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Using Cognitive Modeling to Understand the Roles of Prefrontal and Posterior Parietal Cortex in Algebra Problem Solving

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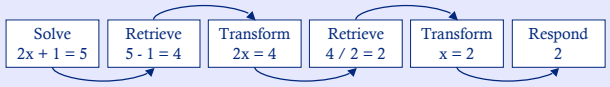
Introduction

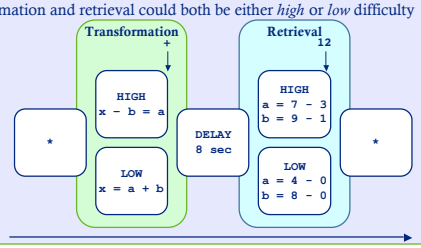
- *Retrieval* and *transformation* are highly correlated in algebra problem solving:



- The current instantiation of the ACT-R theory (Anderson, 2005) associates *retrieval* and *transformation* with activity in *prefrontal* and *posterior parietal cortex*, respectively
- Activity in these regions are likewise correlated during naturalistic problem solving (Anderson et al., 2003)
- Can we isolate the processes of transformation and retrieval in algebra problem solving and manipulate them independently?
- If so, can we also isolate activity in their neural correlates?

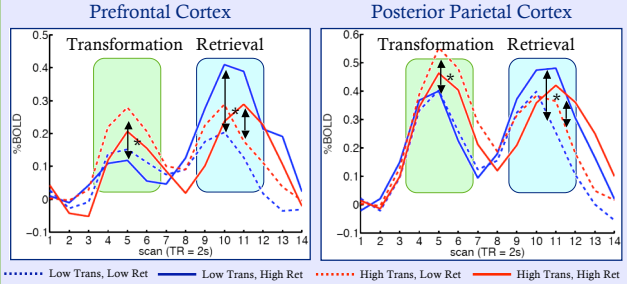
Method

- 20 participants run in a BOLD fMRI study
- Algebra equations were created that needed to be solved in 2 phases:
  - *Transformation phase*: isolate x from a and b
    - Retrievals are delayed until numerical values of a and b are given
  - *Retrieval phase*: calculate the value of x given the numerical values of a and b
- The transformation and retrieval could both be either *high* or *low* difficulty

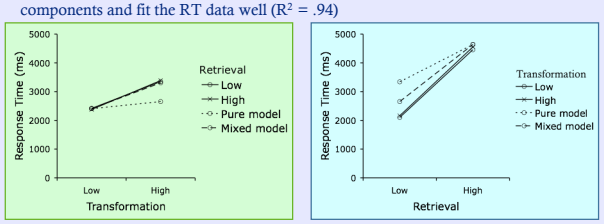


Results and Modeling

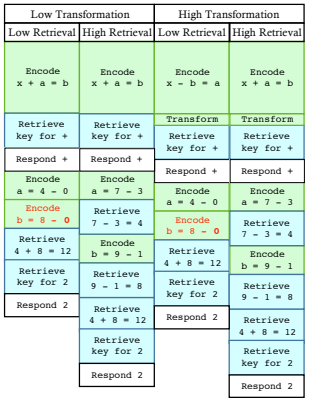
- Manipulating *retrieval load* of algebra problems results in differential activity in both *prefrontal* and *posterior parietal* cortex
- Manipulating *transformational requirements* of algebra problems results in differential activity in both *prefrontal* and *posterior parietal* cortex



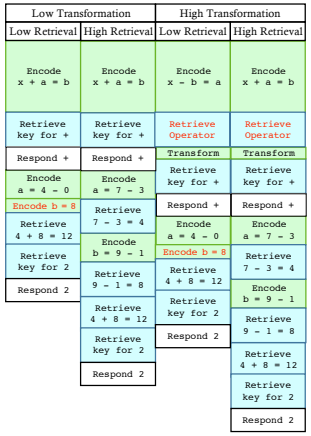
- Why did our manipulations fail to isolate the activity in these regions?
  - **Explanation 1:** These regions are not functionally distinct as characterized by ACT-R
  - **Explanation 2:** Our task manipulations failed to properly isolate retrieval and transformation
- We designed two ACT-R models to determine the plausibility of Explanation 2
  - **Pure Model:** Encompassed our initial assumptions about the design but failed to fit the RT data (R^2 = .50)
  - **Mixed Model:** Assumed that both manipulations had retrieval and transformation components and fit the RT data well (R^2 = .94)



Pure Model



Mixed Model



Conclusions

- There is a lot of difficulty isolating the basic cognitive processes characterized by ACT-R
- The difference between the roles of prefrontal and posterior parietal cortices in algebra problem solving remains unclear
- Using cognitive modeling can help in the interpretation of behavioral and neuroimaging data

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