Declarative Memory Related Issues

In this text we are going to investigate some of the most common problems which can arise when working with models that rely on the use of declarative retrievals when the subsymbolic calculations are enabled and thus activation affects the results. Unlike the models in previous modeling texts, the model which accompanies this text will not be performing any particular task. Instead, it is just a set of productions and declarative knowledge which allows us to see some of the issues which can occur when working with declarative memory and discuss how to determine what has happened and ways to address that in the model.

The Model Design

The model for this exercise, declarative-issues.lisp, is designed to perform a sequence of declarative retrievals and its declarative memory has been initialized with chunks that allow for the demonstration of specific retrieval situations. The **goal** and **imaginal** buffers will be used to control the sequencing of the productions and also to facilitate some of the retrieval situations. The productions are intended to fire in order by the number in their names, from p1 through p8. The specific details of the chunk-types and chunks involved will be described in the sections where it is meaningful below. The subsymbolic calculations for the model have been enabled using all of the activation equation's components. Most of the other parameters are left at their default values, or, in the case of those which are off by default like noise, have been set to values which reflect reasonable starting points based on the models from the tutorial and/or past ACT-R research.

Loading the Model

When we load the model we see the following warnings:

```
#|Warning: Production P3 has a condition for buffer RETRIEVAL with an isa that provides no tests. |#
#|Warning: Production P6 has a condition for buffer IMAGINAL with an isa that provides no tests. |#
```

Those are indications that there are no slots tested in the conditions for the indicated buffers even though a chunk-type has been declared with an isa like this one in P3:

```
(p p3
   =goal>
     isa task-state
     state r3
   =retrieval>
     isa simple-value
 ==>
   =goal>
     state r4
   +retrieval>
     isa simple-fact
```

```
        attribute pink)
```

That warning is a reminder that the isa specification is not in and of itself a condition for the production. That is not a problem in this model because those productions only need to test that there is some chunk in the indicated buffer. So those can be safely ignored, and if you want to just turn off the warnings without fixing the productions you can add a setting of **nil** for the style-warnings to the model:

```
(sgp :style-warnings nil)
```

However, if you want to fix them then one thing that could be done is to just remove the isa and chunk-type specification from those buffer conditions. Alternatively, for the retrieval buffer condition in production **p3** we could avoid the warning by using a query to determine if there is a chunk in the buffer instead of using an =retrieval condition with no slots to test the buffer. We can't use a query for the **imaginal** buffer case in **p6** however because if a production makes a modification or modification request to a buffer as an action it must have an =<buffer> condition on the LHS of the production.

Since there are no other warnings or indicated issues which must be addressed in the model we can go right to trying to run it.

First Retrieval Request

Because there is no task associated with this model we will just use the ACT-R run command to run it. The first retrieval which this model makes specifies the chunk-type simple-value and indicates that it must have some value in the result slot (it is not **nil**) made by this production:

```
(p p1
   ?goal>
     buffer empty
 ==>
   +goal>
     isa task-state
     state r2
   +retrieval>
     isa simple-value
    - result nil)
```

This is the definition of the simple-value chunk-type:

```
(chunk-type simple-value result)
```

and here are the initial chunks specified with that type which are placed into the model's declarative memory with add-dm:

```
(v1 isa simple-value result "true")
(v2 isa simple-value result "false")
(v3 isa simple-value result nil)
```

In addition to that, the initial activations of those chunks have been set as follows:

```
(set-base-levels (v1 1 -1500)
                 (v2 1 -1500)
                 (v3 1 -1500))
```

Those settings reflect one past occurrence for each chunk 1500 seconds ago. We will consider that as an unchangeable property of these chunks for purposes of addressing issues with their retrieval (assume that they were learned as the result of some previous actions which we consider to be working correctly). Based on the initial declarative memory and the request that **p1** makes we expect either chunk **v1** or **v2** to be retrieved. When we run the model however we find that it retrieves **chunk 2-1**:

```
0.000   PROCEDURAL             CONFLICT-RESOLUTION
0.050   PROCEDURAL             PRODUCTION-FIRED P1
0.050   PROCEDURAL             CLEAR-BUFFER GOAL
0.050   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
0.050   DECLARATIVE            start-retrieval
0.050   PROCEDURAL             CONFLICT-RESOLUTION
0.138   DECLARATIVE            RETRIEVED-CHUNK 2-1
0.138   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL 2-1
0.138   PROCEDURAL             CONFLICT-RESOLUTION
```

Chunk 2-1 is defined like this:

```
(2-1 isa math-fact arg1 two arg2 one result one operator subtract)
```

It is created using the chunk-type math-fact, but notice that it does have a slot named result. That's an important thing to remember about requests in productions. The chunk-type specified by isa is **not** part of the request. Thus, all that is being asked for in that request is a chunk which has a value in its result slot, which is true of **chunk 2-1** and all of the other math-fact chunks which are in the model's declarative memory. If we want to restrict the retrieval to only the simple-value chunks then we must specify something in the request which distinguishes them from other chunks.

Currently there are no other slots in the simple-value chunk type which we can use to distinguish it in the request. We could look at the other chunk-types with a slot named result and make the request to explicitly exclude them, for example since all of the math-fact chunks have values in the arg1 slot we could change the request to something like this:

```
+retrieval>
  isa simple-value
  - result nil
  arg1 nil
```

While that would work in this simple demo, it's not really a good solution because it is an arbitrary choice and if this were a more complex model it might be the case that the model could generate some math-fact chunk with an empty arg1 value at some point which could cause problems later. Doing that would also lead to these warnings when the model is loaded since the simple-value chunk-type doesn't have a slot named arg1:

```
#|Warning: Slot ARG1 invalid for type SIMPLE-VALUE but chunk-spec definition still created. |#
#|Warning: Production P1 action has invalid slot ARG1 for type SIMPLE-VALUE. |#
```

We could eliminate the isa specification in the request to avoid that warning:

```
+retrieval>
  - result nil
  arg1 nil
```

But the benefit of using the isa is for consistency and clarity in the model specification which we now lose. Therefore we should look for some way to make the simple-value chunks distinct, and there are basically two options. The first is to change the name of the slot in the simple-value chunk-type from result to something which isn't used elsewhere. The other is to add an additional unique slot to the chunk-type which we can set to a value to mark these chunks as distinct. For this model either of those seems like a reasonable choice. We will choose the second option, and add a slot named simple-value-chunk to the chunk-type and specify that slot with the value **t** in all of the chunks which we create using the simple-value chunk-type:

```
(chunk-type simple-value result simple-value-chunk)

(v1 isa simple-value result "true" simple-value-chunk t)
(v2 isa simple-value result "false" simple-value-chunk t)
(v3 isa simple-value result nil simple-value-chunk t)
```

A potential issue with adding slots to a chunk is that if the model is using spreading activation then having additional slots with chunks in them will affect the fan of the value placed into the slot and the amount of activation which spreads from those chunks with the additional slot if they are in a buffer. To avoid that one can use the special value **t** for the slot because **t** is not a chunk. It represents the Lisp value for true which is the opposite of the Lisp value **nil**, and since **nil** is used to indicate slots that don't exist **t** can be used to indicate slots that do exist without using a chunk to do so.

Now we also need to change the request in production **p1** to specify that slot and value:

```
+retrieval>
  isa simple-value
- result nil
  simple-value-chunk t
```

Later in the tutorial we will introduce a way to handle some of that additional specification with a slot that has a fixed value automatically, but for now we will just make the changes directly to the chunks and the request in the production.

After making that change when we run the model we get the following result:

```
0.000   PROCEDURAL             CONFLICT-RESOLUTION
0.050   PROCEDURAL             PRODUCTION-FIRED P1
```

```
     0.050   PROCEDURAL             CLEAR-BUFFER GOAL
     0.050   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
     0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
     0.050   DECLARATIVE            start-retrieval
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
     1.050   DECLARATIVE            RETRIEVAL-FAILURE
     1.050   PROCEDURAL             CONFLICT-RESOLUTION
     1.050   ------                 Stopped because no events left to process
```

The model stopped because it failed to retrieve a chunk which prevents any further productions from firing. We now need to figure out why it didn't retrieve either of the simple-value chunks we were expecting it to retrieve. There are several ways one could go about doing that, and we will describe several of them here.

One option, is to use the ACT-R command whynot-dm (or whynot_dm in Python) which is similar to the why-not command for productions. It reports on what happened with the last retrieval request which was made. Calling it with no parameters will print out the last retrieval request which was made and then for each chunk in declarative memory print the chunk, its parameters, and an indication of why it wasn't retrieved for that request. Displaying the information for all chunks however is not typically useful because there could be a lot of chunks in declarative memory which makes it difficult to find the important ones, but it is also possible to pass it the names of chunks and it will only print the details for those chunks. Since our model has stopped and the last retrieval request is the one we are interested in we can use that command like this to get the information about the chunks v1, v2, and v3:

```
? (whynot-dm v1 v2 v3)
```

```
>>> actr.whynot_dm('v1','v2','v3')
```

Those print out the following information:

```
Retrieval request made at time 0.050:
 -  RESULT NIL
    SIMPLE-VALUE-CHUNK T

V1
   RESULT  "true"
   SIMPLE-VALUE-CHUNK  T

Declarative parameters for chunk V1:
 :Activation -3.026
 :Permanent-Noise  0.000
 :Base-Level -2.964
 :Creation-Time -1500.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((V1 . 2.0))
 :Similarities ((V1 . 0.0))
 :Last-Retrieval-Activation -3.142
 :Last-Retrieval-Time  0.050

V1 matched the request
V1 was below the retrieval threshold 0.0
```

```
V2
   RESULT  "false"
   SIMPLE-VALUE-CHUNK  T

Declarative parameters for chunk V2:
 :Activation -2.437
 :Permanent-Noise  0.000
 :Base-Level -2.964
 :Creation-Time -1500.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((V2 . 2.0))
 :Similarities ((V2 . 0.0))
 :Last-Retrieval-Activation -2.725
 :Last-Retrieval-Time  0.050

V2 matched the request
V2 was below the retrieval threshold 0.0

V3
   SIMPLE-VALUE-CHUNK  T

Declarative parameters for chunk V3:
 :Activation -1.679
 :Permanent-Noise  0.000
 :Base-Level -2.964
 :Creation-Time -1500.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((V3 . 2.0))
 :Similarities ((V3 . 0.0))

V3 did not match the request
```

There we see that v1 and v2 did match the request, but they were below the retrieval threshold.

Another mechanism for investigating issues with retrievals is to turn on the activation trace in the model and run it again. That is done by setting the :act parameter to a non-nil value. In the unit texts it was set to t, but like the trace-detail parameter, it can also be set to values of high, medium, or low to control how much detail is shown. We will run the model with each value below to show the differences in information provided.

We could make that change in the model file, save the model, and then load it, but since the model itself hasn't changed we don't really need to perform those steps. Instead, we can reset the model (using either the reset command or the Reset button in the Environment) and then just call sgp from the ACT-R prompt to change the parameter value before running it or from the Python interface the function set_parameter_value could be used which takes a string with the name of the parameter and a string of the value in this case:

```
? (sgp :act medium)
```

```
>>> actr.set_parameter_value(':act','medium')
```

Changing the parameters interactively like that can be a convenient way to debug a model, but may not always be possible; particularly if there is additional code involved which is responsible for resetting and running the model. Here is the activation trace with a value of t (which is the same as a value of high and could also be set using True through the Python command):

```
     0.050   DECLARATIVE            start-retrieval
Computing activation for chunk V1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
base-level value: -2.9634798
Total base-level: -2.9634798
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: "true"
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise -0.17835411
Adding permanent noise 0.0
Chunk V1 has an activation of: -3.1418338
Chunk V1 has the current best activation -3.1418338
Computing activation for chunk V2
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
base-level value: -2.9634798
Total base-level: -2.9634798
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: "false"
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.23814109
Adding permanent noise 0.0
Chunk V2 has an activation of: -2.7253387
Chunk V2 is now the current best with activation -2.7253387
No chunk above the retrieval threshold: 0.0
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
```

Here is what we get when it is set to medium:

```
     0.050   DECLARATIVE            start-retrieval
Computing activation for chunk V1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
```

```
base-level value: -2.9634798
Total base-level: -2.9634798
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: "true"
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise -0.17835411
Adding permanent noise 0.0
Chunk V1 has an activation of: -3.1418338
Chunk V1 has the current best activation -3.1418338
Computing activation for chunk V2
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
base-level value: -2.9634798
Total base-level: -2.9634798
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: "false"
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.23814109
Adding permanent noise 0.0
Chunk V2 has an activation of: -2.7253387
Chunk V2 is now the current best with activation -2.7253387
No chunk above the retrieval threshold: 0.0
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
```

Both of those traces display all of the details of the activation calculations for the chunks which matched the request and in this case there isn't any difference between them. The difference would show up if there were chunks in declarative memory which had the slots specified in the request but which failed on some of the constraints specified, for example, if the :recently-retrieved request parameter had been specified. In those situations the high detail trace will also include a line for each of the non-matching chunks whereas the medium detail trace will not show the chunks that didn't match the request.

Here is what we get when it is set to low:

```
     0.050   DECLARATIVE            start-retrieval
Chunk V1 has an activation of: -3.1418338
Chunk V2 has an activation of: -2.7253387
No chunk above the retrieval threshold: 0.0
```

```
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
```

When set to low only the final activation values are shown instead of all the details.

Before looking at the details of that retrieval, we will introduce another command which can also be useful for interactively debugging a model: with-parameters. Instead of changing the value of a parameter with sgp one can use the with-parameters command at the ACT-R prompt to temporarily set parameter values and evaluate some other commands (there is no equivalent to with-parameters available through the remote interface at this time). Thus, instead of setting the activation trace to low and then running the model we could have done the following to set both the activation trace and the standard trace detail to low and then run with those settings:

```
? (with-parameters (:act low :trace-detail low)
    (run 10))
     0.050   PROCEDURAL             PRODUCTION-FIRED P1
     0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
Chunk V1 has an activation of: -3.1418338
Chunk V2 has an activation of: -2.7253387
No chunk above the retrieval threshold: 0.0
     1.050   DECLARATIVE            RETRIEVAL-FAILURE
     1.050   ------                 Stopped because no events left to process
```

After the with-parameters call is done the parameter values will be automatically returned to the values that they had previously.

As for the retrieval, regardless of which trace we look at, the critical line is the last one:

```
No chunk above the retrieval threshold: 0.0
```

No chunk is retrieved because they all have activations below the current retrieval threshold, which is also what we found from whynot-dm.

Another way we could have investigated the chunks' activations is by using the sdp command to see the current declarative parameters for each chunk. That will include the current activation as well as the activation it had the last time it was attempted to be retrieved. When the model stopped we could call sdp to print out all of those chunks and their parameters like this:

```
? (sdp v1 v2 v3)
```

```
>>> actr.sdp('v1','v2','v3')
```

Which would result in the following output:

```
Declarative parameters for chunk V1:
 :Activation -3.387
 :Permanent-Noise  0.000
 :Base-Level -2.964
 :Creation-Time -1500.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((V1 . 2.0))
 :Similarities ((V1 . 0.0))
 :Last-Retrieval-Activation -3.142
 :Last-Retrieval-Time  0.050
Declarative parameters for chunk V2:
 :Activation -2.527
 :Permanent-Noise  0.000
```

```
 :Base-Level -2.964
 :Creation-Time -1500.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((V2 . 2.0))
 :Similarities ((V2 . 0.0))
 :Last-Retrieval-Activation -2.725
 :Last-Retrieval-Time  0.050
Declarative parameters for chunk V3:
 :Activation -1.626
 :Permanent-Noise  0.000
 :Base-Level -2.964
 :Creation-Time -1500.000
 :Reference-Count  1
 :Source-Spread  0.000
 :Sjis ((V3 . 2.0))
 :Similarities ((V3 . 0.0))
```

That doesn't completely explain why things failed, but if we knew the retrieval threshold in advance and suspected that to be the problem then sdp may have been useful without having to run the model again to get the activation trace. That same information is shown in the Declarative tool of the ACT-R Environment, so that could also be used to investigate the chunks' activations, and there is a "Why not?" button that can be used in the Declarative tool as well. It is also possible to record the retrieval information for viewing after the run if desired and that will be described in a later section.

Now that we know the problem is that the chunk activations are below the retrieval threshold there are basically two ways to address that: either lower the retrieval threshold or increase the activation of those chunks in some way. Decreasing the threshold is an easy thing to do since all it takes is adding the parameter setting to the model. Changing the activation of the chunks can be accomplished in several ways, but given our constraint of not adjusting their histories limits us to essentially two options. One way to increase their activations would be to use the :blc (base-level constant) parameter to add a fixed value to all chunk activations. Another way would be to add additional information to those chunks which could provide a way for spreading activation to increase their activations.

As is usually the case, there is no one "right" answer as to how to fix this. A modeler will have to consider his or her theory as to how people are performing the task, any data which is available, and the possible implications of making the change to other components of the model. For this model we do not have a theory or data since we are not modeling a real task. The effects on other parts of the model are also not relevant at this point for the same reason. So, since we don't have any reason to pick one option over the others, for the purpose of the exercise we will set the retrieval threshold lower and then deal with any possible consequences this has later on in the model. Before doing so we will look at some of the potential issues from the other changes which one might want to consider.

If the :blc parameter is adjusted that will affect the activation of all of the chunks which are retrieved by the model. Since the time to retrieve a chunk depends on its activation, not only will setting :blc affect whether a chunk is retrieved but also how long it will take. Thus, that may then necessitate the adjustments of other parameters as well to keep the response times in line with the data if that is important. However, if response time is not important to the data being modeled, then adjusting :blc might be a simple way to help ensure that chunks exceed the retrieval threshold and are retrieved quickly (since a higher activation will mean faster retrieval).

Using spreading activation to increase the activation of the chunks might be a plausible mechanism for the task. If the knowledge is prespecified for the model, like we are doing here, then it may be easy to add some additional context to that information to facilitate spreading activation. For example, although the grouped recall example from unit 5 didn't use spreading activation it did have a chunk which represented the current list itself as a member of the group chunks which could have been used for that purpose. If the model is learning the chunks on its own however then one needs to have a way for the model to generate its own context. One way that is often done is to include the model's current goal or imaginal chunk as a slot value in the memories it creates. That way, each new goal or problem representation provides a particular context. The biggest downside to using this approach is primarily the additional complexity it requires in the model. One now has to have that context information available to spread the activation in a slot of a buffer at the time of retrieval, and it may require additional retrievals to remember past contexts as well as the needed information.

Now that we've covered some of the alternatives, we will set the threshold lower and see how that affects the model. The first question is how low do we want to set it? To really answer that we need to decide how likely we want the model to fail to retrieve a chunk when there is one which can be retrieved, and to determine that we need to know what the activation of the chunks are and how much noise there is in the activations. Knowing the activation and noise value we can compute the recall probability for a chunk using the equation presented in unit 4. However, right now for this model, we just want it to succeed every time. Thus we want to pick a value significantly lower than the activation of the chunks involved. From the activation trace we see that the chunks involved have activations of about -3.14 and -2.73. Therefore if we set the threshold to -10 that should be sufficient since with the model's activation noise set to .25 the recall probability for a chunk with an activation of -3.14 will be extremely close to 1.0 with that threshold.

Before changing the model and reloading it we can actually test that new value now. First we set the retrieval threshold to the value we want:

```
? (sgp :rt -10)
```

```
>>> actr.set_parameter_value(':rt',-10)
```

Then we can use the command simulate-retrieval-request to see what would happen if we were to make that same retrieval request now. The parameters to that command are the slots specified for the request just as they would appear in a production after the +retrieval>:

```
? (simulate-retrieval-request - result nil simple-value-chunk t)
```

```
>>> actr.simulate_retrieval_request('-','result','nil',
                                    'simple-value-chunk','t')
```

For the Python version we could also rely on the fact that the Lisp nil corresponds to None in Python and the Lisp t is equivalent to True in Python and use those values instead of strings with the Lisp values:

```
>>> actr.simulate_retrieval_request('-','result',None,
                                    'simple-value-chunk',True)
```

Those show the following output:

```
Chunk V1 has the current best activation -2.874935
Chunk V2 has activation -2.887749
Chunk V1 with activation -2.874935 is the best
```

The output from calling that command is the low detail activation trace which would result if that request were made at the current time. If we set the retrieval threshold back to 0 and try it again we can see that it indicates the retrieval failure as the trace above does:

```
Chunk V1 has the current best activation -2.874935
Chunk V2 has activation -2.887749
No chunk above the retrieval threshold: 0.0
```

So now that we know a retrieval threshold of -10 will work for the model to be able to retrieve those chunks we will add that additional setting to the sgp call in the model:

```
(sgp :esc t :v t :bll .5 :ans .25 :mas 3 :mp 10 :rt -10)
```

We need to save that change, load the model, and run it again. Here is the trace that we get now if we run for 10 seconds:

```
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.050   PROCEDURAL             PRODUCTION-FIRED P1
     0.050   PROCEDURAL             CLEAR-BUFFER GOAL
     0.050   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
     0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
     0.050   DECLARATIVE            start-retrieval
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
    10.000   ------                 Stopped because time limit reached
```

The model stopped because it reached the end of the 10 seconds we asked it to run and it did not retrieve the chunk in that time. There are a couple of things to consider now. First, did the model successfully retrieve the chunk? If so, why did it take at least 10 seconds to complete? Then we have to decide if that amount of time is reasonable for the model in performing this task.

As to whether or not the model successfully retrieved the chunk we have several options for testing that. First, we could just run the model some more until we find either a successful retrieval or a retrieval failure. In this case that would work just fine because there are no other productions that could fire to interfere with that. Alternatively, we could reset it and enable the activation trace so that we have the details of what happened. Again, for this model that is not a difficult option since this happens early in the run and because there is no task which is running the model it's easy to stop it where we want without having to use the Stepper tool in the ACT-R Environment. Instead of using those however we are going to introduce a new command that can also be helpful in situations like this. That command is called mp-show-queue and it allows us to look ahead in time to see what events the model is scheduled to do in the future without actually running it. It takes no parameters and would be called like this:

```
? (mp-show-queue)
>>> actr.mp_show_queue()
```

This is the output that it shows:

```
Events in the queue:
    15.312   DECLARATIVE            RETRIEVED-CHUNK V2
    15.312   PROCEDURAL             CONFLICT-RESOLUTION
```

That shows us that the model will complete the retrieval at time 15.312 and then perform another conflict-resolution action. Just because we see an event scheduled to occur at some future time with mp-show-queue however does not mean that we will necessarily see that same action in the trace if we continue to run the model. That's because things can happen to change the situation before that time arrives. Thus, looking ahead at the model's actions like that can be very useful in situations where a delayed action, like a retrieval completion, could be superseded by a new retrieval. For example, if another production were to fire and make a retrieval request at time 11.0 that would interrupt the ongoing retrieval and we would not actually see that retrieved-chunk action at time 15.312 if we were to run the model. That doesn't happen in this model, and we would have seen the same results if we were to just run it that long:

```
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.050   PROCEDURAL             PRODUCTION-FIRED P1
     0.050   PROCEDURAL             CLEAR-BUFFER GOAL
     0.050   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
     0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
     0.050   DECLARATIVE            start-retrieval
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
    15.312   DECLARATIVE            RETRIEVED-CHUNK V2
    15.312   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V2
    15.312   PROCEDURAL             CONFLICT-RESOLUTION
    15.320   ------                 Stopped because time limit reached
```

Although it's not really necessary here, mp-show-queue is a useful tool to know about and can be very helpful in some situations.

Now that we know the retrieval did succeed we should consider the time that it took to do so. As shown in unit 4 the time it takes to retrieve a chunk depends on its activation by the equation:

$$Time = Fe^{-A}$$

The activation of our chunk is about -2.73 and the value of F is the latency factor parameter (:lf) which defaults to 1. Since we don't set that parameter in our model the time to retrieve the chunk should be about $e^{2.73} \approx 15.3$ seconds, which is what we see in the trace.

If the model were performing a real task, particularly if we had data for comparison, we would want to consider if a retrieval of that length is acceptable for the model, and if not, what we should do about it. Since this model is not performing any particular task we don't really have any basis for judging the length of that retrieval time, but we can still consider how we would change it if we wanted to. Based on the equation for the retrieval time there are two things we can do to affect the time. The first would be to change the activation of the chunk, and that could be done in the same ways as were discussed previously. The other option would be to change the :lf parameter. The thing to keep in mind when changing :lf is that it will affect all of the retrievals which the model performs. As an example we will change :lf for this model to decrease the time it takes to complete retrievals by setting it to .8:

```
(sgp :esc t :v t :bll .5 :ans .25 :mas 2 :mp 10 :rt -10 :lf .8)
```

Saving that change and then reloading the model here is what the trace looks like now with the activation trace set to low to show that while the time of the retrieval has changed the activations of the chunks are the same as they were previously:

```
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.050   PROCEDURAL             PRODUCTION-FIRED P1
     0.050   PROCEDURAL             CLEAR-BUFFER GOAL
     0.050   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
     0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
     0.050   DECLARATIVE            start-retrieval
Chunk V1 has an activation of: -3.1418338
Chunk V2 has an activation of: -2.7253387
Chunk V2 with activation -2.7253387 is the best
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
    12.259   DECLARATIVE            RETRIEVED-CHUNK V2
    12.259   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V2
    12.259   PROCEDURAL             CONFLICT-RESOLUTION
    ...
```

Second Retrieval Request

The second retrieval request the model makes is very similar to the first one. Except that there are no constraints placed on the request this time:

```
(p p2
   =goal>
     isa task-state
     state r2
   =retrieval>
  ==>
   =goal>
     state r3
   +retrieval>
     isa simple-value)
```

Assuming that we want to restrict the request to the simple-value chunks we should change that request to specify the simple-value-chunk slot before trying to run it as we did for production p1:

```
(p p2
   =goal>
     isa task-state
     state r2
   =retrieval>
  ==>
   =goal>
     state r3
   +retrieval>
     isa simple-value
     simple-value-chunk t)
```

Here is a portion of the trace from running the model for this retrieval with the activation trace enabled:

```
...
    12.309   PROCEDURAL             PRODUCTION-FIRED P2
    12.309   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    12.309   DECLARATIVE            start-retrieval
Computing activation for chunk V1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
base-level value: -2.9675493
Total base-level: -2.9675493
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.08887799
Adding permanent noise 0.0
Chunk V1 has an activation of: -2.8786714
Chunk V1 has the current best activation -2.8786714
Computing activation for chunk V2
Computing base-level
Starting with blc: 0.0
Computing base-level from 2 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
base-level value: -2.2744021
Total base-level: -2.2744021
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
```

```
Adding transient noise 0.07606379
Adding permanent noise 0.0
Chunk V2 has an activation of: -2.1983383
Chunk V2 is now the current best with activation -2.1983383
Computing activation for chunk V3
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
base-level value: -2.9675493
Total base-level: -2.9675493
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise -0.026406968
Adding permanent noise 0.0
Chunk V3 has an activation of: -2.9939563
Chunk V2 with activation -2.1983383 is the best
    12.309   PROCEDURAL             CONFLICT-RESOLUTION
    19.517   DECLARATIVE            RETRIEVED-CHUNK V2
    19.517   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V2
    19.517   PROCEDURAL             CONFLICT-RESOLUTION
...
```

We see that it retrieves chunk v2 again this time, and that this retrieval is faster than the last time requiring only a little more than 7 seconds instead of around 12. That is because the chunk has an extra reference now since it was retrieved previously and thus it has a higher base-level activation than the other two simple-value chunks.

That is the expected result of base-level learning, activation of the chunk increases with practice which makes it more likely to be retrieved and faster when it is. However, there is a potential issue that can arise with respect to base-level learning. The issue to be wary of is that when using requests to declarative memory with few constraints a single chunk may come to dominate and always be retrieved. In some situations that may be desirable, but in other situations one may not want one chunk to dominate like that.

If one does not want a single chunk to dominate, but can't provide additional constraints in the request or change the context to affect the other components of the activation equation, then one may need to take advantage of the declarative finsts which were described in unit 3 of the tutorial. They can be used to suppress the retrieval of a chunk which has been recently retrieved so that a single chunk is not retrieved repeatedly. To do so one needs to add the :recently-retrieved request parameter to the request which is made to the retrieval buffer with a value of nil. That will then remove chunks which are currently marked with a declarative finst from those considered for that request. For demonstration purposes we will make that change to the request made in p2 and see the difference. Here is the new version of p2:

```
(p p2
   =goal>
     isa task-state
```

```
        state r2
      =retrieval>
    ==>
      =goal>
        state r3
      +retrieval>
        isa simple-value
        simple-value-chunk t
        :recently-retrieved nil)
```

and here is the trace showing that retrieval now:

```
...
    12.259   PROCEDURAL             CONFLICT-RESOLUTION
    12.309   PROCEDURAL             PRODUCTION-FIRED P2
    12.309   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    12.309   DECLARATIVE            start-retrieval
Removing recently retrieved chunks:
V2
Computing activation for chunk V1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
base-level value: -2.9675493
Total base-level: -2.9675493
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.08887799
Adding permanent noise 0.0
Chunk V1 has an activation of: -2.8786714
Chunk V1 has the current best activation -2.8786714
Computing activation for chunk V3
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references ()
  creation time: -1500.000 decay: 0.5  Optimized-learning: T
base-level value: -2.9675493
Total base-level: -2.9675493
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot SIMPLE-VALUE-CHUNK
  Requested: = T  Chunk's slot value: T
  similarity: 0.0
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.07606379
Adding permanent noise 0.0
Chunk V3 has an activation of: -2.8914855
Chunk V1 with activation -2.8786714 is the best
    12.309   PROCEDURAL             CONFLICT-RESOLUTION
    26.541   DECLARATIVE            RETRIEVED-CHUNK V1
```

```
    26.541   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V1
    26.541   PROCEDURAL             CONFLICT-RESOLUTION
...
```

This time chunk v1 was retrieved because chunk v2 was removed from consideration since it has a declarative finst on it from the previous retrieval. If one wants to see which chunks are currently marked with a declarative finst the print-dm-finsts command can be used. It takes no parameters:

```
? (print-dm-finsts)
```

```
>>> actr.print_dm_finsts()
```

Here is the output of that after the run shown above:

```
Chunk name     Time Stamp
-------------------------
V1                26.541
```

Note that only v1 currently has a finst on it at this time because the default duration of declarative finsts is 3 seconds and more than that amount of time has passed since v2 was retrieved. If we instead check at time 12.3, after the first retrieval has completed and just before the second request is made, we will see that v2 does have a declarative finst on it:

```
...
    12.309   DECLARATIVE            start-retrieval
    12.309   PROCEDURAL             CONFLICT-RESOLUTION
    12.500   ------                 Stopped because time limit reached

? (print-dm-finsts)

Chunk name     Time Stamp
-------------------------
V2                12.259
```

If one cannot use finsts or some other means of preventing the retrieval of the same chunk repeatedly (extra constraints in the request or spreading activation with values that would favor different chunks for example), but needs to avoid the issue of a single chunk becoming dominant there are some additional options available if one adds optional components to the ACT-R system. Distributed with the ACT-R source code are several extensions which have been developed for ACT-R. Those optional components are found in the extras directory of the distribution and each one is found in a separate subdirectory. Two of the extensions available affect the base-level learning equation and may help avoid the dominant chunk problem. Those two particular extras are in the spacing-effect and base-level-inhibition directories. Because they are not part of the standard ACT-R system we will not be describing them in the tutorial materials, but one can find details and instructions on their use in the extra files provided.

Third Retrieval Request

The next retrieval request this model makes declares the chunk-type simple-fact which is defined like this:

```
(chunk-type simple-fact item attribute)
```

The production which makes the request is this one:

```
  (p p3
     =goal>
       isa task-state
       state r3
     =retrieval>
   ==>
     =goal>
       state r4
     +retrieval>
       isa simple-fact
       attribute pink)
```

The request specifies that a chunk with an attribute slot value of pink should be retrieved from declarative memory.

Here are the simple-fact chunks which the model starts with in its declarative memory from the add-dm command in the model definition:

```
   (f1 isa simple-fact item sky attribute blue)
   (f2 isa simple-fact item rose attribute red)
   (f3 isa simple-fact item grass attribute green)
```

There are no base-level activation values set for those chunks, thus for now they will each have one reference which occurs at time 0 because that's when they are added to the model's declarative memory.

Notice that none of the chunks have an attribute which matches the request which is being made, but this model does have partial matching enabled so perhaps one of them will still be retrieved. We will run it to find out what happens, and here is the result of running the model for 30 seconds:

```
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.050   PROCEDURAL             PRODUCTION-FIRED P1
     0.050   PROCEDURAL             CLEAR-BUFFER GOAL
     0.050   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
     0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
     0.050   DECLARATIVE            start-retrieval
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
    12.259   DECLARATIVE            RETRIEVED-CHUNK V2
```

```
    12.259   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V2
    12.259   PROCEDURAL             CONFLICT-RESOLUTION
    12.309   PROCEDURAL             PRODUCTION-FIRED P2
    12.309   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    12.309   DECLARATIVE            start-retrieval
    12.309   PROCEDURAL             CONFLICT-RESOLUTION
    26.541   DECLARATIVE            RETRIEVED-CHUNK V1
    26.541   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V1
    26.541   PROCEDURAL             CONFLICT-RESOLUTION
    26.591   PROCEDURAL             PRODUCTION-FIRED P3
    26.591   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    26.591   DECLARATIVE            start-retrieval
    26.591   PROCEDURAL             CONFLICT-RESOLUTION
    30.000   ------                 Stopped because time limit reached
```

It has not retrieved a chunk at that point. Instead of continuing to run, we will again look ahead with mp-show-queue:

```
Events in the queue:
 17647.763   DECLARATIVE            RETRIEVAL-FAILURE
 17647.763   PROCEDURAL             CONFLICT-RESOLUTION
```

That shows that the model has failed to retrieve a chunk as a result of that request and that it is going to take over 17000 seconds while trying. First we will look at why the model failed to retrieve a chunk and then we will consider why it takes so long when it fails.

Turning on the activation trace and running again we see these activation computations for this request:

```
    26.591   DECLARATIVE            start-retrieval
Computing activation for chunk F1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.9471392
Total base-level: -0.9471392
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ATTRIBUTE
  Requested: = PINK  Chunk's slot value: BLUE
  similarity: -1.0
  effective similarity value is -10.0
Total similarity score -10.0
Adding transient noise -0.026406968
Adding permanent noise 0.0
Chunk F1 has an activation of: -10.973546
Chunk F1 has the current best activation -10.973546
Computing activation for chunk F2
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.9471392
Total base-level: -0.9471392
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ATTRIBUTE
```

```
  Requested: = PINK  Chunk's slot value: RED
  similarity: -1.0
  effective similarity value is -10.0
Total similarity score -10.0
Adding transient noise -0.42355087
Adding permanent noise 0.0
Chunk F2 has an activation of: -11.370689
Computing activation for chunk F3
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.9471392
Total base-level: -0.9471392
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ATTRIBUTE
  Requested: = PINK  Chunk's slot value: GREEN
  similarity: -1.0
  effective similarity value is -10.0
Total similarity score -10.0
Adding transient noise 0.43639642
Adding permanent noise 0.0
Chunk F3 has an activation of: -10.510742
Chunk F3 is now the current best with activation -10.510742
No chunk above the retrieval threshold: -10.0
```

Each chunk has a base-level activation of around -.947 but then loses more activation because of the mismatch to the requested slot value. Because we have not set any similarities in this model they all default to the worst mismatch value of -1, and because the :mp parameter is set to 10 in the sgp settings for the model, each chunk then has 10 * -1 added to its activation for a total of around -10.947 before noise is added. None of the noise values are large enough to bring a chunk above the retrieval threshold which we set previously at -10. Thus, the model fails to retrieve any of them.

When there is a retrieval failure the time that it will take uses the same equation as for a successful retrieval, except that the retrieval threshold is used instead of a chunk's activation. Thus, with our current parameter settings a retrieval failure will take $.8*e^{10}$ seconds, which is almost 5 hours of simulated time in which the model sits trying to retrieve a chunk before it finally fails. A delay of that long is likely to be unacceptable in any reasonable model, so we need to decide what to do about it. Since we don't have a task to guide us, we're free to explore many possible alternatives for how to address that. First we will consider options for making it more likely that one of the existing chunks will be retrieved, and then we will consider how we can handle things if the model does still have retrieval failures.

If we want one of these chunks to be retrieved then we need to either raise their activations or lower the retrieval threshold again. If we were to lower the threshold then the retrieval of these chunks would take as long as the retrieval failure did now, and the lower we make the threshold the worse things are with respect to the time it takes when there is a failure. So we will not consider that a good choice at this point. Instead, we will look at how we can raise the activation of these chunks.

There are three components to the activation equation: base-level, spreading activation, and partial matching and each of those provides opportunities to increase the chunk's activation. We discussed the spreading activation change with respect to the first retrieval, and again will not choose to modify the model in that way for this retrieval. Instead we will look at the options for affecting the other two components of activation.

For the chunks' base-levels we again have the option of setting the :blc parameter to increase every chunk's base-level. Having seen the problem of very long retrieval times for low threshold and activations, we may want to consider doing that so we can shift things to a level that produces more reasonable times, but we will come back to that in a later section. Another option which we have available for changing the base-level of these chunks is to explicitly set their base-level activations using the set-base-levels command. For the first retrieval we had considered the base-level settings of the chunks involved as fixed values, but for these chunks we will not. Thus, we could set their creation time and number of references to values that provide sufficiently large base-level activations. When choosing to modify the base-levels of chunks one should take into account what those chunks represent and what the values for creation time and references mean for the model. For example, if the chunks represent information which the model would not have learned prior to doing the task then their creation times probably shouldn't be any earlier than when the model would have started the task, and similarly they shouldn't have more references than would be reasonable in that time. However, if the chunks are representing background knowledge that the model had long before doing the task then a much earlier creation time and larger reference count are warranted. For background knowledge of that nature it's often difficult to determine what would be an appropriate creation time and number of references so more arbitrary values are used to achieve an appropriate activation for the task.

Setting the base-levels of the chunks for this retrieval seems like it would be a reasonable thing to do since they are representing facts one would assume a person would have learned long before the task and which have been encountered frequently. Thus, as a first step we will give those chunks a strong history with this setting in the model:

```
(set-base-levels (f1 1000 -10000)
                 (f2 1000 -10000)
                 (f3 1000 -10000))
```

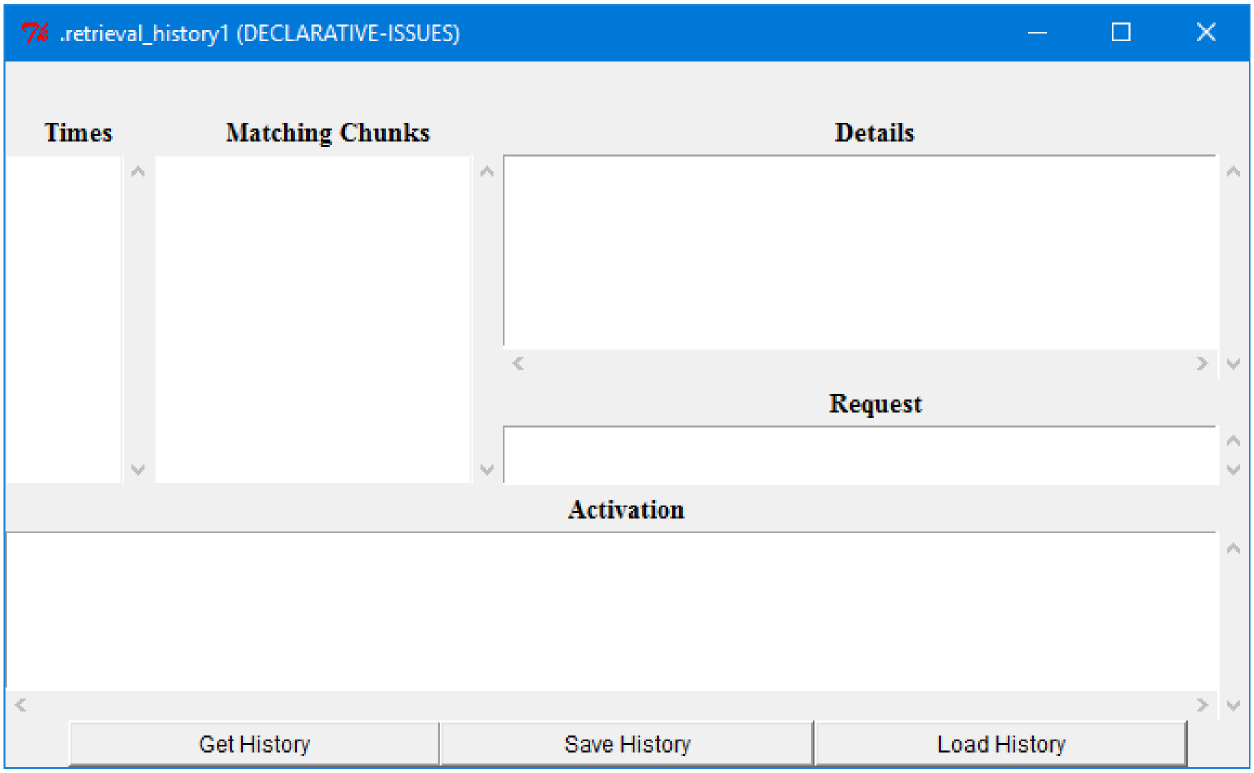
That gives the chunks a history which, while in absolute terms is probably not likely (having only learned the chunk 10000 seconds ago and having used it 1000 times since then), but may be sufficient to provide a fairly stable and relatively strong base-level activation over the course of the current task.

Running the model now we see that it will succeed in retrieving one of those chunks, but it will take a significant amount of time when checked with mp-show-queue:

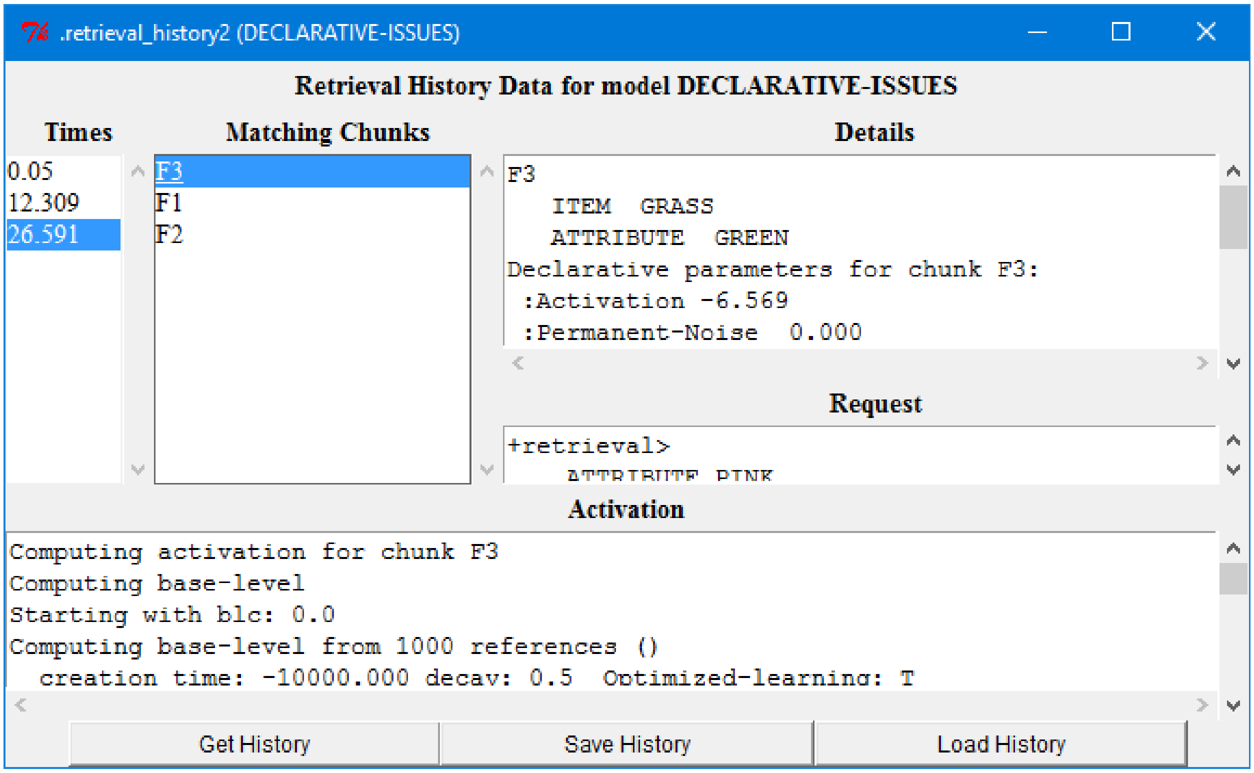
```
...
    26.591   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    26.591   DECLARATIVE            start-retrieval
    26.591   PROCEDURAL             CONFLICT-RESOLUTION
    28.000   ------                 Stopped because time limit reached


Events in the queue:
   596.830   DECLARATIVE            RETRIEVED-CHUNK F3
   596.830   PROCEDURAL             CONFLICT-RESOLUTION
```

We could turn the activation trace on to see why that happens, but instead we will introduce another tool available in the ACT-R Environment. If we open the "Retrieval History" tool before we start running the model it will open a window like the one shown below and start recording the activation information while the model runs.



When the model is done running, clicking the "Get History" button on the bottom left of that window will cause the "Times" section to display all the times in the model run at which a retrieval request was made. Picking one of those times will then cause all of the chunks which matched the request to be displayed in the "Matching Chunks" section and the request which was made to be shown in the "Request" section. The top chunk in the list will be the one which was selected for retrieval, or it will be the symbol :retrieval-failure if there was no matching chunk with an activation above the retrieval threshold. Picking one of those chunks will then cause the "Details" section to display the chunk and its parameters at that time and the "Activation" section to display the complete activation trace for how that chunk's activation was computed for that retrieval request at that time. Here is what we see for the chunk F3 which is the one that will be retrieved for the request made at time 26.591:



and here is all of the information from the activation section:

```
Computing activation for chunk F3
Computing base-level
Starting with blc: 0.0
Computing base-level from 1000 references ()
  creation time: -10000.000 decay: 0.5  Optimized-learning: T
base-level value: 2.9944046
Total base-level: 2.9944046
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ATTRIBUTE
  Requested: = PINK  Chunk's slot value: GREEN
  similarity: -1.0
  effective similarity value is -10.0
Total similarity score -10.0
Adding transient noise 0.43639642
Adding permanent noise 0.0
Chunk F3 has an activation of: -6.5691986
```

Before looking at those results we will first mention that one can also get that information without using the ACT-R Environment. To enable the recording of that information either the :sact parameter must be set to t before the model runs or the record-history command must be used to indicate that the "retrieval-history" should be recorded:

```
? (record-history "retrieval-history")
```

```
>>> actr.record_history('retrieval-history')
```

To access that saved information one can get the raw data using the get-history-data command, but we will not describe the format of that data here other than to say that it is a string which contains the data in a JSON format:

```
? (get-history-data "retrieval-history")

>>> actr.get_history_data('retrieval-history')
```

Probably more useful are the commands for printing the trace information. The saved-activation-history command can be used to get all the times and chunks for which the activation information has been recorded. It returns a list of lists where each sublist starts with the time in milliseconds at which a request was made and the remainder of the list are the chunks which matched the request at that time.

```
? (saved-activation-history)
((50 V1 V2) (12309 V1 V3) (26591 F1 F2 F3))

>>> actr.saved_activation_history()
[[50, 'V1', 'V2'], [12309, 'V1', 'V3'], [26591, 'F1', 'F2', 'F3']]
```

With that information one can use the print-activation-trace or print-chunk-activation-trace command to print all of the activation trace information at a given time, or only the activation trace information for a particular chunk which would look like this to get the trace at time 26591 and the trace for the chunk f3 at that time:

```
? (print-activation-trace 26591)

>>> actr.print_activation_trace(26591)


? (print-chunk-activation-trace f3 26591)

>>> actr.print_chunk_activation_trace('f3',26591)
```

However we get that information, looking at the trace we see that the base-level of that chunk looks strong (it would take less than 50ms to retrieve a chunk with an activation of ~3 with the current parameter settings) but it takes a big negative hit from the partial matching component of the equation. The other two chunks show a similar pattern, and it’s only the noise value which differentiates them making f3 the one to be retrieved. Since the base-level looks strong we will now consider adjusting the partial matching component of the activations.

For partial matching there are three things to consider: what values are requested in the slots of the retrieval request, what the similarities are between those requested values and the values in the slots of the chunks in declarative memory, and the mismatch penalty parameter (:mp) value. We will consider some of the issues related to each of those, and then decide what changes, if any, to make to the model.

Choosing how specific to make the retrieval request can be important in determining how likely that request is to succeed when using partial matching because each additional constraint in the request is an added opportunity to decrease the activation of the target chunks. That is because partial matching provides a penalty to chunks which do not match the request – it does not increase the activation of chunks which do (at least not under default and recommended parameter settings). If there is a chunk which matches the request then the specificity of the request doesn't really matter since there will be no penalty to that matching chunk. However, when the model is making requests in situations where it may not have a perfectly matching chunk (for instance in the 1-hit blackjack game from the unit 5 assignment) one will need to carefully determine what is important to put in the request. If there are too many constraints the model may fail to find any chunk which is close enough to all of the constraints to be above the threshold, but conversely if there are two few constraints put on the request it may retrieve a chunk which is not really relevant to the current situation. In the current model the chunks of interest for this request do not have a lot of slots to test and the request for a chunk based on a single constraint seems reasonable for the chunks involved. So, we will not adjust that aspect of the model.

The settings of the similarities between items and the :mp parameter are related, so we will discuss them together. By default a chunk is maximally similar to itself and it is maximally dissimilar to all other values. To have chunks related by some intermediate similarity the modeler must set those values. The question becomes how to decide what to make similar and how to set those similarities so that they provide the desired effects. In setting the similarities there are two things to consider: the magnitude of the effect a single mismatch will have on the activation and the relative similarity values among the items involved.

The total effect of similarity depends on how many mismatches there are as discussed with respect to the specificity of the request above, but the effect that each individual mismatch has is based on the similarity setting between the items involved and the setting of :mp. The default range for similarities is from -1 to 0, and the similarity value between the items is multiplied by the setting of the :mp parameter to determine the penalty to the activation. Setting similarities in the default range and then using :mp to scale them often works out well. However, because the :mp parameter is a constant used in all retrieval requests, when one needs there to be different similarity effects for different types of items it may be necessary to change the range of similarities instead of just scaling them all with :mp. To do that one can change the similarity range by setting the :md and :ms parameters (maximum difference and maximum similarity respectively). The recommendation is to always leave :ms at 0, but :md can be set to any value needed to provide an appropriate range. When changing the range, it's often best to then just set :mp to 1 so the similarity values directly reflect the effect on activation, but that's not required and one can still scale them with :mp as well if desired.

How to set the relative similarities between items depends on what sorts of effects one would like the model to show. While it is possible to set each possible similarity value explicitly in the model to produce specific results, it's usually more plausible to set them systematically. In some situations one can rely on other experimental results for guidance in how to set them, for instance research on numbers, language, or perceptual effects may provide a general equation or metric to use in those situations, but other times one may need to determine values appropriate for the current task by parameter exploration or analysis of the data. If parameter estimation is required, one thing that may be useful in determining similarity values is to look at the activations of the competing chunks at the time of the request along with the activation noise value. Assuming all the chunks are sufficiently above the retrieval threshold this equation describes the probability of chunk i being retrieved among those which are being considered (the set j):

$$\Pr obability(i) = \frac{e^{A_i/\sqrt{2}s}}{\sum_j e^{A_j/\sqrt{2}s}}$$

Using that equation for probability of retrieval one can then determine the expected changes in retrieval probability based on the differences in similarity values. Of course, that level of analysis will not always be necessary, but sometimes it's useful to be able to investigate things in that way.

For this model we do not have any similarity values set and thus since there is no chunk which has an attribute of pink they all get the maximum penalty of -10 (:mp of 10 times the default mismatch value of -1). If we want the model to have a preference for particular items then we will need to set some similarities and we may want to adjust the :mp value as well. Based on this retrieval request and the initial declarative memory chunks, all we need are the similarities between pink and each of blue, red, and green since those are the only items involved that could be partial-matched to the request. However, if this were a task which required a richer set of information and which may involve requests for any color then we would likely want to set all of the possible similarities, and using a sim-hook function like the 1-hit blackjack model does for similarities between numbers might be a good way to do so. For the purposes of the demonstration model however we will just set one similarity value so that red is considered more similar to pink than pink is to blue or green. That way the model will be most likely to retrieve the chunk f2 when requesting a chunk with an attribute of pink, and since we are not concerned with exactly how similar the items are or exactly how much more likely it should be for this model we will just set that to a similarity of -.4 by adding this setting to the model definition:

```
(set-similarities (pink red -.4))
```

and then investigate the effect that has before considering further changes.

Here is the trace of the model run with that addition made:

```
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.050   PROCEDURAL             PRODUCTION-FIRED P1
     0.050   PROCEDURAL             CLEAR-BUFFER GOAL
     0.050   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
     0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
     0.050   DECLARATIVE            start-retrieval
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
    12.259   DECLARATIVE            RETRIEVED-CHUNK V2
    12.259   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V2
    12.259   PROCEDURAL             CONFLICT-RESOLUTION
    12.309   PROCEDURAL             PRODUCTION-FIRED P2
    12.309   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    12.309   DECLARATIVE            start-retrieval
    12.309   PROCEDURAL             CONFLICT-RESOLUTION
    26.541   DECLARATIVE            RETRIEVED-CHUNK V1
    26.541   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V1
    26.541   PROCEDURAL             CONFLICT-RESOLUTION
    26.591   PROCEDURAL             PRODUCTION-FIRED P3
```

```
    26.591   PROCEDURAL              CLEAR-BUFFER RETRIEVAL
    26.591   DECLARATIVE             start-retrieval
    26.591   PROCEDURAL              CONFLICT-RESOLUTION
    29.931   DECLARATIVE             RETRIEVED-CHUNK F2
    29.931   DECLARATIVE             SET-BUFFER-CHUNK RETRIEVAL F2
...
```

Now we see that the chunk f2 is retrieved in about 3 seconds for this request. That is sufficient for this demonstration so we will not change anything else to affect that retrieval.

Fourth Retrieval Request

The next retrieval request this model makes is very similar to the previous one, except this time the request is for a chunk with an attribute of black:

```
(p p4
   =goal>
     isa task-state
     state r4
   ?retrieval>
     state free
 ==>
   =goal>
     state r5
   +retrieval>
     isa simple-fact
     attribute black)
```

Like the previous request there is no matching chunk and thus this request will either fail or be satisfied by a partially matched result if there is one above the retrieval threshold. If we run this model for 30 seconds the request is made and then we can look at when the request will be satisfied with mp-show-queue:

```
...
    29.981   PROCEDURAL              PRODUCTION-FIRED P4
    29.981   PROCEDURAL              CLEAR-BUFFER RETRIEVAL
    29.981   DECLARATIVE             start-retrieval
    29.981   PROCEDURAL              CONFLICT-RESOLUTION
    30.000   ------                  Stopped because time limit reached

Events in the queue:
   261.522   DECLARATIVE             RETRIEVED-CHUNK F1
   261.522   PROCEDURAL              CONFLICT-RESOLUTION
```

It will retrieve the chunk f1 after more than a 200 second delay. That delay seems unreasonable thus we need to do something to change that, and there are multiple options available depending on what exactly we want to have happen in the model.

If we want it to retrieve some chunk in a reasonable amount of time, then we will need to do something to either change the retrieval time or activation values. The options for doing that have been discussed in previous sections, and we will just summarize them here. We can change the latency factor parameter to make the retrieval faster. We can increase the activation of the potential chunks by changing their base-level activation either by giving them a stronger history or setting the base-level constant. We can decrease the penalty for partial matching by setting similarity values or changing the :mp parameter. Finally, we can add additional context to the buffers so that spreading activation will increase the chunk's activation.

If we don't mind having the request fail, then we can increase the retrieval threshold so that the model fails to retrieve in a shorter time than that. Since the time for a failure is determined by the setting of the retrieval threshold and the latency factor the settings of those parameters effectively specify the upper bound for how long the model can take to perform any retrieval. However, changing those parameters will affect all of the retrieval requests which the model makes.

Another way to handle that would be to use the temporal module in the model so that it can monitor the time that has passed explicitly and then stop waiting once too much time has passed. That allows the model to have a flexible "failure time", but it will typically require the model having additional productions to set up and use the temporal information. Details on using the temporal module are not yet available in the tutorial, but you can find information on using it in the ACT-R reference manual. If it's possible for the model to produce the response without completing the retrieval, for example if it can also find the information by searching for it visually, then that can also be used to finish before the retrieval failure time passes. In situations like that, while the retrieval is happening the model can also be engaged in the alternate process of determining the information. If the retrieval completes before the other method then the model can stop and use the retrieved information. If the other method completes first, then the model will not have to wait until the retrieval succeeds or fails. That can work very well in a learning model as long as the result of the alternate process results in strengthening the same declarative information each time. Then, as the activation of that chunk increases the model will shift from always having to do the deliberate process to being able to rely entirely on the retrieved information. That is similar to how the zbrodoff model in unit 4 of the tutorial operated, except that it did not perform the retrieval of the information in parallel with the alternative mechanism since in that case, the other process, counting, also required the use of declarative retrievals and the model can only perform one retrieval at a time.

In this model we would like some chunk to be retrieved and there is no alternative method available for producing a result. Thus, we need to make some adjustment to change the retrieval time. We are again going to avoid using spreading activation. So that leaves us with partial matching, base-level activation, or the latency factor to be adjusted. For partial matching we could adjust the similarities as we did with the previous retrieval, but that doesn't seem as appropriate to do for black and the target colors. We could also adjust the mismatch penalty, which might work well in this situation though changing it will also affect all of the other partially matched retrievals as well. Since we have already set the chunks' base-level histories to something fairly strong, we don't want to adjust that any further. Changing the base-level constant would also affect the base-level activations, but we will again avoid doing that. If we change the latency factor that is going to affect all of the retrievals which the model makes, and while that might be useful we are not going to do so here. So, among the options available, changing the mismatch penalty is the one that we will investigate further for this retrieval.

The current setting in the model is 10 and with the default maximum dissimilarity value of -1 causes the chunks which mismatch the requested value of black in the attribute slot to have -10 added to their activations. We want the activation of those chunks to be higher so that they are retrieved faster, thus we need to decrease the penalty. If we had data to fit, that would give us a guide as to how long the retrievals should be taking and suggest a more specific change to make, but since this is just for demonstration purposes we will just set it to something lower and look at the result. If we decrease the :mp value to 2 and run the model again here is what we get:

```
     0.000   PROCEDURAL             CONFLICT-RESOLUTION
     0.050   PROCEDURAL             PRODUCTION-FIRED P1
     0.050   PROCEDURAL             CLEAR-BUFFER GOAL
     0.050   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
     0.050   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK0
     0.050   DECLARATIVE            start-retrieval
     0.050   PROCEDURAL             CONFLICT-RESOLUTION
    12.259   DECLARATIVE            RETRIEVED-CHUNK V2
    12.259   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V2
    12.259   PROCEDURAL             CONFLICT-RESOLUTION
    12.309   PROCEDURAL             PRODUCTION-FIRED P2
    12.309   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    12.309   DECLARATIVE            start-retrieval
    12.309   PROCEDURAL             CONFLICT-RESOLUTION
    26.541   DECLARATIVE            RETRIEVED-CHUNK V1
    26.541   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL V1
    26.541   PROCEDURAL             CONFLICT-RESOLUTION
    26.591   PROCEDURAL             PRODUCTION-FIRED P3
    26.591   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    26.591   DECLARATIVE            start-retrieval
    26.591   PROCEDURAL             CONFLICT-RESOLUTION
    26.727   DECLARATIVE            RETRIEVED-CHUNK F2
    26.727   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL F2
    26.727   PROCEDURAL             CONFLICT-RESOLUTION
    26.777   PROCEDURAL             PRODUCTION-FIRED P4
    26.777   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    26.777   DECLARATIVE            start-retrieval
    26.777   PROCEDURAL             CONFLICT-RESOLUTION
    26.855   DECLARATIVE            RETRIEVED-CHUNK F1
    26.855   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL F1
    26.855   PROCEDURAL             CONFLICT-RESOLUTION
 ...
```

The fourth retrieval now completes in less than 200 ms as does the third retrieval which previously took more than 3 seconds. If we look closely at the activation traces we will see that without any similarities set f1 is the chunk chosen here because of noise since the other activation quantities of the potential chunks are very similar to each other, with the only difference being that f2 has a slightly higher base-level activation than f1 and f3 since it has an extra reference. We are going to consider that a reasonable time for this retrieval, but before moving on there is one other option to consider when adjusting the mismatch penalty.

If we didn't want to affect the timing of the third request but still wanted to speed up the fourth one it is possible to override the global :mp value in a request. That may be necessary in tasks where different types of information need to be retrieved and some require more specificity than others i.e. how close it must be to the requested values. That is done using the :mp-value request parameter in the retrieval request. If we set the global mp value back to 10 and change the request in production **p4** like this:

```
+retrieval>
  isa simple-fact
  attribute black
  :mp-value 2
```

we get the following result from running it:

```
 ...
    26.541   PROCEDURAL              CONFLICT-RESOLUTION
    26.591   PROCEDURAL              PRODUCTION-FIRED P3
    26.591   PROCEDURAL              CLEAR-BUFFER RETRIEVAL
    26.591   DECLARATIVE             start-retrieval
    26.591   PROCEDURAL              CONFLICT-RESOLUTION
    29.931   DECLARATIVE             RETRIEVED-CHUNK F2
    29.931   DECLARATIVE             SET-BUFFER-CHUNK RETRIEVAL F2
    29.931   PROCEDURAL              CONFLICT-RESOLUTION
    29.981   PROCEDURAL              PRODUCTION-FIRED P4
    29.981   PROCEDURAL              CLEAR-BUFFER RETRIEVAL
    29.981   DECLARATIVE             start-retrieval
    29.981   PROCEDURAL              CONFLICT-RESOLUTION
    30.059   DECLARATIVE             RETRIEVED-CHUNK F1
    30.059   DECLARATIVE             SET-BUFFER-CHUNK RETRIEVAL F1
    30.059   PROCEDURAL              CONFLICT-RESOLUTION
...
```

The third retrieval request again takes about 3 seconds to complete but the fourth one is still around 200ms.

Fifth Retrieval Request

Up to this point we have avoided the effects of spreading activation on retrievals, but for this request we will investigate issues related to using it. To do that we are going to use chunks based on the following chunk-types:

```
  (chunk-type number representation)
  (chunk-type math-fact arg1 arg2 result operator)
  (chunk-type context val1 val2 val3 goal)
```

and these initial chunks in declarative memory:

```
(zero isa number representation "0")
(one isa number representation "1")
(two isa number representation "2")
(three isa number representation "3")

(1-1 isa math-fact arg1 one arg2 one result zero operator subtract)
(2-1 isa math-fact arg1 two arg2 one result one operator subtract)
(3-2 isa math-fact arg1 three arg2 two result one operator subtract)
(1+1 isa math-fact arg1 one arg2 one result two operator add)
(1+2 isa math-fact arg1 one arg2 two result three operator add)
```

The first thing to consider when using spreading activation is which buffers the model is going to use as sources for spreading activation. By default, only the imaginal buffer is considered a source of activation, but occasionally one also will want to use the goal buffer to spread activation (note previous versions of ACT-R used the goal buffer as the only buffer to spread activation by default, but with version 7 the imaginal buffer is now the only one to spread activation by default). Doing that will require setting the :ga parameter to enable the goal buffer as a source. For this model we will only be using the imaginal buffer as a source since our goal buffer is only being used to hold state information which is not related to items in declarative memory.

The default weight for activation spreading from the imaginal buffer is 1 and that is sufficient for our purposes here so we do not need to change any parameters. The value used in setting the source spread from a buffer is often set at 1, but other values may be used and some researchers have found that adjustments to the source spread parameters can account very well for differences between individuals. For this model we will not adjust that setting, but you may want to investigate that on your own after working through the demonstrations to see how it affects things.

The only other parameter required for using spreading activation is :mas which when set to a number both enables spreading activation and specifies the value of S in the equation for S_{ji} values. In this model we have set that parameter to a value of 2 initially, but we may need to modify that as we go along.

The next request which the model makes is with this production:

```
(p p5
   =goal>
     isa task-state
     state r5
   ?imaginal>
     state free
   =retrieval>
 ==>
   =goal>
     state r6
   +imaginal>
     isa context
     val1 one
     val2 two
   +retrieval>
     isa math-fact
     - arg1 nil
     - arg2 nil
     - result nil)
```

That production makes both a request to the imaginal buffer to create a chunk with values in the val1 and val2 slots and a retrieval request for a chunk which has values in the arg1, arg2, and result slots. Running the model with the activation trace enabled produces this output for that retrieval request (with the :mp parameter set back to 2 again):

```
...
    26.905   PROCEDURAL             PRODUCTION-FIRED P5
    26.905   PROCEDURAL             CLEAR-BUFFER IMAGINAL
    26.905   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    26.905   DECLARATIVE            start-retrieval
Computing activation for chunk 1-1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.9530089
Total base-level: -0.9530089
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: ZERO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.36828277
Adding permanent noise 0.0
Chunk 1-1 has an activation of: -0.5847261
Chunk 1-1 has the current best activation -0.5847261
Computing activation for chunk 2-1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.9530089
Total base-level: -0.9530089
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise -0.17789373
Adding permanent noise 0.0
```

```
Chunk 2-1 has an activation of: -1.1309026
Computing activation for chunk 3-2
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.9530089
Total base-level: -0.9530089
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: THREE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.33106902
Adding permanent noise 0.0
Chunk 3-2 has an activation of: -0.6219399
Computing activation for chunk 1+1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.9530089
Total base-level: -0.9530089
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise -0.38912883
Adding permanent noise 0.0
Chunk 1+1 has an activation of: -1.3421377
Computing activation for chunk 1+2
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
```

```
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.9530089
Total base-level: -0.9530089
Computing activation spreading from buffers
Total spreading activation: 0.0
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: THREE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.0474016
Adding permanent noise 0.0
Chunk 1+2 has an activation of: -0.9056073
Chunk 1-1 with activation -0.5847261 is the best
    26.905   PROCEDURAL             CONFLICT-RESOLUTION
...
```

The thing to note there is that there is no spreading activation occurring even though that production made a request to create a chunk in the imaginal buffer. The reason for that is because the sources of activation are determined at the time the request is made, but it takes the imaginal module time to create the chunk. Thus, there is no chunk in the imaginal buffer at the time the retrieval request occurs from which to spread activation. Since we want to see the effects of spreading activation from that chunk we will change the model so that production p5 does not make a retrieval request and then look at the next production, p6, which makes that same request:

```
(p p5
   =goal>
     isa task-state
     state r5
   ?imaginal>
     state free
   =retrieval>
  ==>
   =goal>
     state r6
   +imaginal>
     isa context
     val1 one
     val2 two)
```

```
(p p6
   =goal>
     isa task-state
     state r6
   =imaginal>
 ==>
   +retrieval>
     isa math-fact
     - arg1 nil
     - arg2 nil
     - result nil
   =goal>
     state r7
   =imaginal>
     val3 add)
```

Production p6 will not be selected and fire until there is a chunk in the imaginal buffer since it has a test for a chunk in the buffer on its LHS. It then modifies the chunk in the imaginal buffer along with making a retrieval request for a math-fact. Thus, there should now be some activation spreading and here is the activation trace generated from this request:

```
...
    27.155   PROCEDURAL             PRODUCTION-FIRED P6
    27.155   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    27.155   DECLARATIVE            start-retrieval
Computing activation for chunk 1-1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.95763344
Total base-level: -0.95763344
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.0 from source ADD level  0.33333334 times Sji 0.0
    Spreading activation  0.13018736 from source ONE level  0.33333334 times Sji 0.39056206
    Spreading activation  0.0 from source TWO level  0.33333334 times Sji 0.0
Total spreading activation: 0.13018736
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: ZERO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
```

```
Adding transient noise 0.36828277
Adding permanent noise 0.0
Chunk 1-1 has an activation of: -0.45916334
Chunk 1-1 has the current best activation -0.45916334
Computing activation for chunk 2-1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.95763344
Total base-level: -0.95763344
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.0 from source ADD level  0.33333334 times Sji 0.0
    Spreading activation  0.13018736 from source ONE level  0.33333334 times Sji 0.39056206
    Spreading activation  0.069413505 from source TWO level  0.33333334 times Sji 0.20824051
Total spreading activation: 0.19960088
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise -0.17789373
Adding permanent noise 0.0
Chunk 2-1 has an activation of: -0.9359263
Computing activation for chunk 3-2
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.95763344
Total base-level: -0.95763344
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.0 from source ADD level  0.33333334 times Sji 0.0
#|Warning: Calculated Sji value between ONE and 3-2 is negative, but using a value of 0. |#
    Spreading activation  0.0 from source ONE level  0.33333334 times Sji 0.0
    Spreading activation  0.069413505 from source TWO level  0.33333334 times Sji 0.20824051
Total spreading activation: 0.069413505
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: THREE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
```

```
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.33106902
Adding permanent noise 0.0
Chunk 3-2 has an activation of: -0.55715096
Computing activation for chunk 1+1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.95763344
Total base-level: -0.95763344
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.20456855 from source ADD level  0.33333334 times Sji 0.61370564
    Spreading activation  0.13018736 from source ONE level  0.33333334 times Sji 0.39056206
    Spreading activation  0.069413505 from source TWO level  0.33333334 times Sji 0.20824051
Total spreading activation: 0.4041694
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise -0.38912883
Adding permanent noise 0.0
Chunk 1+1 has an activation of: -0.94259286
Computing activation for chunk 1+2
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.95763344
Total base-level: -0.95763344
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.20456855 from source ADD level  0.33333334 times Sji 0.61370564
#|Warning: Calculated Sji value between ONE and 1+2 is negative, but using a value of 0. |#
    Spreading activation  0.0 from source ONE level  0.33333334 times Sji 0.0
    Spreading activation  0.069413505 from source TWO level  0.33333334 times Sji 0.20824051
Total spreading activation: 0.27398205
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
```

```
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: THREE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.0474016
Adding permanent noise 0.0
Chunk 1+2 has an activation of: -0.6362498
Chunk 1-1 with activation -0.45916334 is the best
    27.155   PROCEDURAL             CONFLICT-RESOLUTION
    28.421   DECLARATIVE            RETRIEVED-CHUNK 1-1
    28.421   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL 1-1
...
```

Before looking at the final result of the request we will first look at what the sources of activation are. From the activation trace we see that it lists these three chunks as sources: add, one, and two for all of the chunks:

```
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
```

The thing to note is that the chunk add being in a slot of the imaginal buffer chunk was the result of a modification to the chunk made as an action in the production which makes the retrieval request. Modifications made directly by the production will always take effect before the retrieval request starts. If we enable the high detail trace and run it again that can be seen in this sequence of events following the production firing:

```
...
    27.155   PROCEDURAL             PRODUCTION-FIRED P6
    27.155   PROCEDURAL             MOD-BUFFER-CHUNK GOAL
    27.155   PROCEDURAL             MOD-BUFFER-CHUNK IMAGINAL
    27.155   PROCEDURAL             MODULE-REQUEST RETRIEVAL
    27.155   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    27.155   DECLARATIVE            start-retrieval
...
```

The mod-buffer-chunk actions for the goal and imaginal buffer occur before the declarative module starts the retrieval. Also worth noting is that the clearing of buffers by the production will also precede the start of the declarative retrieval. Using the high detail trace can be helpful to determine why items are or are not sources when looking at other situations because to be a source the change must occur prior to the start-retrieval action of the declarative module.

Looking at the result of that retrieval we see that it retrieved the chunk 1-1:

```
    28.421   DECLARATIVE            RETRIEVED-CHUNK 1-1
    28.421   DECLARATIVE            SET-BUFFER-CHUNK RETRIEVAL 1-1
```

which looks like this:

```
1-1
   RESULT  ZERO
   ARG1  ONE
   ARG2  ONE
   OPERATOR  SUBTRACT
```

That seems unusual given that we have sources of one, two, and add and there's another chunk which looks like this that seems like it should be getting more spreading activation:

```
1+2
   RESULT  THREE
   ARG1  ONE
   ARG2  TWO
   OPERATOR  ADD
```

We will look at the activation trace for those two items to see what causes the difference, and here are the relevant traces:

```
Computing activation for chunk 1-1
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.95763344
Total base-level: -0.95763344
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.0 from source ADD level  0.33333334 times Sji 0.0
    Spreading activation  0.13018736 from source ONE level  0.33333334 times Sji 0.39056206
    Spreading activation  0.0 from source TWO level  0.33333334 times Sji 0.0
Total spreading activation: 0.13018736
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: ZERO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.36828277
Adding permanent noise 0.0
Chunk 1-1 has an activation of: -0.45916334
...
Computing activation for chunk 1+2
Computing base-level
Starting with blc: 0.0
Computing base-level from 1 references (0.000)
  creation time: 0.000 decay: 0.5  Optimized-learning: T
base-level value: -0.95763344
Total base-level: -0.95763344
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
```

```
    Spreading activation  0.20456855 from source ADD level  0.33333334 times Sji 0.61370564
#|Warning: Calculated Sji value between ONE and 1+2 is negative, but using a value of 0. |#
    Spreading activation  0.0 from source ONE level  0.33333334 times Sji 0.0
    Spreading activation  0.069413505 from source TWO level  0.33333334 times Sji 0.20824051
Total spreading activation: 0.27398205
Computing partial matching component
  comparing slot ARG1
  Requested: - NIL  Chunk's slot value: ONE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot ARG2
  Requested: - NIL  Chunk's slot value: TWO
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
  comparing slot RESULT
  Requested: - NIL  Chunk's slot value: THREE
  similarity: -1.0
  negation test with similarity not ms has no effect
  effective similarity value is 0.0
Total similarity score 0.0
Adding transient noise 0.0474016
Adding permanent noise 0.0
Chunk 1+2 has an activation of: -0.6362498
```

Looking at those traces we see that those two chunks have the same base-level activation and chunk 1+2 does have a higher total spreading activation value. Chunk 1-1 gets a greater boost from noise than 1+2, so the first though might be that it's just an issue with noise. However, a closer look at the spreading activation calculations reveals a warning and raises some interesting questions:

```
Computing activation for chunk 1-1
...
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.0 from source ADD level  0.33333334 times Sji 0.0
    Spreading activation  0.13018736 from source ONE level  0.33333334 times Sji 0.39056206
    Spreading activation  0.0 from source TWO level  0.33333334 times Sji 0.0
Total spreading activation: 0.13018736

Computing activation for chunk 1+2
...
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.20456855 from source ADD level  0.33333334 times Sji 0.61370564
#|Warning: Calculated Sji value between ONE and 1+2 is negative, but using a value of 0. |#
    Spreading activation  0.0 from source ONE level  0.33333334 times Sji 0.0
    Spreading activation  0.069413505 from source TWO level  0.33333334 times Sji 0.20824051
Total spreading activation: 0.27398205
```

Ignoring the warning for now, one question is why does the S_{ji} from one to 1-1 differ from the S_{ji} from one to 1+2, and another is why is the S_{ji} from one to 1+2 zero?

The answer to the first issue has to do with how S_{ji}s are computed when there are multiple references within a chunk. The equation for S_{ji} from the main unit 5 text:

$$S_{ji} = S - \ln(fan_j)$$

is a simplification of the full calculation which is only true when there's a single link between chunks j and i, but in this case the chunk one occurs in two different slots of the chunk 1-1. The complete form of the equation for S_{ji} uses the value fan_{ji} instead of fan_j where fan_{ji} is defined as:

$$fan_{ji} = \frac{1 + slots_j}{slotsof_{ji}}$$

***slots$_j$*:** the number of slots in which *j* is the value across all chunks in declarative memory

***slotsof$_{ji}$*:** the number of slots in chunk *i* which have *j* as the value (plus 1 if chunk *i* is chunk *j*)

In this case, j is the chunk one and i is the chunk 1-1. Chunk one is a value in nine slots of the chunks in declarative memory, so that is $slots_j$, and it occurs in two slots of chunk 1-1, so that is the value for $slots_{ji}$. Combining that with the value of 2 for S as was set in the model we get:

$$S_{ji} = 2 - \ln\left(\frac{1+9}{2}\right) = 2 - 1.609438 = 0.39056206$$

which is what we see in the trace. For the S_{ji} between the chunk one and the chunk 1+2 the equation is:

$$S_{ji} = 2 - \ln\left(\frac{1+9}{1}\right) = 2 - 2.3025851 = \text{-}0.30258512$$

which is actually a negative spreading of activation. The warning before that calculation:

```
#|Warning: Calculated Sji value between ONE and 1+2 is negative, but using a value of 0. |#
```

indicates that a negative activation spread is treated as 0 by default. This is a safety test that is enabled by default to prevent negative associations since they would be inhibiting the retrieval of related information instead of supporting it. The easy way to fix that is to make sure that the S value is set high enough to avoid the negative value. Occasionally situations occur where one may want that inhibitory behavior, and in those situations it's still advised to set S high enough that items don't automatically get negative S_{ji} values. Instead, the recommendation is to set those desired negative associations explicitly with the add-sji command.

To fix the issue with negative associations in the model we will set our S value to 4 which should be sufficient to keep all S_{ji} values positive (as long as fan_{ji} is less than 54 it will be positive). When we run the model after making that change we see that the model does retrieve the chunk we would expect it to:

```
...
    27.155   PROCEDURAL             PRODUCTION-FIRED P6
    27.155   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
    27.155   DECLARATIVE            start-retrieval
```

```
    27.155   PROCEDURAL             CONFLICT-RESOLUTION
    27.381   DECLARATIVE            RETRIEVED-CHUNK 1+2
```

However, to be sure things are doing what we expect we should look at the activation trace to make sure, and here is the trace with the base-level and similarity sections removed since those are identical among these chunks:

```
Computing activation for chunk 1-1
...
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.0 from source ADD level  0.33333334 times Sji 0.0
    Spreading activation  0.796854 from source ONE level  0.33333334 times Sji 2.390562
    Spreading activation  0.0 from source TWO level  0.33333334 times Sji 0.0
Total spreading activation: 0.796854
...
Adding transient noise 0.36828277
Adding permanent noise 0.0
Chunk 1-1 has an activation of: 0.20750335

Computing activation for chunk 2-1
...
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.0 from source ADD level  0.33333334 times Sji 0.0
    Spreading activation  0.796854 from source ONE level  0.33333334 times Sji 2.390562
    Spreading activation  0.73608017 from source TWO level  0.33333334 times Sji 2.2082405
Total spreading activation: 1.5329342
...
Adding transient noise -0.17789373
Adding permanent noise 0.0
Chunk 2-1 has an activation of: 0.39740703

Computing activation for chunk 3-2
...
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.0 from source ADD level  0.33333334 times Sji 0.0
    Spreading activation  0.56580496 from source ONE level  0.33333334 times Sji 1.6974149
    Spreading activation  0.73608017 from source TWO level  0.33333334 times Sji 2.2082405
Total spreading activation: 1.3018851
...
Adding transient noise 0.33106902
Adding permanent noise 0.0
Chunk 3-2 has an activation of: 0.67532074

Computing activation for chunk 1+1
...
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.87123525 from source ADD level  0.33333334 times Sji 2.6137056
    Spreading activation  0.796854 from source ONE level  0.33333334 times Sji 2.390562
    Spreading activation  0.73608017 from source TWO level  0.33333334 times Sji 2.2082405
Total spreading activation: 2.4041696
...
Adding transient noise -0.38912883
Adding permanent noise 0.0
```

```
Chunk 1+1 has an activation of: 1.0574073

Computing activation for chunk 1+2
...
Computing activation spreading from buffers
  Spreading 1.0 from buffer IMAGINAL chunk CHUNK1-0
    sources of activation are: (ADD ONE TWO)
    Spreading activation  0.87123525 from source ADD level  0.33333334 times Sji 2.6137056
    Spreading activation  0.56580496 from source ONE level  0.33333334 times Sji 1.6974149
    Spreading activation  0.73608017 from source TWO level  0.33333334 times Sji 2.2082405
Total spreading activation: 2.1731205
...
Adding transient noise 0.0474016
Adding permanent noise 0.0
Chunk 1+2 has an activation of: 1.2628886
Chunk 1+2 is now the current best with activation 1.2628886
```

Looking over the spreading activation values shows that in fact the chunk 1+1 gets more spreading activation than chunk 1+2 and it is only because of noise that we retrieved 1+2 this time. The reason for that is because the chunk 1+1 is also receiving activation spread from each of the sources since it also contains the chunk two in its result slot, and since it has two occurrences of the chunk one it has a greater S_{ji} from one than the chunk 1+2 does.

This highlights a big distinction between spreading activation and partial matching. Spreading activation is a bottom-up mechanism which increases the activation of chunks relative to how well they match the current context without regard for the specific structure of that information in the target chunks. Whereas partial matching is a top-down process which penalizes those chunks which do not match the specific pattern provided in the request. In models of simple tasks often only one effect or the other is desired and to keep things simple only that particular mechanism is enabled, as was the case for the tutorial unit models, but in more complex models both effects may be desirable in which case one has to be more careful about both maintaining an appropriate context and making appropriate requests to achieve the desired results.

If we want this model to be relatively certain of retrieving the fact associated with adding one and two we will need to add that pattern of information into the request. We will not make that change to the model as part of the demonstration, but you should feel free to try that and see how the activations change. You may also want to try changing the similarities between the number chunks to see how that affects things as well because the current model does not set any similarities between the number chunks.

Last two productions

The final issue we will look at does not involve a retrieval. Instead we will look at a potential issue which can arise when creating chunks that will be merged into declarative memory. In most situations chunks will merge and strengthen existing declarative chunks as one would expect, but there is a situation which can sometimes occur which is worth discussing here because it can be confusing. The issue can arise when a model creates a chunk which has slot values that are chunks which are not in declarative memory (typically because they reference a chunk currently in a buffer) and then merges that chunk into declarative memory.

For the example we will investigate what happens when these two productions fire:

```
(p p7
     =goal>
       isa task-state
       state r7
     =imaginal>
     =retrieval>
   ==>
     =goal>
       state r8
     =imaginal>
       goal =goal)

  (p p8
     =goal>
       isa task-state
       state r8
   ==>
     +goal>
     -imaginal>)
```

in the context of these chunks which are in declarative memory:

```
   (g1 isa task-state state r8)
   (old-context isa context val1 one val2 two val3 add goal g1)
```

Before running the model we will look at what we might expect to happen. Production p7 waits for the previous retrieval to complete and then modifies the chunks in the goal and imaginal buffers. The goal chunk is modified such that it now looks just like g1 and the imaginal chunk has that current goal buffer chunk placed into its goal slot. Production p8 fires next since the goal buffer state matches and then it performs two actions. It makes a request to the goal module to create a new chunk, which will implicitly clear the current chunk from the goal buffer, and it clears the chunk from the imaginal buffer. What we might expect to happen here is that the goal buffer's chunk will merge with chunk g1 and then the imaginal buffer's chunk will merge with the chunk old-context.

After running the model here is what we see in declarative memory with respect to chunks with a state slot (task-state chunks) and chunks with a goal slot (the context chunks) which are found using the sdm command here (with a mix of Lisp and Python calls for examples), but could also be found using the filter at the top of the Declarative viewer of the ACT-R Environment which allows one to restrict the display to contain only chunks which have the particular set of slots chosen as the filter:

```
...
     27.431   PROCEDURAL             PRODUCTION-FIRED P7
     27.431   PROCEDURAL             CLEAR-BUFFER RETRIEVAL
     27.431   PROCEDURAL             CONFLICT-RESOLUTION
     27.481   PROCEDURAL             PRODUCTION-FIRED P8
     27.481   PROCEDURAL             CLEAR-BUFFER IMAGINAL
```

```
    27.481   PROCEDURAL              CLEAR-BUFFER GOAL
    27.481   GOAL                    SET-BUFFER-CHUNK GOAL CHUNK2
    27.481   PROCEDURAL              CONFLICT-RESOLUTION
    27.481   ------                  Stopped because no events left to process
```

```
? (sdm - state nil)
G1
   STATE  R8
```

```
>>> actr.sdm('-','goal','nil')
OLD-CONTEXT
   VAL1  ONE
   VAL2  TWO
   VAL3  ADD
   GOAL  G1
CHUNK1-0
   VAL1  ONE
   VAL2  TWO
   VAL3  ADD
   GOAL  G1
```

We see that there is only one task-state chunk as we expected, but there are two apparently identical context chunks. One way to see why that happens would be to step through the actions which occur as a result of that production firing and inspect things carefully after each event. If you would like to do that you can do so, but here we will just inspect the actions in the trace and explain the outcome.

Before doing that, there is something else which we can do that might make things clearer. If we turn off the :ncnar parameter the model will not automatically normalize the chunk names when chunks are merged and that might also help to see what has happened. Before running the model again we need to turn that off by adding this to the sgp call in the model:

```
  (sgp ... :ncnar nil)
```

Now, after we run the model this is what is shown for the task state chunks in declarative memory:

```
G1
   STATE  R8
```

There is still only one chunk named g1. For the context chunks in declarative memory there are again two, but they look different now:

```
OLD-CONTEXT
   VAL1  ONE
   VAL2  TWO
   VAL3  ADD
   GOAL  G1

CHUNK1-0
   VAL1  ONE
   VAL2  TWO
   VAL3  ADD
   GOAL  CHUNK0-0
```

However, although they appear to have different values in their goal slots there is no difference between them in terms of the model's operation because both of those names are referencing the same chunk. If we print out those two chunks we see that chunk0-0 actually names the same chunk g1 as indicated by that name in parentheses:

```
? (pprint-chunks g1 chunk0-0)
G1
   STATE  R8

CHUNK0-0 (G1)
   STATE  R8
```

Changing the :ncnar parameter only changes how the information is provided to the modeler – when :ncnar is true it will always show the "true name" for a chunk which appears in a slot of other chunks regardless of any other names for that chunk which may exist. The true name is the name of the chunk which is in the model's declarative memory with which the other chunk(s) have merged.

Here are the events from the high detail trace for production **p8** firing, which may suggest what has happened, but we will still go over the details:

```
    27.481   PROCEDURAL             PRODUCTION-FIRED P8
    27.481   PROCEDURAL             MODULE-REQUEST GOAL
    27.481   PROCEDURAL             CLEAR-BUFFER IMAGINAL
    27.481   PROCEDURAL             CLEAR-BUFFER GOAL
    27.481   GOAL                   CREATE-NEW-BUFFER-CHUNK GOAL
    27.481   GOAL                   SET-BUFFER-CHUNK GOAL CHUNK2
```

Although all of those events are listed as occurring at the same time, as we've seen using the stepper, each is executed individually in the order that they are shown. Thus, first the production fires, then the request is made to the goal buffer, then the imaginal buffer gets cleared, and finally the goal buffer gets cleared.

The important question is then how does declarative memory handle merging chunks? The answer is that it only attempts to merge chunks immediately upon their being cleared from a buffer, and it will only merge chunks if all of their contents are perfect matches. When the slot values are chunk names a perfect match means that they must refer to the same chunk (note however that that doesn't mean that the slot values must have the same chunk name because merged chunks can still be referenced by either name).

Thus, when the imaginal buffer gets cleared the chunk in it looks like this:

```
CHUNK1-0
   VAL1  ONE
   VAL2  TWO
   VAL3  ADD
   GOAL  CHUNK0-0
```

At that time the chunk chunk0-0 is still in the goal buffer and has not been merged with chunk g1 in declarative memory. Because of that the chunk chunk1-0 is not a perfect match to the chunk old-context which is in declarative memory since the value of their goal slots, chunk0-0 and g1, are different chunks. That means chunk1-0 must be added to declarative memory as a new chunk. Then, the goal buffer gets cleared. Because chunk chunk0-0 is a perfect match to the chunk g1 those two chunks are then merged. The merging of those two chunks does not make the declarative module retroactively merge the chunks old-context and chunk1-0. Thus, declarative memory still has two context chunks; one with a value of g1 in the goal slot and one with a value of chunk0-0 in the goal slot, but both of those values now reference a single chunk.

That may seem like a problem with how merging works, but there are good reasons for having it work sequentially like that. One of those reasons is that it allows the modeler to control what happens – sometimes one might want separate chunks instead of having them merged. If we do not want separate chunks, then we have to ensure that all the chunks in the slots of the chunk we want to merge into declarative memory are merged into declarative memory first (in this case the chunk in the goal buffer must be merged into declarative memory before the chunk in the imaginal buffer since that goal buffer chunk is in a slot of the chunk in the imaginal buffer). If we want that to happen within a single production, then this becomes one of the rare situations where controlling the order in which a production's actions occur matters.

Generally, the order in which a production performs its actions does not matter since they are all happening at the same time and there are usually no interactions among them. However, since the simulation has to perform the actions sequentially, in situations like this one the modeler may need to make sure some things happen in a particular order, but the modeler cannot arbitrarily order a production's actions. A production will always perform its actions in the following order: all user actions (!eval!, !bind!, and !output!), all buffer modifications, all requests, then all buffer clearing actions. Within a particular type of action it will perform the explicit actions in the order provided in the production followed by any implicit actions of that type (like clearing the buffer due to strict harvesting or as a result of a request) in no particular order. Thus, if we want the goal buffer to be cleared prior to the imaginal buffer we will have to explicitly perform that action in the production instead of letting it happen implicitly, and it will have to be placed before the imaginal buffer clearing.

Here is a modified version of p8 which adds an explicit clearing of the goal buffer before the clearing of the imaginal buffer:

```
(p p8
   =goal>
     isa task-state
     state r8
   ==>
   +goal>
   -goal>
   -imaginal>)
```

When we run the model after saving that change and reloading we get the following result for the context chunks in declarative memory:

```
? (sdm - goal nil)
OLD-CONTEXT
   VAL1  ONE
   VAL2  TWO
   VAL3  ADD
   GOAL  G1
```

which shows that there is only one chunk now thus the imaginal chunk has been merged with the old-context chunk. If we wanted to investigate further we could make sure that that chunk has two references by looking at the details in the declarative viewer or by using the sdp command to check its parameters, and if we do so we find that it does have a value of two for its reference-count:

```
>>> actr.sdp('old-context')
Declarative parameters for chunk OLD-CONTEXT:
 :Activation  0.190
 :Permanent-Noise  0.000
 :Base-Level -0.270
 :Creation-Time 0.000
 :Reference-Count  2
 :Source-Spread  0.000
 :Sjis ((OLD-CONTEXT . 4.0) (ONE . 1.6974149) (TWO . 2.2082405) (ADD . 2.6137056)
 (G1 . 3.3068528))
 :Similarities ((OLD-CONTEXT . 0.0))
```