Comparing Learning Capacity Across Species and Age to Identify Origins of Human Uniqueness

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Background

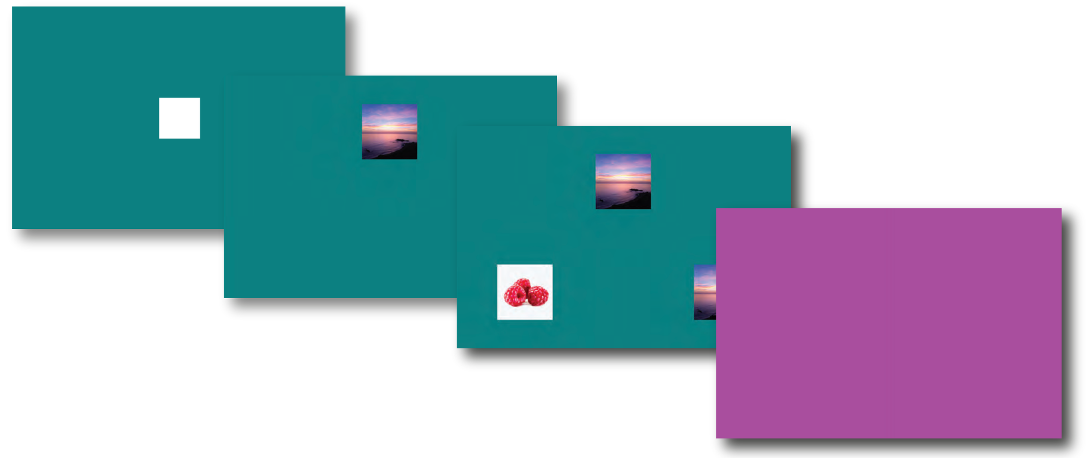
The human brain has tripled in size over the past 3MYA, but brain size alone does not explain differences in human and non-human intelligence.
The new functions afforded by increased human brain size are unclear.

Domain-specific hypotheses claim humans are unique in adaptation to specific skills, such as social competition (Byrne & Whiten, 1988), recursive thought (Ferrigno et al., 2020), relational reasoning (Penn et al., 2008), and cultural transmission (Herrmann et al, 2007).

Dominant theories do not address the learning differences across species and domain-specific tasks; an alternative hypothesis is that general information-processing capacity explains performance differences across domains.

Information processing capacity could describe differences in learning across tasks — both developmentally and evolutionarily.

Methods



Subjects

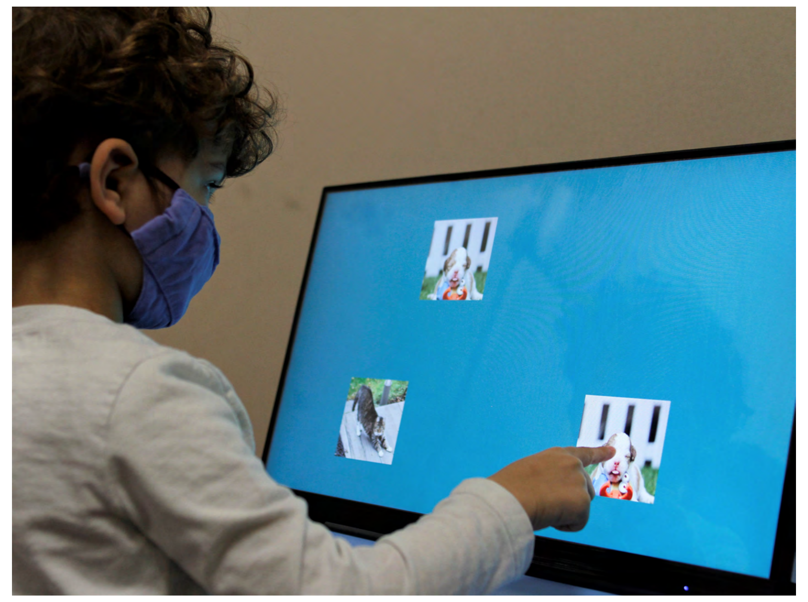
Human Children: (N=20)
Age 3-4 (N=8)
Age 4-5 (N=12)

Monkeys: (N=6)
Macaca mulatta (N=3)
Papio anubis (N=3)

A simple matching task was presented to all subjects. without explanation of the rule. Correct trials were reinforced with a positive tone and purple sceen, and incorrect trials caused a time out of 300ms. Monkeys also recieved a bioserv pellet upon completing a trial correctly.

Total Images: 343 Trials per child: 40-280 Trials per monkey: 4k-22k

CMU Children's School



The Primate Portal (Seneca Park Zoo)

Model & Analyses

Logistic Growth: Stages

Initial learning, low accuracy
Improvement, reaching threshold
Plateau, peak performance

Parameters

Prior understanding – β0
Learning rate – β1
Limit on peak accuracy - lapse

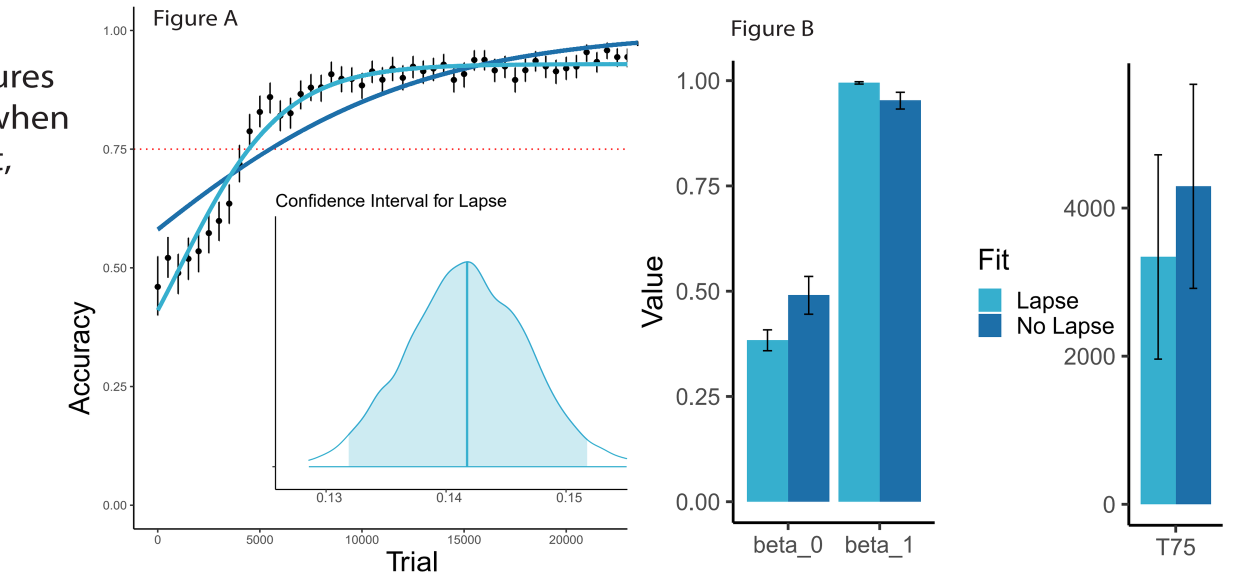
Analyses

Model coded in Stan, assessed using RStan
Individual parameters computed by converging 4 chains of Bayesian analysis over 5000 iterations
Average 95% CI range - Lapse (0.24) β0 (0.24) β1 (0.47)

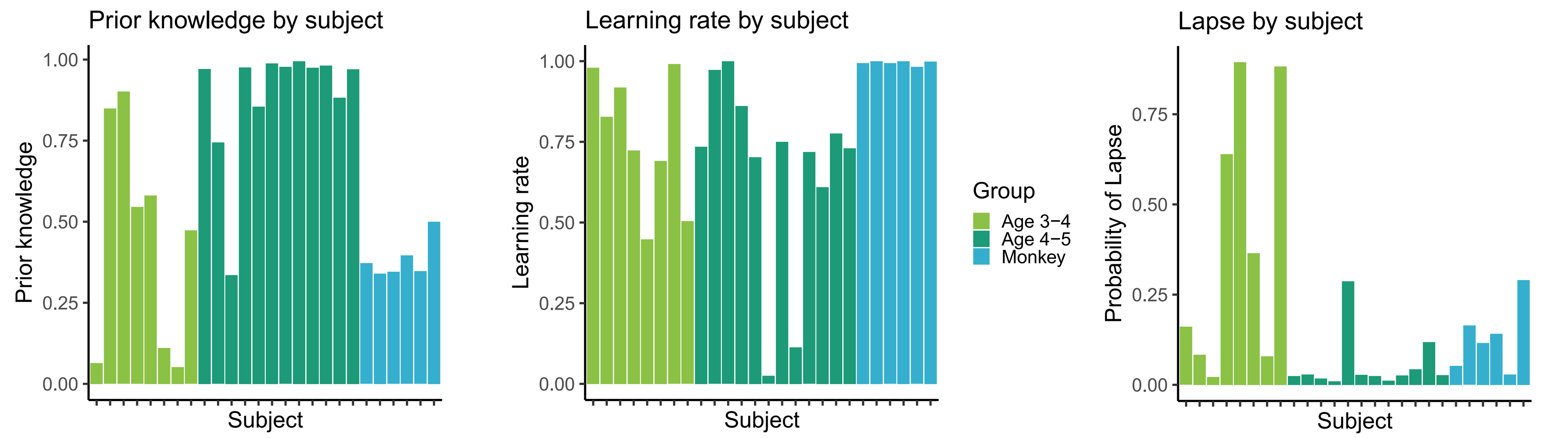
Figure A is a comparison of the logistic fit to individual data with and without lapse, the probability a trial response will be incorrect due to executive function constraints alone.

More accurate measures of learning, such as when 75% threshold is met, are made with this model (Figure B).

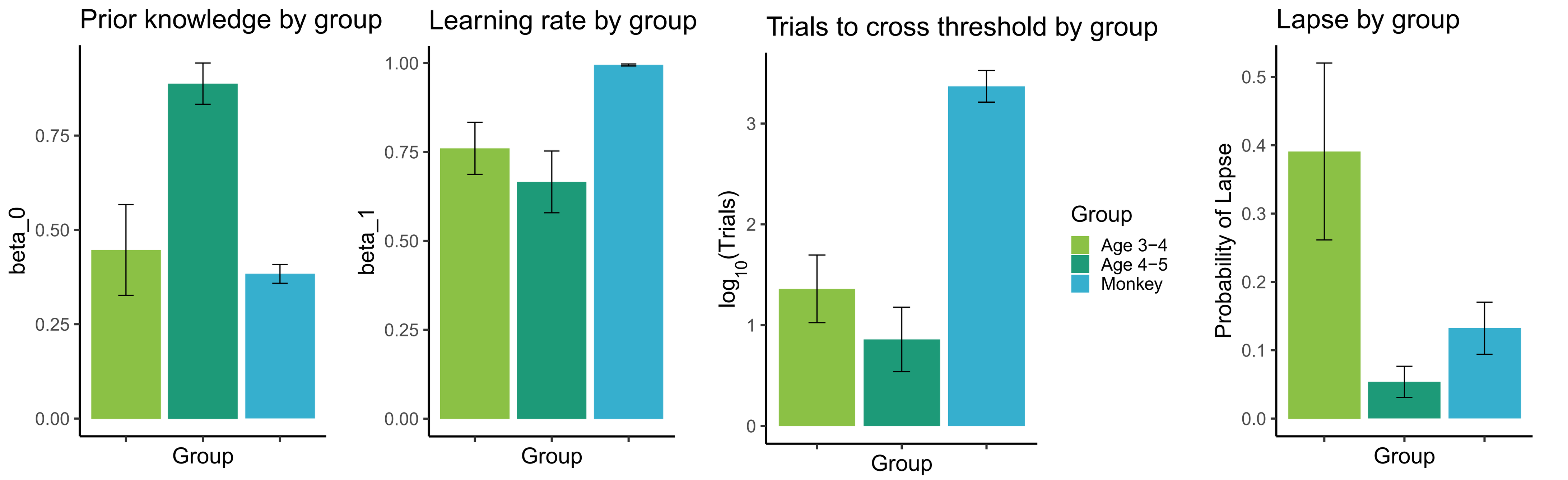
$$\frac{1 - lapse}{1 + e^{-(\beta_0 + \beta_1 x)}}$$



Within-Group Comparison



Group Comparison



Conclusions

Lapse models account for learning better than non-lapse models across species and age groups.

Children age 4-5 exhibited highest prior knowledge (Mean β0 = 0.89), followed by children age 3-4 (Mean β0 = 0.45), and monkeys (Mean β0 = 0.39)

Monkeys had the highest learning rate (Mean β1 = 0.99), followed by children age 3-4 (Mean β1 = 0.76), with children age 4-5 learning most slowly (Mean β1 = 0.67)

Children reached 75% threshold far before monkeys (Mean difference = 3205 trials)

Lapse rate in humans quickly decreased with age, (3-4 Mean = 0.39, 4-5 Mean= 0.05) and monkeys exhibited a moderate lapse rate in comparison (Mean = 0.13)

Information processing capacity could distinguish human learning from non-human learning early in development.

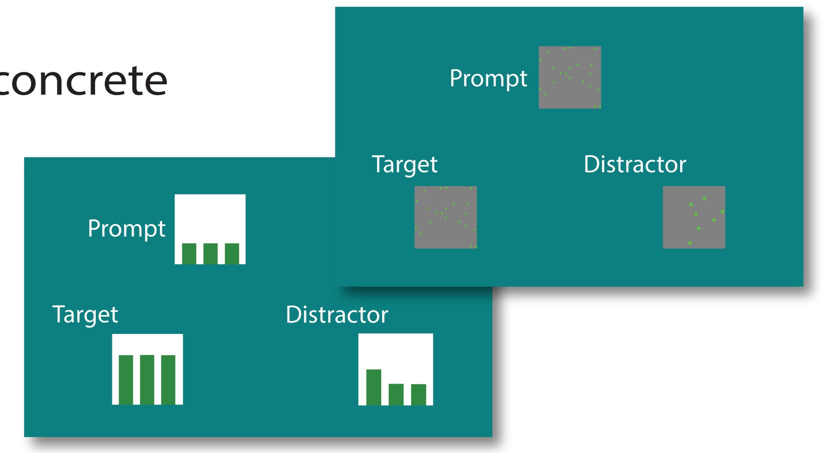
Future Directions

To better understand how general learning capacity impacts the learning of logically complex tasks, we are presenting novel stimuli that will allow for direct comparison of similarities between target and distractor.

Numerosity - Comparison of ratios and visual noise between stimuli

Relational - Comparisons of patterns or concrete measures within and between stimuli

In this stage we will parameterize relational complexity within the preexisting lapse model.



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