ACT-R 5.0 Subsymbolic

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Parameters and Equations

- Reduce number of parameters and rationalize the equations
- Increase symmetry between declarative and procedural parts
- Changes:
  - Simplification of utilities parameters from q, a, r and b to p and c
  - Production strength is eliminated from retrieval time equation
  - Generalized base-level activation provides precision and efficiency
  - Noise added to retrieval (and utility) threshold unifies chunk choice and retrieval probability equations into single equation
  - Competitive latency equation is symmetrical to chunk choice equation and yields fan effect and number and similarity of distractors
  - Similarities and associations are left basically as is for now (with a minor reworking) but similarities become the default associations
Equations

Declarative

1. $A_i = B_i + \sum_j W_j S_{ji} + \sum_k P_k M_{ki}$
   j sources and k probes

2. $P(i) = \frac{e^{A_i/t_a}}{\sum_j e^{A_j/t_a} + e^{\tau_a/t_a}}$

3. $T(i) = F \frac{\sum e^{A_j/t} + e^{\tau_a/t}}{e^{A_i/t}}$

Procedural

1. $U_i = P_i G - C_i$
   note $G \approx 20$

2. $P(i) = \frac{e^{U_i/t_u}}{\sum_j e^{U_j/t_u} + e^{\tau_u/t_u}}$

3. $T(i) = 50 \text{ ms}$?
Production Utility

• Get rid of q, a, r and b and instead use simply p and c
• Solves problem with q and with too many parameters
• Chance and effort used as before but correspond to p and c
• One of the few changes that is not backward-compatible
• Consistent with loss of goal stack as architectural primitive
• No subgoal discounting: G remains fixed (unit task level?)
• Lack of structured learning, i.e. “seeing across subgoals”
• No architectural role in goal selection?
• Automatic success if goal changes w/o explicit outcome?
• Popping upon failure is off by default
Strength and Approximation

• Production strength is out
  – Misfit with activation scale for chunks and utility for productions
  – Contradiction between effect on retrieval speed but not probability
  – Still used in old latency equation and can be printed on demand

• Generalized base-level approximation
  – OL can be either nil, t or a positive number m (recent references)

\[
B = \log\left( \sum_{i=1}^{m} t_{n-i}^{-d} + \frac{(n - m)(t_0^{1-d} - t_{n-m}^{1-d})}{(1 - d)(t_0 - t_{n-m})} \right)
\]

  – Combines precision of exact formula with efficiency of approximation
  – But is the short-term boost really right (see last year’s discussion)?
Noisy Threshold

- Add noise to retrieval threshold (and utility threshold too)
- Unifies retrieval probability and chunk choice equation into a new generalized equation in which the threshold is just another competitor:

\[ P(i) = \frac{e^{A_i/t_a}}{\sum_{j} e^{A_j/t_a} + e^{\tau_a/t_a}} \]

- Increases variability in behavior (probability and latency)
- Only transient activation noise (interpretation of threshold)
- Different noise every cycle or retrieval (no difference in 5.0)
- Requires minor parameter adjustment to noise value (s-> t)
Competitive Latency

- Retrieval latency is symmetric with chunk choice equation:
  \[ T(i) = F \frac{\sum e^{A_j l_i^t} + e^{\tau_a l_i^t}}{e^{A_i l_i^t}} \]

- Equivalent to activation scaling to enforce log odds rule
- Factors in the number, similarity and priming of distractors
- Can account for systematic varying of parameters (F, \( \tau \))
- Result from basic inhibition between competing chunks
- Works best with indirect partial matches
  - Direct matches: **only 1 considered** (or partial match header?)
  - Exact matching: **usually 1 match** (or consider all chunks?)
- Old latency equation is still available as option
Similarities and Associations

• Associations and similarities both provide context-sensitivity
• More similar than different: unify into single mechanism
• Little support for strengths of association as currently defined
• Main function of strengths assumed by competitive latency
• Current definition of strengths violates integration constraint
• Very few uses of associative learning compared to others
• Co-occurrences learned from source to any slot in any chunk
• Most stringent test to date yielded definite predictions
• They were consistently not supported by the data
• There are other pathologies
Prospective Memory Example

- ? (sdm isa lexicon word spread)
  - Lexicon0 : 2.577
  - isa LEXICON
  - context nil
  - word Spread
  - spelling S-P-R-E-A-D
- (LEXICON0)
- ? (sdp lexicon0)
- Parameters for chunk Lexicon0:
  - :Activation : 2.577
  - :Source nil
  - :Base-Level : 2.191
  - :Creation-Time : 0.000
  - :References (1.0)
  - :Source-Spread : 0.000
  - :As ((S-P-R-E-A-D : 3.466) (Spread : 3.466) (Lexicon0 : 4.159))
  - :Creation-Cycle : 0.000
  - :Needed : 0.000
  - :Contexts : 0.000

  (Lexicon0)
- ? (inspect-activation)
- SETTING-TABLE BLL CNTXT SPELL
  - SPREAD : 0.558 0.000 2.853
  - CLEAR-DESK BLL CNTXT SPELL
  - OPEN : -0.135 0.000 3.466

  (study *prospective*)
  - 0.5243
  - ? (inspect-activation)
  - SETTING-TABLE BLL CNTXT SPELL
  - SPREAD 0.156 0.000 3.178
  - CLEAR-DESK BLL CNTXT SPELL
  - OPEN 0.156 0.000 3.178

  (study *neutral*)
  - 0.6466
  - ? (inspect-activation)
  - SETTING-TABLE BLL CNTXT SPELL
  - SPREAD 0.156 0.000 3.178
  - CLEAR-DESK BLL CNTXT SPELL
  - OPEN 0.375 0.397 2.912

  (study *neutral*)
  - 0.53
  - ? (inspect-activation)
  - SETTING-TABLE BLL CNTXT SPELL
  - SPREAD 0.529 0.284 2.773

  (study *neutral*)
  - 0.5216000000000001
  - ? (inspect-activation)
  - SETTING-TABLE BLL CNTXT SPELL
  - SPREAD 0.529 0.284 2.773

  (study *neutral*)
  - 0.5216000000000001
  - ? (inspect-activation)
  - SETTING-TABLE BLL CNTXT SPELL
  - SPREAD 0.156 0.000 3.178
  - CLEAR-DESK BLL CNTXT SPELL
  - OPEN 0.156 0.000 3.178

  (study *neutral*)
  - 0.6466
  - ? (inspect-activation)
  - SETTING-TABLE BLL CNTXT SPELL
  - SPREAD 0.375 0.397 2.912
Activation Equation

\[ A_i = B_i + \sum_j W_j S_{ji} + \sum_k P_k M_{ki} \]

- Similarities \( M_{ki} \) scaled from *max-sim* to *max-dif*
- *max-sim* is positive (1.0) and provides boost of activation
- *max-dif* is very negative (-10.0) and provides inhibition
- *mismatch-penalty* \( P_k \) defaults to 1.0
- *goal-activation* \( W_j \) defaults to 0.0
- Divide \( P \) by \( n \) as with \( W \)?
- Ultimately (6.0?) \( P \) becomes \( W \) and \( M_{ki} \) become strengths \( S_{ji} \)