7258689,0.83136684,0.9512403,0.9014862,0.8248126],
[\"MANUAL\",0.0,7.644197e-
6,0.16520275,0.6360622,0.8401629,0.80478805,0.83551353,0.90869796,0.90315866,0.8238402,0.6
8716526,0.60576695,0.74826914,0.8280213,0.9317747,0.9849308,0.97761714,0.97401214,0.979419
6,0.8654458,0.88512737,1.0,0.9143645,0.8569625,0.8477906,0.835447,0.8043358,0.672511,0.668
027,0.7860037,0.7932323,0.6808443,0.7057584]]"

5> (process-history-data "bold-prediction-with-time-scaled" nil nil (4 30))
"[[\"time\",5,7,9,11,13,15,17,19,21,23,25,27,29],
[\"GOAL\",0.0,0.5526537,0.790827,0.84611046,1.0,0.84520996,0.5415381,0.2205246,0.19118564,
0.12769677,0.39235902,0.76047546,0.90742326],
[\"MANUAL\",0.0,0.61424035,0.88049155,0.83434474,0.8744264,0.9698962,0.96267015,0.8591985,
0.6809048,0.57471997,0.76061535,0.86465275,1.0]]"
```

Commands

predict-bold-response

Syntax:

predict-bold-response {*start* {*end* {*output*}}} -> ((buffer bold-data*)*)

Arguments and Values:

start ::= a time in seconds
end ::= a time in seconds
output ::= a generalized boolean indicating whether to print the results
buffer ::= the name of a buffer
bold-data ::= the prediction for the BOLD response of a buffer during a time interval

Description:

The predict-bold-response function can be used to get the predictions for the BOLD response from the recorded buffer-trace history information. It has two optional parameters which can be used to specify a starting and ending time to limit the range over which the predictions are computed, and a third optional parameter which indicates whether the data should be printed to the command trace (the default is to print the data). It returns a list of lists of where the first item in a sublist is the name of a buffer and the rest of the list is the BOLD prediction data for each time step in the range of times requested (which is 0 to current time if neither is provided).

If there is no current model a warning will be printed and **nil** will be returned. If either start or end is not a number or the interval between start and end is less than :bold-inc seconds a warning will be printed to indicate the issue.

Examples:

```
1> (load "ACT-R:tutorial;lisp;zbrodoff.lisp")
T

2> (record-history "buffer-trace" "goal" "manual")
T
T
T

3> (zbrodoff-set)

              2 ( 8)      3 ( 8)      4 ( 8)
Block  1  2.295 ( 8)  2.807 ( 8)  3.320 ( 8)
((2.2949998 2.8075 3.32) (8 8 8))

> (predict-bold-response)
    time    GOAL  MANUAL
   1.000   0.004   0.000
   3.000   0.121   0.000
   5.000   0.272   0.015
   7.000   0.363   0.059
   9.000   0.402   0.078
  11.000   0.411   0.075
  13.000   0.437   0.078
  15.000   0.411   0.085
  17.000   0.361   0.084
  19.000   0.309   0.077
  21.000   0.304   0.064
  23.000   0.293   0.056
  25.000   0.337   0.070
  27.000   0.397   0.077
  29.000   0.421   0.087
  31.000   0.403   0.092
  33.000   0.371   0.091
  35.000   0.355   0.091
  37.000   0.353   0.091
  39.000   0.311   0.081
  41.000   0.325   0.082
  43.000   0.368   0.093
  45.000   0.373   0.085
  47.000   0.403   0.080
  49.000   0.379   0.079
  51.000   0.343   0.078
  53.000   0.332   0.075
  55.000   0.323   0.063
  57.000   0.318   0.062
  59.000   0.364   0.073
  61.000   0.415   0.074
  63.000   0.394   0.063
  65.000   0.361   0.066

((MANUAL 0.0 7.116422e-7 0.015379674 0.059214685 0.07821559 0.074922346 0.07778276
0.08459592 0.084080234 ...)
 (GOAL 0.0036787947 0.12099249 0.27242562 0.36315846 0.40226096 0.41133723 0.4366023
0.41118938 0.36133355 ...))

> (predict-bold-response 0 (mp-time) nil)
((MANUAL 0.0 7.116422e-7 0.015379674 0.059214685 0.07821559 0.074922346 0.07778276
0.08459592 0.084080234 ...)
 (GOAL 0.0036787947 0.12099249 0.27242562 0.36315846 0.40226096 0.41133723 0.4366023
0.41118938 0.36133355 ...))

> (predict-bold-response 4 13 t)
    time    GOAL  MANUAL
   5.000   0.272   0.015
```

```
   7.000   0.363   0.059
   9.000   0.402   0.078
  11.000   0.411   0.075

((MANUAL 0.015379674 0.059214685 0.07821559 0.074922346) (GOAL 0.27242562 0.36315846
0.40226096 0.41133723))

E> (predict-bold-response 1 (mp-time) nil)
#|Warning: Start time should be a multiple of :bold-inc (2).  Using start time of 0. |#
((MANUAL 0.0 7.116422e-7 0.015379674 0.059214685 0.07821559 0.074922346 0.07778276
0.08459592 0.084080234 ...)
 (GOAL 0.0036787947 0.12099249 0.27242562 0.36315846 0.40226096 0.41133723 0.4366023
0.41118938 0.36133355 ...))

E> (predict-bold-response 'a (mp-time) nil)
#|Warning: Start time for predicting BOLD response must be a number, but A given.  Using 0
instead. |#
((MANUAL 0.0 7.116422e-7 0.015379674 0.059214685 0.07821559 0.074922346 0.07778276
0.08459592 0.084080234 ...)
 (GOAL 0.0036787947 0.12099249 0.27242562 0.36315846 0.40226096 0.41133723 0.4366023
0.41118938 0.36133355 ...))

E> (predict-bold-response 50 'bad nil)
#|Warning: End time for predicting BOLD response must be a number, but BAD given.  Using
current-time instead. |#
((MANUAL 0.077776566 0.07488024 0.062607914 0.062190473 0.073173605 0.073846556 0.06338371
0.06570311)
 (GOAL 0.34314317 0.33192348 0.32307497 0.3179245 0.36359704 0.41549307 0.39395335
0.36075956))

E>(predict-bold-response 1 2 nil)
#|Warning: Sample time too short for BOLD predictions - must be at least :bold-inc seconds
(currently 2) |#
((MANUAL) (GOAL))

E> (predict-bold-response)
#|Warning: Predict-bold-response requires a current model. |#
NIL
```

Checking and testing version information

If one wants to access the ACT-R version in code there are multiple ways to do so, along with a command that can be added to a model file to compare the version for which the model was written to the current version and warn if they may be incompatible. There is also a command one can use to test the version of a specific module.

Feature tests

One option for testing the version is through the use of keywords on the Lisp *features* list. Two or three keywords will be added to the *features* list indicating the ACT-R version details when it is loaded. The first is :act-r-7 which will always be on the list. The second will include the major software version number like this :act-r-7.X where X is the major version number e.g. :act-r-7.0. If there is a minor version number then an additional keyword will be added indicating both the major and minor versions like this :act-r-7.X.Y where X is the major and Y the minor version numbers e.g. :act-r-7.0.1.

```
> *features*
(:ACTR-ENVIRONMENT :ACT-R-7.26.1 :ACT-R-7.26 :ACT-R-7 :ACT-R  ...)
```

System parameters

The other way to test the version is through system parameters that hold the version information. There are four system parameters which hold the version details. None of those parameters can be changed using ssp, they are effectively read-only – it will output a warning indicating that they cannot be modified if they are attempted to be set.

:act-r-version

This parameter always returns the string with the complete version specification, and it cannot be changed:

```
> (ssp :act-r-version)
("7.26.1-<internal>")

> (ssp :act-r-version "1.1")
#|Warning: System parameter :ACT-R-VERSION cannot take value 1.1 because it must be
unmodified. |#
(:INVALID-VALUE)
```

:act-r-architecture-version

This parameter always returns the current architecture version number, and it cannot be changed:

```
> (ssp :act-r-architecture-version)
(7)

> (ssp :act-r-architecture-version 8)
```

```
#|Warning: System parameter :ACT-R-ARCHITECTURE-VERSION cannot take value 8 because it
must be unmodified. |#
(:INVALID-VALUE)
```

:act-r-major-version

This parameter always returns the current major version number, and it cannot be changed:

```
> (ssp :act-r-major-version)
(26)

> (ssp :act-r-major-version 2)
#|Warning: System parameter :ACT-R-MAJOR-VERSION cannot take value 2 because it must be
unmodified. |#
(:INVALID-VALUE)
```

:act-r-minor-version

This parameter always returns the current minor version number, and it cannot be changed:

```
> (ssp :act-r-minor-version)
(1)

> (ssp :act-r-minor-version 4)
#|Warning: System parameter :ACT-R-MINOR-VERSION cannot take value 4 because it must be
unmodified. |#
(:INVALID-VALUE)
```

Version test commands

written-for-act-r-version

Syntax:

written-for-act-r-version *version-string* {*description*} -> [**t** | **nil** | **:invalid-value**]

Remote command name:

written-for-act-r-version

Arguments and Values:

version-string ::= a string containing a valid ACT-R version which would be of the form:
A{**.***B*{**.***C*}}{-<*tag*>} where A, B, and C are integers and tag is any text.
description ::= a string containing additional text to display in the warning

Description:

The written-for-act-r-version command will test a specified version string against the version of the currently loaded ACT-R system and print a warning if the specified version may not be compatible with the current version and return the value **nil**. If they are compatible then no warning will be

printed and it will return **t**. If an invalid version string is provided it will print a warning indicating that and return the keyword **:invalid-value**.

If a description string is provided then that will be shown in the warning when an incompatible version is detected.

The intention for this function is to use it at the top level of a model file, new module, or other extension code specifying the version of ACT-R in which it was written and run. That way if that code is made available to others and someone later tries to use it in a potentially incompatible version there will be a warning about that when it is loaded. Two recommended places to place this call would be immediately after the call to clear-all in a model file or just before the first call to define-model or define-module in a file.

Examples:

These examples were run with this version of ACT-R:

```
> (ssp :act-r-version)
("7.26.1-<internal>")

> (written-for-act-r-version "7.26.1-<internal>")
T

> (written-for-act-r-version "7")
T

> (written-for-act-r-version "7.26" "Test code")
T

> (written-for-act-r-version "7.26.1")
T

E> (written-for-act-r-version "8")
#|Warning: Current ACT-R architecture 7 is not the same as 8 specified in 8. |#
NIL

E> (written-for-act-r-version "7.2")
#|Warning: Current ACT-R major version 26 is newer than major version 2 specified in 7.2.
           It may not be backward compatible. |#

E>  (written-for-act-r-version "7.27")
#|Warning: Current ACT-R major version 26 is older than major version 27 specified in 7.27.
           Some features may not be implemented. |#
NIL

E> (written-for-act-r-version "7.27" "Example model")
#|Warning: Current ACT-R major version 26 is older than major version 27 specified in 7.27
for Example model.
           Some features may not be implemented. |#
NIL

E> (written-for-act-r-version 7)
#|Warning: Invalid version specified in written-for-act-r-version: 7.  Version must be an
ACT-R version string. |#
:INVALID-VALUE

E> (written-for-act-r-version "bad")
#|Warning: Invalid version specified in written-for-act-r-version: "bad".  Version must be
an ACT-R version string. |#
:INVALID-VALUE
```

check-module-version

Syntax:

check-module-version *module version-string* {*warn-if-newer*} -> [**t** | **nil**]

Arguments and Values:

module ::= the name of an existing module
version-string ::= a string containing a sequence of numbers separated by periods
warn-if-newer ::= a generalized boolean indicating whether the test should warn for newer versions too

Description:

The check-module-version command will compare the version string given against the version string of the named module. If there is not a module with the specified name, the version string given is not a string of numbers separated by periods, or the module's version is not a string of numbers separated by periods then it will print a warning and return **nil**. If all of the values are valid, then it will compare the numbers from the two versions left to right one at a time. If the module's number is less than the specified number it will print a warning indicating the version mismatch and return **nil**. If the numbers are the same it will test the next numbers if there are any. If the module's number is greater than the specified number and warn-if-newer was given as a non-**nil** value then it will print a warning indicating the version mismatch and return **nil**, otherwise it will test the next numbers if there are any. If there were more numbers provided for the version-string than there are in the module's version number it will print a warning indicating a mismatch and return **nil**. If none of the mismatching conditions have resulted in a warning then it will return **t**.

The intention for this function is to use it at the top level of a model file, new module, or other extension code that requires a specific version of a module. That way if that code is made available to others and someone later tries to use it in a potentially incompatible version there will be a warning about that when it is loaded. Two recommended places to place this call would be immediately after the call to clear-all in a model file or just before the first call to define-model or define-module in a file.

Examples:

These examples were run with this version of the ACT-R vision module:

```
VISION                : 10.0        A module to provide a model ...


> (check-module-version :vision "10")
T

> (check-module-version :vision "10.0")
T

> (check-module-version :vision "8")
T

> (check-module-version :vision "8" t)
```

```
#|Warning: Module :VISION with version "10.0" is newer than the version test for "8" |#
NIL

> (check-module-version :vision "10.0.1")
#|Warning: Module :VISION with version "10.0" does not meet the version test for "10.0.1"|#
NIL

> (check-module-version :vision "11")
#|Warning: Module :VISION with version "10.0" does not meet the version test for "11" |#
NIL

E> (check-module-version "not-a-module" "1")
#|Warning: Cannot check version because no module with name "not-a-module" |#
NIL

E> (check-module-version :vision 1)
#|Warning: Version number 1 given to check module :VISION is not a string of numbers |#
NIL
```

Loading Extra Components

Included with the ACT-R software are some optional extensions which have been written to extend or modify the operation of the software. These extensions can be found in the extras directory of the distribution. Each of the extras includes documentation that describes how to load and use it, which typically requires explicitly loading files or moving them into other directories so that the ACT-R code will load them automatically. However, for convenience many of the extra components can also be loaded with a command called require-extra which can be added to a model file to have an extra automatically loaded instead of having to manually load the file(s). This can be useful when providing models to other users so that they do not have to load additional files or reconfigure their ACT-R code to be able to run the model.

Commands

require-extra

Syntax:

require-extra *name* -> [**t** | **nil**]

Arguments and Values:

name ::= a string which names an extra component that should be loaded if necessary

Description:

Require-extra can be used to compile and load the code necessary to use an extension to ACT-R found in the extras directory of the source code distribution. The name provided should be the name of the directory in extras that contains the extension, but not all of the extras directories have files that need to be loaded with require-extra (see an extra's documentation for details). Require-extra can only be used when there are no current models defined. Thus, the recommended place to put it in a model file is directly following the call to clear-all. If the necessary components to use that extra have not already been loaded then they will be compiled (if necessary) and loaded. If that is successful **t** will be returned. If the extra has already been loaded then **nil** will be returned, and if there are any problems then a warning will be displayed and **nil** will be returned.

Examples:

```
1> (require-extra "blending")
T

2> (require-extra "blending")
NIL

E> (require-extra "blending")
#|Warning: Cannot require an extra when there is a current model. |#
NIL

E> (require-extra "bad-name")
```

```
#|Warning: Directory C:\actr7.x\extras\bad-name\ for specified extra bad-name not found.|#
NIL

E> (require-extra "chunk-tree-viewer")
#|Warning: Load file for extra chunk-tree-viewer at location C:\actr7.x\extras\chunk-tree-
viewer\chunk-tree-viewer.lisp not found. |#
NIL
```

Creating Visual Features

Instead of (or in addition to) using a device like the AGI to generate visual features for a model the modeler can also create custom visual features using the same commands that are used by the AGI. The commands described below allow one to create features, modify those features, and remove those features from the visicon. Those features may contain any information the modeler wants to provide to the model, and the only constraint is that each one must specify an x,y position (the z position will be set by the default viewing distance if not provided).

The features created using the add-visicon-features command map a location chunk to an object chunk for each feature. The result of creating a feature is three items: the visual feature (which is the combination of the location and object information), the visual location chunk, and the visual object chunk. There is no built-in mechanism to support a single object having multiple location chunks or vice-versa at this time, but a generalization of the scale ability that was possible for text features in prior versions may be reintroduced with a future update. However, there is a device which can be installed that allows the modeler to create the visual object chunks dynamically (described below) which could be used to return the same object for different locations, but it would still be necessary to create those individual location features.

Using any of these commands will cause the vision module to update the visicon information and reprocess the features for possibly stuffing a chunk into the visual-location buffer and/or re-encoding the currently attended location. That update is scheduled at the current time if there is not one already scheduled to occur and the vision module can safely update the visicon. If the module cannot safely update the information at the current time then the update will be delayed and scheduled to occur when it is safe to do so (it is unsafe to update the information during the firing of a production which is making a visual buffer request). All of the changes which have been made will be processed during that update – it does not process each one separately. The updating will generate two events. The first will have an action of proc-display and the second will be a signal which can be monitored called visicon-update. Here is how those will look in the trace (the visicon-update only displays in the high detail level):

```
0.000   VISION                  PROC-DISPLAY
0.000   VISION                  visicon-update
```

Object-creator device

There is a device called object-creator which can be installed for the vision interface that allows the modeler to provide a command for creating visual object chunks. When installing that device the details of the device (the third element of the list) must be a valid command. That command will be called whenever the vision module needs to create a visual object chunk for a feature from the visicon. That command will be passed the feature id of the feature which is being attended by the model. If the command returns a chunk then that chunk will be used as the visual object that is attended, otherwise the original visual object from the feature will be used.

Examples

Examples of creating custom visual features and using an object-creator device can be found in the examples/vision-module directory of the distribution.

Commands

add-visicon-features

Syntax:

add-visicon-features *feature-description** -> (feature-id*)

Remote command name:

add-visicon-features ' *feature-description** '

Arguments and Values:

feature-description ::= (feature-spec*)
feature-spec ::= [[slot | **isa**] [value | (loc-value obj-value)] | feat-param param-val]
slot ::= the name of a slot for the feature
value ::= the value for the corresponding slot of the feature
loc-value ::= [the value for the corresponding slot of the feature's location | **nil**]
obj-value ::= [the value for the corresponding slot of the feature's object | **nil**]
feat-param ::= [**:x-slot** | **:y-slot** | **:z-slot** | **:width-fn**]
param-val ::= the value for the corresponding feature parameter
feature-id ::= [feat-name | **nil**]
feat-name ::= a name for referring to a created feature

Description:

The add-visicon-features command is used to create visual features for the current model. A visual feature is a combination of a visual location and a visual object. This command allows the modeler to specify a visual location and visual object for any number of features and it will create the feature information from each of those pairs to add to the visicon and return the ids for referring to those features for use with the modify-visicon-features and delete-visicon-features commands. When the model finds a feature through a visual-location buffer request the visual location chunk from that feature will be placed into the visual-location buffer, and when that feature is attended through a move-attention request to the visual buffer (or the automatic re-encoding of an already attended feature) the visual object chunk will be placed into the visual buffer (unless the object-creator device is installed and provides an alternate object chunk).

The visual location and visual object chunks for a feature are specified in a format very similar to that of the define-chunks and add-dm commands – a list of slot value pairs with an optional chunk-type declaration specified with isa. The difference is that both chunks are specified in a single list. If a value for a slot (or the isa declaration) is specified with an atomic element (not a list) then that slot and value will appear in both the visual location and visual object unless it is one of the position slots (which are screen-x, screen-y, and distance by default) in which case it only belongs to the visual location chunk. If a slot is specified with a list of two values then the first of those values will be the value for the visual location chunk and the second will be the value for the visual object chunk.

When specifying that list of two values a value of **nil** can be used to indicate that the corresponding chunk not have that slot. If the visual location for a feature does not contain an x and y position then the feature is not created. If the visual location does not have a z position then that slot will be added with a value of the :viewing-distance parameter. If the visual location does not have a value for the size slot then a size will be computed for it using the values from the height and width slots of the location chunk if it has them otherwise it will get the default size value of 1.0. Finally, if the visual location chunk does not have a value for a slot named kind and there was a chunk-type declared with isa for the visual object chunk then the visual location chunk will get a kind slot with a value that is the chunk-type declared for the visual object.

In addition to the slots for the visual location and visual object chunks there are four parameters which can be specified to indicate some configuration information about the feature. Three parameters :x-slot, :y-slot, and :z-slot allow one to change the names of the slots used to hold the position information in the visual location chunk. The default slot names are screen-x, screen-y, and distance, but the default values can be changed using set-default-vis-loc-slots if one does not want to set the parameters for every feature explicitly. A value for one of those parameters changes the name of the slot that will be used to hold the corresponding position value instead of the default slot for that position. The :width-fn parameter can be specified with a valid command as a value and that command will be called when the motor module needs to determine the effective width of the item for computing a time to move to it using Fitts's law. That command will be passed four parameters: the feature id, the angle of the approach (in radians), and the x and y starting position for the approach. If it returns a number then that will be used as the width of the item (in degrees of visual angle) otherwise the default calculation will be performed to compute a width.

The features which are available for the model to find using a visual-location buffer request are the union of the slots and values from the visual-location and visual-object chunks with the value from the visual object being used if both chunks have a value for the slot, and that is the information which is displayed by the print-visicon command.

If there is no current model then this command will print a warning and return **nil**. If there is a current model, then the return value from this command is a list with the same number of elements as there were feature descriptions provided. If the corresponding feature description resulted in a valid feature being created then the return list will contain an id for that feature, but if the feature could not be created then the value in the return list will be **nil** and a warning will be printed to indicate the invalid feature.

Examples:

Only examples of the warning messages are shown here. For actual examples of using the command see the examples/vision-module directory of the distribution.

```
E> (add-visicon-features '(screen-x 0 screen-y 0) '(bad-slot 0))
#|Warning: Extending chunks with slot named BAD-SLOT because of chunk definition (BAD-SLOT 0) |#
#|Warning: Visicon feature (BAD-SLOT 0) did not contain a valid feature and was not created. |#
(VISICON-ID2 NIL)

E> (add-visicon-features '(screen-x 10 screen-y 10))
#|Warning: get-module called with no current model. |#
NIL
```

modify-visicon-features

Syntax:

modify-visicon-features *feature-modification** -> (mod-result*)

Remote command name:

modify-visicon-features ' *feature-modification** '

Arguments and Values:

feature-modification ::= (mod-id mod*)
mod-id ::= the name of a feature that has been added to the visicon
mod ::= slot [value | (loc-value obj-value)]
slot ::= the name of a slot for the feature
value ::= the value for the corresponding slot of the feature
loc-value ::= [the value for the corresponding slot of the feature's location | **nil**]
obj-value ::= [the value for the corresponding slot of the feature's object | **nil**]
mod-result ::= [mod-id | **nil**]

Description:

The modify-visicon-features command is used to modify visual features for the current model which were created with add-visicon-features. This command allows the modeler to modify both the visual location and visual object of a feature. The modifications for a feature are specified in a format very similar to that of add-visicon-features. The first element of a modification specification must be the name of a visicon feature which was previously added to the visicon, and the remainder is a set of slot value pairs to indicate the modifications. If a value for a slot is specified with a value that is not a list of 2 values then that slot of both the visual location and visual object chunks will be modified to contain the new value (unless it is one of the position slots in which case it is only modified for the visual location chunk). If a slot is specified with a list of two values then the first of those values will be the modified value for the visual location chunk and the second will be the modified value for the visual object chunk. When specifying that list of two values a value of **nil** can be used to indicate that the corresponding chunk should not have its slot modified.

If there is no current model then this command will print a warning and return **nil**. If there is a current model, then the return value from this command is a list with the same number of elements as there were modification lists provided. If the corresponding modification resulted in a valid modification then the return list will contain the id for that feature, but if the feature could not be modified then the value in the return list will be **nil** and a warning will be printed to indicate the invalid modification.

Examples:

Only examples of the warning messages are shown here. For actual examples of using the command see the examples/vision-module directory of the distribution.

```
E> (modify-visicon-features '(bad-feature screen-x 10))
#|Warning: Provided update (BAD-FEATURE SCREEN-X 10) does not contain a valid visual
feature modification. |#
(NIL)

E> (modify-visicon-features )
#|Warning: get-module called with no current model. |#
NIL
```

delete-visicon-features

Syntax:

delete-visicon-features *feature-id** -> (del-result*)

Remote command name:

delete-visicon-features

Arguments and Values:

feature-id ::= the name of a feature that has been added to the visicon
del-result ::= [feature-id | **nil**]

Description:

The delete-visicon-features command is used to remove visual features from the current model which were created with add-visicon-features. It takes any number of parameters and for each one that is the name of a visual feature in the current model it will remove that feature from the visicon.

If there is no current model then this command will print a warning and return **nil**. If there is a current model, then the return value from this command is a list with the same number of elements as there were items provided. If a provided name was in the visicon and could be deleted then the return list will contain that name in the corresponding position, but if the item did not name a feature in the visicon then the value in the return list will be **nil** and a warning will be printed to indicate the invalid value.

Examples:

Only examples of the warning messages are shown here. For actual examples of using the command see the examples/vision-module directory of the distribution.

```
E> (delete-visicon-features 'bad-name)
#|Warning: Feature BAD-NAME is not a valid feature name and cannot be removed. |#
(NIL)

E> (delete-visicon-features)
#|Warning: get-module called with no current model. |#
NIL
```

delete-all-visicon-features

Syntax:

delete-all-visicon-features -> [**t** | **nil**]

Remote command name:

delete-all-visicon-features

Description:

The delete-all-visicon-features command is used to remove all of the visual features from the current model which were created with add-visicon-features.

If there is no current model then this command will print a warning and return **nil**. If there is a current model, then the return value from this command will be **t**.

Examples:

```
> (delete-all-visicon-features)
T

E> (delete-all-visicon-features)
#|Warning: get-module called with no current model. |#
NIL
```

set-default-vis-loc-slots

Syntax:

set-default-vis-loc-slots *x-slot y-slot z-slot* -> [**t** | **nil**]
set-default-vis-loc-slots-fct *x-slot y-slot z-slot* -> [**t** | **nil**]

Remote command name:

set-default-vis-loc-slots

Arguments and Values:

x-slot ::= the name of a slot to use for the x position coordinate
y-slot ::= the name of a slot to use for the y position coordinate
z-slot ::= the name of a slot to use for the z position coordinate

Description:

The set-default-vis-loc-slots command is used to change the default names for the position slots used in visual features for the current model. If the three names provided are valid slot names for chunks in the current model then those slots will be considered as the ones which represent the position information in visual-features created after that call.

If the values are all different valid slot names then those names will be used and it will return **t**. If there is no current model, the names do not name valid slots, or there are duplicates among them then this command will print a warning and return **nil**.

Examples:

Only examples of the warning messages are shown here. For actual examples of using the command see the examples/vision-module directory of the distribution.

```
E> (set-default-vis-loc-slots a b c)
#|Warning: get-module called with no current model. |#
#|Warning: No vision module available in call to set-default-vis-loc-slots. |#
NIL

E> (set-default-vis-loc-slots-fct 'screen-x 'screen-y 'bad-slot)
#|Warning: Slot BAD-SLOT is not valid in call to set-default-vis-loc-slots. |#
NIL

E> (set-default-vis-loc-slots screen-x screen-x screen-y)
#|Warning: Duplicate slot names provided for set-default-vis-loc-slots: SCREEN-X, SCREEN-
X, SCREEN-Y |#
NIL
```

Adding new production compilation types

Not yet documented.

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