The role of conceptual development in children's analogical reasoning

Matthew Slocombe[1*], Michael S. C. Thomas[1], Andrew Tolmie[2]

[1] Developmental Neurocognition Lab, Birkbeck College, University of London
[2] Centre for Educational Neuroscience, UCL Institute of Education
[*] Corresponding author: msloco01@mail.bbk.ac.uk | matthewslocombe.com

Birkbeck UNIVERSITY OF LONDON

Introduction

Analogical reasoning allows children to rapidly construct new knowledge through making inferences based on analogies. Development is thought to rest upon acquiring the necessary relational-concepts[1, 2] and maturation of executive function systems[3, 4]. We hypothesise that the strength of any necessary concepts also plays a key role in development – whilst children may possess the required relational-concepts, if they are relatively weak due to recent acquisition or lack of regular use, children may use stronger object and semantic associated concepts leading them to make errors when analogically reasoning.

Dog is to puppy as cat is to ?

Embodied accounts of cognition argue that the neural structure that instantiates a relational-concept such as 'offspring' is in part formed from representations for the objects commonly found in an instance of what the concept refers to[5, 6]. For example, the concept 'offspring' is in part formed of abstract representations for 'dog' and 'puppy', 'parent' and 'child' etc.

As the neural structure for a relational-concept is formed in part from its associated object-concepts, we argue that the strength of a relational-concept can be determined by measuring how strongly its constituent object-concepts prime each other. We define strength of concept as how easily activation spreads through the neural structure to produce a given conceptual representation.

If strength of necessary relational-concepts impacts upon children's analogical reasoning ability, we predict that how much the concepts used in analogy problems prime each other will predict performance in analogy problems.

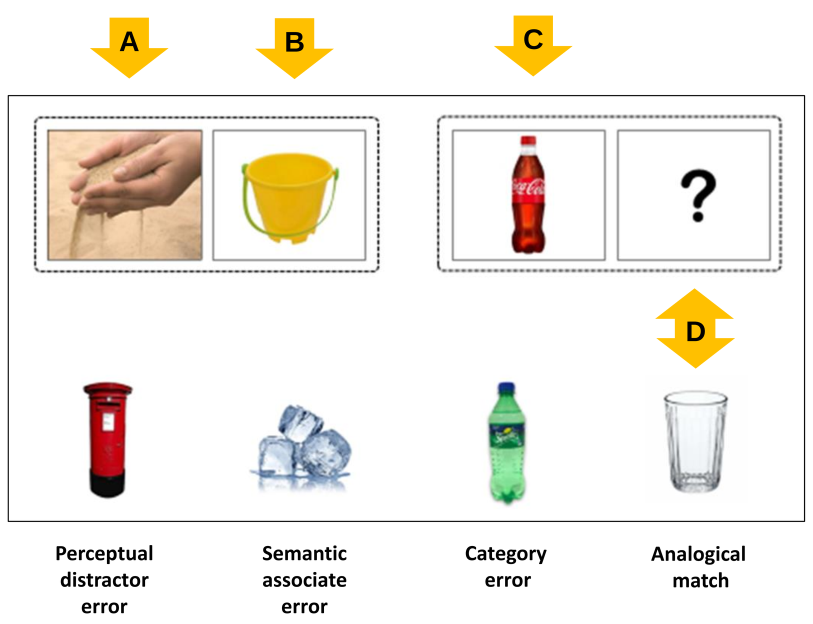
Experiment

Cross-section design, n = 50 TD children (24 female), 5.04-7.65 y/o (*M* = 6.31, *SD* = .83), 60 more participants to test.

Dependent variables: Analogy problems

Nine A:B::C:D proportional analogy problems were used to measure children's analogical reasoning ability. Children received a score for number of responses made for each response type.

The original set of problems comprised of 12 items although 3 were removed as they proved too difficult for the children to answer.



Independent variables of interest: Cued-recall priming task

A cued-recall task was used to measure strength of association between the concepts used in the analogy problems.

Children first listened to word-pairs (cue and target) before having to recall the target words upon hearing the cue words. The word-pairs referred to the A-B and C-D term concepts used in the analogy problems.

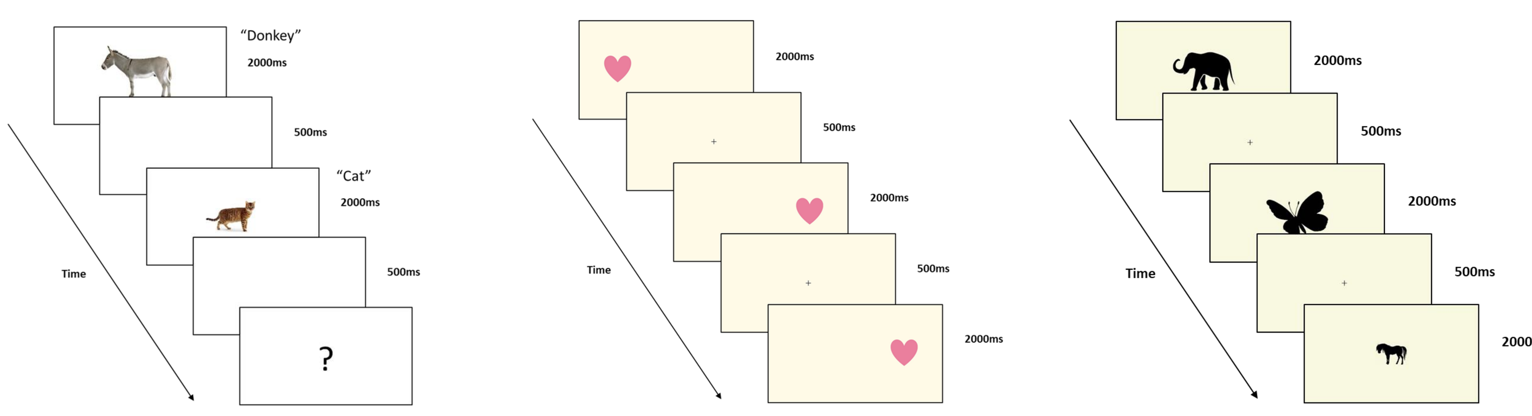
The cued-recall task was completed 10-12 days after the analogy problems.

Mean age of acquisition for the A-B words was 4.01 years (*SD* = .70) compared with 3.31 years (*SD* = .65) for the C-D words.

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

Control variables: Working memory and inhibitory control

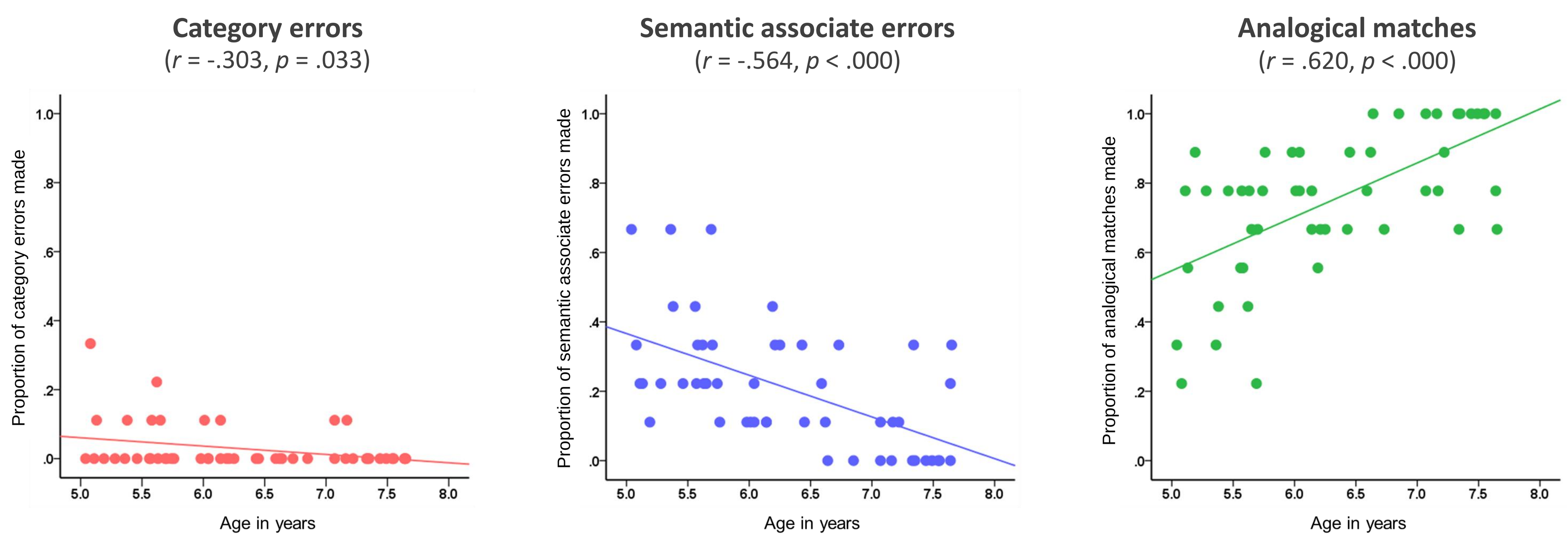
To control for development due to maturation of executive systems, children completed a list sorting working memory task as well as the Hearts and Flowers and Animal Stroop inhibitory control tasks.



Preliminary results

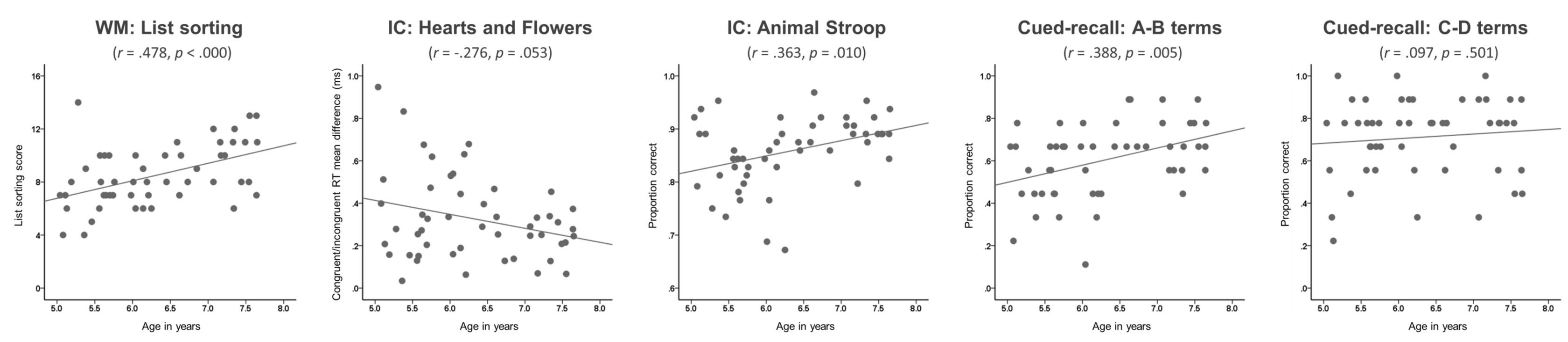
Analogy problem response type across age-range

In line with previous research, semantic associate errors decreased with age and analogical matches increased with age. The majority of children did not make category errors with only four children making one perceptual error each.



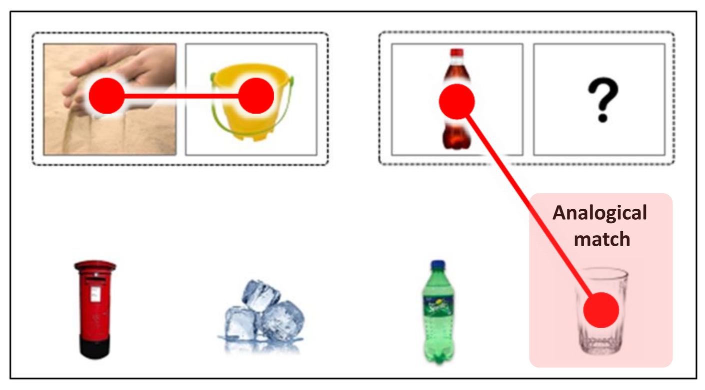
Predictor variables across age-range

All IV measures showed increasing performance with age apart from cued-recall for the C-D terms. This may be due to the lower age of acquisition for C-D items compared with A-B items.



What predicts analogical matches?

Cued-recall for both the A-B and C-D terms in the analogy problems independently predicted successful analogical reasoning. Working memory trended towards significance with poorer performance in the Animal Stroop IC task unexpectedly predicting successful analogical reasoning.



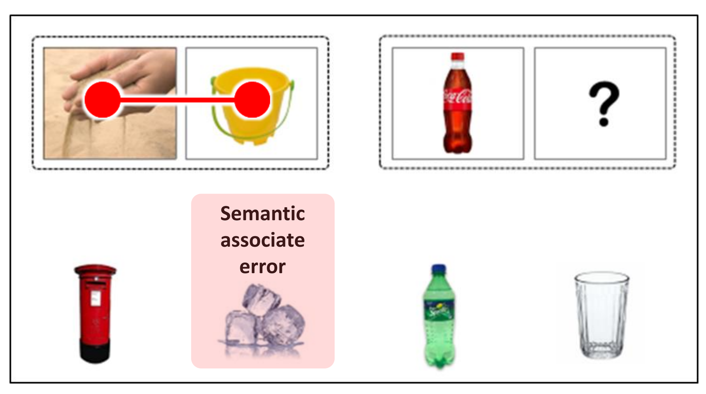
DV: Number of correct analogical matches

	Model 1			Model 2			Model 3		
	B	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*
Age	.155	.028	**.620*****	.132	.034	**.527*****	.100	.031	**.401****
WM: List sorting				.025	.011	**.278***	.019	.010	.210^
IC: Hearts & Flowers				-.049	.121	-.047	-.139	.109	-.133
IC: Animal Stroop				-.451	.377	-.143	-.756	.346	**-.239***
Cued-recall: A-B terms							.462	.133	**.385****
Cued-recall: C-D terms							.236	.111	**.210***
R^2		.385***			.466***			.604***	
R^2 change					.017			.138**	

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ^ $p < 0.1$

What predicts semantic associate errors?

Cued-recall for A-B terms in the analogy problems independently predicted semantic associate errors with better performance in the Animal Stroop IC task unexpectedly predicting semantic associate errors.



DV: Number of semantic associate errors

	Model 1			Model 2			Model 3		
	B	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*
Age	-.120	.025	**-.564*****	-.109	.031	**-.514****	-.082	.029	**-.387****
WM: List sorting				-.016	.010	-.212	-.011	.009	-.146
IC: Hearts & Flowers				.062	.110	.070	.138	.102	.154
IC: Animal Stroop				.521	.343	.194	.795	.322	**.296***
Cued-recall: A-B terms							-.408	.123	**-.400****
Cued-recall: C-D terms							-.172	.103	-.181
R^2		.318***			.389***			.527***	
R^2 change					.032			.138**	

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ^ $p < 0.1$

Conclusions

In line with our predictions, strength of association between concepts in analogy problems predicted both successful analogical reasoning and semantic associate errors whilst controlling for age, working memory and inhibitory control. This supports our hypothesis that strength of conceptual representations plays a key role in the development of analogical reasoning.

We suggest that better Animal Stroop performance negatively predicting analogical reasoning and positively predicting errors could be the result of instability within the models due to sample size or an interaction between inhibitory control mechanisms and strength of concepts. We did not find significant effects for other executive functioning measures although this could well be due to the current power of the regression models. We will be conducting an additional data collection shortly to examine these effects with more power.

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