Pervasive Activation: Applying the mechanism to declarative and procedural memory

Ronald S. Chong (rchong@gmu.edu)
Humans Factors and Applied Cognition
Department of Psychology
George Mason University

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Michael Schoelles, Christian Lebiere

SOAR AND SHORT-TERM MEMORY EFFECTS

- **Newell (1990) proposed Soar as a candidate UTC.**
- **UTC constrains mechanisms to those that are *functionally* necessary for producing intelligent behavior.**

  "[Soar] is entirely functional...No mechanisms...have ever been posited just to produce some empirically known effect..." (pp. 309-310)

- **No mechanism for short-term memory effects...**

  "...the only short-term memory effects...are those rooted in mechanisms that have some functional role..." (Ibid)

- **Example: Functional limit on WM capacity in sentence comprehension (Young & Lewis, 1999).**

- **Consequences**
  - *Plausible* and *principled* modeling of some behavior can be difficult or impossible.
  - Example: Behavior where performance is influenced by short-term-memory effects.
  - With no *architectural* mechanism, the modeler has to create with their own "model" for short-term memory effects.
  - Soar contributes little to this important modeling area.
- **Solution**

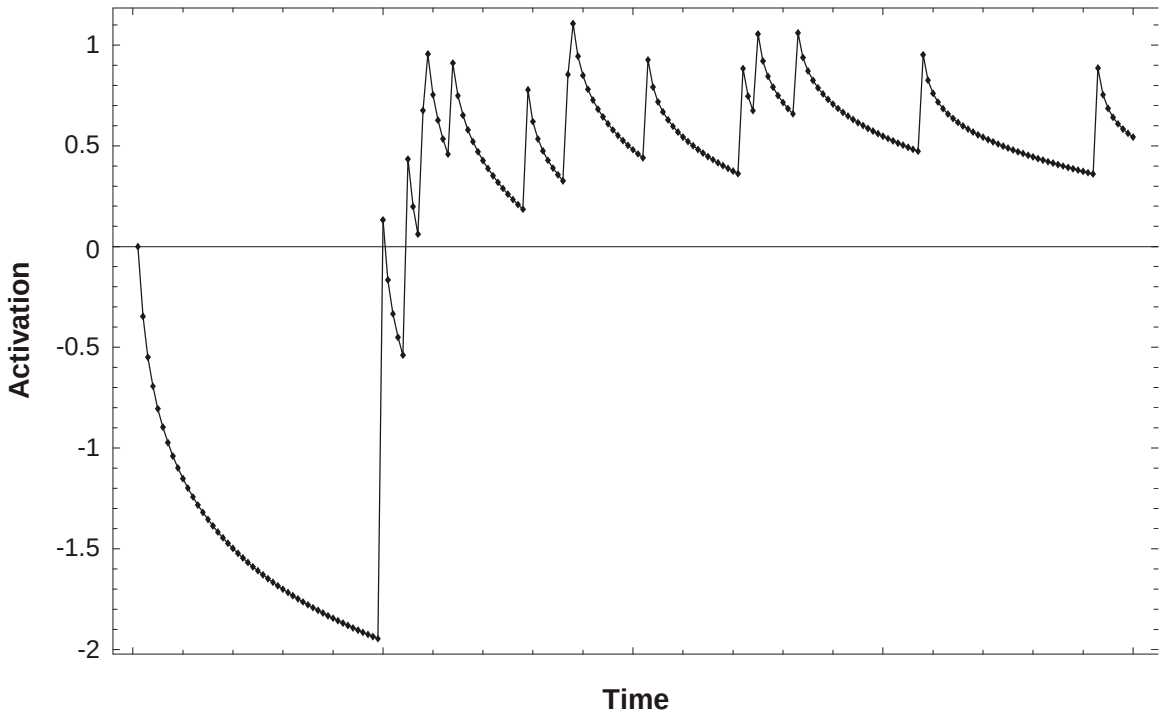
  "...To exhibit [short-term memory] effects, Soar would need to be augmented with additional architectural assumptions about these mechanisms and their limitations." (Ibid)

- **Borrow the activation and decay mechanisms as defined and used in ACT-R 4.0**
  - Rudimentary implementation was done in 2000.
  - Significant improvements were recently made.
- **Altmann & Schunn (2002) propose a functional role for decay.**

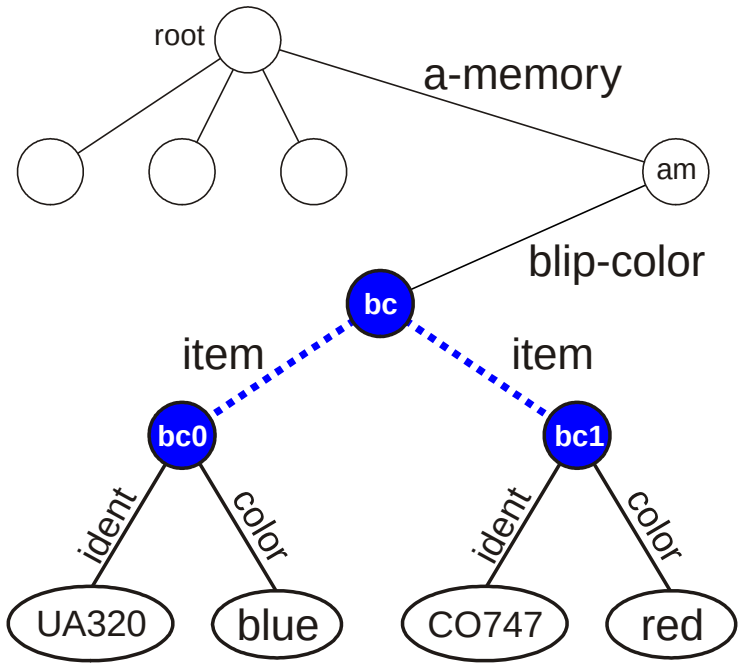
  "We argue, based on a simple functional analysis, that...distracting information must decay to allow the cognitive system to have any hope of retrieving target information amidst the unavoidable clutter of a well-stocked memory."

- **Perhaps this new mechanism is not breaking with the UTC philosophy after all.**

- **Basics:**
  - Based on ACT-R.
  - When a WME is created, it is given an initial (*base-level*) activation.
  - Activation is a function of the recency and use.
  - Activation decays exponentially.
  - An element is "forgotten" when its activation falls below the *retrieval threshold*.



- ACT-R
  - All WMEs (working memory elements; chunks) have activation.
- Soar
  - A *partition* of elements in WM have activation.
  - a-memory is the "activated" partition.
  - blip-color is like an ACT-R "chunk-type".
  - items are instances of a type.
  - (bc item bc0) and (bc item bc1) are flagged as having activation.



- **Equation 1:** $A_i = B_i + \Sigma W_j S_{ji} + \varepsilon_1 + \varepsilon_2$

  A WME's activation (A_i) is the sum of its "inherent" activation (B_i), the contribution of associated WMEs ($\Sigma W_j S_{ji}$) and one noise terms (ε_1, ε_2)

- **Equation 2:** $B_i = \beta + \ln(\Sigma t_j^{-d})$

  A WME's "inherent" activation (B_i) is the sum of its initial (base-level) activation (β) and a calculation of the recency and frequency of use

- **Equation 3:** $\varepsilon_{1,2} = ns_{1,2} * \log[(1.0 - p) / p]$

  $p = \text{rand}[0.0, 1.0]$

  Noise terms (ε_1, ε_2) are sampled from a logistic distribution

- ACT-R
  - decay-rate (d)
  - retrieval threshold (rt)
  - base-level constant (β)
  - permanent noise (ε_1)
  - transient noise (ε_2)
- Soar
  - decay-rate (d)
  - ~~permanent noise (ε_1)~~
  - retrieval threshold (rt)
  - base-level constant (β)
  - NEW: transient noise (e_2)

- ACT-R
  - A WME used to fire a production
  - A new WME, created internally or by the environment, is identical to an existing WME; “chunk merging”.
- Soar
  - An *activated* WME is used to fire a production (with one exception).
  - NEW: A new activated WME, created internally or by the environment, is identical to an existing WME; “WME merging”.
  - NEW: When deciding between a number of competing operators, only the activated WME in the proposal of the selected operator is boosted.

WHAT HAPPENS TO A "DECAYED" WME…

- ACT-R
  - When a WMEs activation falls below threshold, it remains in memory but is not available to match productions.
- Soar
  - Version 0: The sub-retrieval-threshold WME was removed from working memory.
  - This is no longer the case.
  - NEW: The sub-retrieval-threshold WME is removed from the Rete (to prevent it from matching productions) but remains in working memory (to facilitate debugging and WME merging).

- **Activation-based operator selection**
  - Indifferent preferences direct the decision procedure to randomly pick among candidates.
  - Instead of choosing randomly, the decision procedure can be made to choose the proposal that referenced the most highly *activated* WME/s.
  - This is similar to activation-based retrieval in ACT-R 4.0; WME activation is one of the criteria used to select which instantiation to fire.

- ACT-R
  - ACT-R uses spreading activation to cause the cue to increase the activation of the target.
- Soar
  - Unimplemented (for the moment).
  - When a WME has been merged, a special recognition WME will be added to WM.
  - This recognition WME has activation and will decay if not used.

APPLYING ACTIVATION TO PROCEDURAL MEMORY

- A fundamental feature/commitment of Soar is that learned knowledge cannot be forgotten.
- In general, "Practice makes perfect" is not applicable to Soar models.
- Mechanism only applies to chunks (learned productions).
- Rules written by the modeler are *not* subject to forgetting.
- Frequently used (practiced) chunks have their activation reinforced.
- Infrequently used (unpracticed) chunks would be forgotten.
- Forgotten rules can *usually* be learned again; depends on the context.
- Relearning tends to reduce the likelihood a chunk will be forgotten again.
- Have a basic implementation, but still debugging...

- **Combining tested mechanisms from other architectures.**
- **New Soar modeling opportunities:**
  - Used in a model of eye scan patterns and overall performance in a simulated ATC task.
  - Certain errors are emergent.
  - Used in a new Soar category learning model.
  - Models now sensitive to time.
  - Efficiency improvements to the mechanism and explorations in episodic learning and memory—graduate student research @ Michigan.

- **Runtime costs.**
- **What's missing?**
  - Spreading activation
  - Influence of activation on cycle time

    activation ➠ *match time* ➠ *cycle time*
  - An account of interference
- **How to "rehearse" chunks?**