Adults and preschoolers seek visual information to support language comprehension in noisy environments

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Language and Cognition

Language Learning Lab
Center for Infant Studies

COGSCI 2018
changing / minds

Yurovksy et. al., 2015

“Look at the ball!”

Yurovksy et. al., 2015

"Look at the ball!"

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"Look at the ball!"

how do children understand language despite **noisy input** and **constraints** on processing capabilities?

Yurovksy et. al., 2015

Bloom, 2002; Clark, 2009; Lieberman et al., 2014

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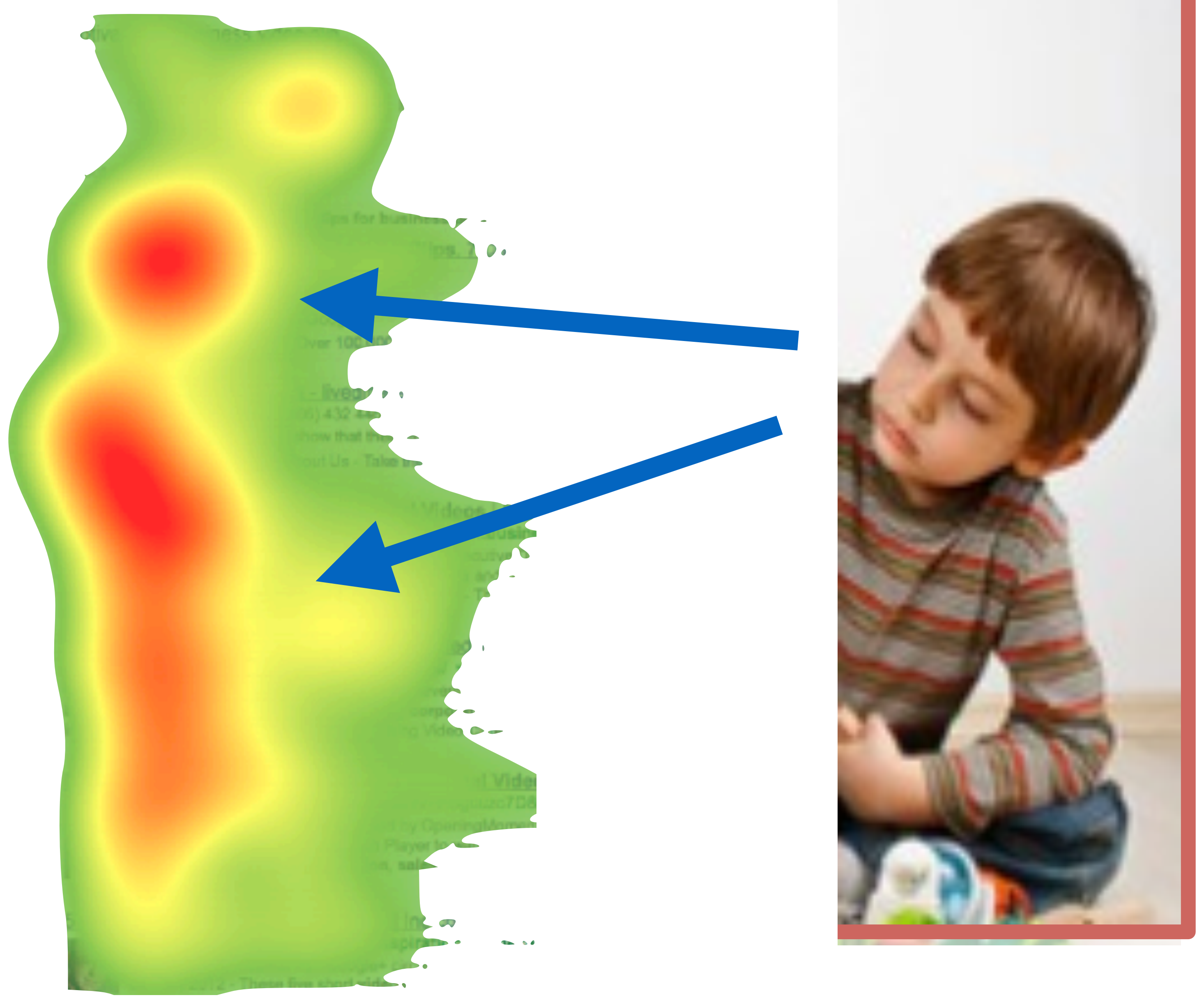

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How do listeners decide what (and how much) visual information to gather during language comprehension?

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Theory: eye movements as foraging decisions to gather language-relevant information

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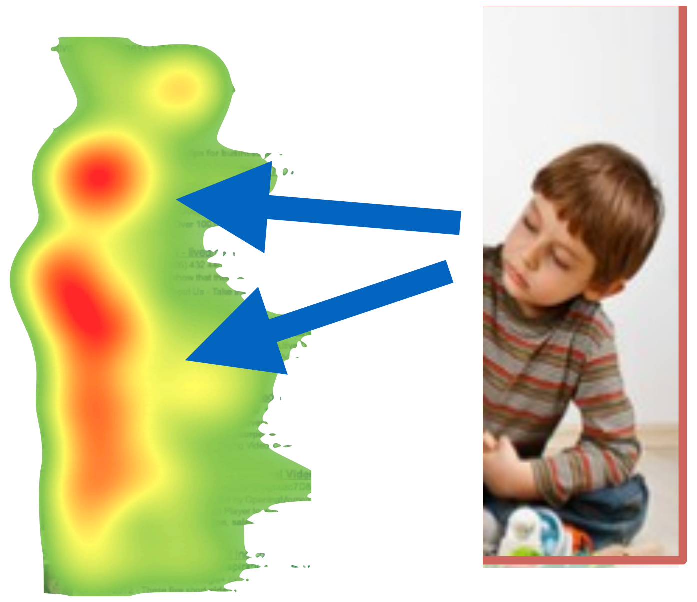
Theory: eye movements as foraging decisions to gather language-relevant information

Experiment: compare dynamics of eye movements during noisy vs. clear speech processing [**children & adults**]

Eye movements as foraging for language-relevant information

Hayhoe and Ballard (2005); Salverda et al., (2011)

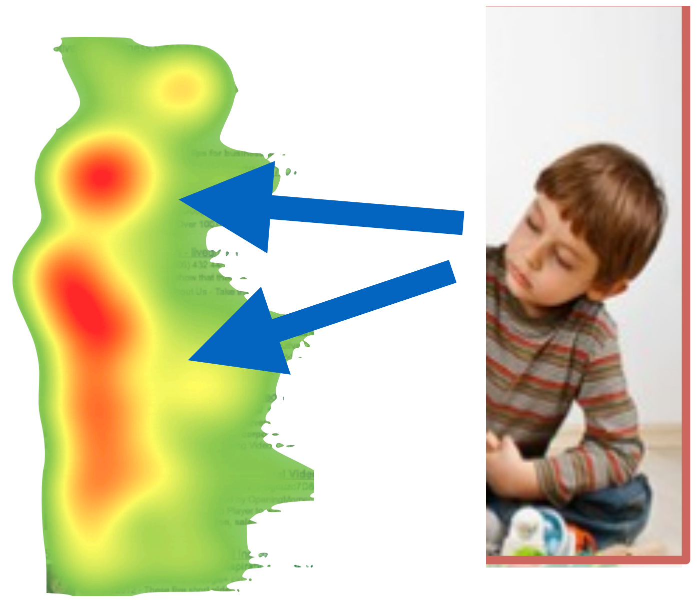
Eye movements as foraging for language-relevant information



$$\frac{\textbf{\textit{Information}}}{\textbf{\textit{Time}}}$$

Hayhoe and Ballard (2005); Salverda et al., (2011)

Eye movements as foraging for language-relevant information



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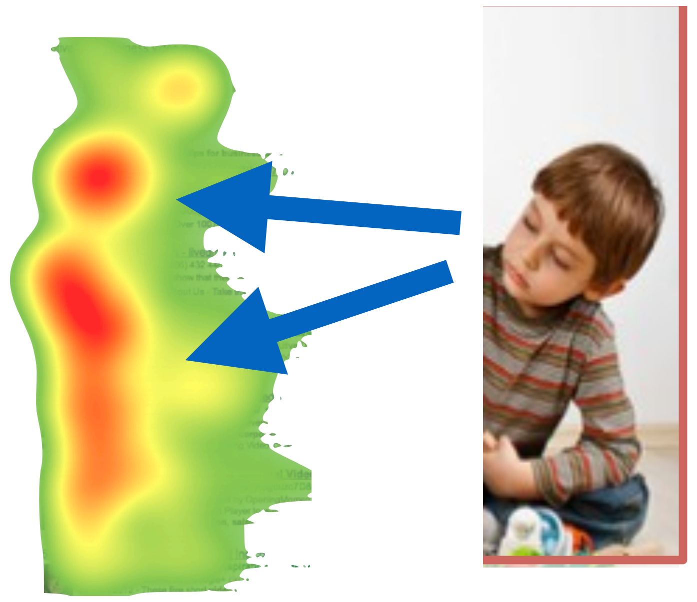

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Lower ⟷ Higher

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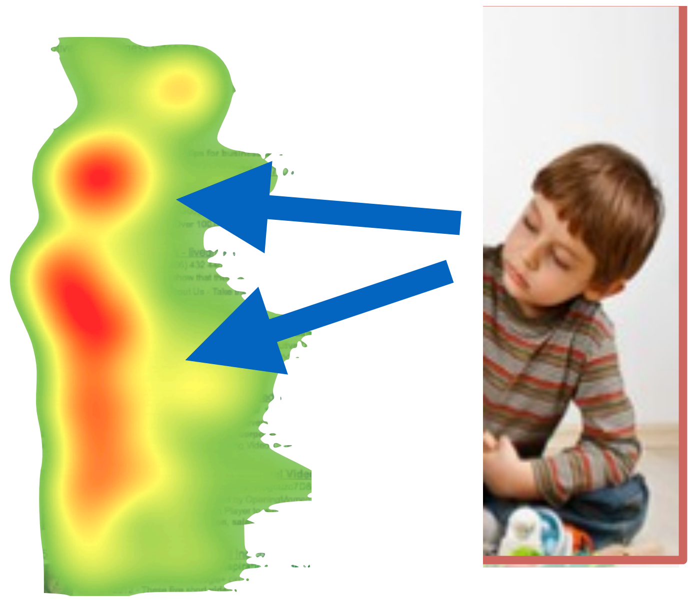

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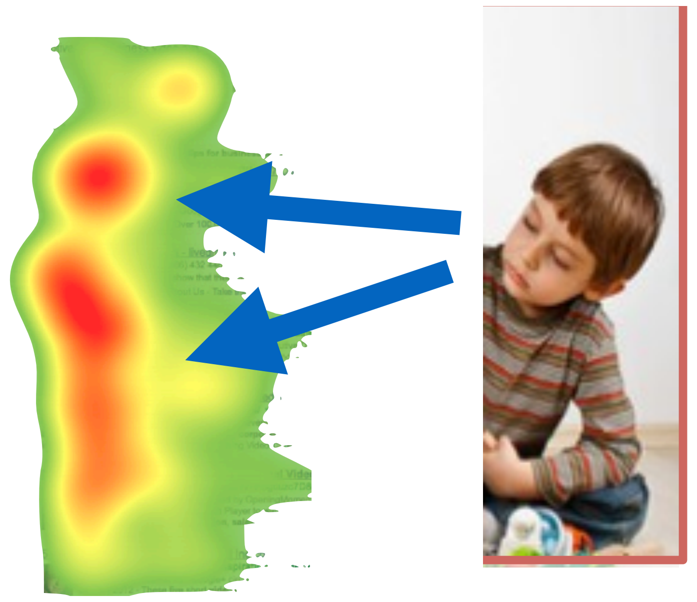

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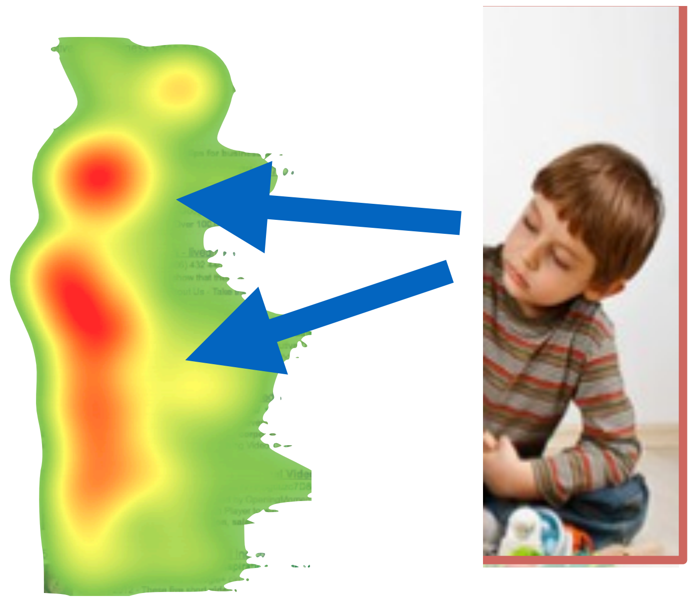

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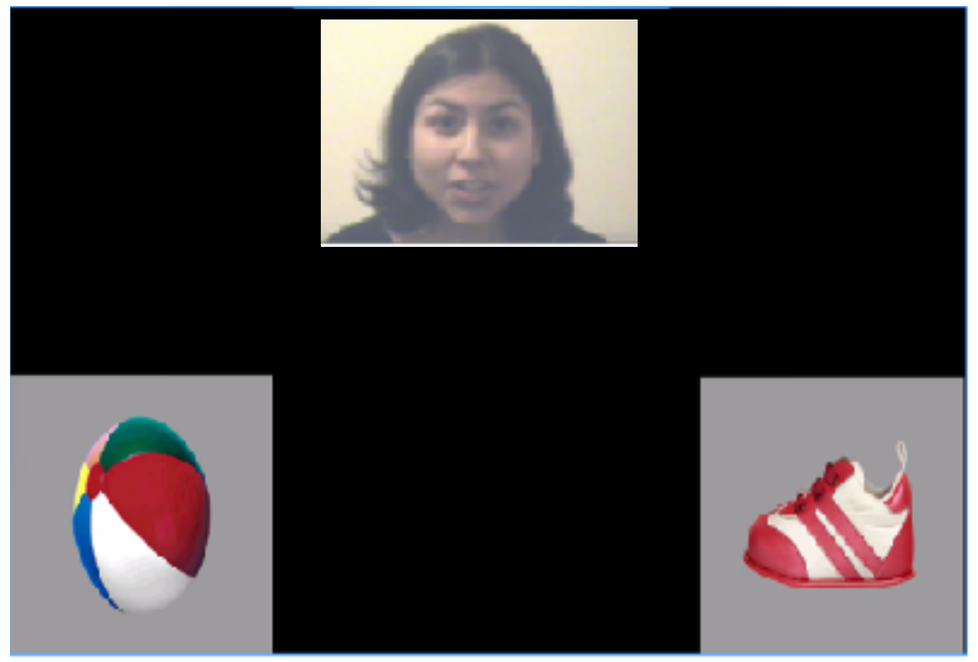
Comparing eye movements of children learning sign vs. spoken language

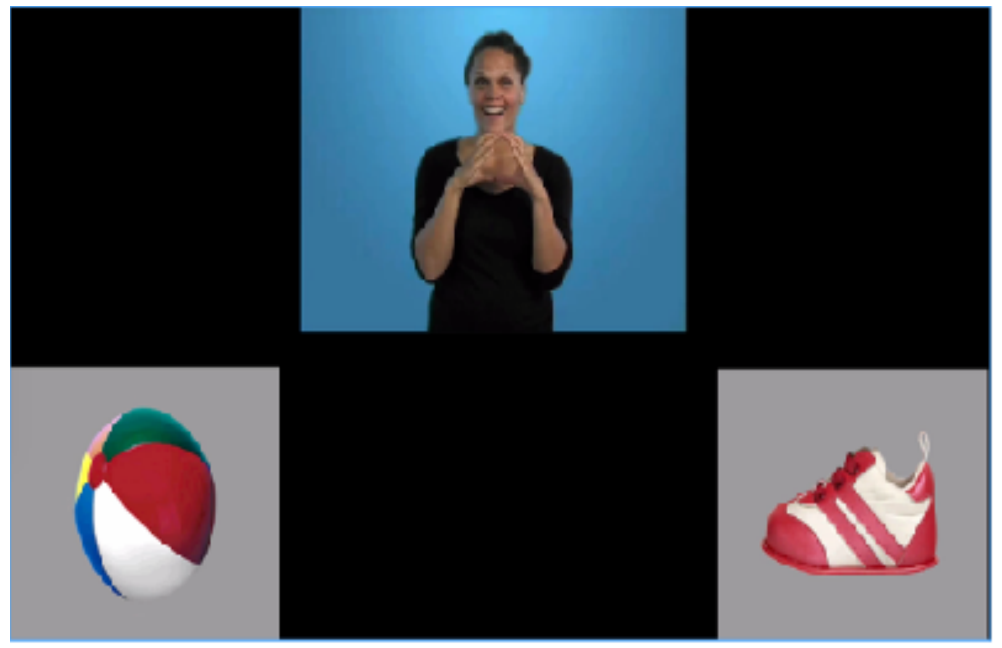
MacDonald et al. Cog. Sci. (2017); Dev. Sci. (2018)

Comparing eye movements of children learning sign vs. spoken language

English



ASL



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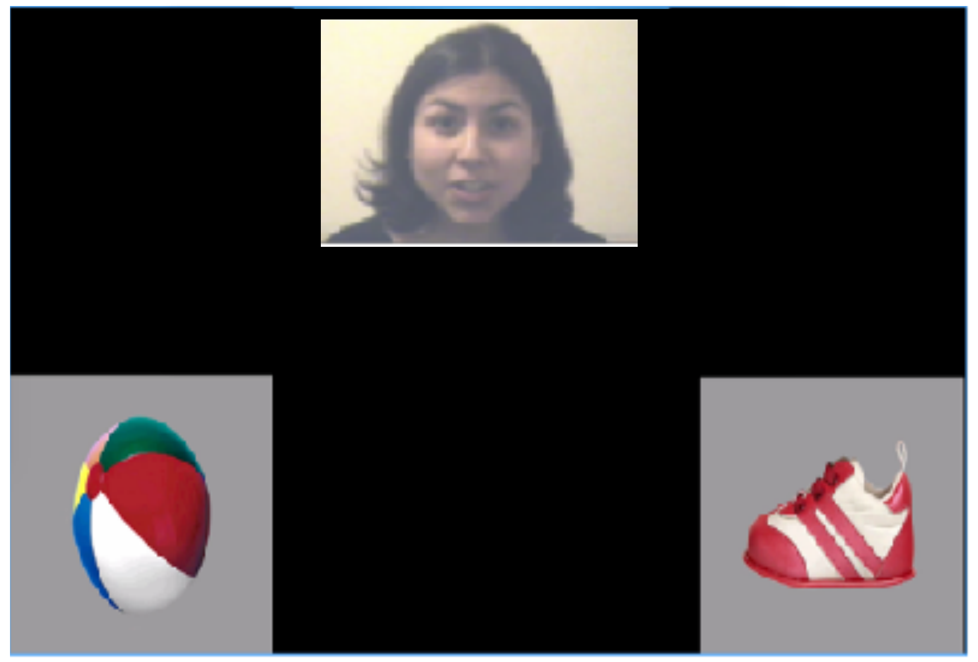

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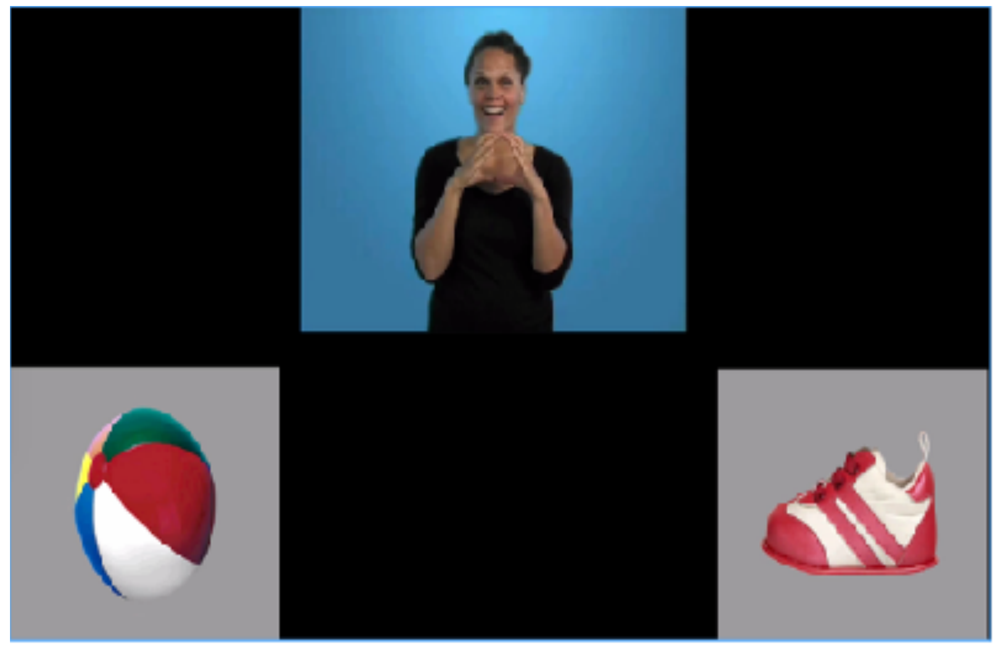

ASL learners:

MacDonald et al. Cog. Sci. (2017); Dev. Sci. (2018)

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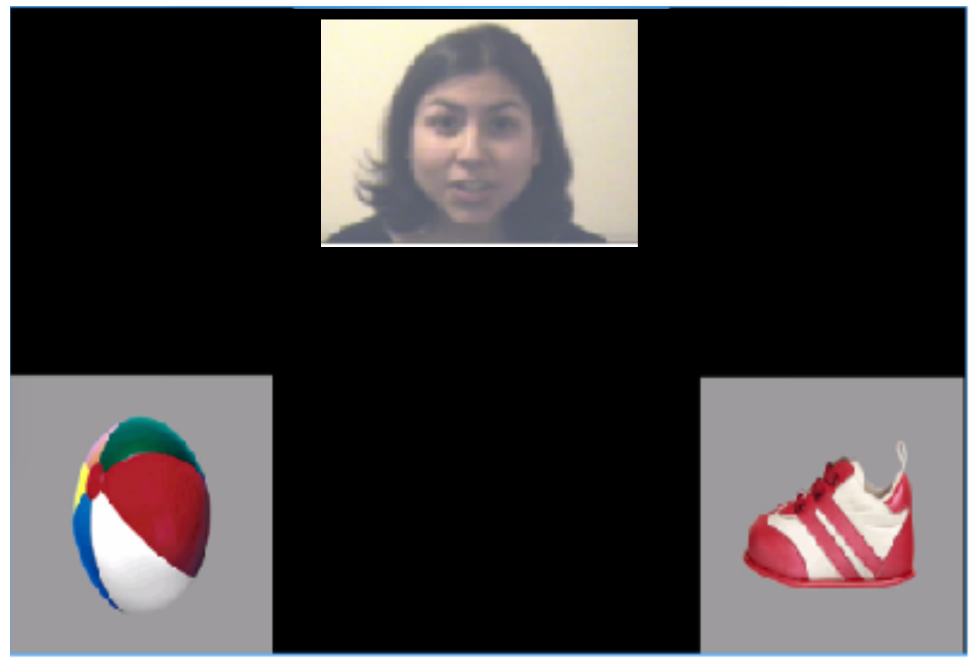

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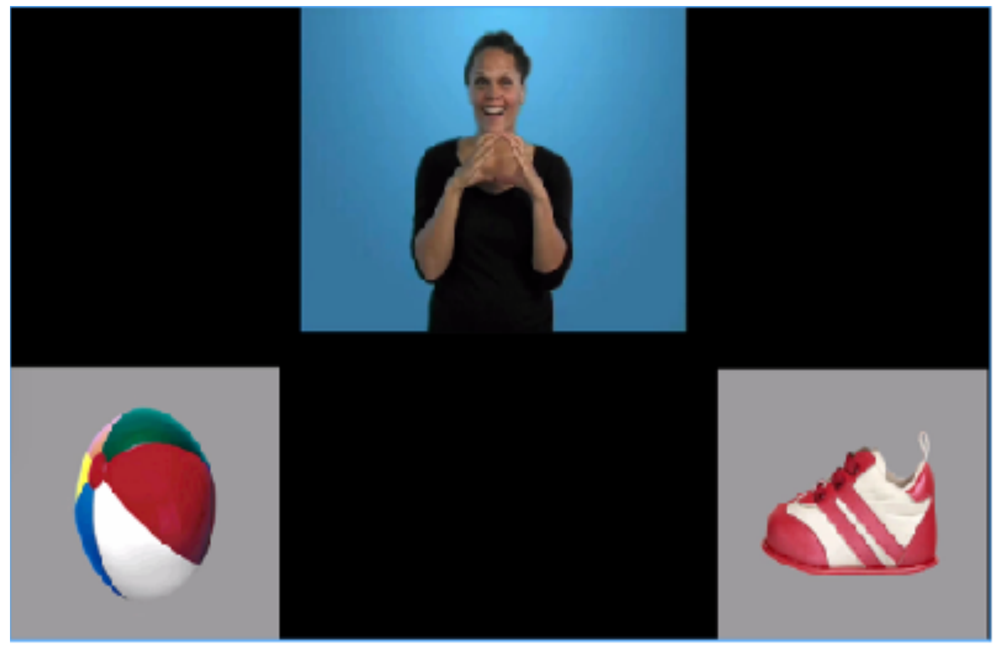

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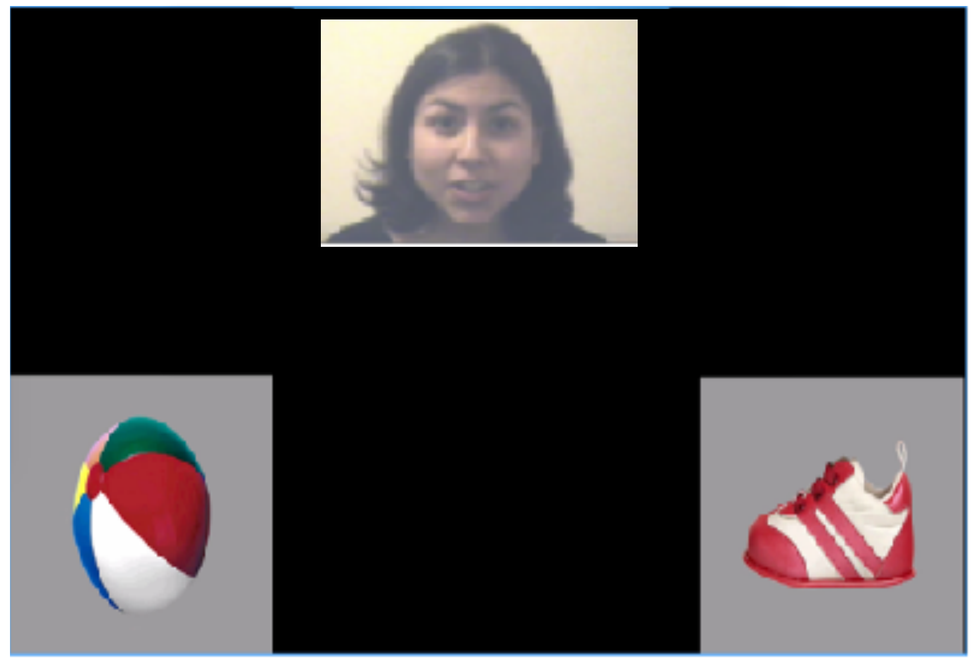

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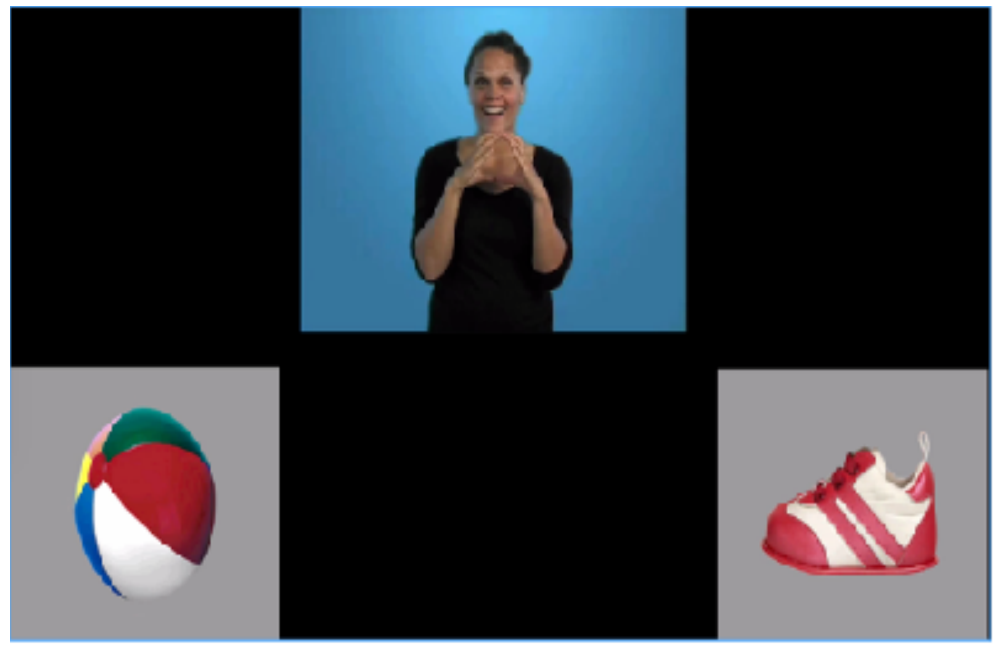

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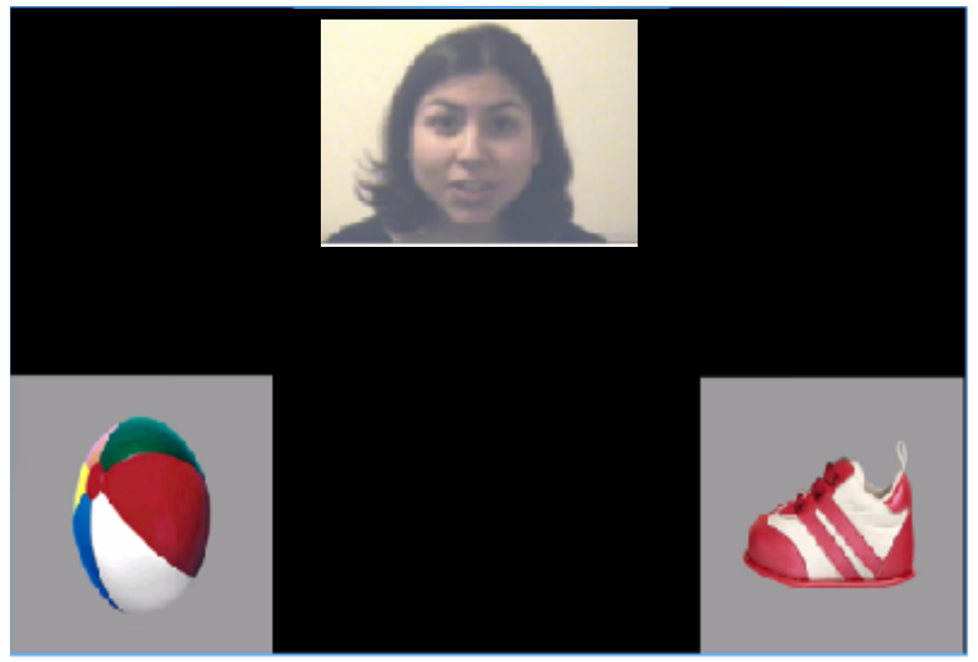

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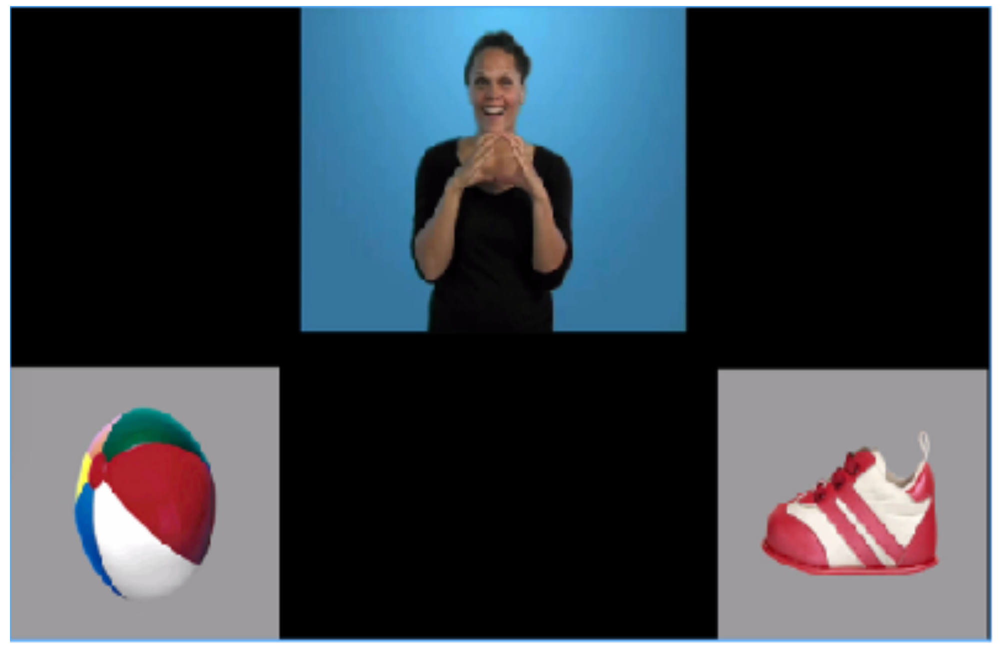

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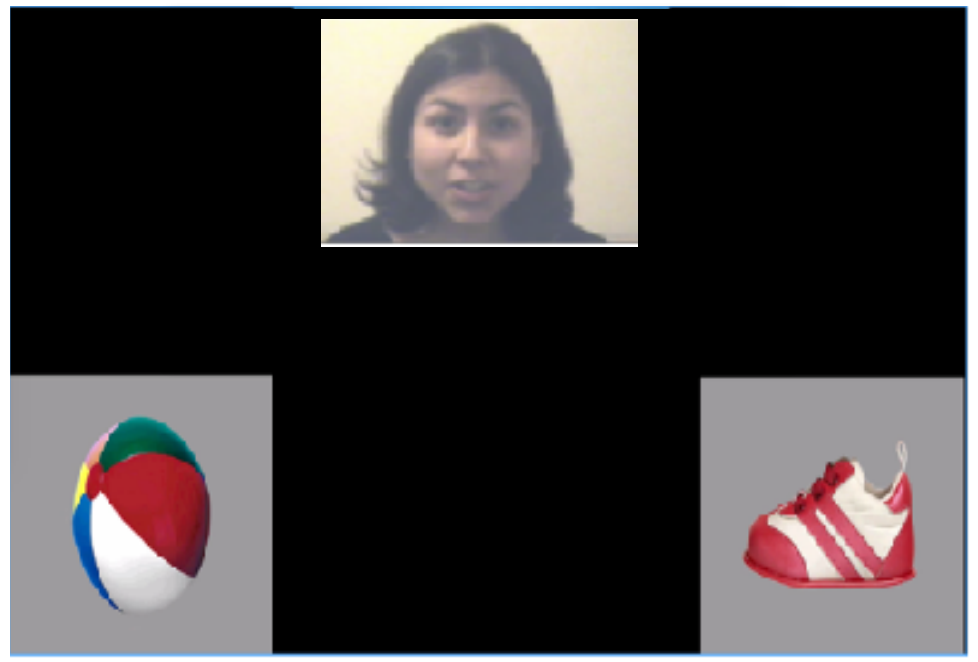

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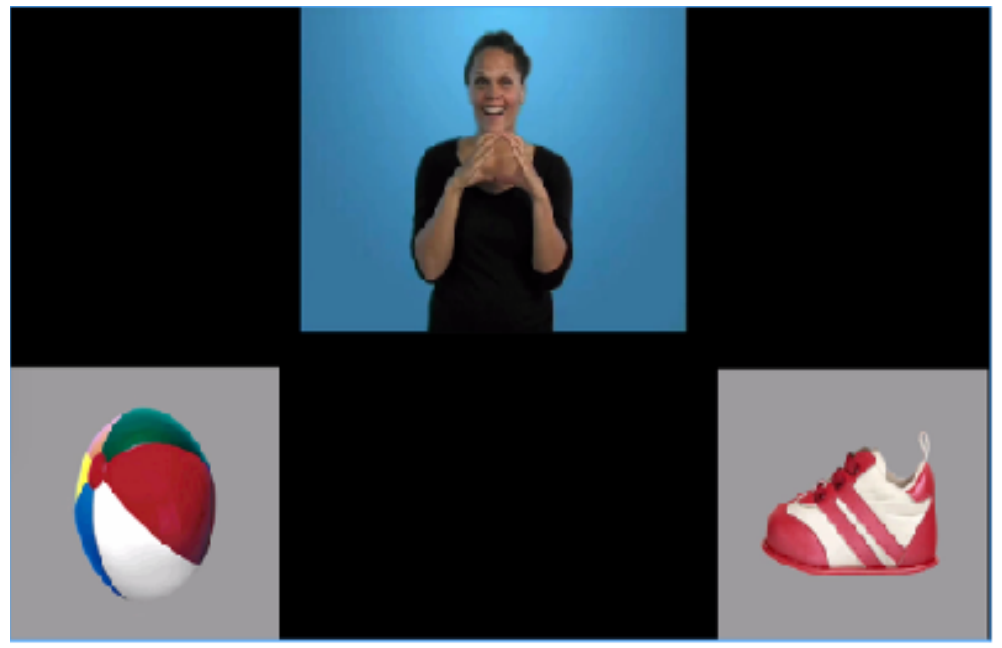

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ASL learners gather more information prior to generating an eye movement

MacDonald et al. Cog. Sci. (2017); Dev. Sci. (2018)

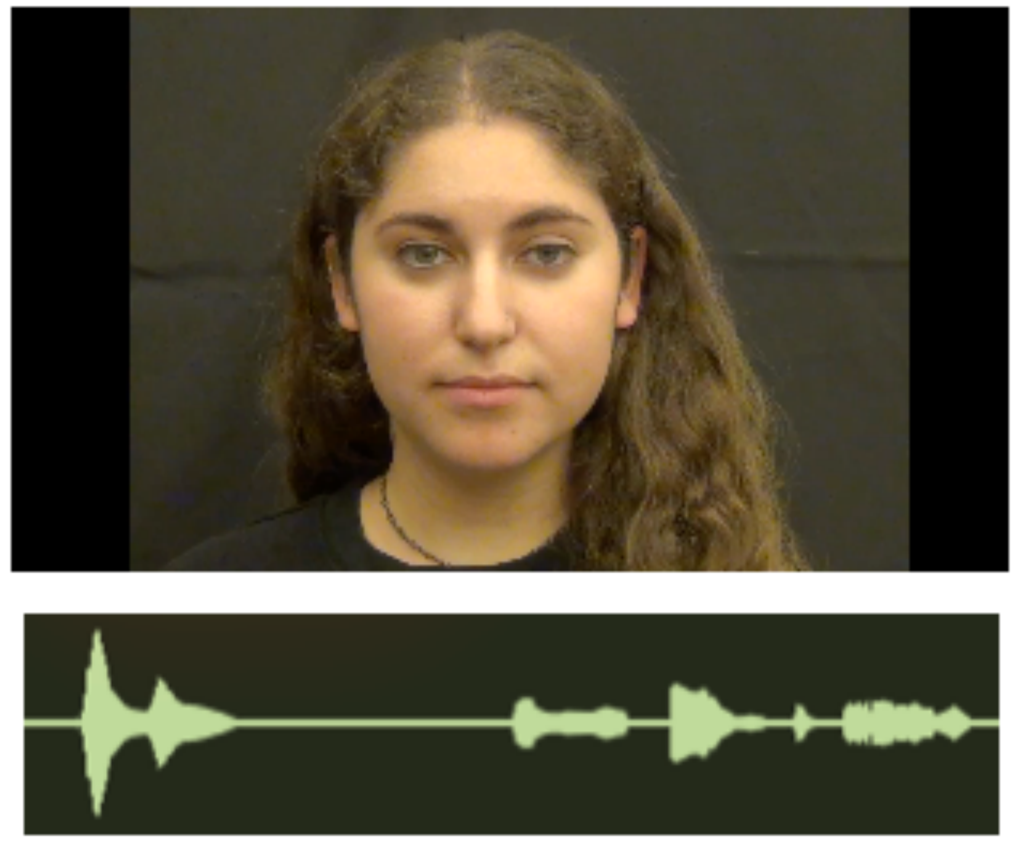
Experiment: children and adults processing of clear vs. noisy speech

n_adults = 31; undergrads (2 blocks of 32 trials)
n_kids = 39; 3-5 year-olds (2 blocks of 16 trials)

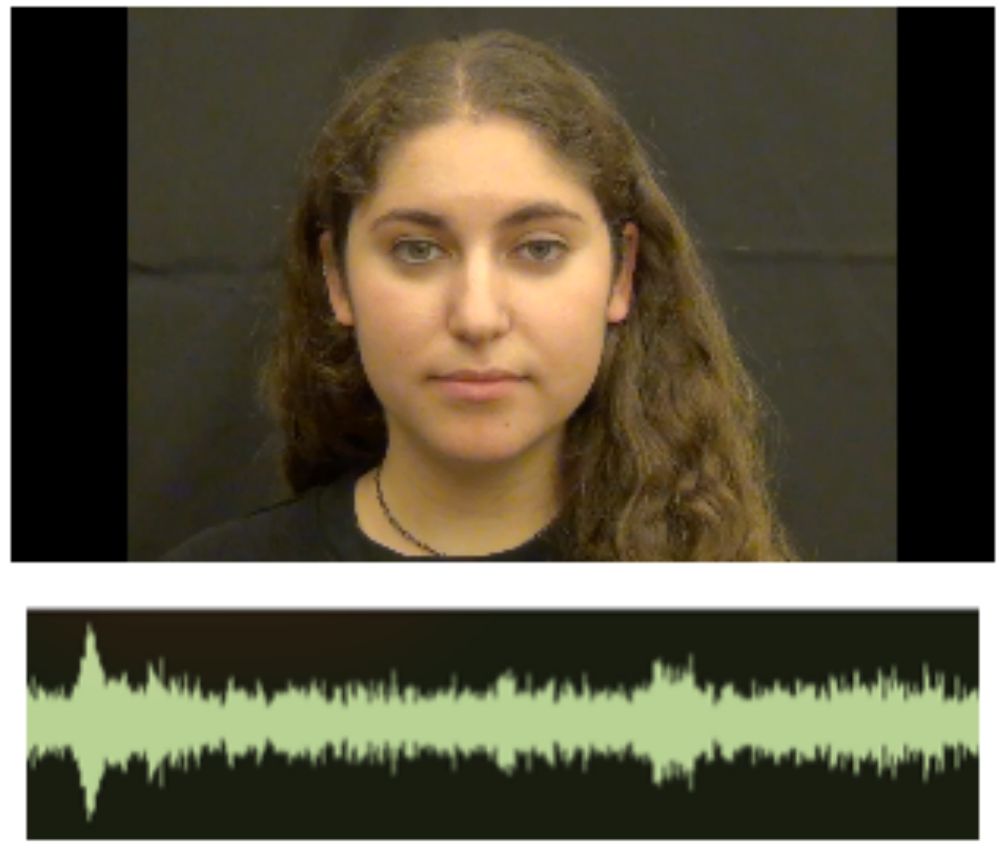
SNR clear = 35 dB
SNR noise = 2.87 dB

Experiment: children and adults processing of clear vs. noisy speech

clear



noisy



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Look! Where’s the **boat**?

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Images appear for 2s prior to center stimulus

Look! Where's the **boat**?

Images appear for 2s prior to center stimulus

Center stimulus appears

Carrier phrase

Look! Where's the **boat**?

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Carrier phrase

Target noun onset

2s to look at the images

Look! Where's the **boat**?

Images appear for 2s prior to center stimulus	Center stimulus appears	Carrier phrase	Target noun onset	2s to look at the images

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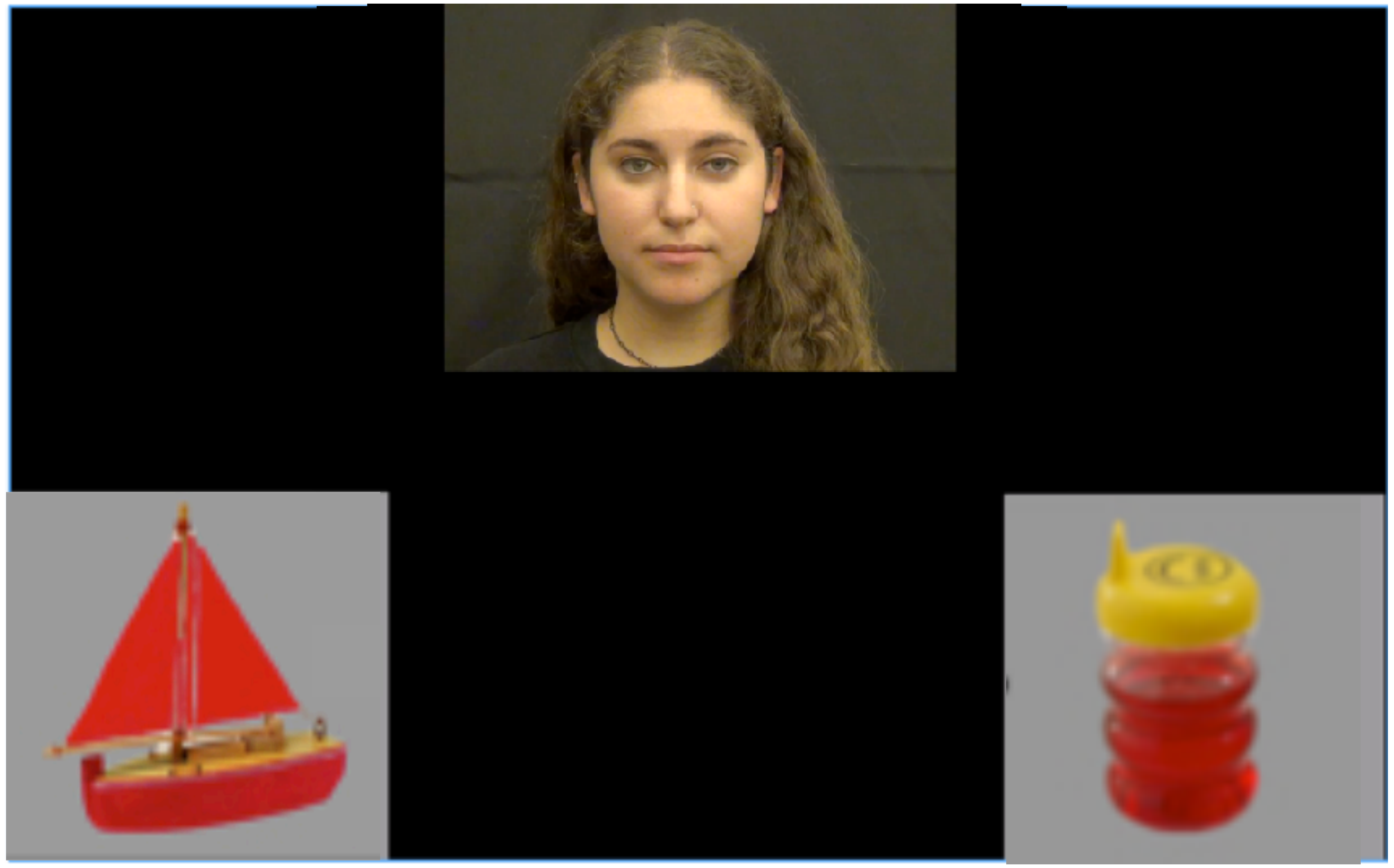

Look! Where's the **boat**?

Images appear for 2s prior to center stimulus

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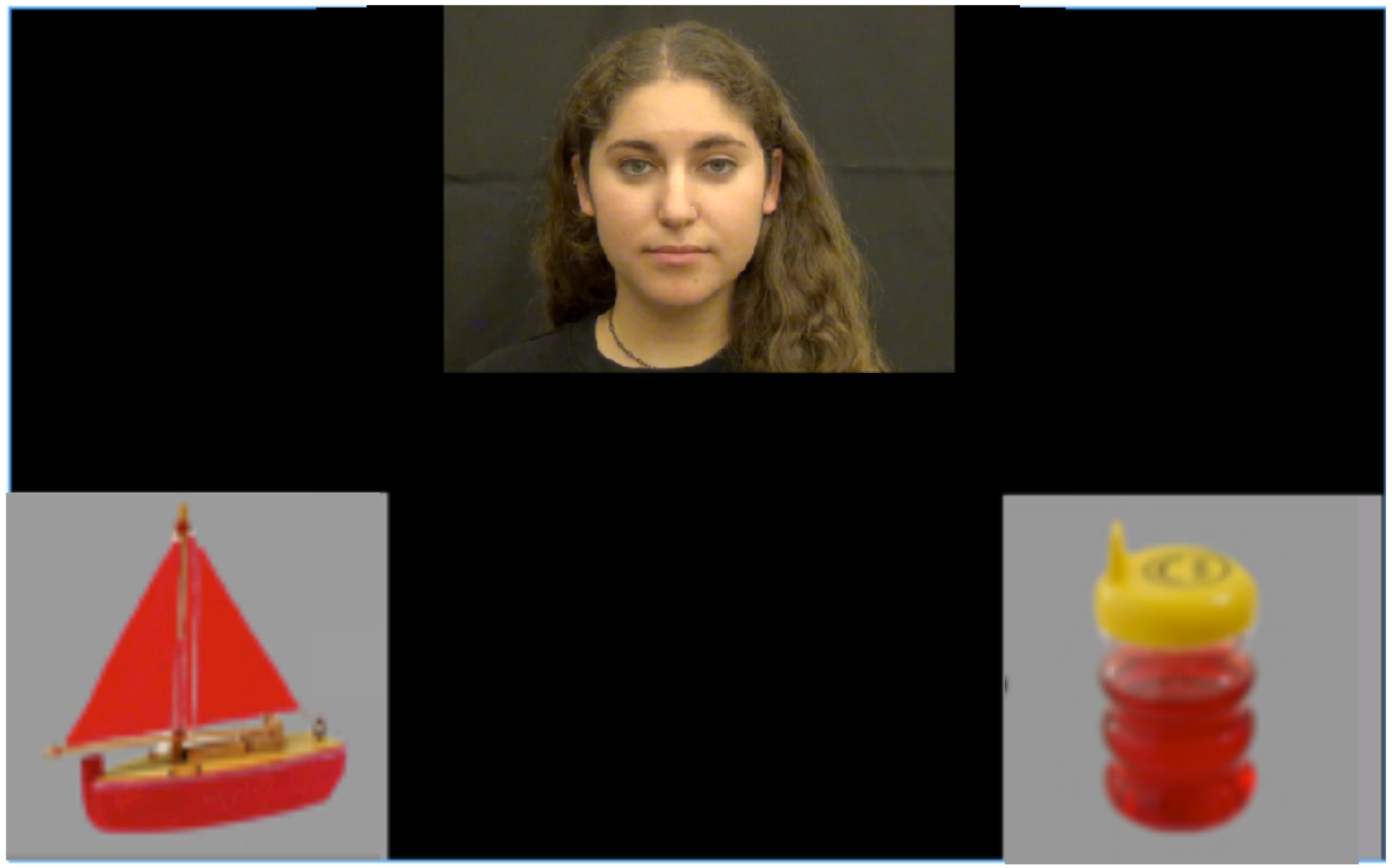
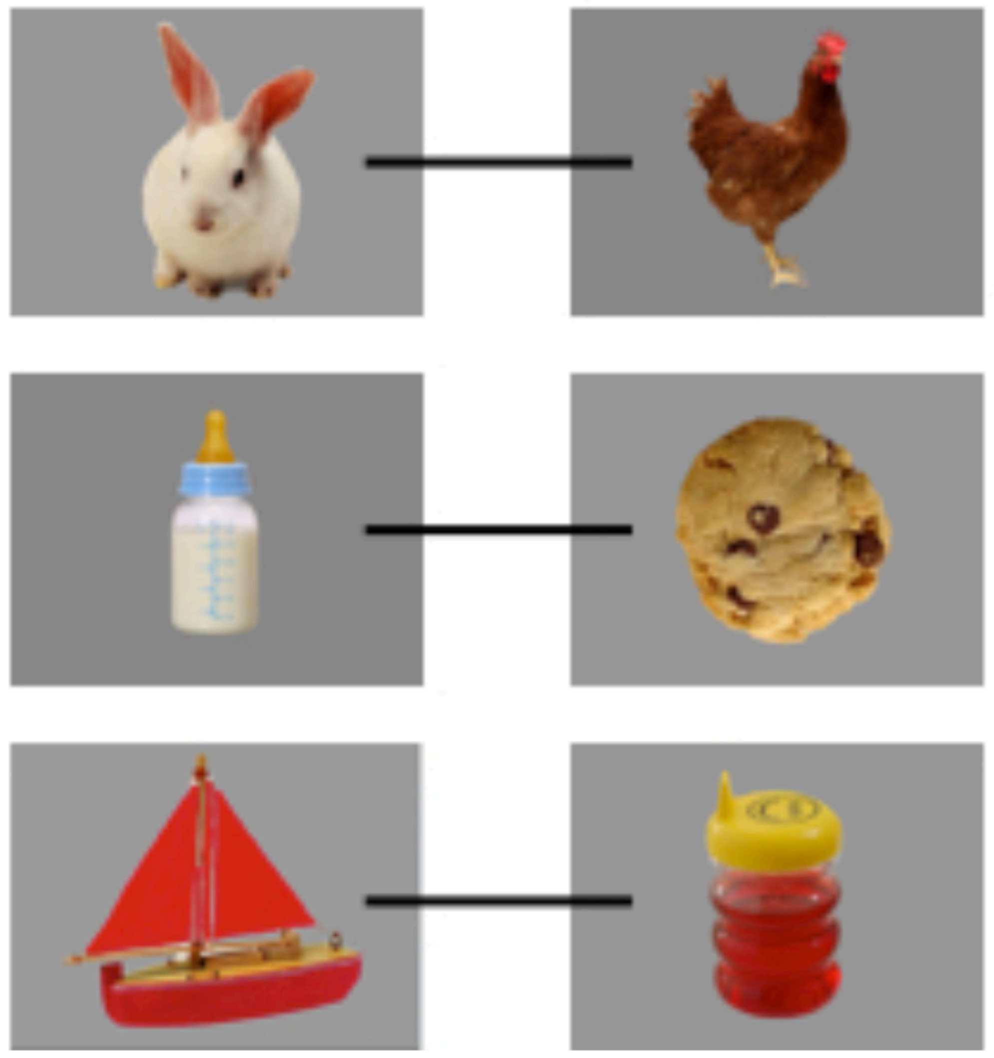
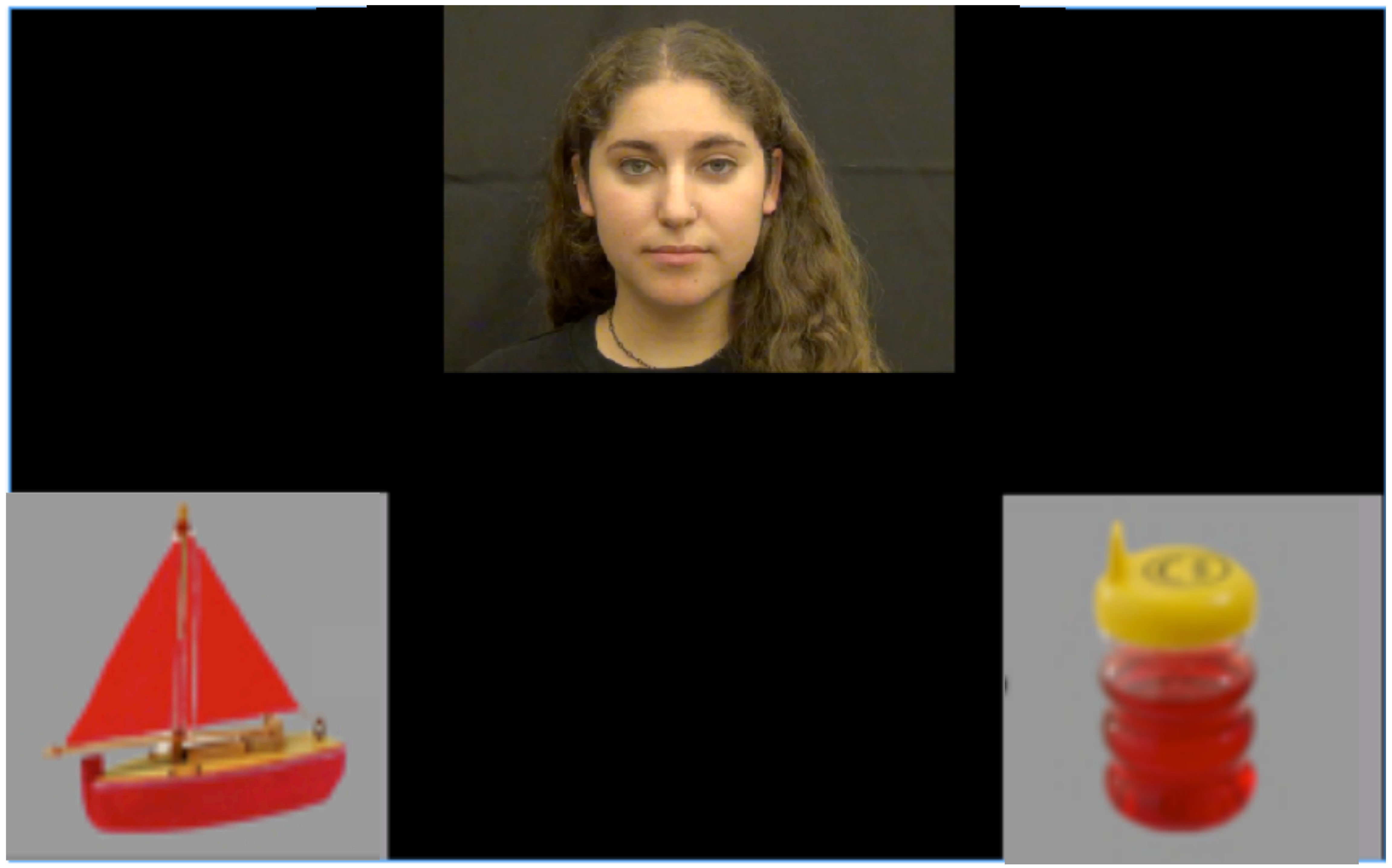


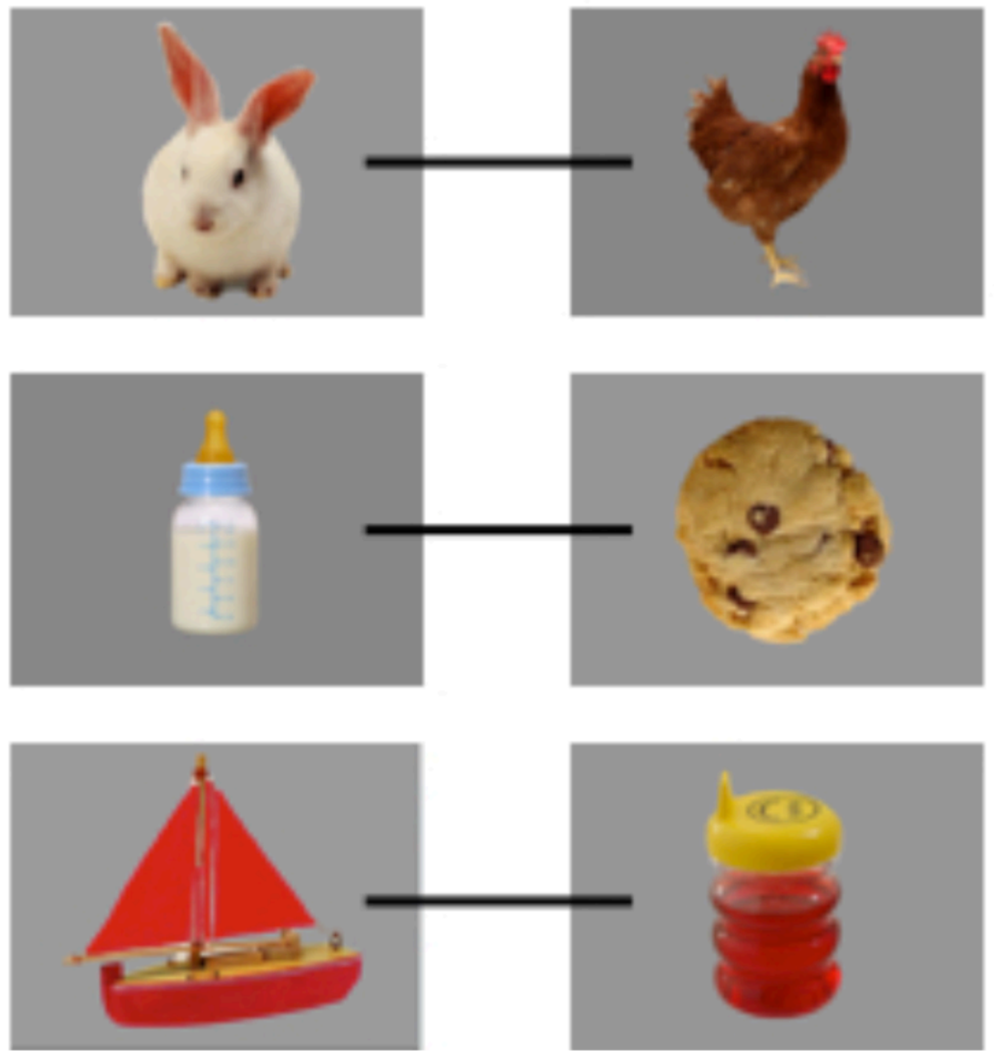


Look! Where's the **boat**?

decision to shift away from the center

Images appear for 2s prior to center stimulus	Center stimulus appears	Carrier phrase	Target noun onset	2s to look at the images





First shift analysis plan

Vandekerckhove & Tuerlinckx, 2007; Ratcliff & Childers, 2015; Wiecki, Sofer, & Frank, 2013

First shift analysis plan

First shift RT and Accuracy **"simple"**

Vandekerckhove & Tuerlinckx, 2007; Ratcliff & Childers, 2015; Wiecki, Sofer, & Frank, 2013

First shift analysis plan

First shift RT and Accuracy — **"simple"**

Exponentially Weighted Moving Average model (EWMA) — **"guessing model"**

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First shift analysis plan

First shift RT and Accuracy	**“simple”**
Exponentially Weighted Moving Average model (EWMA)	**“guessing model”**
Drift Diffusion Model (DDM)	**“decision model”**

Vandekerckhove & Tuerlinckx, 2007; Ratcliff & Childers, 2015; Wiecki, Sofer, & Frank, 2013

Predictions from an information-foraging account

value for
comprehension

Lower ⟷ Higher

Predictions from an information-foraging account

$$\frac{\textbf{\textit{Information}}}{\textbf{\textit{Time}}}$$

value for
comprehension

Lower ⟷ Higher

Predictions from an information-foraging account

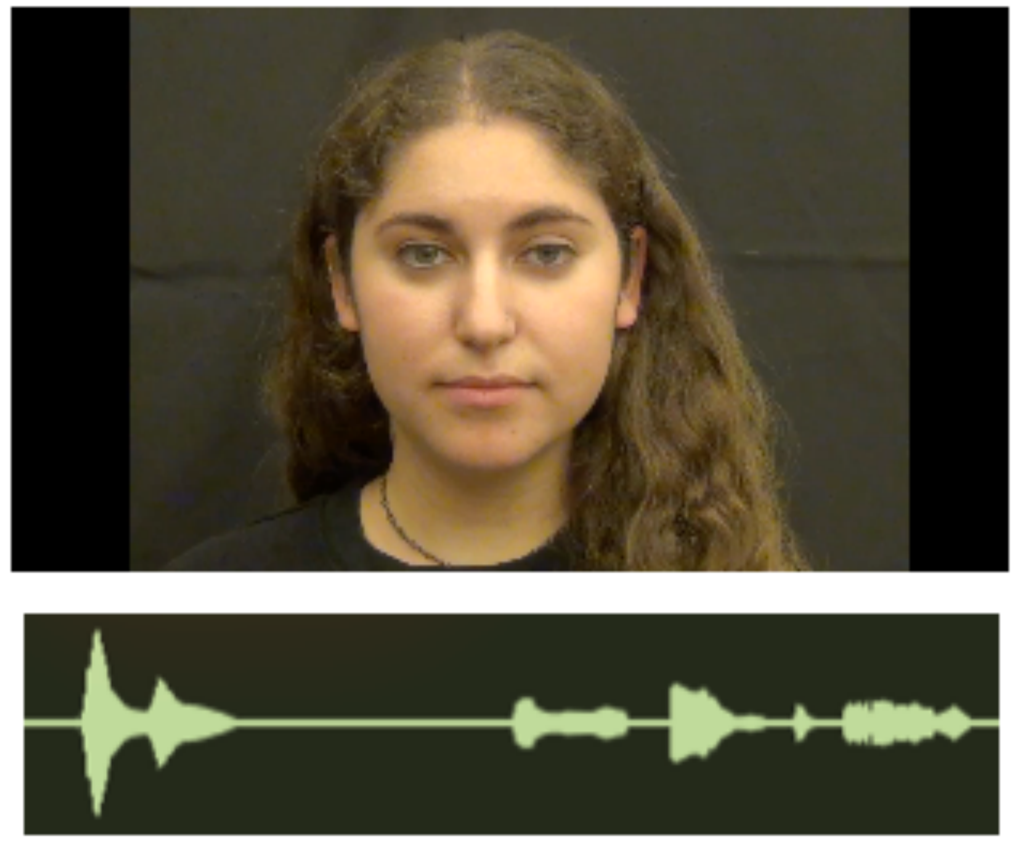
Information

Time

clear

noisy

Faster



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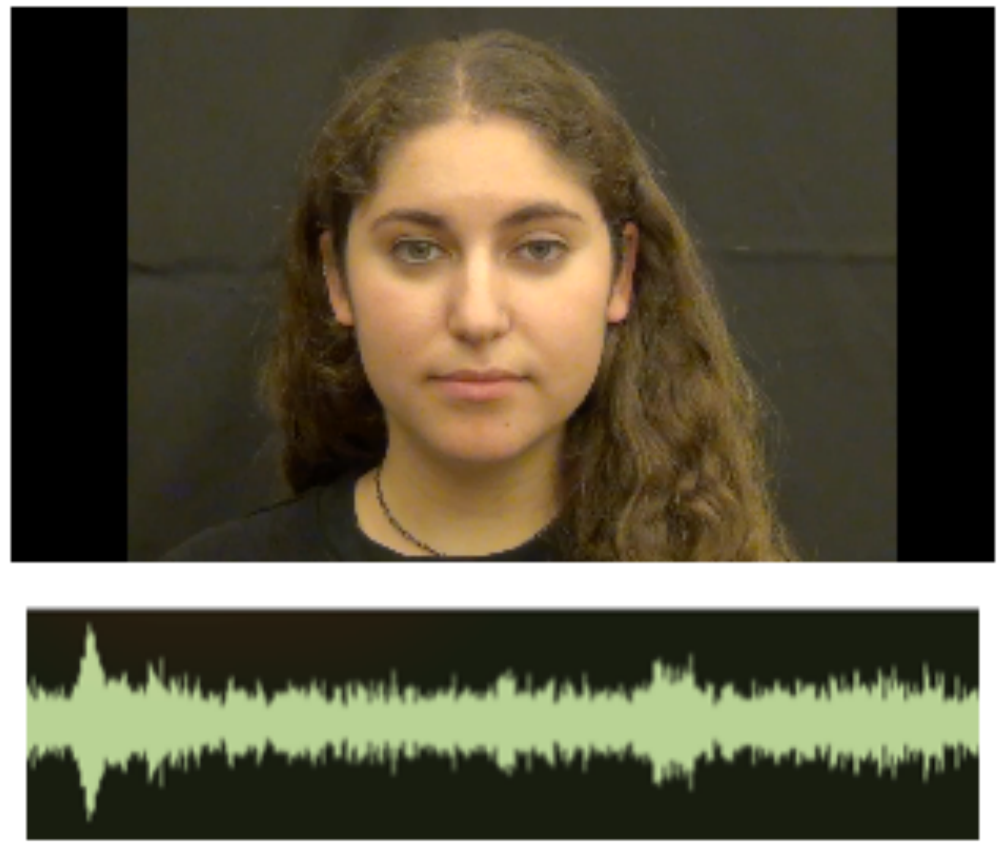
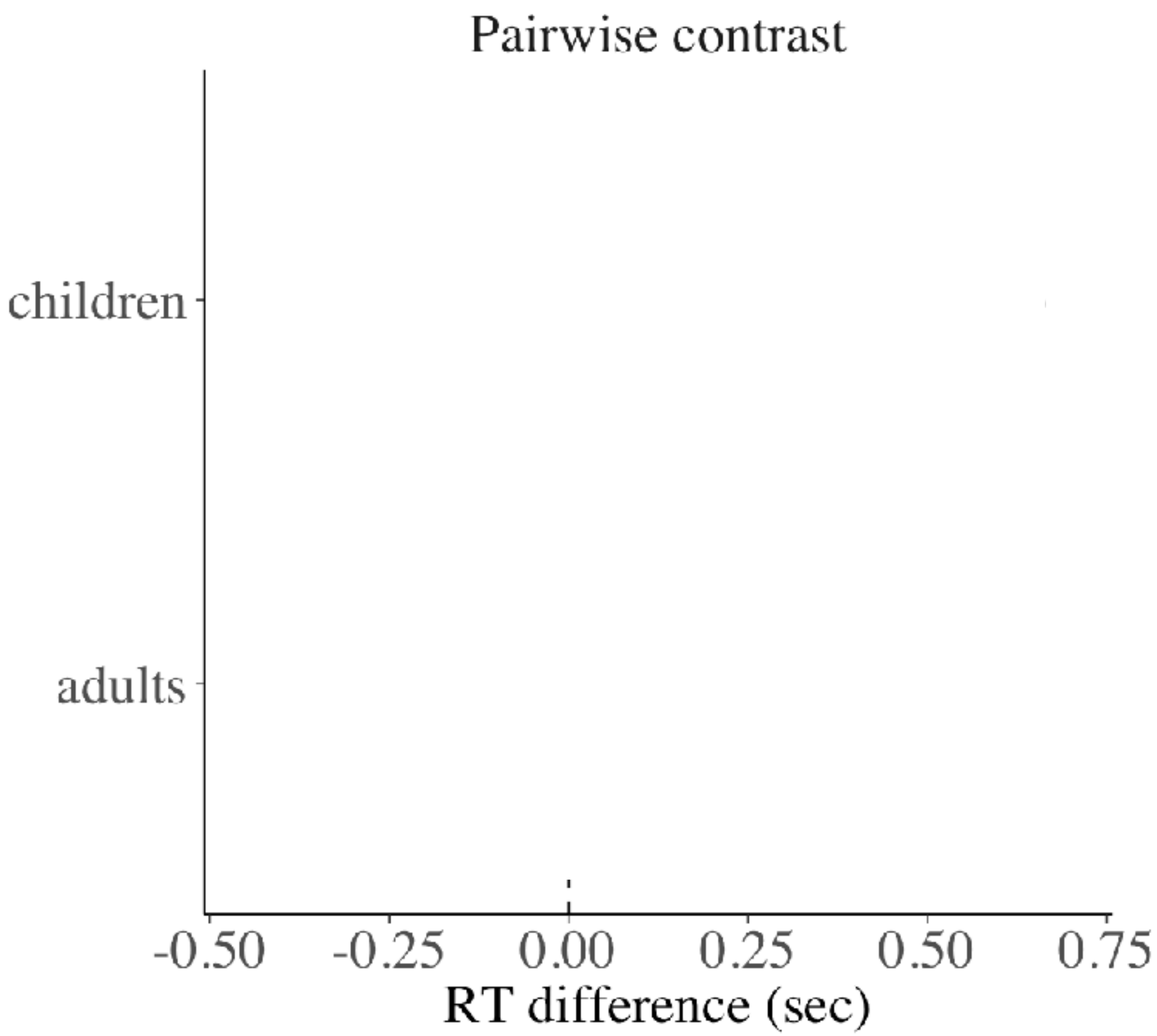


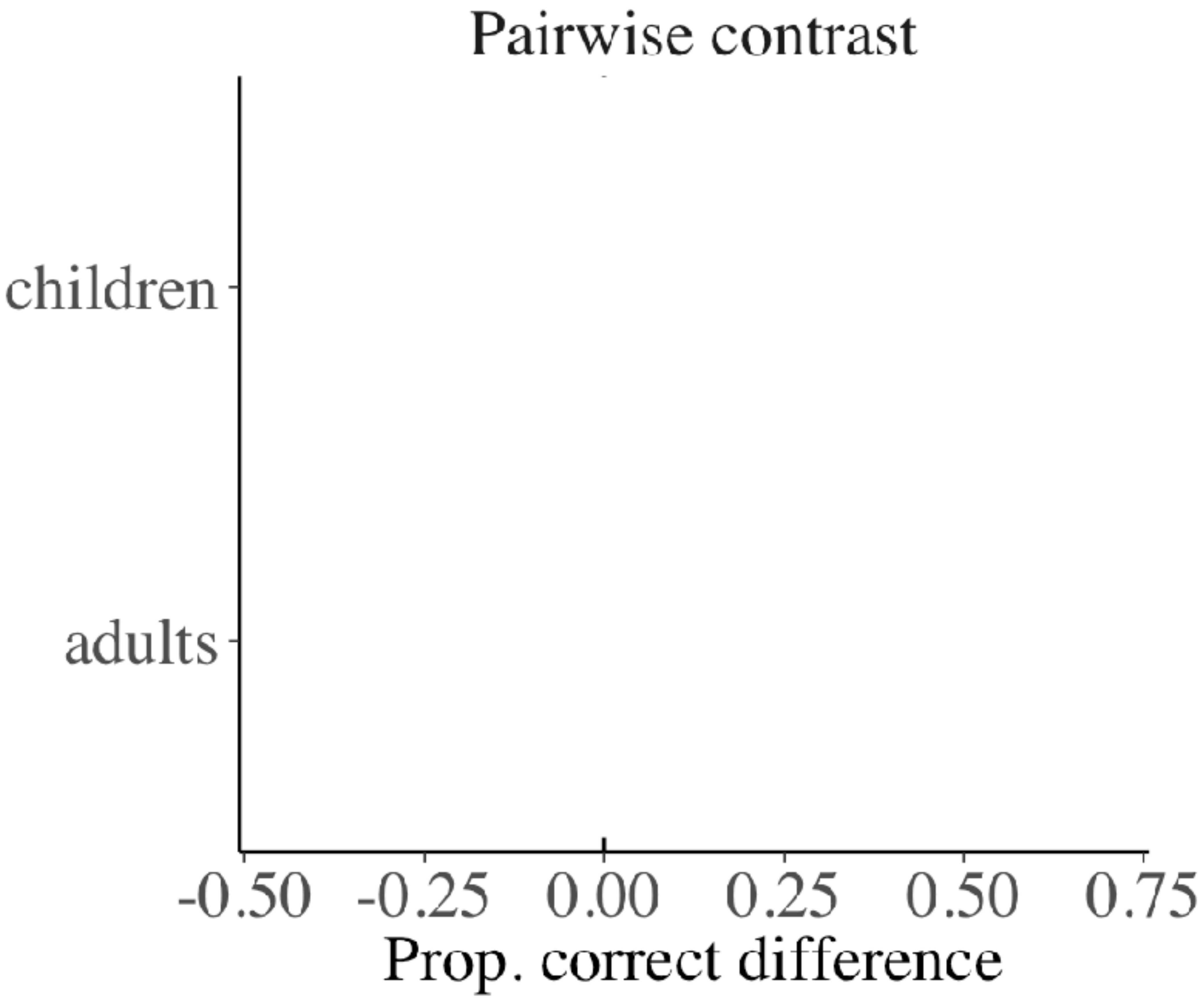
Slower

value for comprehension

Lower ⟷ Higher

How does noise change first shift RT and Accuracy?





Higher values = slower in noise

Higher values = more accurate in noise

Error bars represent 95% credible intervals

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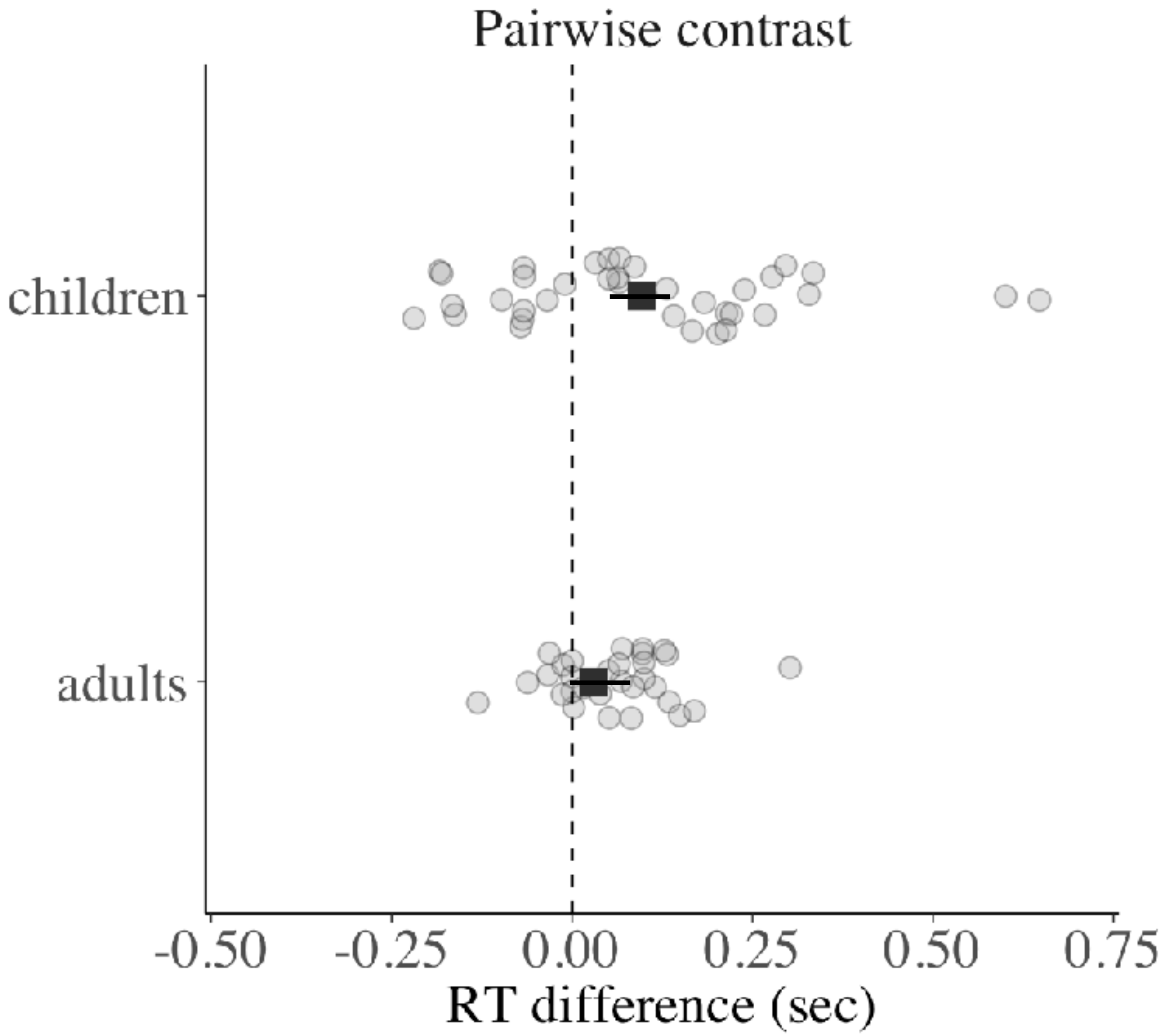

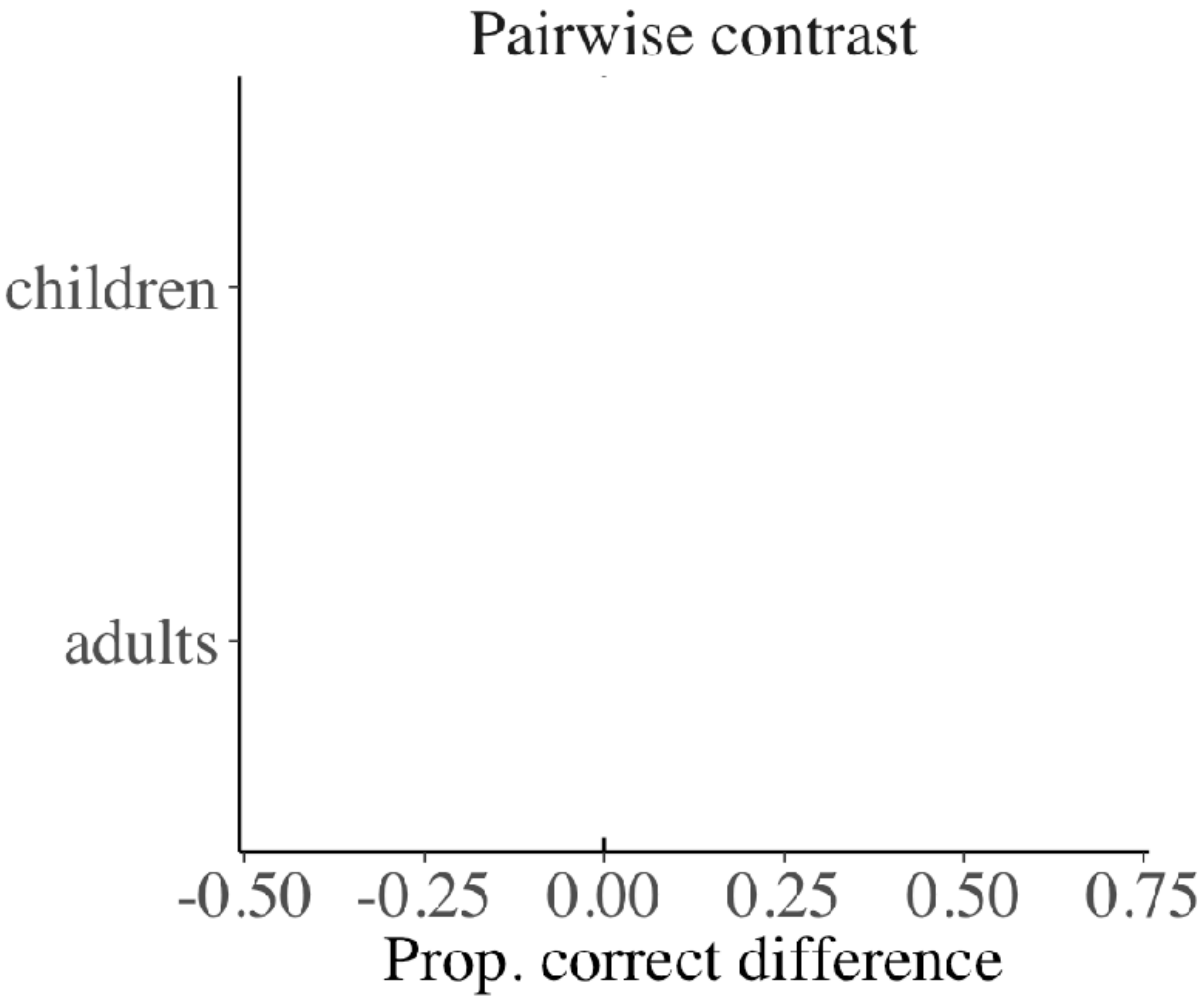

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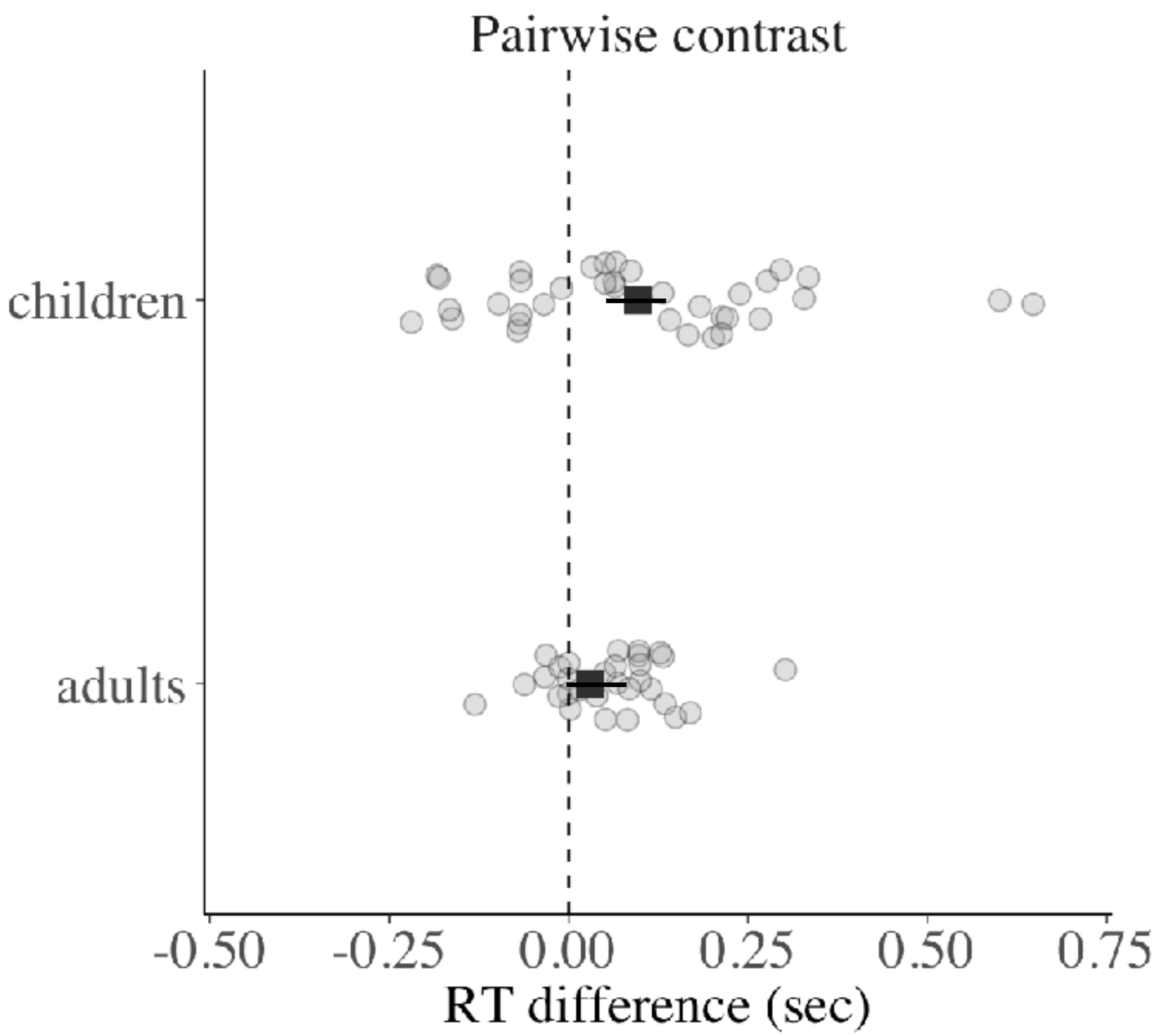

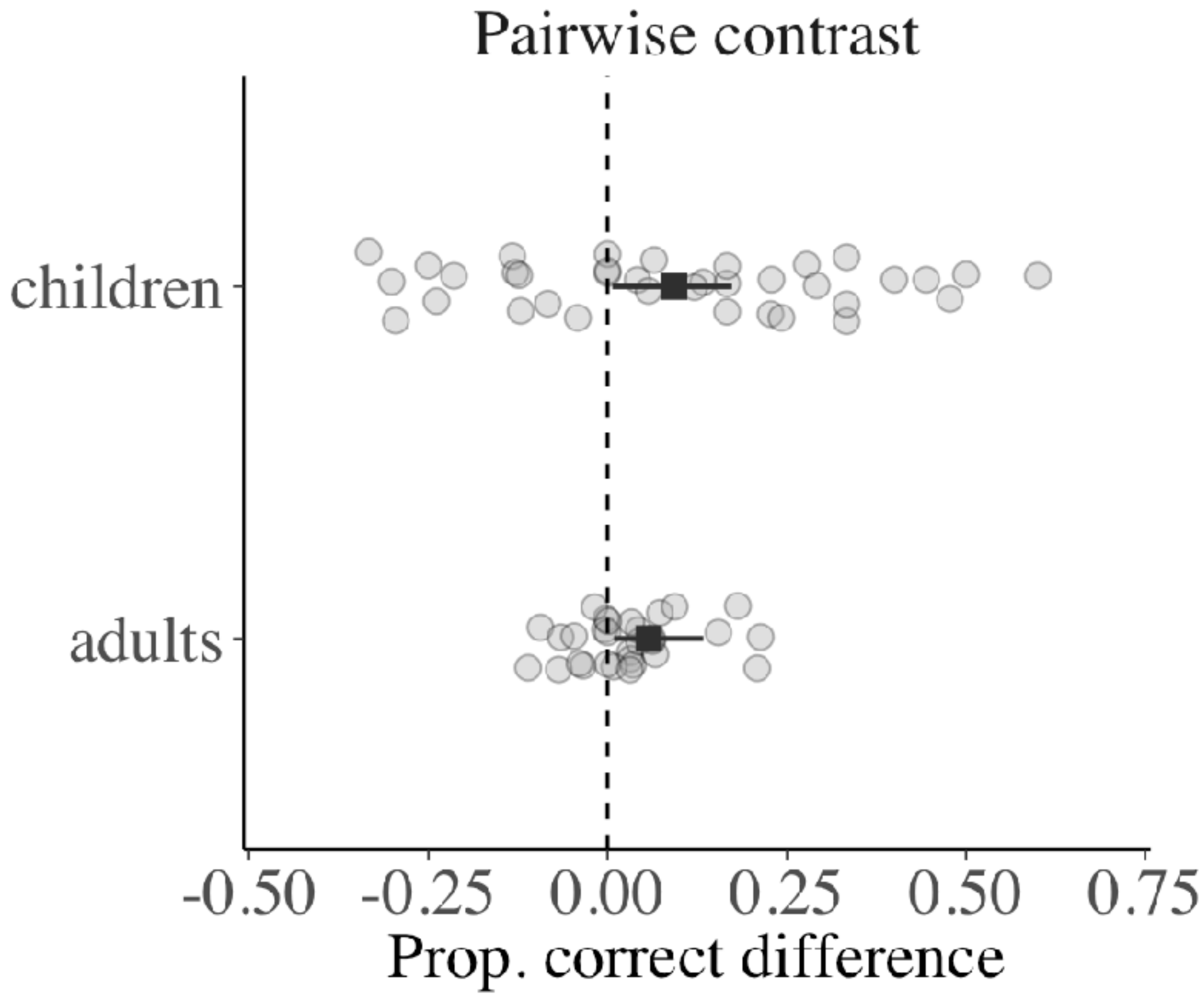

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EWMA: Quantifying the tendency to generate early, random eye movements (“guessing model”)

Vandekerckhove & Tuerlinckx, 2007

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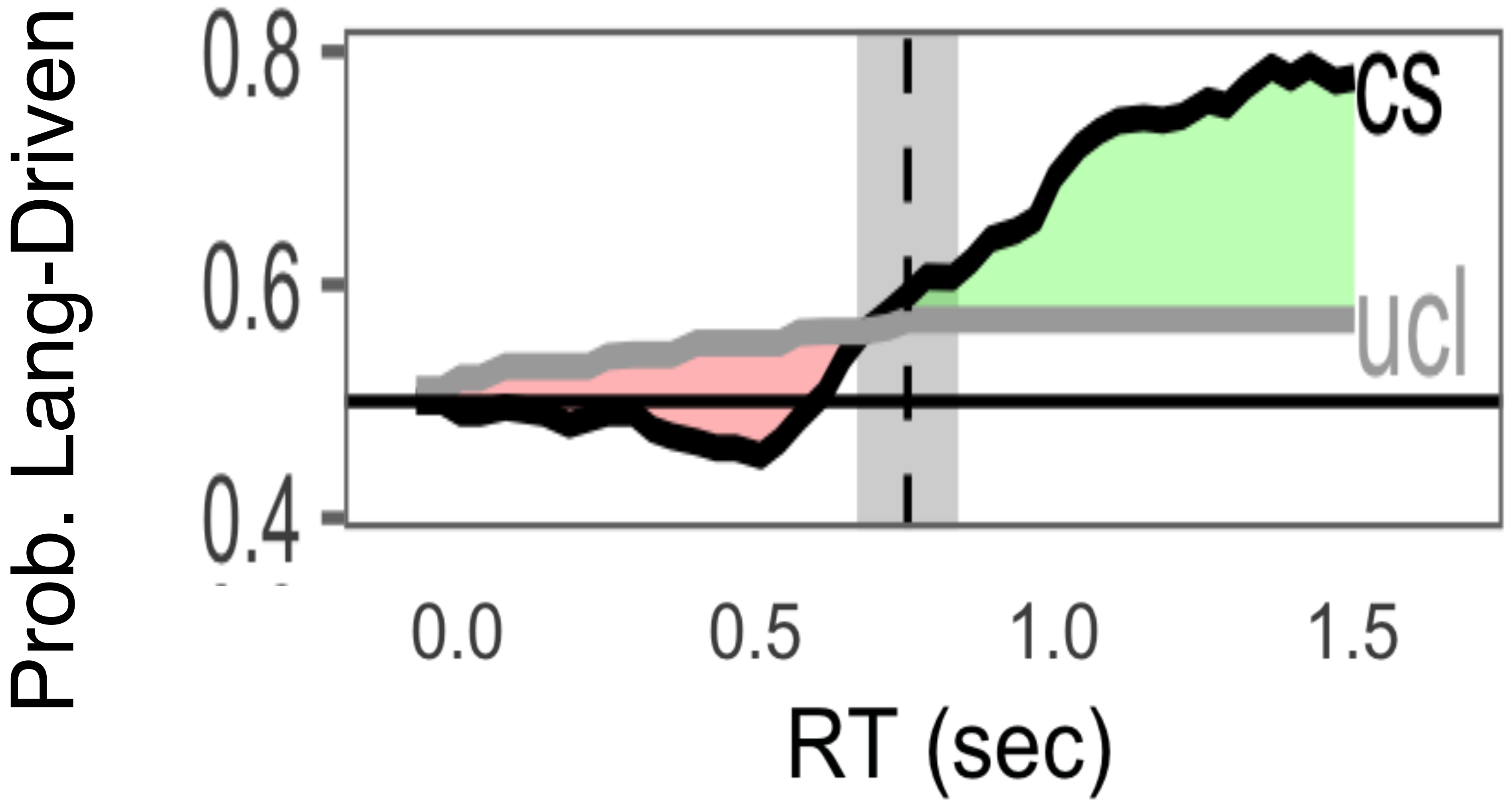

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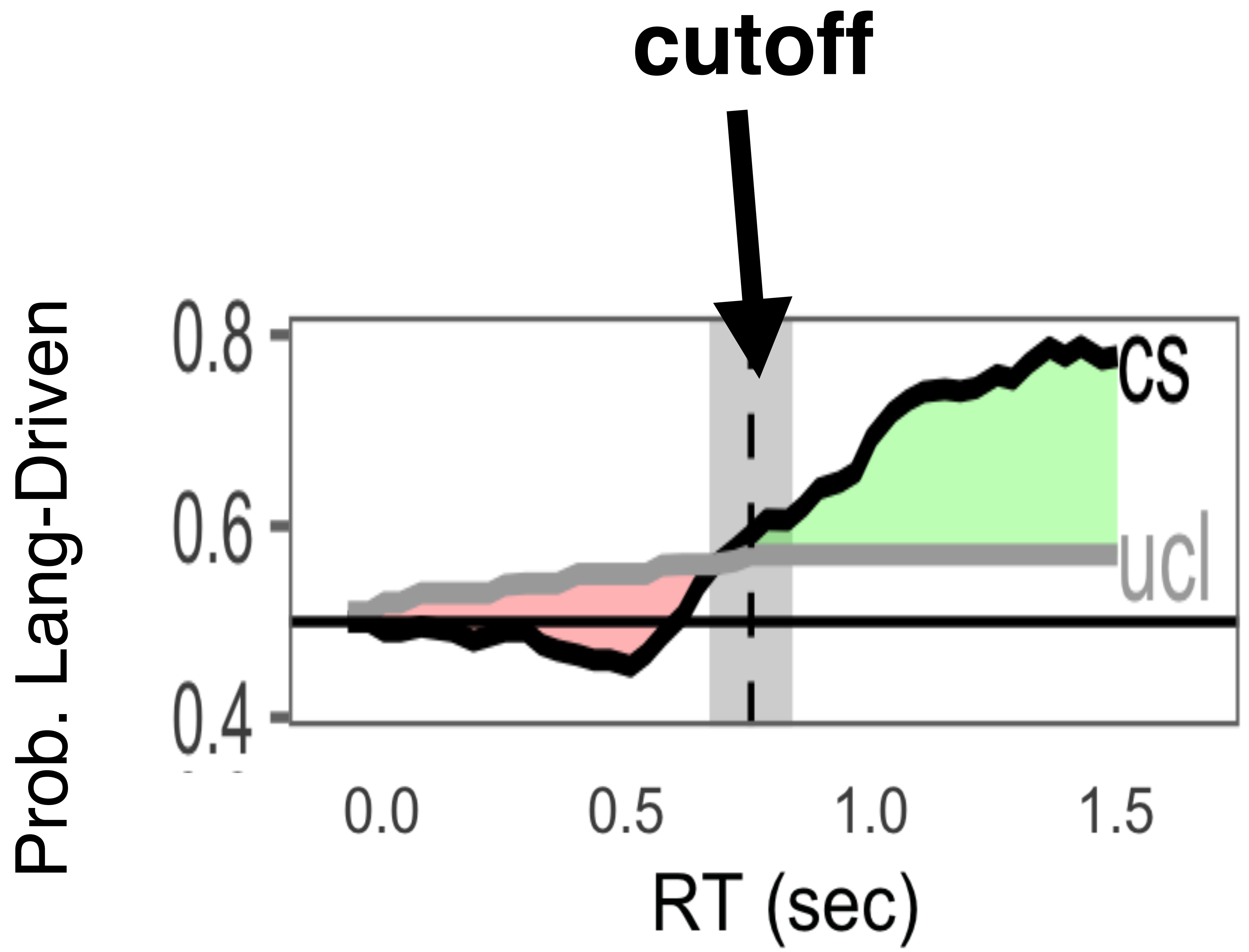

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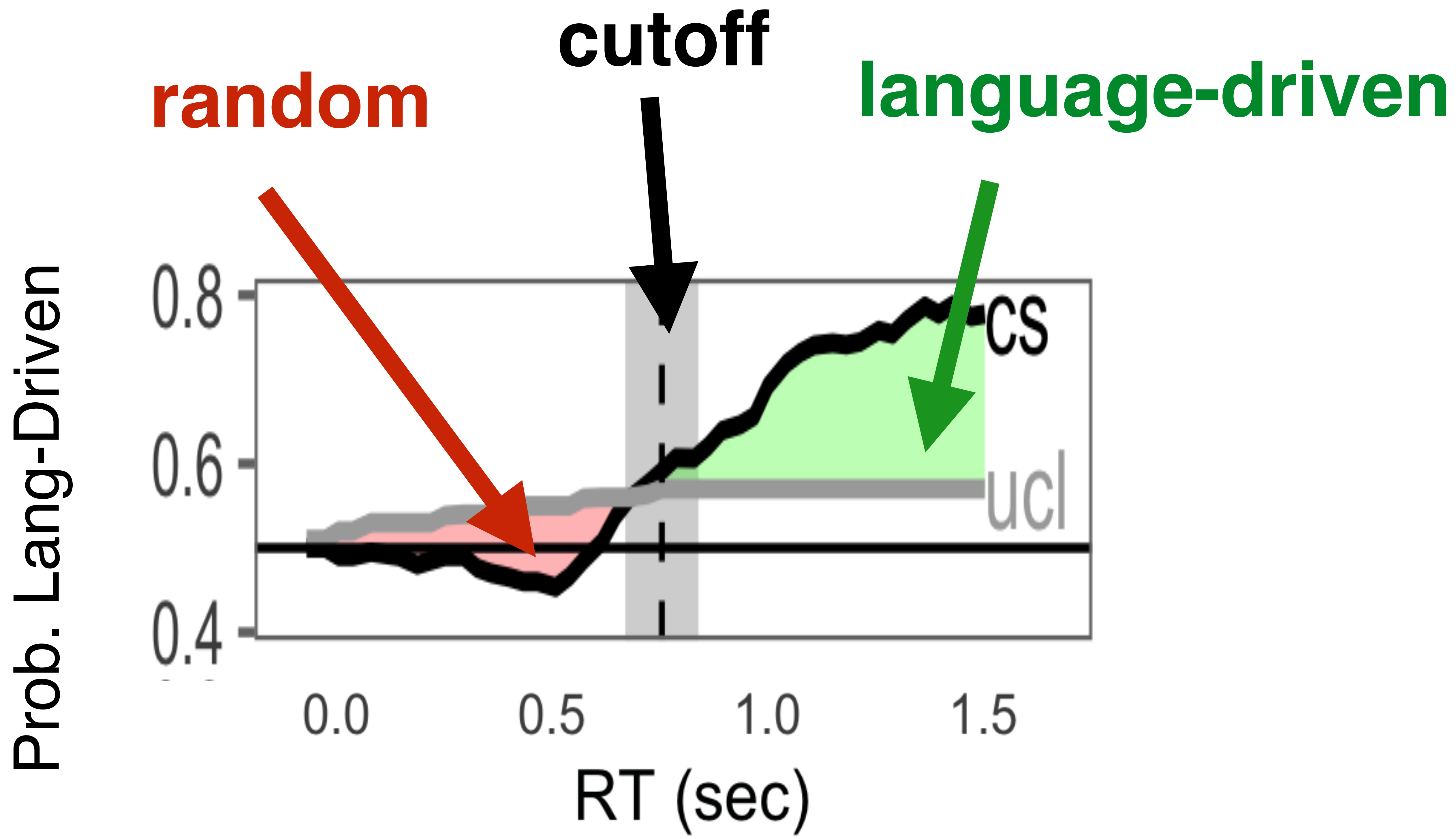
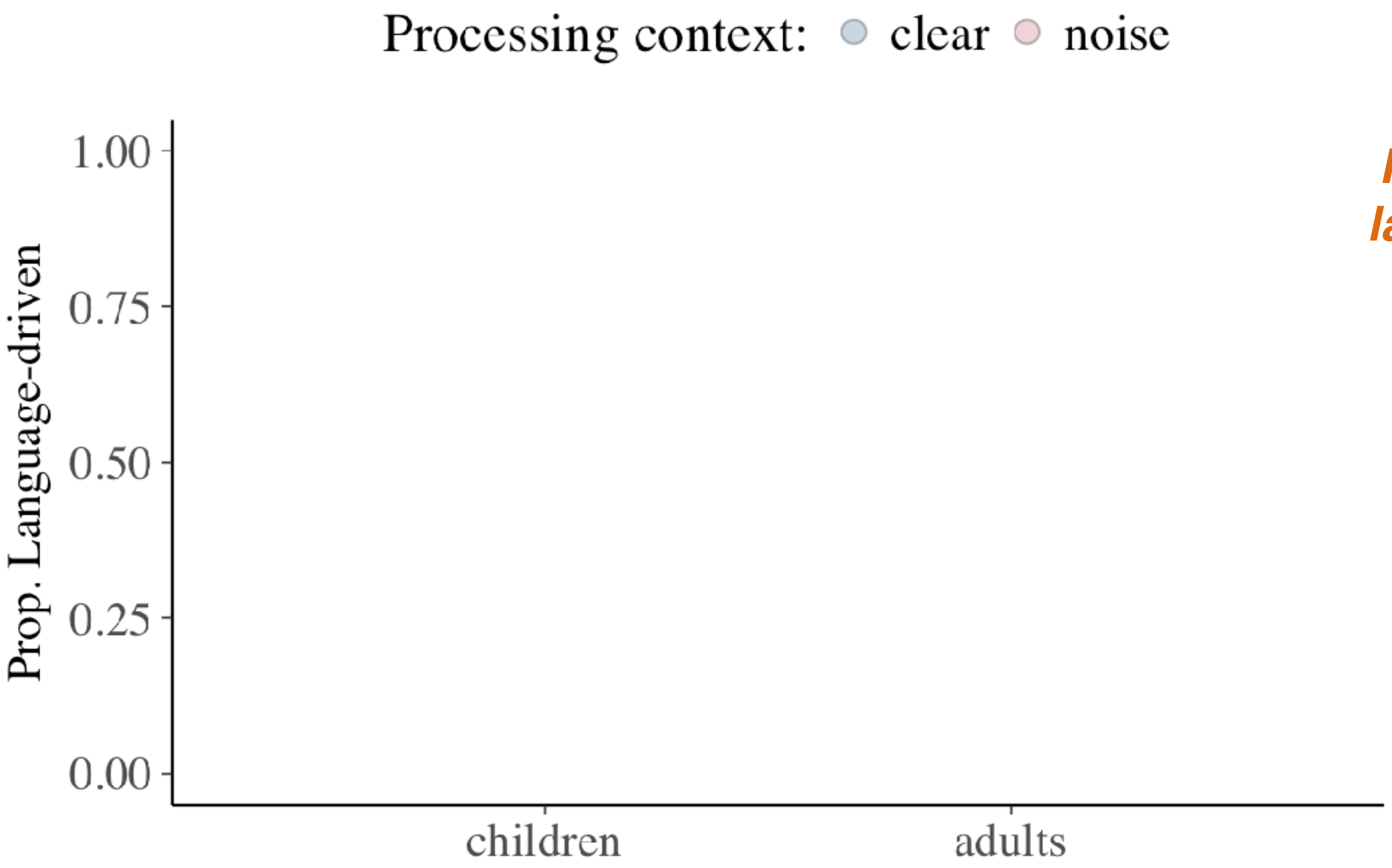


Vandekerckhove & Tuerlinckx, 2007

How does the tendency to generate fast, random gaze shifts change in noisy context?



Higher values = more language-driven shifts

Error bars represent 95% credible intervals

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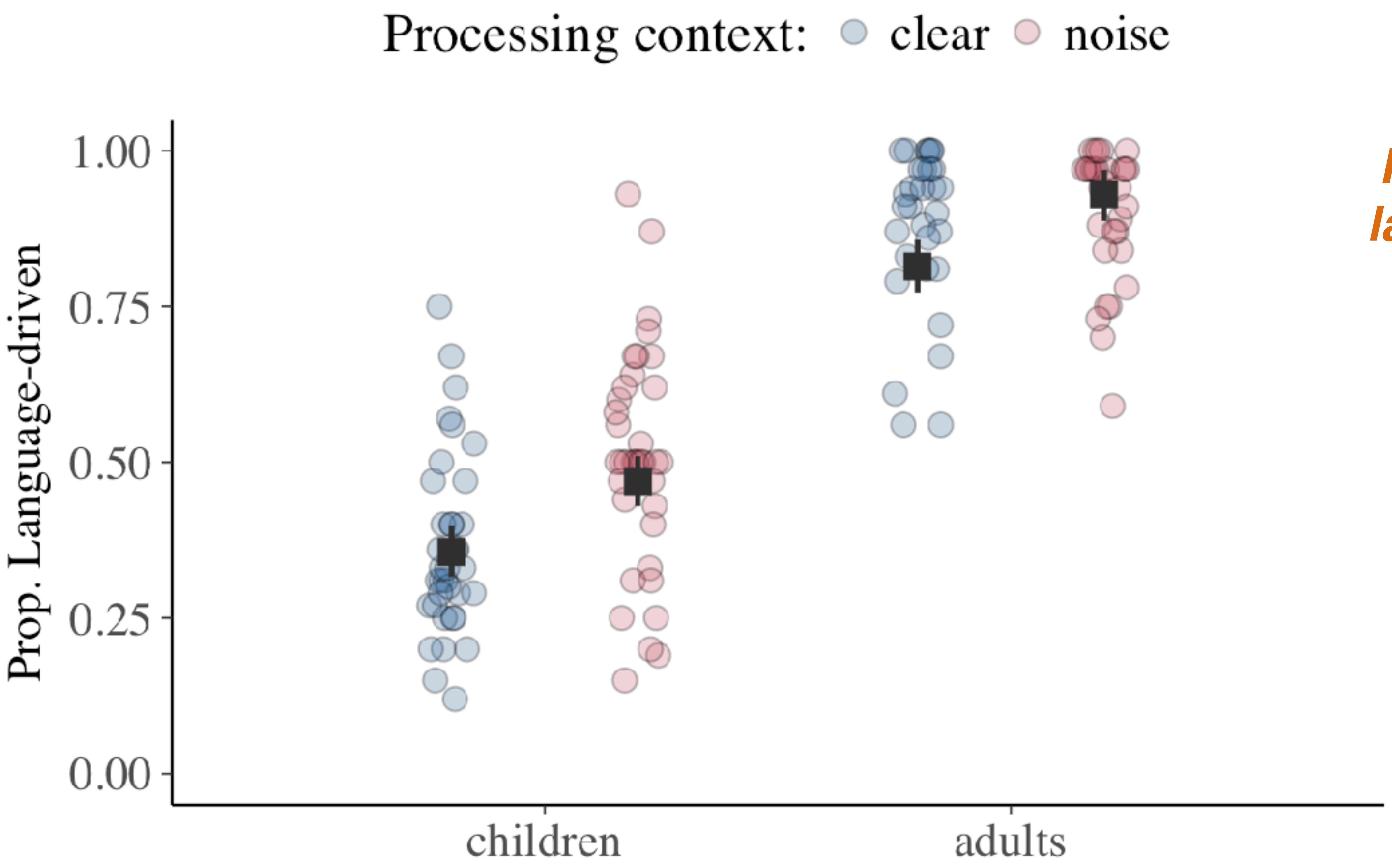

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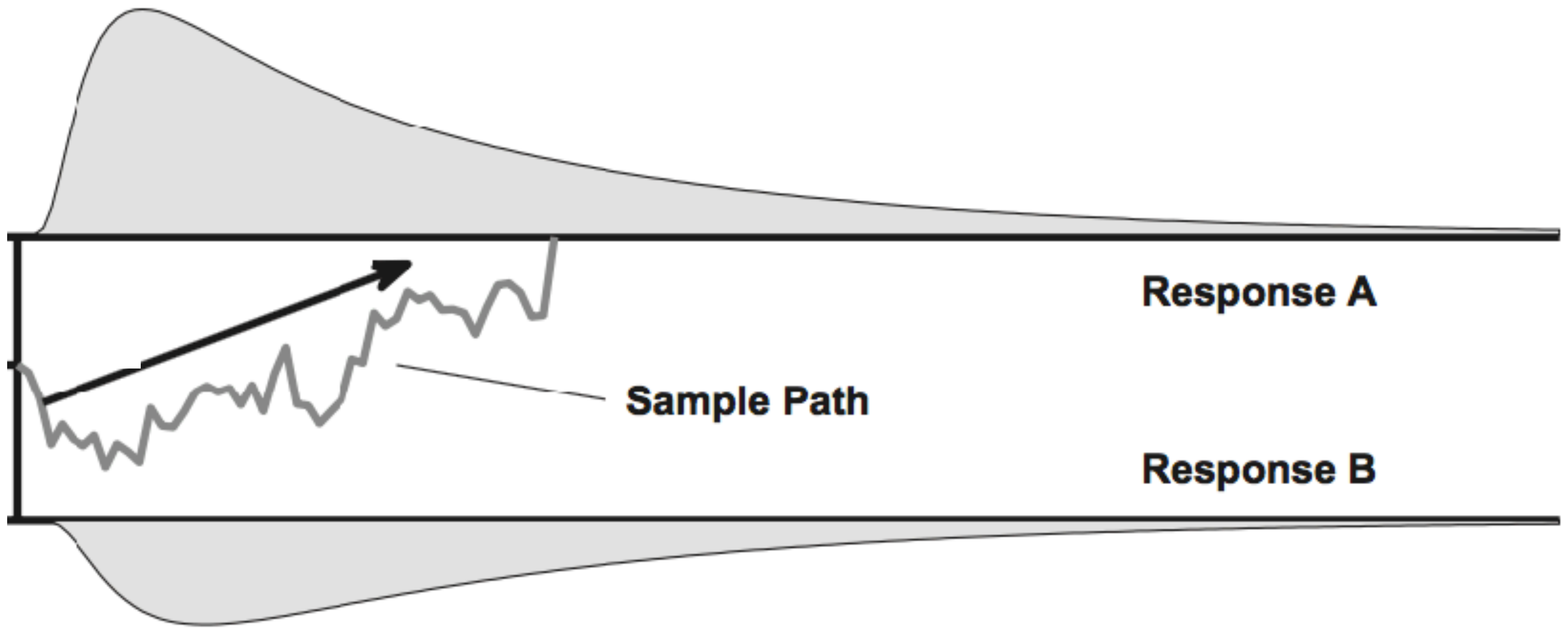
DDM: decision model of rapid, two-alternative forced choice tasks



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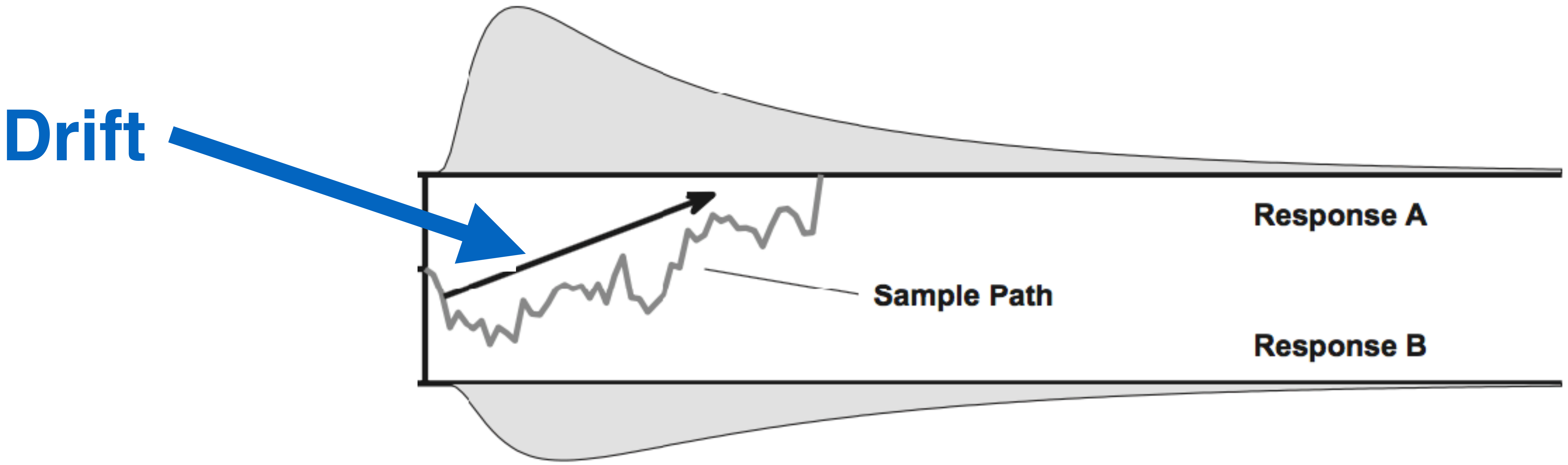

- **Drift rate - ** speed of processing (higher values suggest more efficient processing)

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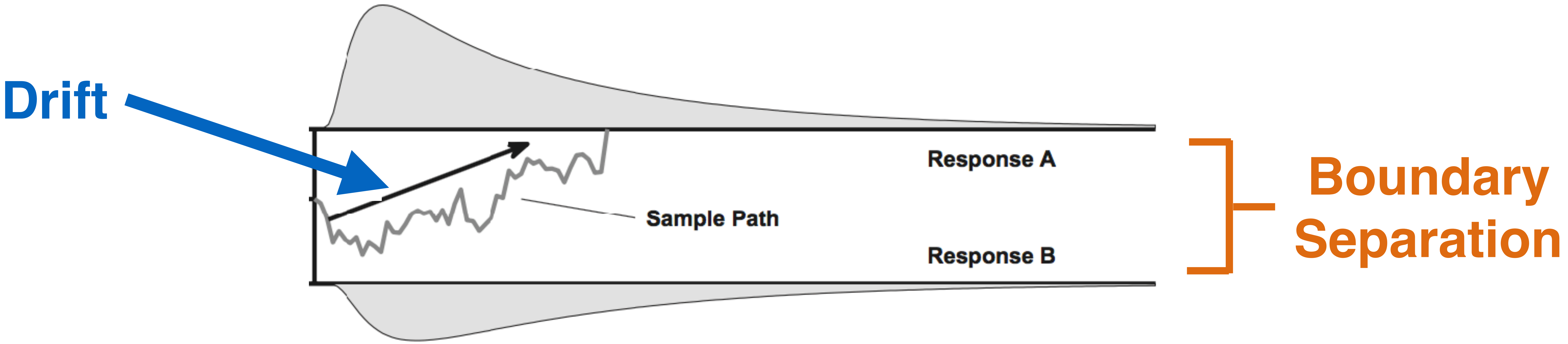
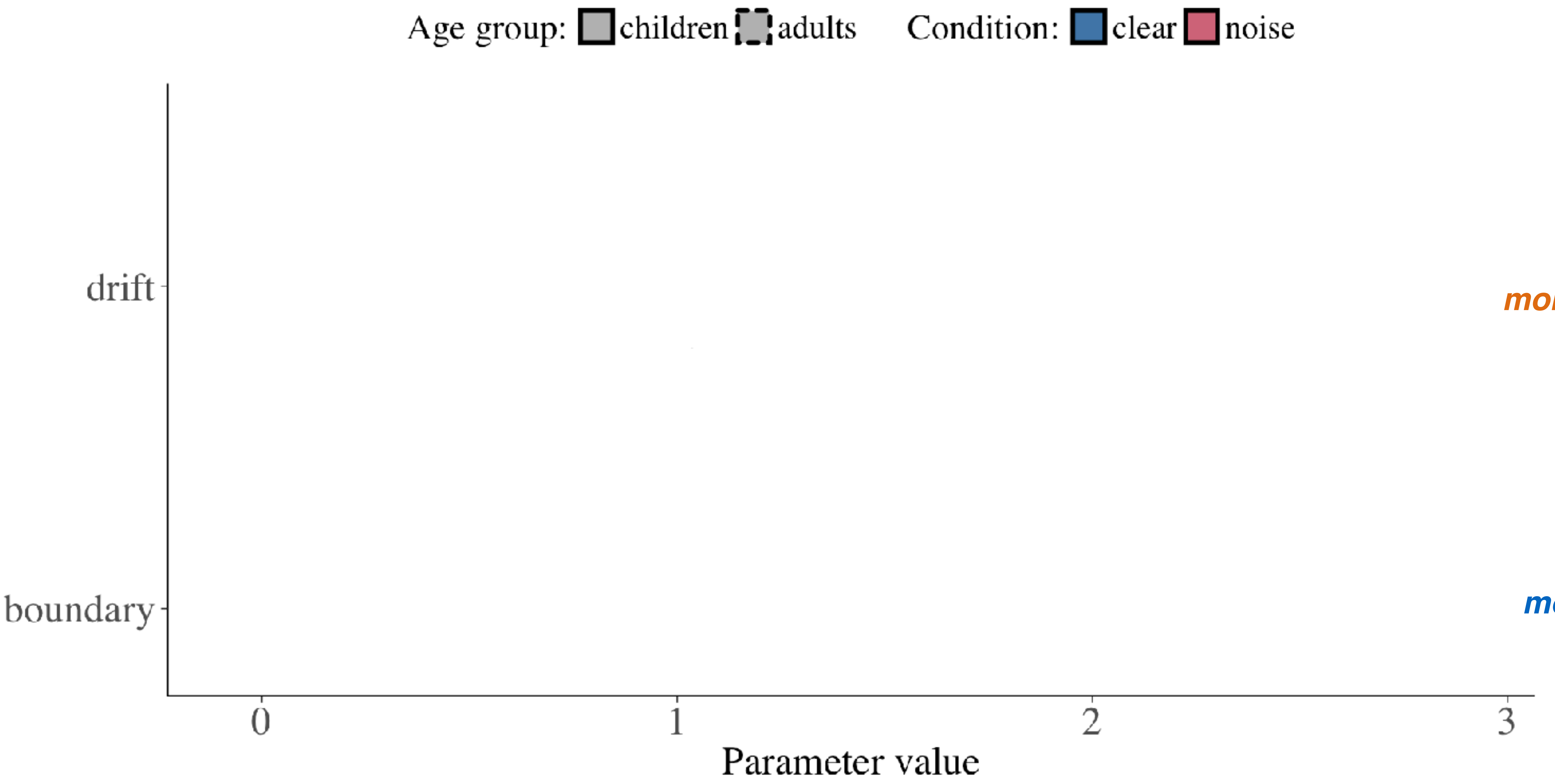


- **Drift rate -** speed of processing (higher values suggest more efficient processing)
- **Boundary separation -** decision threshold (higher values suggest a prioritization of accuracy over speed)

Ratcliff & Childers, 2015; Wiecki, Sofer, & Frank, 2013

What component of decision making best explains the behavioral differences?



higher values =
more efficient processing

higher values =
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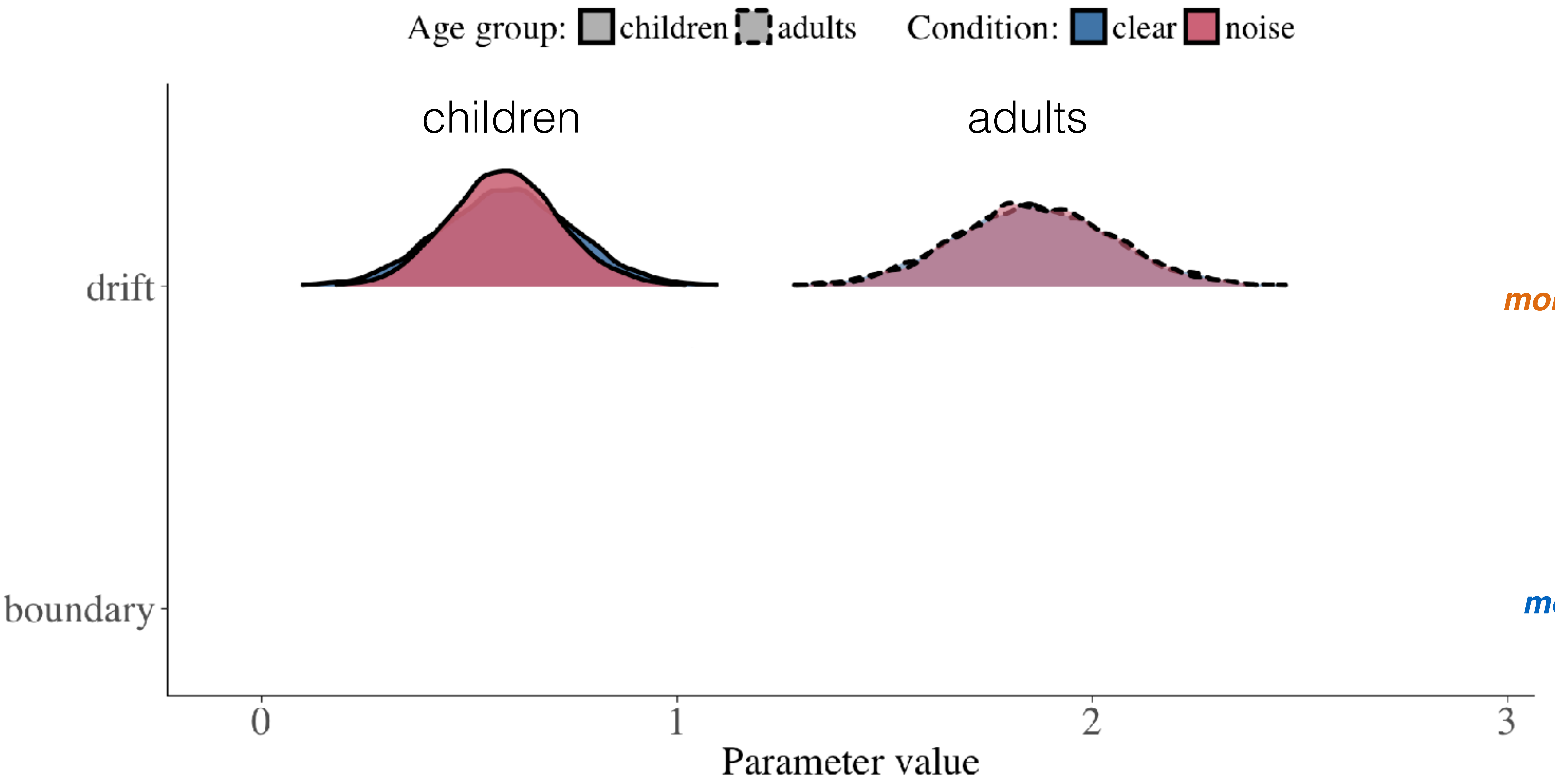

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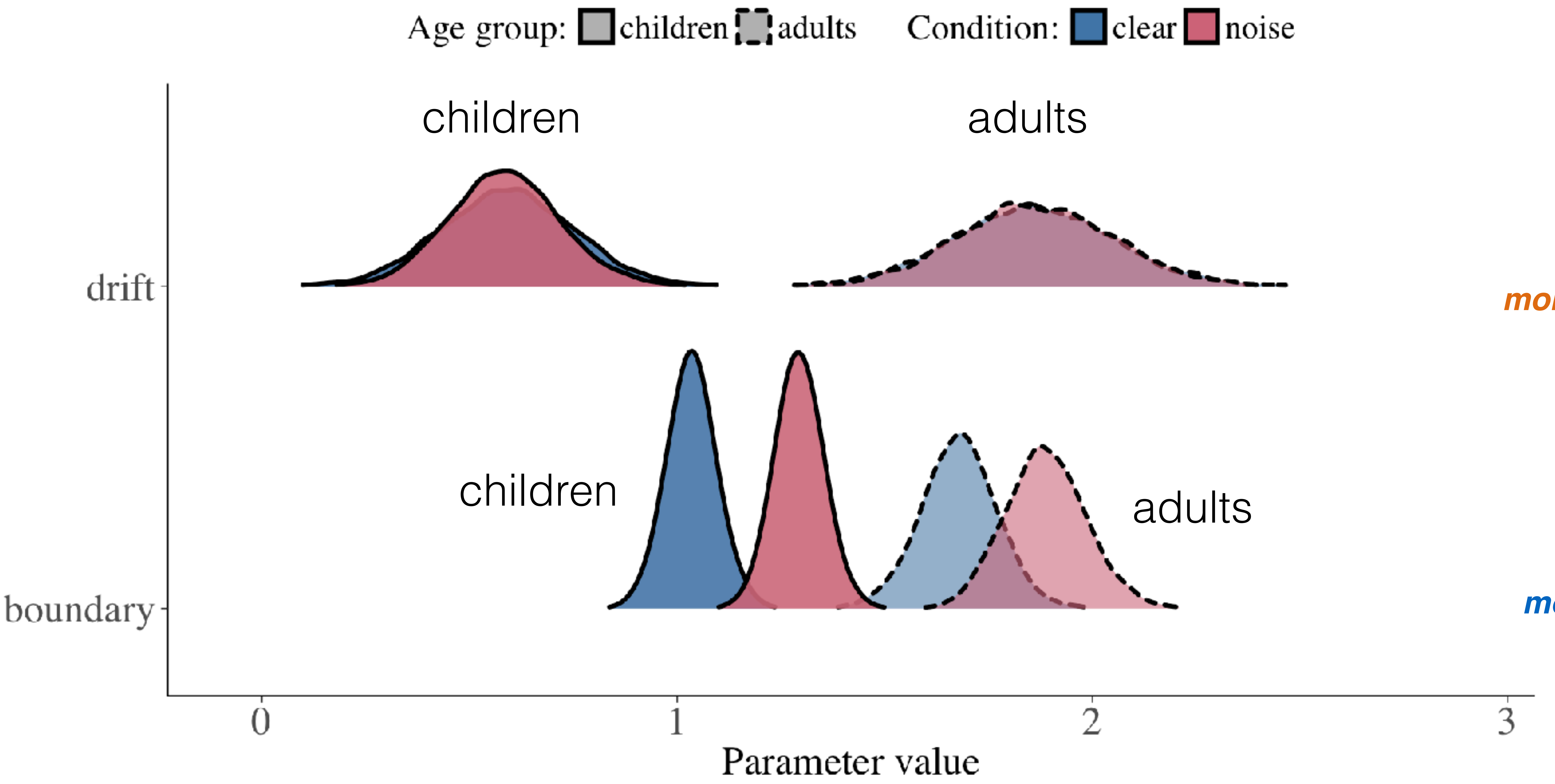

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- fewer early, random shifts away from the speaker (**guessing model)**
- prioritized information accumulation over speed (**decision model**)

Young language learners show signatures of information seeking in response to demands of language processing

Thank you

Todd LaMarr

Aviva blonder

Tami Alade

Hannah Slater

Melina Wailing

Olivia Homer

Grace Bennet-Pierre

All experiments, data, and analysis code are available at: https://github.com/kemacdonald/speed-acc

email: kyle.macdonald@stanford.edu