

# The balance between conceptual strength and inhibitory control in children's analogical reasoning

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## Introduction

Analogical reasoning allows us to rapidly construct new conceptual knowledge through making inferences based on analogies.

### Mitochondria are like the batteries of a cell

Development is characterised by children's increasing ability to make inferences based on abstract relations and shared roles (...provides energy) over inferences based on perceptual features and object attributes (...made of metal) and erroneous relations (...can be replaced). This change is believed to be caused by domain-specific conceptual development<sup>1, 2</sup> and increases in working memory and inhibitory control<sup>3, 4</sup>. How these separate developmental factors interact with each other is not well understood with multiple hypotheses offering differing accounts.

One proposed function of inhibitory control is to suppress unnecessary feature and relational information during reasoning<sup>5, 6</sup>. In this account, increases in inhibitory control and conceptual development are in a moderating relationship. To test this hypothesis, we took measures of children's task-specific conceptual development and individual differences in inhibitory control. We then used these to predict children's performance in a set of analogy problems using regression models with interaction terms to investigate moderation effects.

To measure task-specific conceptual development we used a cued recall priming task. Based on the assumption that objects become associated with increasingly richer relational-concepts through conceptual development<sup>7, 8</sup>, we hypothesised that the extent to which object-concepts prime each other can be used as a proxy for measuring the strength of associated relational-concepts.

### Predictions:

- Individual differences in how much the object-concepts used in analogy problems prime each other will predict performance in the same analogy problems
- Inhibitory control development will predict analogical reasoning performance
- The extent to which object priming effects predict analogy problem performance will be moderated by inhibitory control

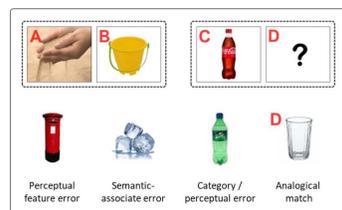
## Methods

Cross-sectional design. N = 84 typically developing children (41 girls), 4.17-7.95 years old (M = 6.14, SD = 1.04).

### Dependent measure: Analogy problems

Ten A:B::C:D proportional analogy problems were used to measure children's analogical reasoning ability. Problems offered four possible responses associated with developmental changes in analogical reasoning.

Children received scores for number of matches made for each response type.



### Conceptual strength IVs: Cued-recall priming task

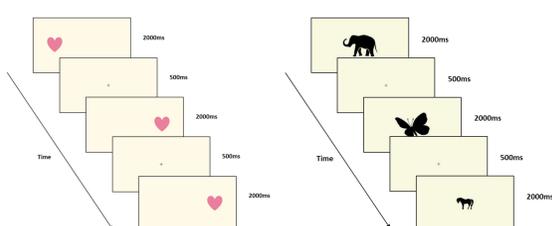
A cued-recall task was used to measure priming effects between the concepts used in the analogy problems. Children first listened to pairs of words (cue and target) before having to recall the targets words upon hearing the cue words. The cued recall items were yoked to the AB and CD terms in the analogy problems. The cued recall task was completed 10-12 days after the analogy problems.

Children received a score for the number of correct AB items recalled and a separated score for the number of CD items recalled.

Cue	Target	
Peel	Orange	1
Painting	Brush	3
Tunnel	Train	5
Bed	Cat	2
Kennel	Dog	4
Plant	Water	6

### Inhibitory control IVs: Animal Stroop and Hearts & Flowers

Children completed two inhibitory control measures: Animal Stroop for semantic inhibition and the Hearts & Flowers task for rule-based inhibition. Working memory was also measured with a list sorting task and covaried for in the analyses.

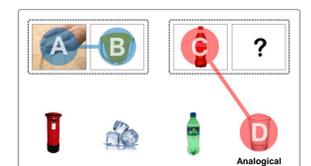


## Results

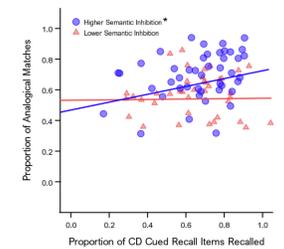
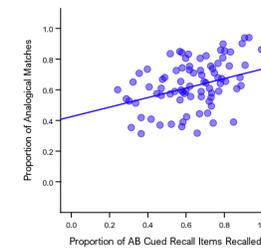
Separate linear regression models were used to predict different analogy problem response types. As few perceptual-feature or perceptual-category errors were made, data for both were collapsed into one 'perceptual error' variable. Age, executive function and cued recall variables were entered as predictors, with cued-recall\*Animal Stroop interaction terms entered to examine moderation effects between conceptual strength and semantic inhibition.

### Predictors of analogical matches

**Main effects:** Higher cued recall score for the AB terms in the analogy problems and higher list sorting score. **Interaction effects:** CD cued recall \* Stroop. Plots revealed cued recall score for the CD terms was positively associated with analogical responses only in participants with higher levels of semantic inhibition as indexed by their Stroop score.

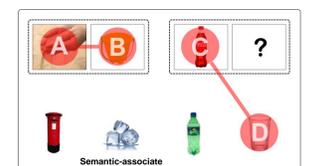


DV: No. of analogical matches	B	S.E.	$\beta$
Age	.031	.017	.215 <sup>*</sup>
List sorting	.016	.006	.303 <sup>*</sup>
Animal Stroop	-.007	.004	-.165 <sup>*</sup>
Hearts & Flowers	.004	.003	.128
AB Cued-recall	.200	.084	.236 <sup>*</sup>
CD Cued-recall	.008	.077	.009
AB*Animal Stroop	.004	.019	.018
CD*Animal Stroop	.030	.013	.222 <sup>*</sup>

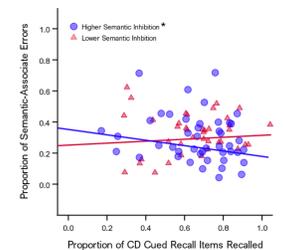
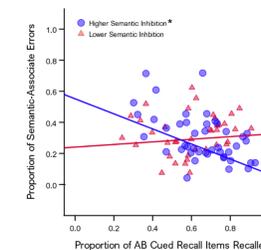


### Predictors of semantic-associate errors

**Main effects:** Lower list sorting score and lower Hearts & Flowers performance. **Interaction effects:** AB cued recall \* Stroop and CD cued recall \* Stroop. Plots revealed a negative association between both AB and CD cued recall scores and semantic associate errors, again, only in children with higher semantic inhibition.

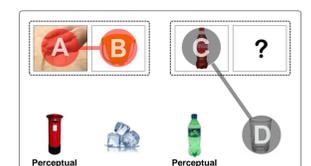


DV: No. of semantic-associate errors	B	S.E.	$\beta$
Age	.011	.018	.080
List sorting	-.014	.006	-.300 <sup>*</sup>
Animal Stroop	.003	.003	.086
Hearts & Flowers	-.015	.004	-.384 <sup>***</sup>
AB Cued-recall	-.229	.084	-.286 <sup>**</sup>
CD Cued-recall	.050	.077	.064
AB*Animal Stroop	-.040	.019	-.216 <sup>*</sup>
CD*Animal Stroop	-.026	.013	-.200 <sup>*</sup>

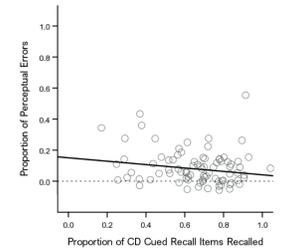
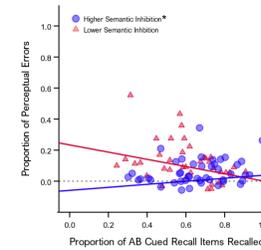


### Predictors of perceptual errors

**Main effects:** Lower Animal Stroop score and an unexpected effect of better Hearts & Flowers performance. **Interaction effects:** AB cued recall \* Stroop. Plots revealed the unexpected finding of a negative association between AB cued recall score and perceptual errors only in children with lower semantic inhibition as indexed by their Stroop score.



DV: No. of perceptual errors	B	S.E.	$\beta$
Age	-.041	.012	-.398 <sup>**</sup>
List sorting	.000	.004	-.010
Animal Stroop	-.007	.002	-.294 <sup>**</sup>
Hearts & Flowers	-.008	.003	-.274 <sup>**</sup>
AB Cued-recall	.027	.060	.045
CD Cued-recall	-.075	.055	-.128
AB*Animal Stroop	-.037	.013	-.264 <sup>**</sup>
CD*Animal Stroop	-.004	.010	-.040



## Conclusions

In line with our predictions, both the cued recall and inhibitory control measures predicted different response types in analogy problems. Moreover, several interactions between cued recall and Animal Stroop scores were observed providing support for the hypothesis that children's developing inhibitory control acts to moderate conceptual strength as they learn to reason by analogy. We suggest that the paradoxical results in the perceptual errors model could be due to (a) instability in the model due to low numbers of perceptual errors, (b) processing differences – the AB term is not used to guide reasoning if a perceptual error is made, or (c) an interaction – paradoxical effects were also observed for the Animal Stroop score in the semantic error model prior to entering interaction terms.

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