

Exploring relations between approximate number processing skills, eye movements, and math ability

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Kids' Thinking Lab

Brain Bag, Fall 2020



University of
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Many decisions are guided by our intuitions of quantity

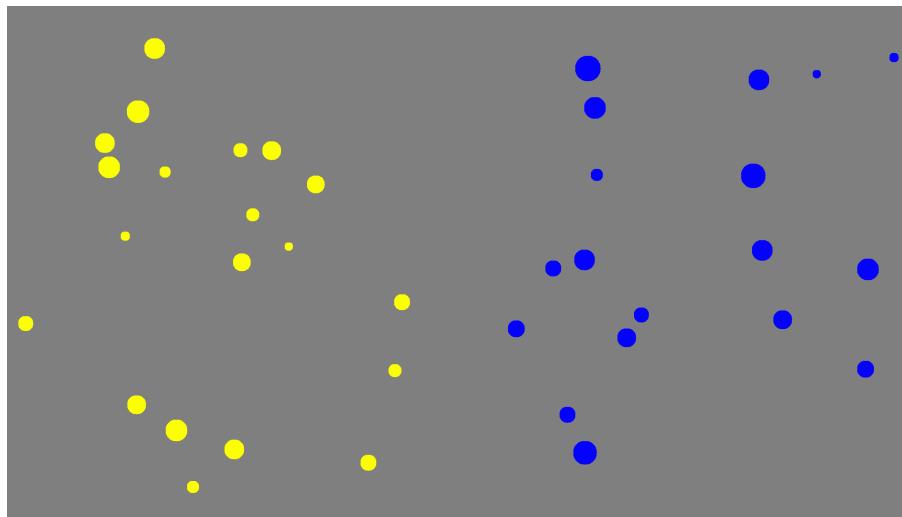
- This “number sense” supported by the approximate number system (ANS)
- The ANS underlies our ability to rapidly and intuitively estimate and compare quantities > 4

Big question: How are people making choices involving approximate quantities?

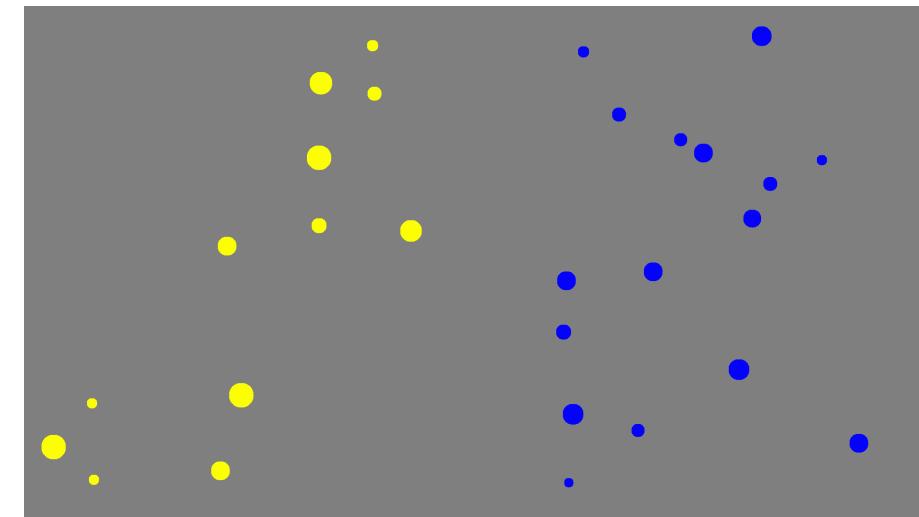


Indexing approximate number processing skills with a dot comparison task

- “Are there more yellow or blue dots?”
- Performance is ratio-dependent
- Individual differences in approximate number processing skills are associated with children and adults’ formal math abilities



1.11 (20 to 18 dots)



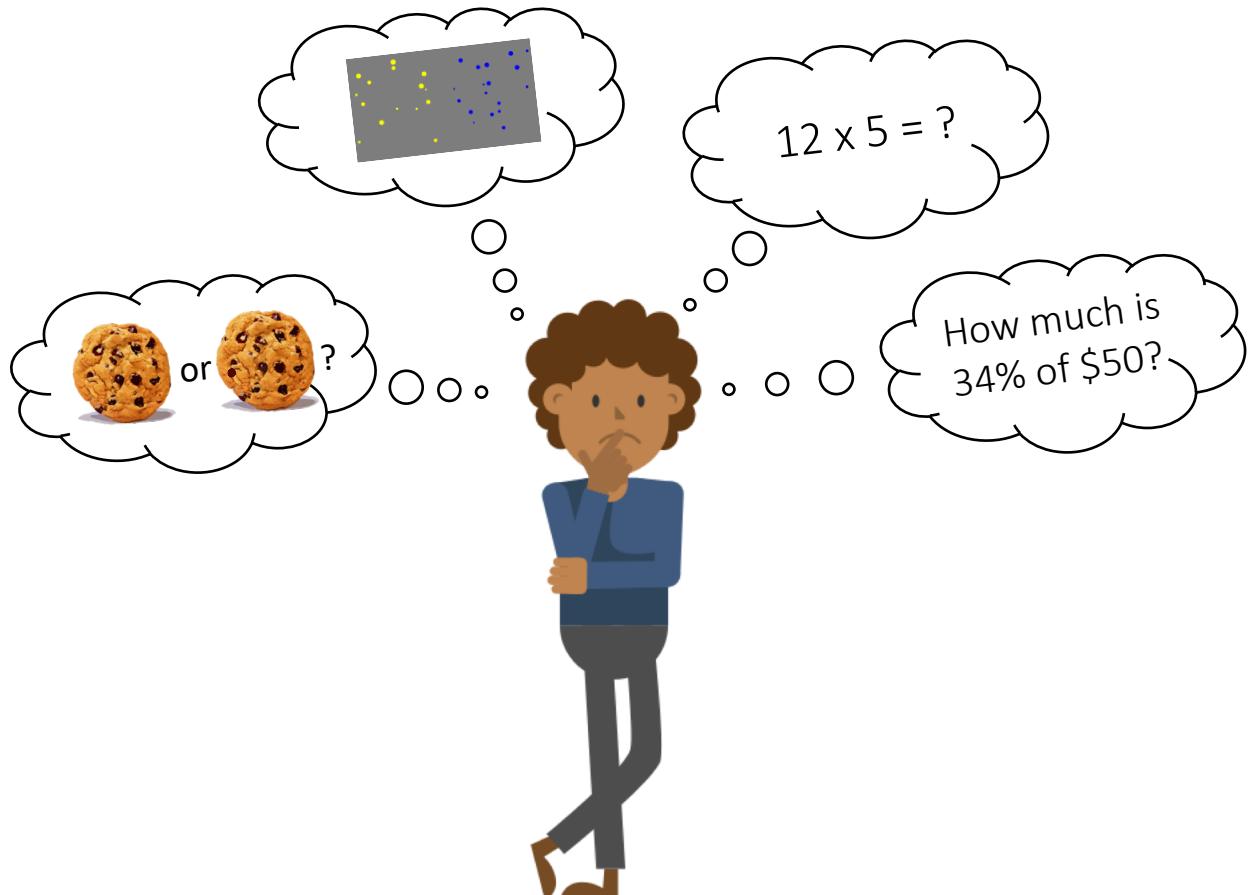
1.33 (16 to 12 dots)

Approx. # processing skills relate to formal math ability

- How are math skills measured?
 - Rapid and mental arithmetic
 - Applied word problems

RQ 1a: Does math ability relate to approximate number processing skills?

RQ 1b: Does it matter how we measure math skills?



Eye movements during dot comparison may reflect information processing or task difficulty

Individuals tend to...

- Gaze longer at more numerous arrays
- Spend more time looking at the array that they end up selecting as the one with “more”
- Switch between arrays more often as the trials increase in difficulty (e.g., ratio of larger to smaller quantities → 1)

Mental arithmetic?
Math problem solving?

RQ 2: Does frequent switching during dot comparison relate to accuracy?

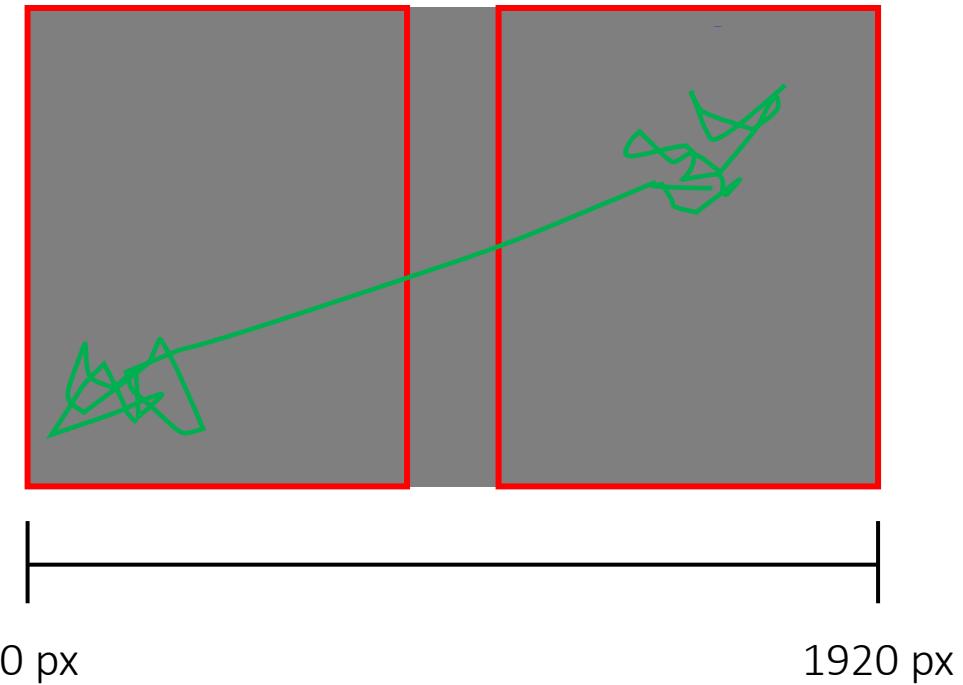
RQ 3: How do math ability and switching frequency ***interact*** to predict accuracy?

Method

- Adult college students ($n=157$, $M_{age}=19.86$ years) participated in a laboratory study
- Participants reported being in their first ($n=84$), second ($n=27$), third ($n=22$), fourth ($n=17$), or fifth year of college ($n=1$)
- Procedure
 - Dot comparison task
 - Math assessments

Dot comparison task

- “Are there more blue or yellow dots?”
- Variables of interest:
 - Accuracy
 - Switching frequency
 - Response time (RT)
 - Ratio



Math assessments

Woodcock-Johnson Tests of Achievement

- *Applied problems* – measured the ability to analyze and solve math word problems
- *Calculation* – measured the ability to perform mathematical computations in a written format (e.g., “Evaluate the definite integral...”)
- *Math fluency* – measured the ability to rapidly complete arithmetic problems (e.g., $4 \times 5 = \underline{\hspace{2cm}}$)

Models

Does math ability relate to approx. # processing skills?

$$Y_{\text{approx.number}} = \beta_0 + \beta_1 X_{\text{math}} + \beta_2 X_{\text{RT}} + \beta_3 X_{\text{ratio}}$$

Does switching frequency relate to approx. # processing skills?

$$Y_{\text{approx.number}} = \beta_0 + \beta_1 X_{\text{math}} + \beta_2 X_{\text{RT}} + \beta_3 X_{\text{ratio}} + \beta_4 X_{\text{switches}}$$

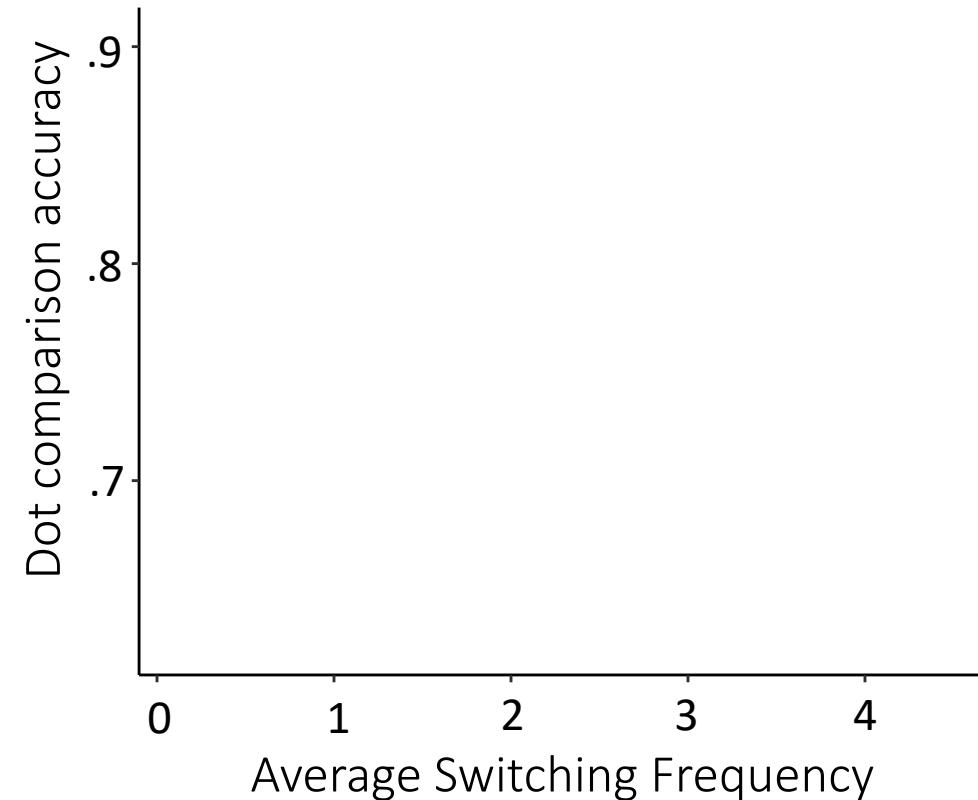
1. Applied Problems
2. Calculation

Does math ability moderate the relation between switching frequency and approx. # processing skills?

$$Y_{\text{approx.number}} = \beta_0 + \beta_1 X_{\text{math}} + \beta_2 X_{\text{RT}} + \beta_3 X_{\text{ratio}} + \beta_4 X_{\text{switches}} + \beta_5 X_{\text{math}} X_{\text{switches}}$$

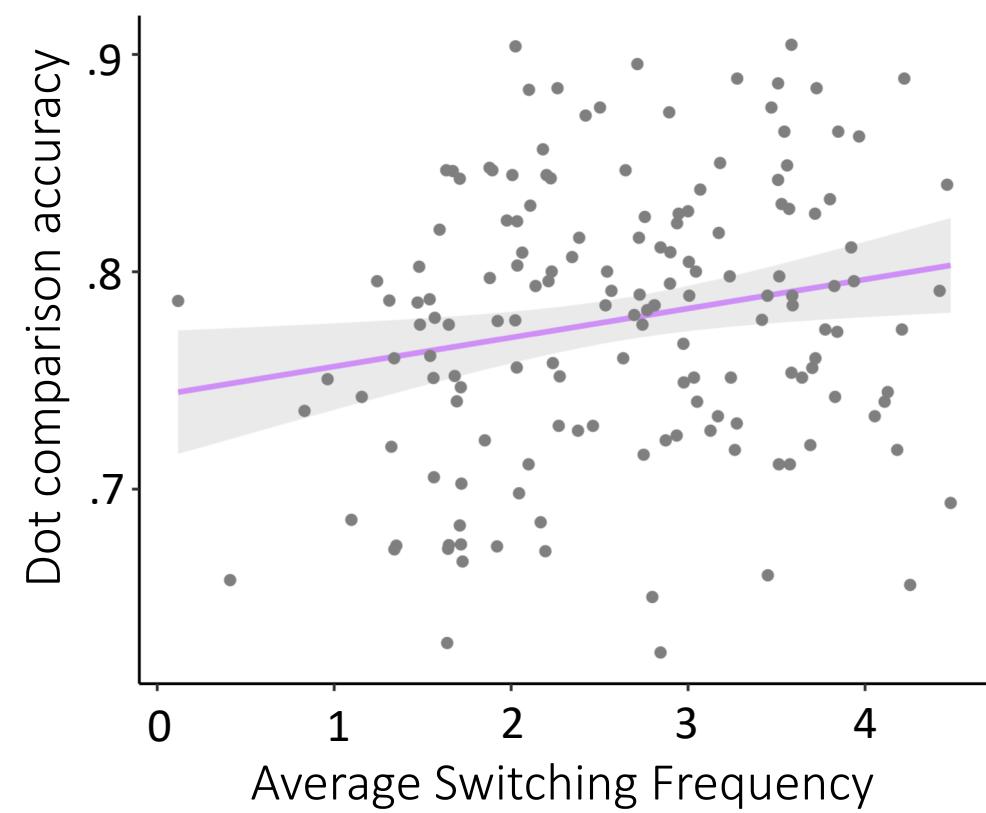
Results

- Math ability related to approximate number processing skills.
- Switching frequency related to approximate number processing.



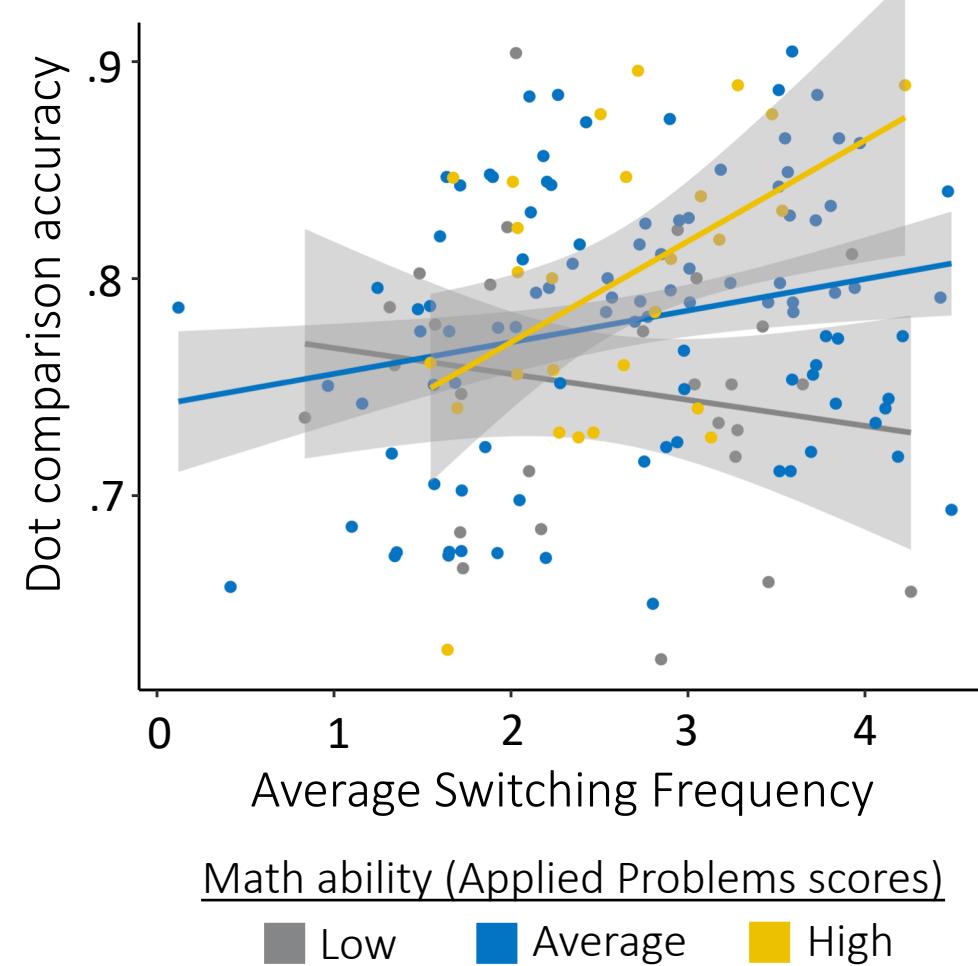
Results

- Math ability related to approximate number processing skills.
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Conclusions

- Math ability and switching frequency relate to approximate number processing skills.
- Individuals' applied math problem solving abilities modulates the relation between switching frequency and approximate number processing.
 - Differences in Calculation (measured with geometry, trigonometry, calculus problems) depend more on the recency of instruction or use of math concepts.
 - Differences in Math Fluency (rapid arithmetic) reflect the ability to recall math facts.

Conclusions

What does the significant interaction between switches and math ability mean?

Do switches index one construct (e.g., information processing)?

- High math → gathering and processing relevant info
- Low math → not obtaining, integrating, or retaining relevant info

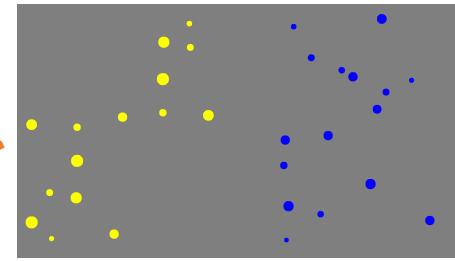
Do switches mean different things to different people?

- High math → information processed
- Low math → state of uncertainty

Limitations and future directions

- Inclusion of other ET metrics (e.g., fixation duration, pupil dilation)
 - Are switches a unique signature of a cognitive process?
- Control for visual working memory and/or inhibitory control
- Are eye movement patterns reflective of a stable individual trait or are they driven by state changes?

Pooh trying to figure out which side has more dots:



*computers weren't around
when Pooh was born so
scientists used paper

Thank you for listening!

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Darko Odic

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