Differences in the development of analogy across cultures: 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 capacity (e.g., Halford, 2005)
- We have previously argued that inhibitory control in working memory is an important part of analogical processing that likely develops during childhood (Morrison, Doumas, & Richland, 2006)
- Here we demonstrate that a model combining the dual constraints of developing relational representations and changes in working memory capacity provides a good fit of data on analogical development from across cultures

DORA 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, 1197, 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 (fig.1) of single-place predicates (figs. 2-3) 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

Figure 1: Binding

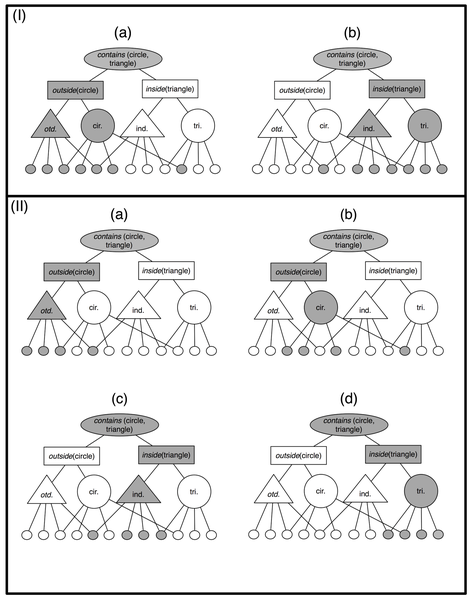


Figure 2: Predicate Discovery

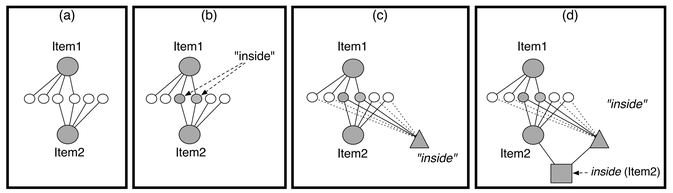


Figure 3: Predicate Refinement

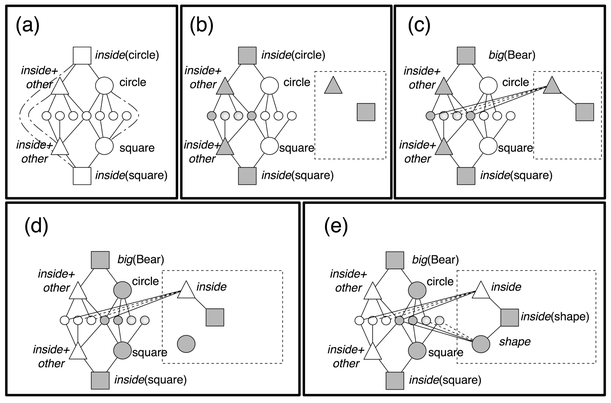


Figure 4: Making Multi-Place Relations

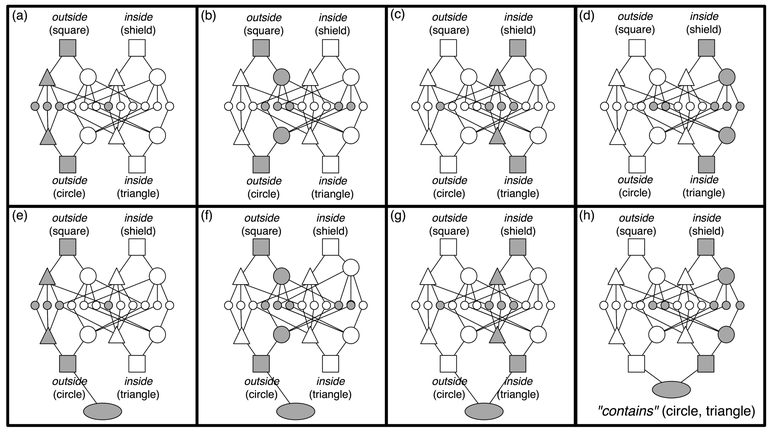
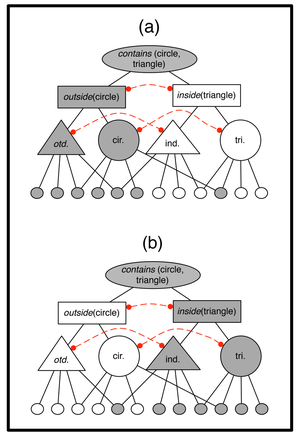


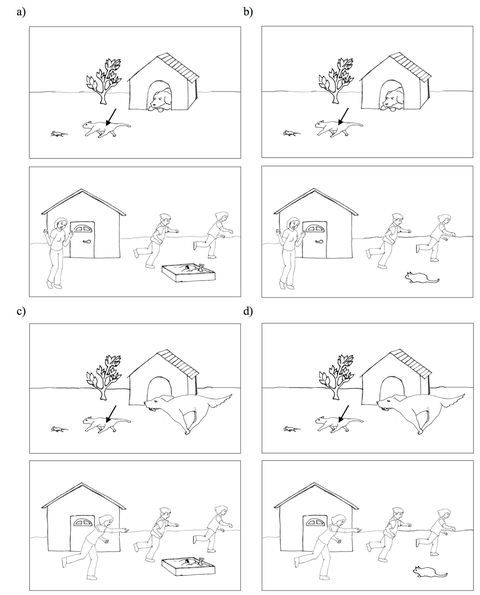
Figure 4: Lateral inhibition and WM



Simulations

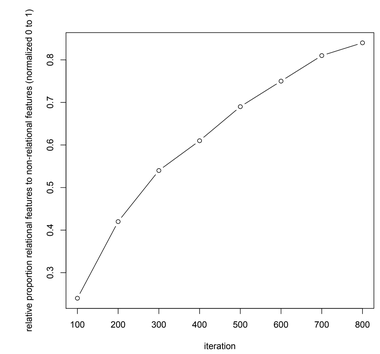
- Richland et al. (2006, 2010) developed an analogy task that manipulates relational complexity and featural distraction (figure 6) and tested children in US and Hong Kong
- Results indicated an effect of featural distraction in both US and Hong Kong children, but relational complexity only among US children
- We used DORA to simulate the findings of Richland et al. (2006, 2010)
- Main theoretical assumption we are testing is that the differences in performance on relationally complex tasks is due to more refined relational representations NOT greater WM
- We simulated the results in two parts: (1) learning relational representations, and (2) simulation of the Richland et al. analogy task

Figure 6: Examples of scene analogy problems from Richland et al.

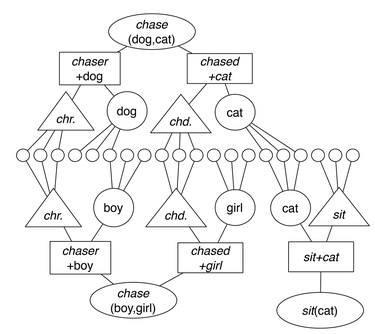


Part 1: Learning Relations

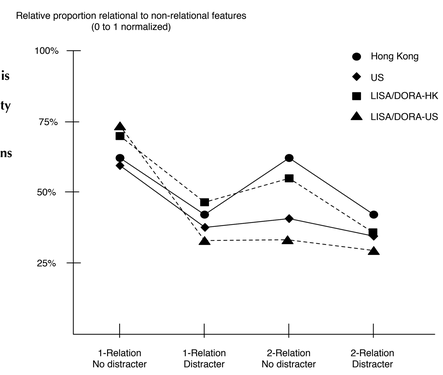
- Started DORA with representations of 100 objects attached to random sets of features
- Defined 4 relations each consisting of 2 roles
- Each role consisted of 3 features (e.g., for *chase* relation, but *chaser* and chased *roles* are defined by 3 features)
- Each object was attached to the features of between 1 and 3 of these relations (chosen at random)
- 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 4 representations and let DORA compare them
- Reflecting the finding that children we ran DORA with reducled inhibition levels (Morrison, Doumas, & Richland, 2006)
- Inhibition level = .7 ± .1



Part 2: Simulating Richland et al. (2006, 2010)



- Simulation used representations of scene problems composed of relations DORA learned during part 1
- The theoretical assumption we are testing is that the differences in performance on problems with greater relational complexity in Hong Kong children is due to more refined relational representations
- Simulated US children using representations DORA had learned after 400 iterations
- Simulated Hong Kong children using representations DORA had learned after 800 iterations
- DORA was presented with and compared the A and B terms and attempted to map elements
- Whatever maps to B term is chosen as answer
- Take what DORA mapped in the target object as DORA's answer to the problem
- If no choice maps to B, then DORA "guesses"



Discussion

- We used DORA's learning algorithm to account for the development of structured relational representations from unstructured examples
- DORA's relation learning accounts for variations in performance on problems with increased relational complexity by 4 year olds from the US and Hong Kong
- 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
- Changes in knowledge are sufficient to account for cross-cultural similarities and differences in performance by children on analogy problems

References

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