Modeling Working Memory Decay in Soar

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Motivation

- Soar as a cognitive architecture
  - Improve accuracy of cognitive models
- Soar as a programming language
  - Increase functionality of the architecture

Memory decay in Soar

- Equation governing memory decay is based on psychological foundations
- Each wme has an associated *activation level*, representing its current strength
  - Depends on use of memory in productions (references)
    - When the wme is tested by a firing production
    - When the wme is created/recreated
  - Depends on the passage of time

Memory decay (cont.)

- Boosting refers to a wme being referenced, raising its activation level
- Every wme has been referenced in one or more productions
- The time of each reference j is recorded, and used to calculate t_j

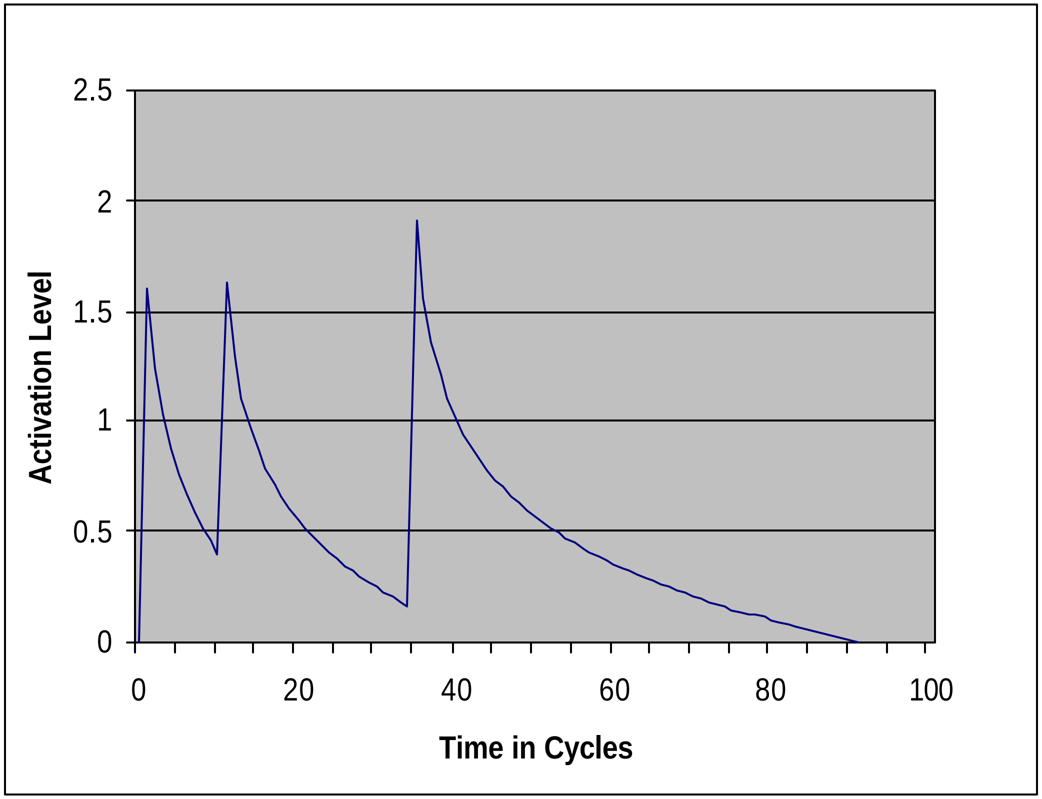
$$t_j = t_{now} - t_{of\ reference\ j}$$

Memory decay (cont.)

$$A_i = log\left(\sum_{\substack{References\ j\\ of\ wme\ i}} t_j^{-d}\right) + log(c)$$

- The decay exponent d governs the rate of decay
- Activation levels also include a constant factor, c

Activation level changing with time



Action	Cycle
Wme created	1
One new reference	12
Two new references	36
Wme removed	92

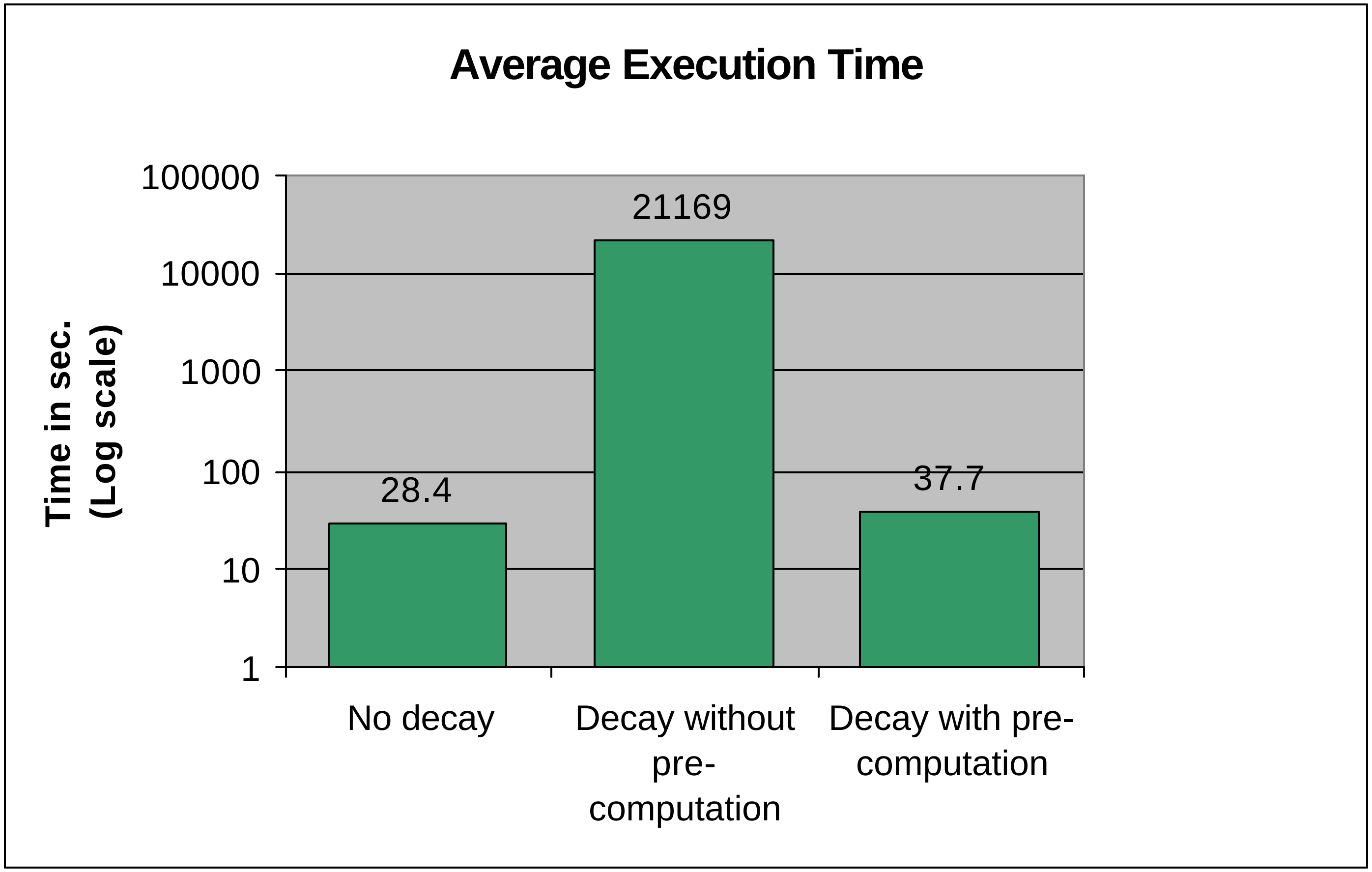
Memory decay (cont.)

- A wme is removed when its activation level drops below a preset level
- Directly affects only o-supported wmes
- Indirectly affects firing of productions

Computational costs

- Significant computational costs arise from the many t_j^{-d} calculations
- Can pre-compute these calculations
  - Cycles have integer numbering
  - Decay has a max time limit
  - Pre-computation drastically reduces overhead

Computational costs (cont.)



Creating psychological models

- Models simulate solving an instance of Towers of Hanoi (TOH)
  - TOH has human performance data available
  - Can build models with and without memory decay
  - Including simulation of other activities such as physical movement and perception

Creating psychological models

- Used existing ACT-R models as a basis
- Compared against human performance on the same task
- Classified processing by function
- Aspects of psychological plausibility were also considered

Converting models to Soar

- Exploring how decay can be used in Soar
- A way to compare the cognitive architectures

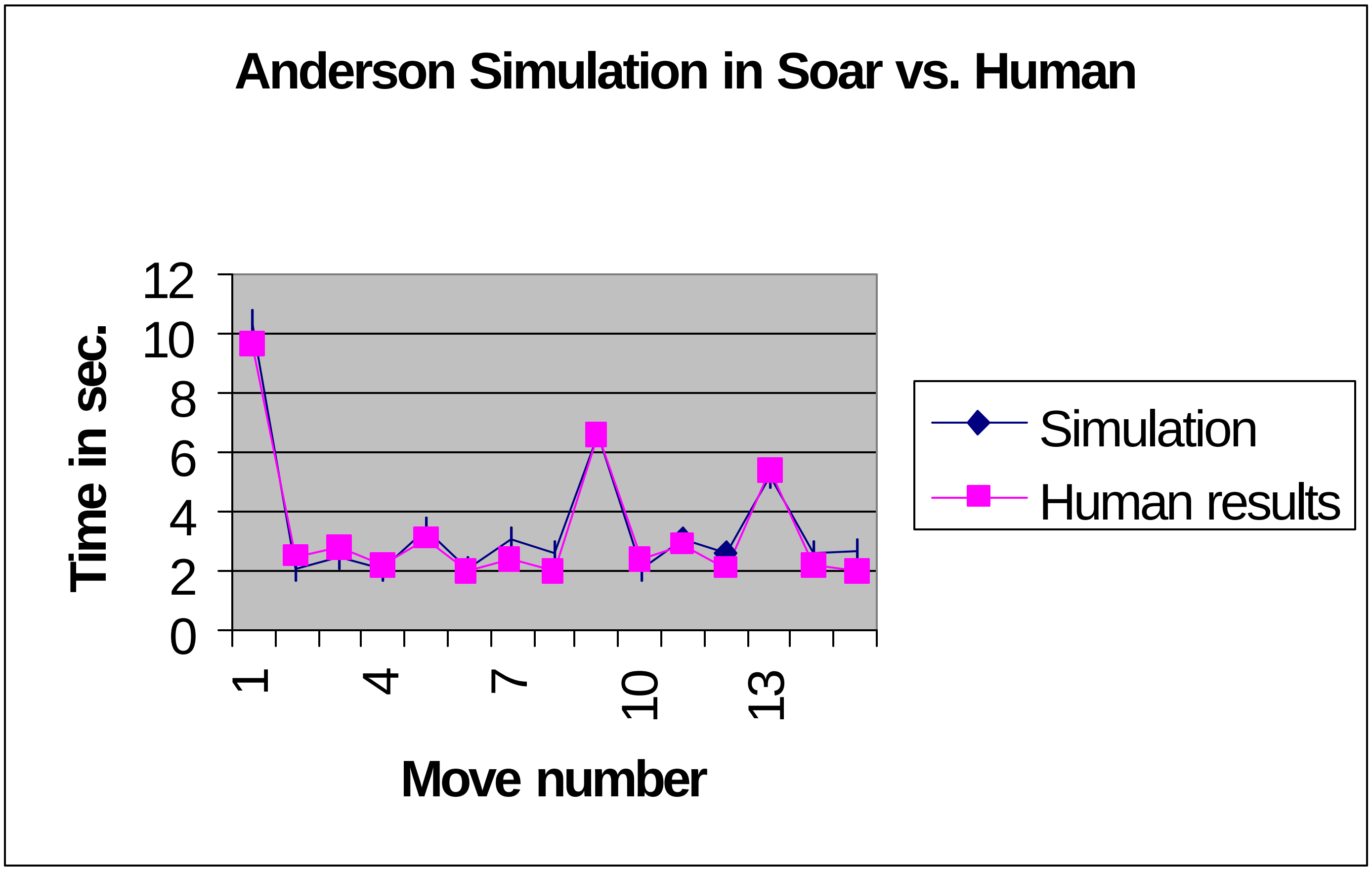
Corresponding aspects of Soar and ACT-R 4.0

Soar	ACT-R
Impasses used to form substates	Subgoals put onto goal stack
Single operator per cycle	Single production per cycle
Fixed amount of time per cycle	Variable amount of time per cycle
Knowledge-based control structure	Activation-based control structure

Cognitive models of TOH

- Anderson’s model
  - Uses goal stack
  - No memory decay
  - Large spikes explained by encoding
- Altmann’s model
  - No goal stack, saves plans instead
  - Memory decay used
  - Large spikes explained by saving plans

Anderson conversion



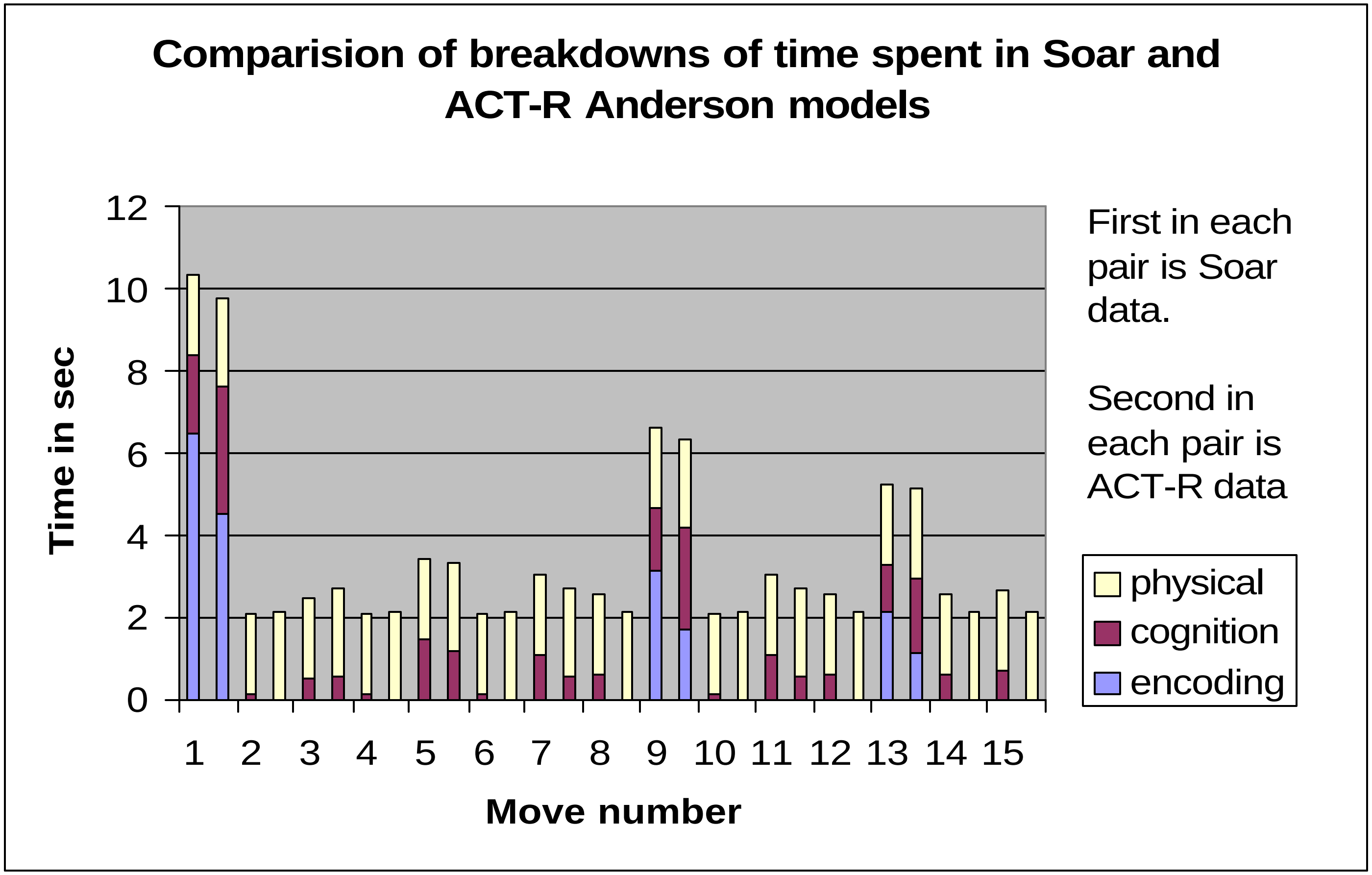
Anderson conversion (cont.)

- Good match for timing data
- Correlation of .986
- Correlation of .995 in ACT-R
- 70 productions used
  - 39 actually model behavior
  - Rest used to simulate actions, etc.
- 13 productions used in ACT-R

Anderson conversion (cont.)

- Very similar to ACT-R breakdown
- Encoding accounts for "spikes"
- Cognition accounts for smaller perturbations

Anderson conversion (cont.)



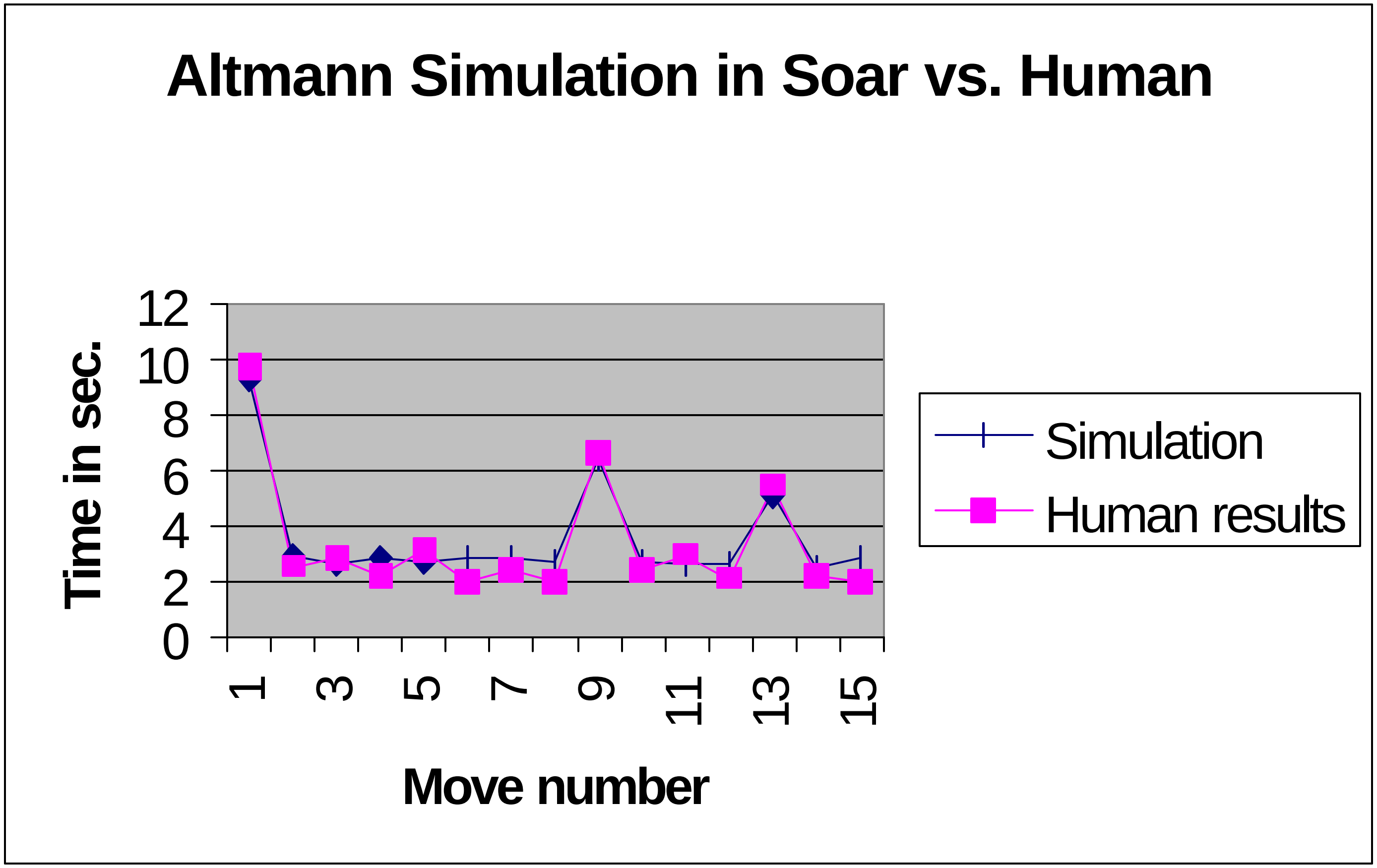
Psychological implausibility

- Both models have assertions that are not plausible
- Anderson has the encoding occur at convenient times
- Altmann uses varying times for saving a plan

Improved Altmann model

- Constant amount of time for saving plans
- Added encoding
- Still good fit to human data
- Correlation of 0.982
- Correlation of 0.995 in original ACT-R model

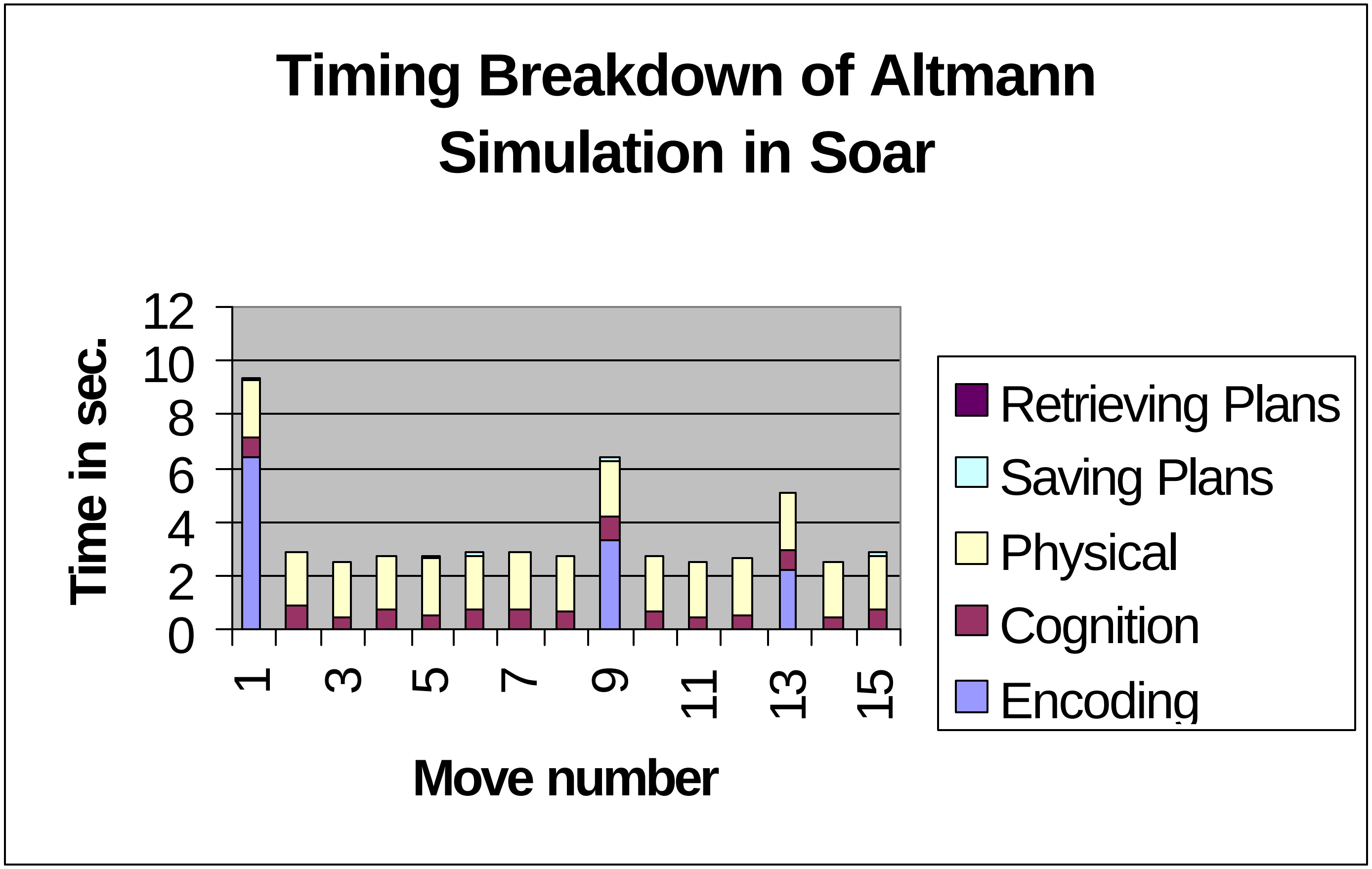
Improved Altmann (cont.)



Improved Altmann (cont.)

- Becoming more similar to Anderson model
- No goal stack
- Saves and retrieves plans
- 140 productions used
  - 49 actually model behavior
  - Rest used to simulate actions, control memory, etc.
- 29 productions used in original ACT-R model

Improved Altmann (cont.)



Nuggets and coal

- Nuggets
  - Moderate overhead added by memory decay
  - Many corresponding aspects of ACT-R and Soar
  - Improved plausibility of Altmann model
- Coal
  - Cognitive models less accurate than in ACT-R
  - Modeling actions not precise
  - More work on plausibility of Anderson model