Learning and Memory in Act-R and Soar

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Primary Theoretical Differences

- Act-R
  - LTM
    - Procedural Rules
    - Declarative (Associative)
  - Learning (only two of several mechanisms)
    - Strength Learning: Rules get stronger (and fire faster) with practice and weaker with disuse
    - Base level learning: Declarative memory elements increase their activation with use and decay with disuse. Increased activation increases probability and speed of retrieval
- Soar
  - LTM
    - Procedural Rules
  - Learning
    - All learning through chunking (knowledge compilation)

Discriminating Between Soar and Act-R

- Previous results (e.g., VanLehn, 1996)
  - » Parallel power curves for computation and memory retrieval
    - – Retrieval practice speeds retrieval
    - – Computation practice speeds computation
  - » Procedural knowledge is subject to asymmetric access
    - – If 5 + 3 then 8 (Forward reasoning only)
  - » Declarative knowledge is subject to symmetric access
    - – 5 + 3 = 8 can be accessed given any combination of cues.

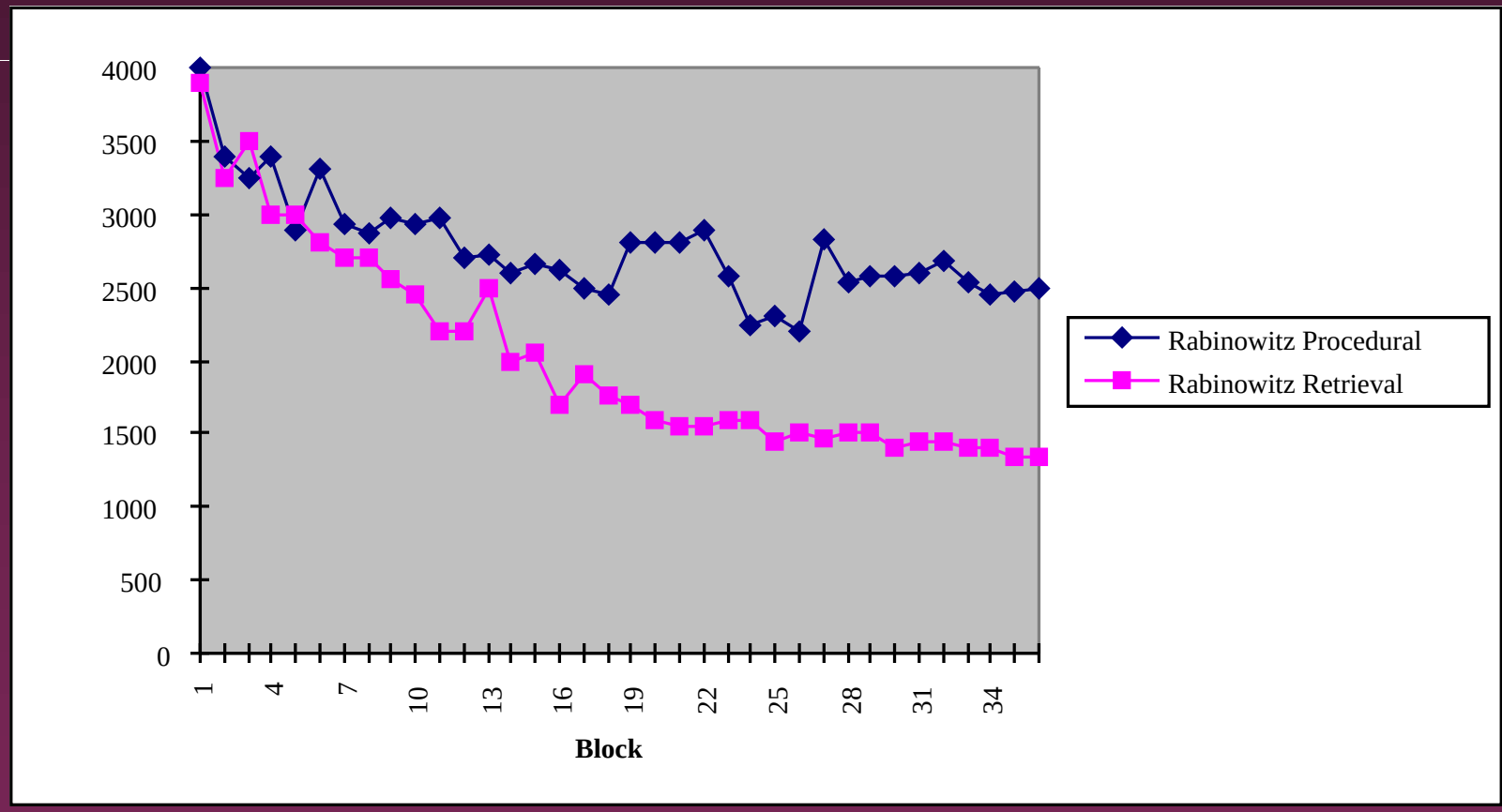
Rabinowitz and Goldberg Alphabet Arithmetic Experiments

- Examines
  - The effect of practice on the latency of computation and retrieval
  - Asymmetry of procedural knowledge
  - Symmetry of declarative knowledge
- Alphabet arithmetic
  - A + 3 = ? (Answer: D)
  - D - 3 = ? (Answer: A)

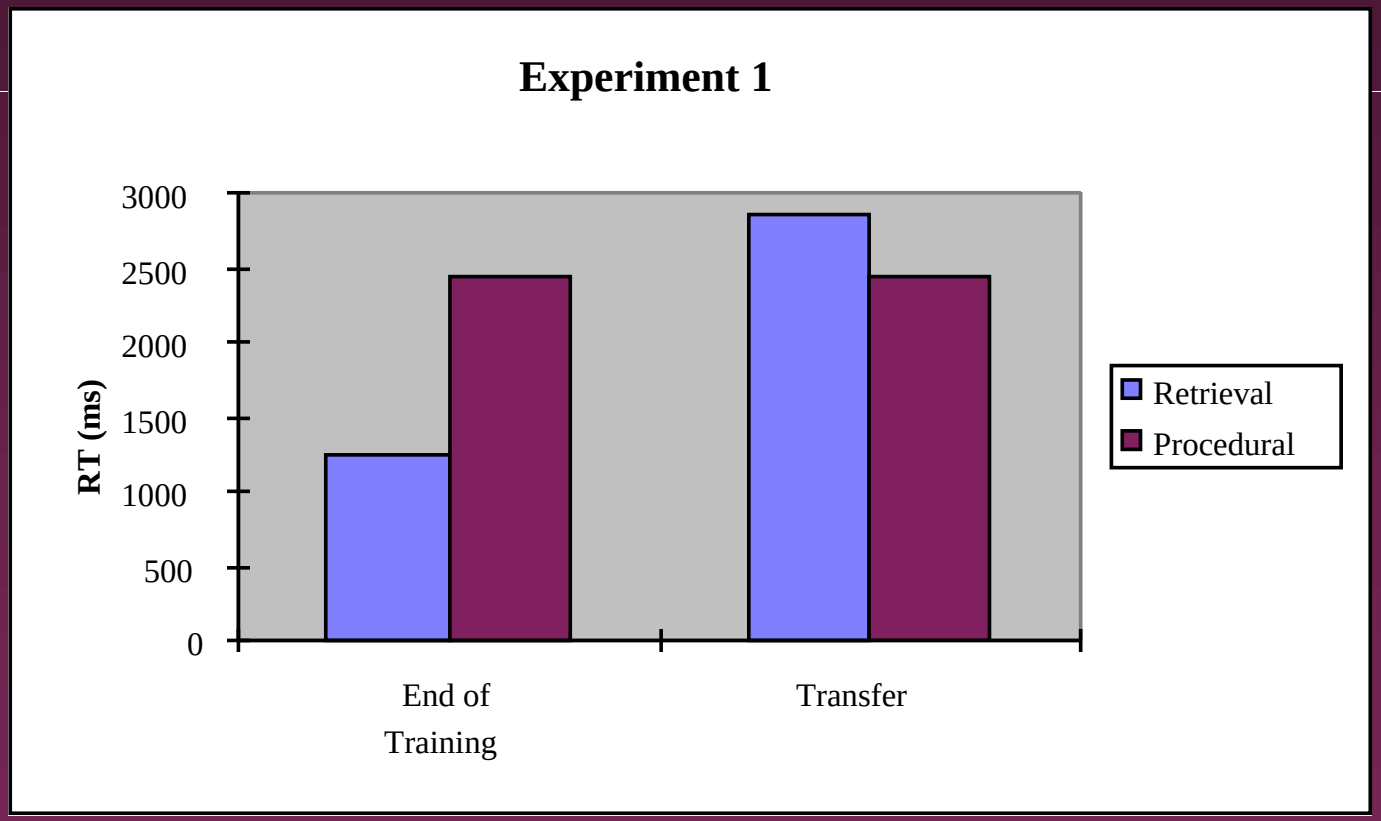
Experiment 1

- Training: 432 addition problems
  - » Retrieval Group
    - – 12 different addition problems presented 36 times
    - – Addends from 1-6. 2 letters per addend.
  - » Procedural Group
    - – 72 different addition problems presented 6 times
    - – Addends from 1-6. 12 letters per addend.
- Transfer
  - » 36 new addition problems presented twice

Experiment 1 Results Training



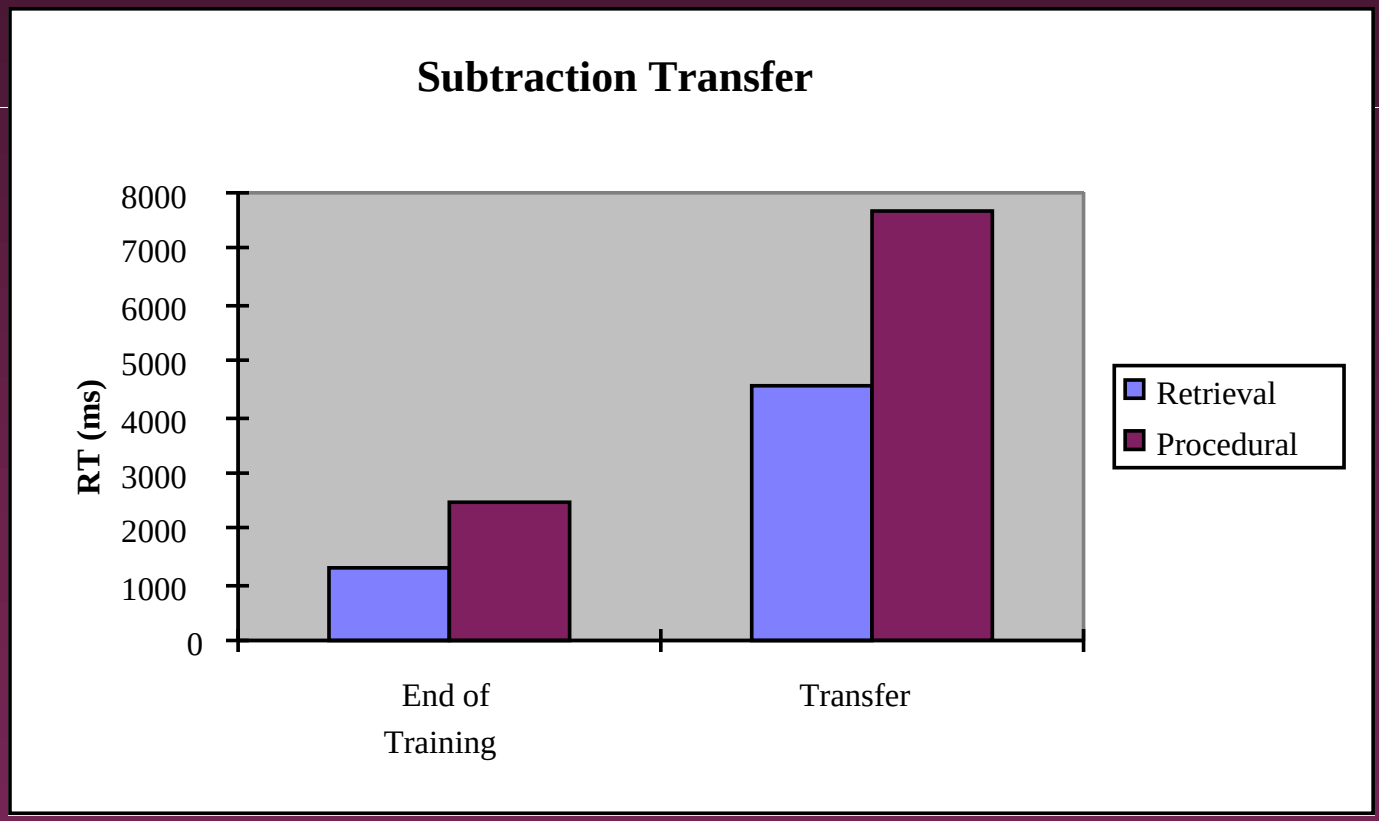
Experiment 1 Results Addition Transfer



Experiment 2

- Training: Identical to Exp. 1
- Transfer
  - » 12 subtraction problems presented 3 times
  - » Each subtraction problem was the inverse of a previously seen addition problem
    - – A + 3 = D
    - – D - 3 = A

Experiment 2 Results



Act-R Model

- Main Rules for Top Goal
  - » Retrieve-plus-result
    - – If the goal is to determine letter + number =
      and there is a chunk letter + number = letter2
      then give letter2 as the result
  - » Retrieve-minus-from-plus-result
    - – If the goal is to determine letter - number =
      and there is a chunk letter2 + number = letter
      then give letter2 as the result
  - » Subgoal-count
    - – If the goal is to determine letter +/- number =
      then set a subgoal to count up or down the alphabet

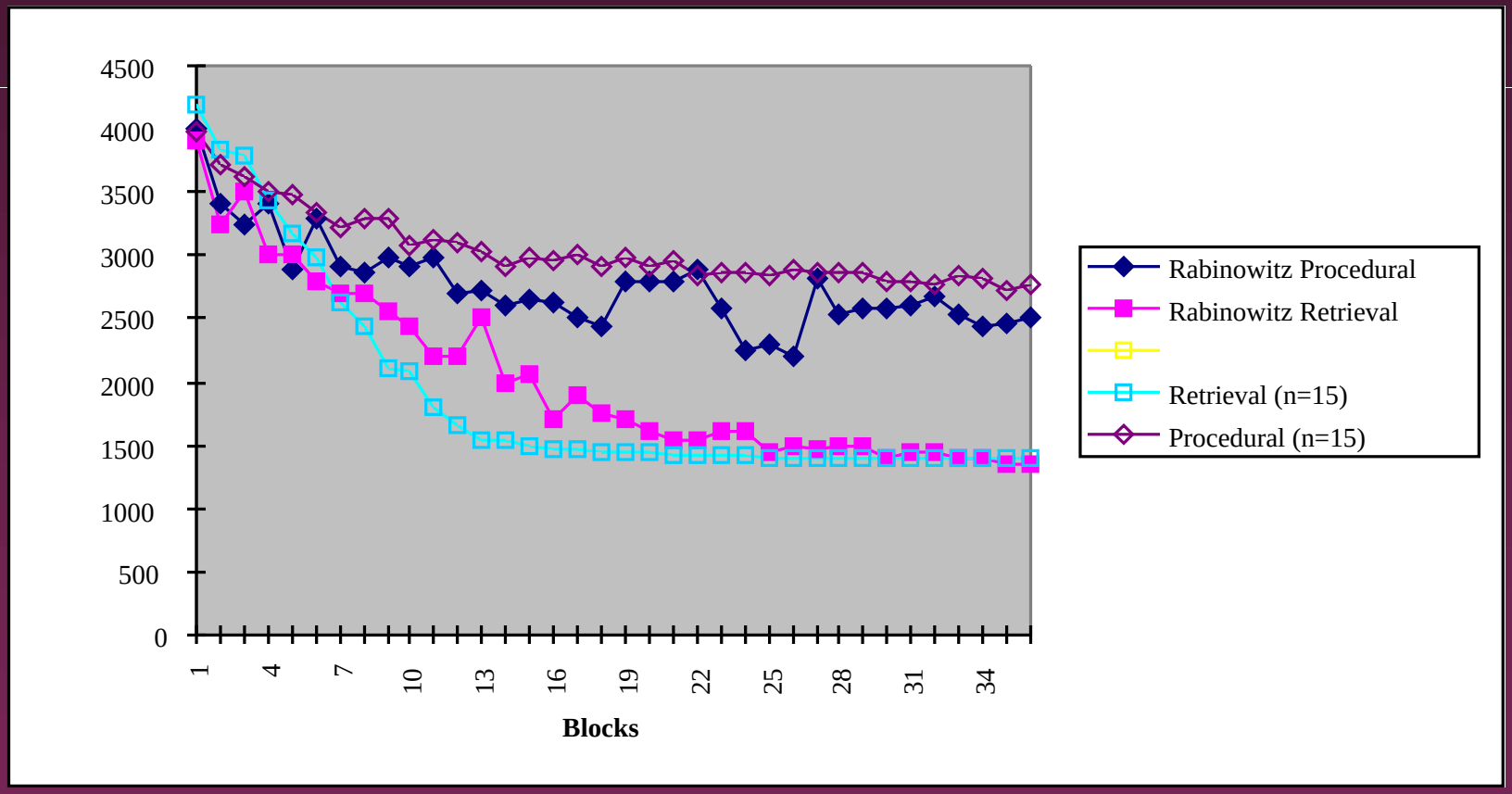
Subgoal Count

- Number representation
  - (one isa character next two)
- Alphabet representation
  - Chunks as in the ABC song
    - ABCD EFG HIJK LMNOP...
    - (alpha1 ISA item
      first a
      second b
      third c
      fourth d
      next alpha2)
  - Given a letter (c):
    - Recall the alpha chunk (alpha1)
    - Serially search for the position of the letter (a b c)
    - Then begin counting up or down
    - Counting up is relatively fast because of the pointer to the next alpha chunk
    - Counting down requires an indirect match

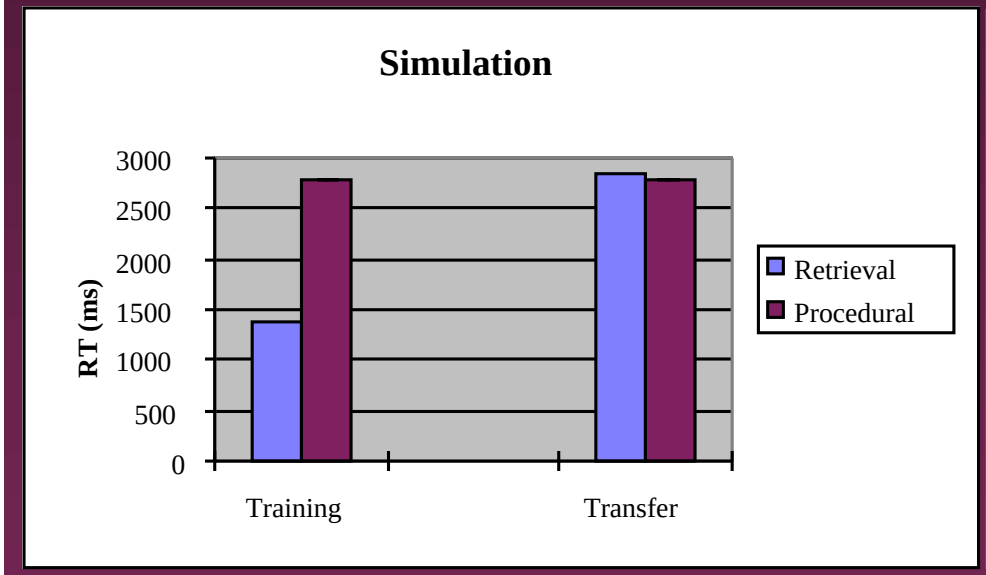
Learning and Parameters

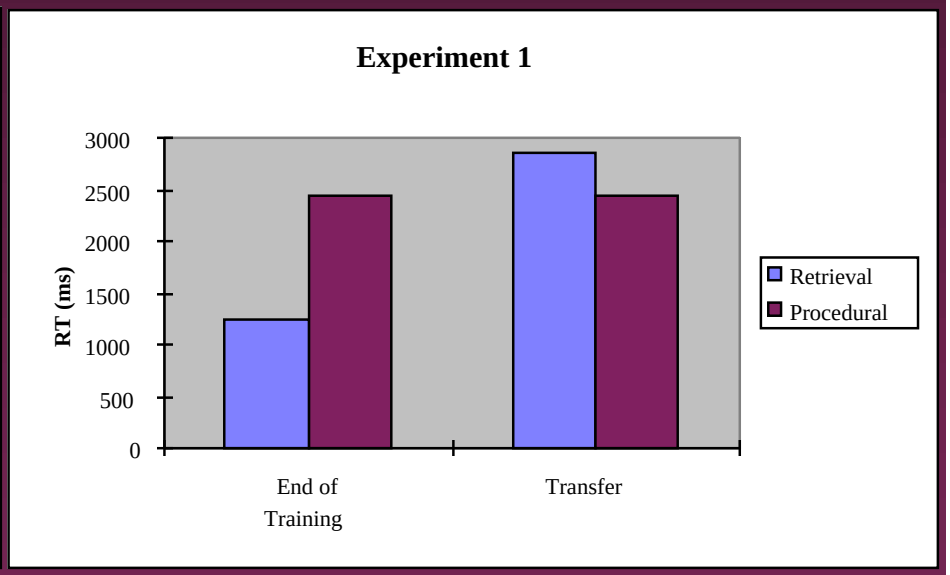
- Base level Learning: decay = 0.7
- Strength learning: decay = 0.5
- Subgoal-count r = 0.9
- Retrieve r = 1
- To avoid high matching failure times all rule strengths were set to 0.486 (spp :creation-time -1000 :references 25)
- Reading + Responding Effort = 1.25 sec
- Retrieval threshold = 0.55
- Initial base levels = 0.974 (setallbaselevels 100 -1000)
- Permanent activation noise = 0.15

Training Results

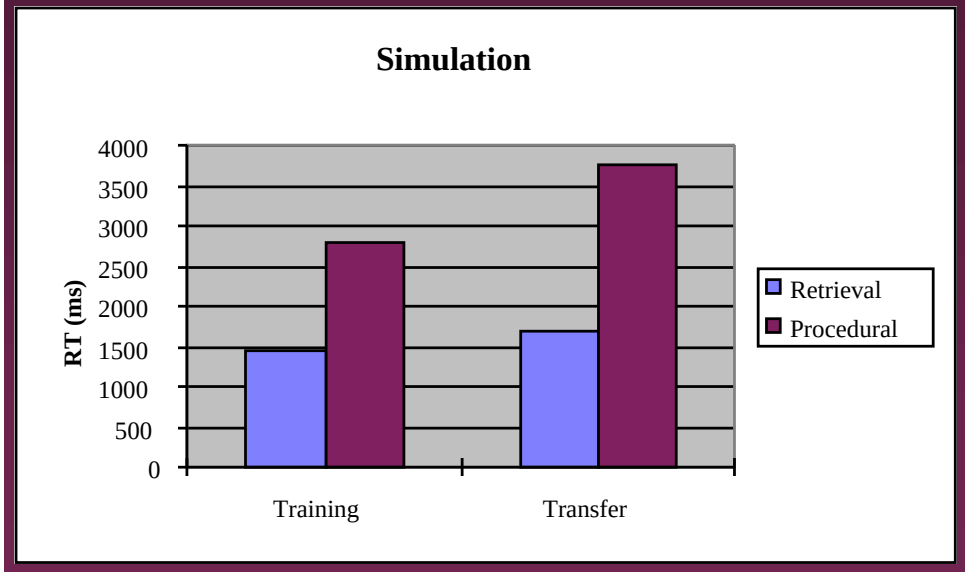


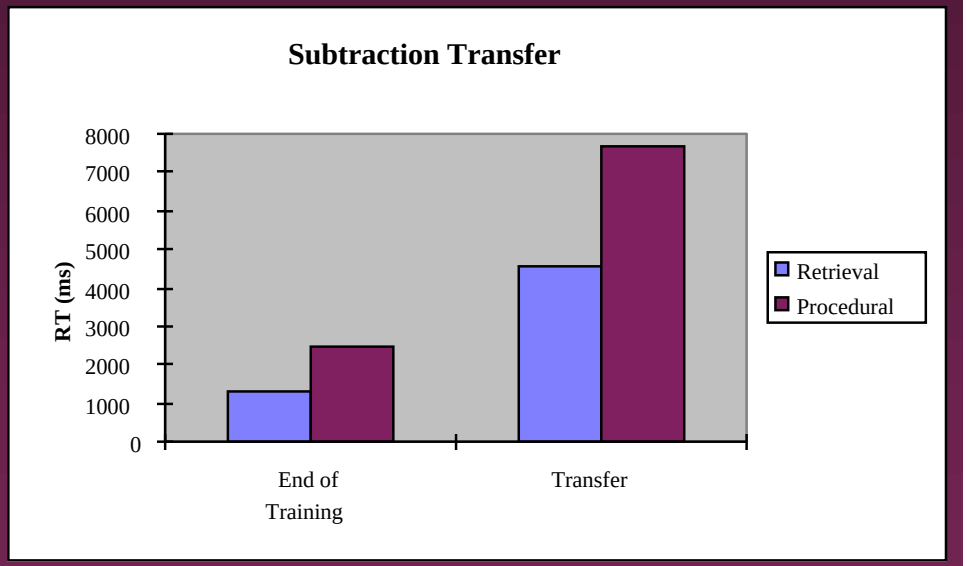
Addition Transfer





Subtraction Transfer





Conclusion

- Act-R can clearly account for this data
- But these results seem problematic for Soar
  - The best Soar model probably requires the use of SCA or the combination of recognition and retrieval rules

References

- VanLehn, K. (1996). Cognitive Skill Acquisition. *Annual Review of Psychology, 47*, 513-539.
- Rabinowitz, M., & Goldberg, N. (1995). Evaluating the structure-process hypothesis. In F. E. Weinert & W. Schneider (Eds.), *Memory Performance and Competencies: Issues in Growth and Development* (pp. 225-242). Hillsdale, NJ: Lawrence Erlbaum.