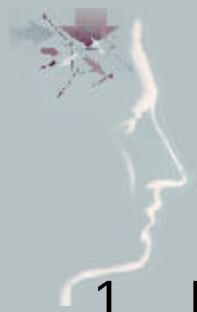
FAQ: Can ACT-R Provide What IA/Connectionist Models Lack?

Answer: Yes

Production Systems and Control

1. Newell (1973) Production systems: Models of control structures
2. Anderson (1976) ACT = Adaptive Control of Thought

Thank you, Rick Cooper, for making it possible for us come out of the closet.



The (Shared?) Theoretical Agenda

1. Have a system that can display the complex control of behavior that humans display (but any computer can do that).
2. That displays the ability to generate novel behavior that is adaptively flexible (but maybe some non-human system can do this).
3. That breaks down in the ways that humans do (surely only humans would work this way)
4. That has the same brain signatures as humans do (just to make sure).

But in our desire to show incompetence we have sometimes lost sight of competence. It is an important constraint that the model can engage in non-routine sequential behavior.

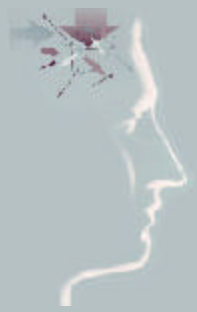
Routine versus Non-Routine Behavior

My “Routine” for Raisin Bran Cereal in the morning

Get Bowl
Pour Cereal
Pour Milk
Get Spoon
Repetitively eat until empty
Clean bowl

Classic Routine errors:

anticipation/omission (forget milk),
substitution/wrong object (too big bowl),
post-completion (don’t clean bowl),
preservation (get second spoon),
capture/intrusion (pour sugar).



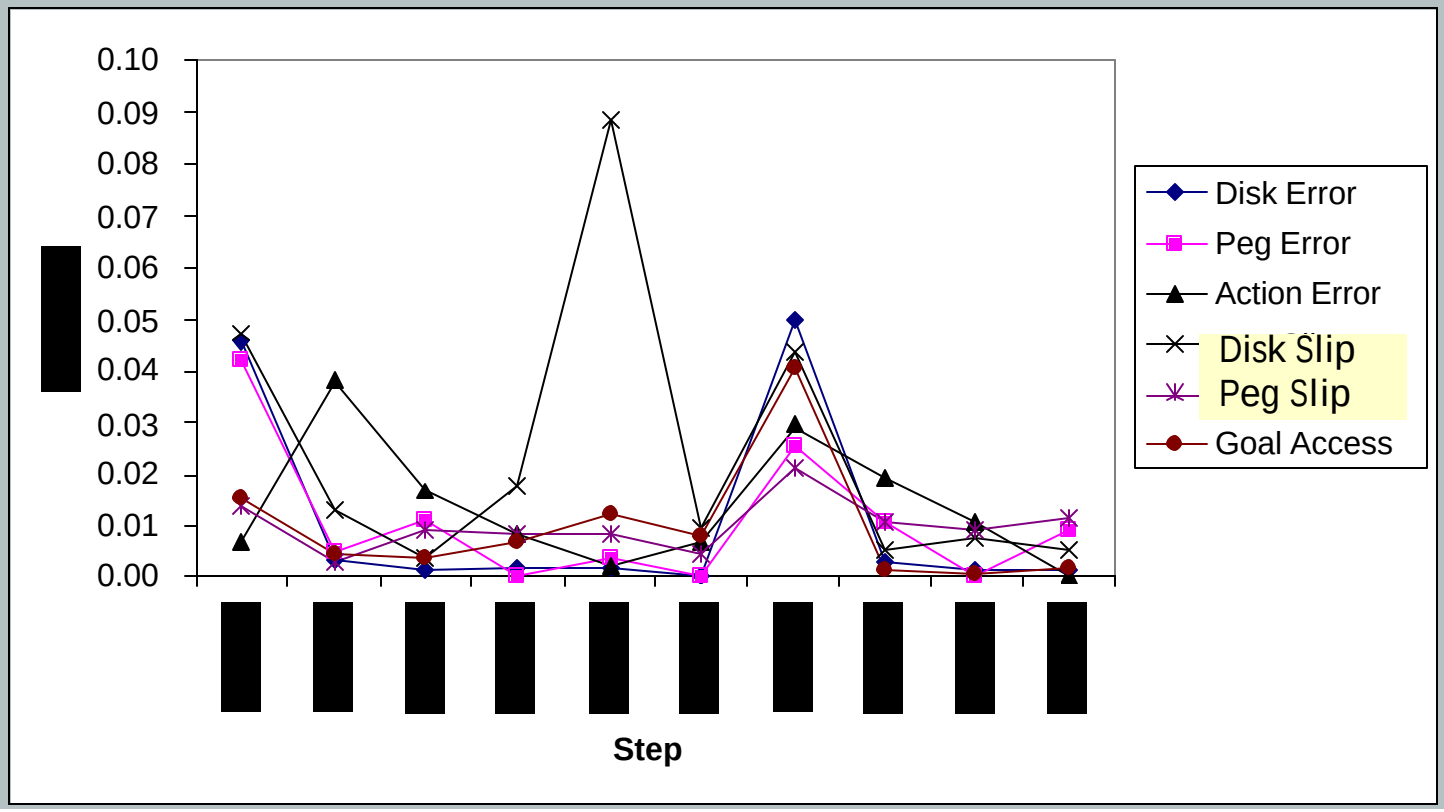
Newell: The distinction between routine and non-routine behavior is an illusion. If something unusual happens we are still in a problem space where we are flexibly and creatively planning.

1. Our response to classic errors.
2. Our response to novel problems -- not enough raisins, burglar alarm, Lynne cuts herself
3. Missing components -- bowls, milk
4. Our ability to intelligently interleave with other goals -- watching news at the same time

A theory of routine sequential behavior must be capable of fitting in seamlessly with non-routine sequential behavior just as humans can. Data from non-routine tasks become an important constraint on such a theory.

A Non-Routine Task: Tower of Hanoi

Error Distribution on 3-Disk Subsequence

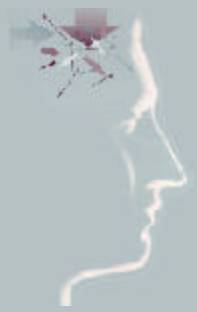


What is the Difference between ACT-R and Cooper and Shallice?

Botvinick & Plaut: “An illustration of the state-of-the-art is provided by Cooper and Shallice (2000). Their model addresses the everyday routine of making a cup of coffee. As in Estes (1972) and Rumelhart and Norman (1982), the processing system is structured as a hierarchy of nodes or units, with units at the lowest level representing simple actions (such as pouring or tearing), and nodes at higher levels representing progressively larger-scale aspects of the task.”

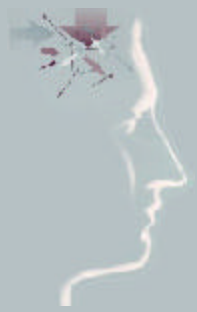
Cooper and Shallice provide a more detailed implementation (and perhaps more accurate)of the sort of computations assumed by ACT-R.

ACT-R generates a “virtual” hierarchy on the fly rather than assuming it. As the behavior gets routinized much of the on-line calculation is compiled out but the basic structure is still there to deal with the unexpected.



Some Data To Be Accounted For

- Routine (sequential) action and its breakdown
- Action monitoring and error recovery
- Further neuropsychological deficits
- Learning (e.g., the power law of practice)
- Between trial effects in RT tasks
- PRP effects and dual task behaviour
- Negative priming and inhibition of return
- Interruptions and interleaving of tasks



Routine (sequential) action and its breakdown

Altmann & Trafton, Anderson & Douglass -- Tower of Hanoi. The key concept is that goals are retrieved from declarative memory rather than a goal stack. Activation controls success.

Decay

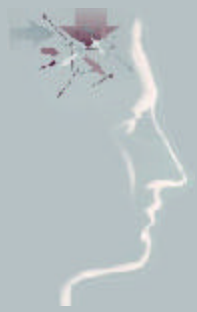
Contextual Priming

Partial Matching

$$A_i \; ? \; B_i \; ? \; \sum_j W_j S_{ji} + \sum_k P_k M_{ki}$$

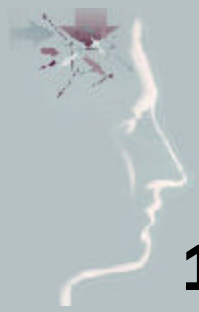
Frontal Connection

The same concepts are at work in models of serial recall and other routine tasks.



Action Monitoring and Error Recovery

1. This is something seldom incorporated into ACT-R models.
2. Seen in aborted premature moves in the 3-disk on Tower of Hanoi (i.e., not specific to routine behavior).
3. Something that can be done relatively easily in ACT-R 5.0.
4. Points out the need for a more reflective ACT-R models.



Neuropsychological Comments

1. Basal Ganglia: One can view this as a serious challenge to the claim that there is no neurophysiological evidence for a central processor.

2. Anterior Cingulate Cortex: (Conflict Detection?)
Botvinick et Cam Carter

--lights up in incongruent Stroop trials(response override)
--lights up in verb generation (underdetermined response)
--lights up after error (error detection/processing)
--but it lights up in any difficult task like algebra that involve none of the above
--unlike DLPFC it is in response to difficulty not in anticipation of difficulty.
--Suggestion: ACC modulates W (source activation) in response to things like challenge, caffeine, fatigue, or brain damage.

Further Neuropsychological Deficits

Dopamine Disorders and Conflict Resolution:

$$P(i) \; ? \; \frac{e^{V_i / t}}{\sum_j e^{V_j / t}}$$

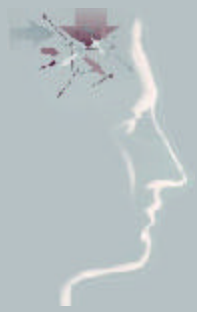
- Amphetamine psychosis: (increased dopamine)
  – highly stereotyped behaviour
  – low values of t
- Bradykinesia: (decreased dopamine)
  –slowed action initiation
  – high values of t
- Like Cohen & Servan-Schreiber (1992) hypothesis
- But it is has got to be more than this--learning deficits, preservation associated with dopamine depletion

Between trial effects in RT tasks
Indeed ACT-R can deal with them

Speed-accuracy trade-off -- Altmann: Adjust threshold in ACT-R to optimize between hits and false-alarms.

Stroop effects--Altmann, Lovett: retrieval of declarative code -- combination of base-level activation favoring words and associations favoring congruent, density effect produced by tuning of production parameters

Task switching-- Altmann & Gray, Sohn & Anderson: declarative access to task identification



PRP effects and Dual-task Behaviour

"EPIC demonstrates that PRP effects can be accounted for without appeals to bottlenecks or resource limitations" but actually they have bottlenecks everywhere but the central processor.

ACT-R is more compatible with rampant dual-task decrements

Coordination point in ACT-R facilitates learning

However, ACT-R 5.0 owes a great deal to EPIC including the way it accounts for dual-task behavior and perfect time sharing ("Can't we all just get along?" -- Rodney King). Cooper -- Production systems win

Negative priming and inhibition of return

Reder's model: It is not a matter of inhibition but a matter of competition with a better alternative.
Fundamental Equation:

$$P(i) \propto \frac{e^{V_i / t}}{\sum_j e^{V_j / t}}$$

Impicitly Inhibition

Spatial negative priming: competition among production rules that orient to different locations -- depends on recency boost

Object negative priming: declarative competition among "ignore me" and "attend me" tags.

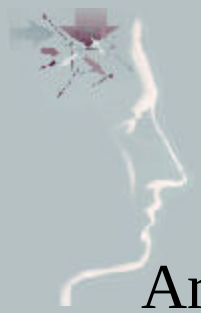
Interruptions and interleaving of tasks

Salvucci & Macuga (2001): ACT-R/PM model of the effects of cell-phone dialing on driving

– ACT-R (production systems in general?) provides the necessary machinery for interleaving, but …

– Are there generic strategies for interleaving that might be encoded via generic productions?

--This is a key issue if a cognitive architecture is going to deliver on one of its promises.



ACT-R addresses Cooper's list but…

Are the same mechanisms being used in all cases or is it a matter of Three-card Monte like connectionism? **It is basically one system.**

But can the parameters be made consistent? **Not sure but it is a good sign that we can ask the question.**

How does the system configure itself to do these individual tasks? **Production compilation and learning from instructions but more work needs to be done.**

What about generic processes such as strategy generation, monitoring, and error recovery in ACT-R? **This seems a good question -- ACT-R needs more self-reflection.**