Executive Functions explain Individual Differences and Longitudinal Development Trends in the Development of Analogical Reasoning: A Computational Account

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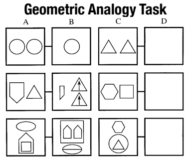
Background

- Past accounts of the development of analogical reasoning have focused either on the development of knowledge representation (e.g., Goswami, 2001; Gentner & Rattermann, 1991) or on changes in working memory (e.g., Halford, 2005)
- We have argued that executive functions, particularly inhibitory control in working memory, is an essential part of analogical processing that develops during along with relational knowledge during childhood (Morrison, Doumas, & Richland, 2011)
- Here we provide evidence that inhibitory control in working memory and relational knowledge changing together provide a more complete account of the development of childrens' analogical reasoning

Method

- Hosenfeld et al. (1997) repeatedly administered a geometric analogy task to 6-8 year olds
- Results indicated three distinct learning profiles among children
- Using DORA (Doumas et al., 2008) and LISA (Hummel and Holyoak, 2003) we simulated Hosenfeld et al.'s results in two parts: (1) learning relational representations, and (2) geometric analogy task performance

Geometric Analogy Task



Hosenfeld et al. (1997) developed a geometric analogy task with problems of varying complexity created using relations familiar to children (e.g., above/below). They administered the task to 6 year old children eight times over the course of one year. They described three groups of children who differed in their learning profiles.

Results

Simulation 1

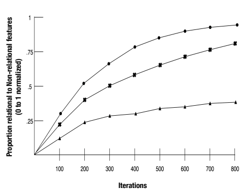
- DORA's learning algorithm coupled with variation in inhibition level during learning accounted for the development of structured relational representations from unstructured examples

Simulation 2

- Using the representations generated by DORA under varying inhibition levels we used LISA to solve the analogy problems using the same inhibition levels for each group
- DORA/LISA successfully accounted for variations in how all three groups of 6-8 year olds respond to repeated experiences with geometric analogies:
  - Lower inhibition: errors based on perceptual mapping and minimal learning over time
  - Medium inhibition: a transition between early perceptual errors and later relational mapping
  - High inhibition: consistently relational mapping

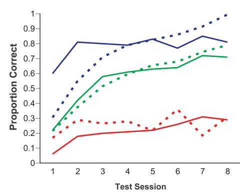
Simulation 1: Learning Relations

- Started DORA with representations of 100 objects attached to random sets of features
- Defined 5 transformations each consisting of 2 features (2 for each role of a relational transformation)
- Each object was attached to the features of between 2 and 4 of these relations
- Presented DORA with sets of objects selected at random, allowed to to compare and learn from these objects
- As DORA learned new representations it also used these representations to make comparisons
- On each trial we selected between 2 and 6 representations and let DORA compare them
- We ran DORA with 3 inhibition levels (Morrison, Doumas, & Richland, 2011)
  - Inhibition level 1: .4 ± .2
  - Inhibition level 2: .6 ± .2
  - Inhibition level 3: .8 ± .2



Simulation 2: Analogy

- Learned representations from Simulation 1 were placed in LISA's Long-Term Memory (LTM)
- LISA compared the A and B terms to retrieve relevant predicates from LTM
- LISA uses the retrieved predicates to represent A, B, and C and choice terms
- LISA maps A and B in driver to C and possible D choices in recipient
- Whatever maps to B term is chosen as answer
- If no choice maps to B, then LISA "guesses"

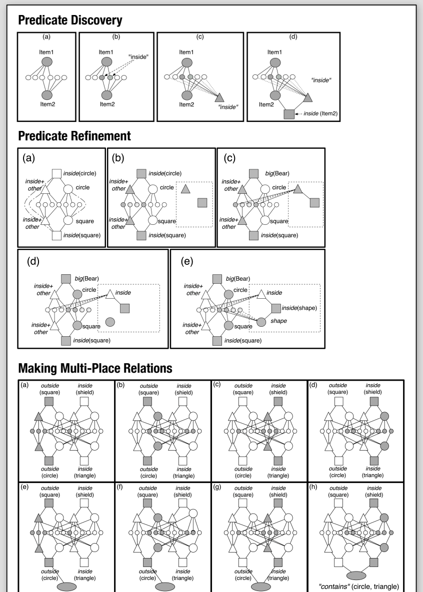


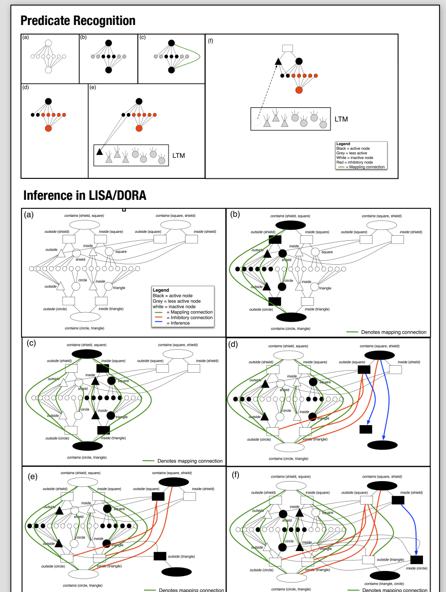
Conclusion

- Using this approach we effectively captured the discontinuous change in geometric analogy performance identified by Hosenfeld et al (1997)
- The development of relational (i.e., structured) thought is a likely a product of both maturational changes in frontal lobe function (e.g., inhibition/working memory) and changes in relational knowledge as a result of experience.

DORA/LISA Model

- DORA (Discovery of Relations by Analogy; Doumas et al., 2008) is a theory of how we learn relational (i.e., structured) representations from unstructured input
- DORA is based on the LISA model (Hummel & Holyoak, 1997, 2003) model of analogy (and "matures" to take LISA as a special case—i.e., DORA develops into LISA through learning)
- Starting with representations of objects attached to features, DORA learns structured representations of single-place predicates and multi-place relations (fig.4) through a process of comparison-based intersection discovery
- Accounts for over 20 phenomena from the literature on children′s and adults′ relation learning and relational reasoning as well as the 30+ phenomena accounted for by LISA
- We have extended DORA to additionally account for recognizing known relations from novel stimuli





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