Development of reasoning: Behavioral evidence to support reinforcement over cognitive control accounts

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Abstract

Speed's theory makes two predictions for the development of analogical reasoning. Firstly, young children should not be able to reason analogically due to an undeveloped PFC neural network. Secondly, category knowledge enables the reinforcement of structural features over surface features, and thus the development of sophisticated, analogical, reasoning. We outline existing studies that support these predictions and highlight some critical remaining issues. Specifically, we argue that the development of inhibition must be directly compared alongside the development of reasoning strategies in order to support Speed's account.

Introduction

Speed suggests that during development, neurons become organized along the posterior-anterior axis of the prefrontal cortex (PFC) such that anterior regions are tuned to increasingly abstract and complex situations. Speed's theory proposes that these changes occur through "reinforcement-driven discrimination" (pg26), such that the response preferences of neurons in PFC are tuned through reinforcement of particular relationships. We can therefore derive two key predictions for the development of analogical reasoning:

1. Young children should not be able to reason analogically due to an undeveloped PFC neural network (although Speed does not detail the timecourse of this development).
2. Analogical reasoning must be learned. Specifically, knowledge of the category of interest enables the reinforcement of "structural" features over "surface" features, and thus more sophisticated reasoning.

Support for Prediction 1

There is evidence that young children focus on perceptual over category information when making generalizations about the properties / behavior of new items. Sloutsky, Kloos and Fisher (2007) found that four to five year old children could successfully learn to group novel animals into categories, even when category information was pitted against obvious surface cues (shape / colour). However, in a subsequent induction task, children reverted back to grouping objects in terms of obvious surface information, rather than basing induction decisions on category information. We have replicated this finding using biologically plausible novel animals (Badger & Shapiro, 2010), and additionally show that children shift from perceptual induction to category induction around age seven. These data suggest that young children's natural default is to focus on surface features, and the ability to use structural features develops gradually during early childhood. According to Speed, this ability is constrained by the development of the PFC network.

Support for Prediction 2

There is evidence that children can be trained to focus on non-obvious, or unobservable biological features within a particular domain. For example, Au, Chan, Chan, Cheung, Ho and Ip (2008) found that training that focused on the biological causal mechanism for cold and flu transmission was considerably more effective in impacting on children's reasoning about infectious diseases and preventative behavior than rule-based training programs. These data fit with Speed's hypothesis that category knowledge reinforces PFC response preferences that correspond to structural over surface features of the domain.

Outstanding Issues

There is an alternative interpretation of these data. Specifically, Gelman (e.g., 2003; see also Bulloch & Opfer, 2009) argues that even young children are biased towards essentialist (internal, intrinsic) causes, and thus should show a natural default towards category induction. Thus, any bias towards surface / perceptual features in early reasoning must be interpreted as an inability to inhibit the "obvious" perceptual response over the less salient category-based default. Similarly, Au et al.'s findings must be interpreted as improving children's ability to inhibit obvious /observable explanations, enabling their natural bias towards "essentialist" causes to be expressed.

Our research (Badger & Shapiro, 2010) directly tests perceptual-bias vs. inhibition interpretations of early perceptual induction. As in Sloutsky et al., we trained children to categorize novel insects according to a non-obvious category-membership rule (head shape). The salient perceptual cues (e.g. overall size, shape, colour) were not predictive of category membership. Children then performed a triad induction task in which they were asked to generalize a hidden property of the target to one of two test items (same-category choice or perceptual distractor). Unlike previous studies, we compared induction choices when the distractor items were at different levels of similarity to the target. As expected, children made significantly more perceptual (distractor) choices when this item was highly similar to the target. However, this effect did not interact with age. Thus, increased inhibition abilities cannot be driving children's shift from perceptual to category induction. Instead, this shift is likely to be triggered by the development of more sophisticated reasoning abilities. These findings support Speed's PFC account of analogical reasoning, over competing accounts based on cognitive control, and highlight the need for developmental evidence to back up claims about the neural mechanisms of analogical processing.

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