Word Learning through Pragmatic Inference in Children with Autism: a Web-Based Eye-Tracking Study

Katherine Trice, Angelina DiNardo, Zhenghan Qi

Northeastern University


What a
cool gaz!


What a
cool gaz!

Look! The dog is eating a stad!

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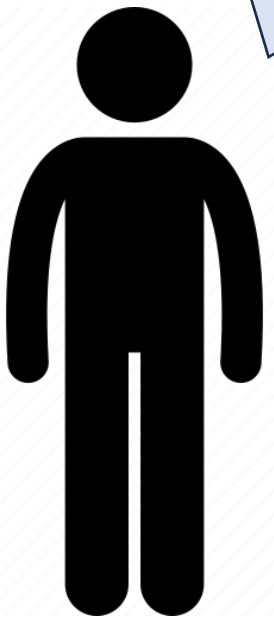

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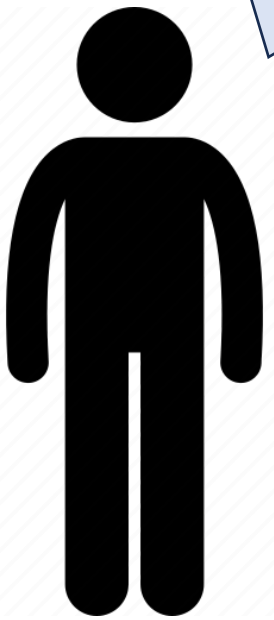

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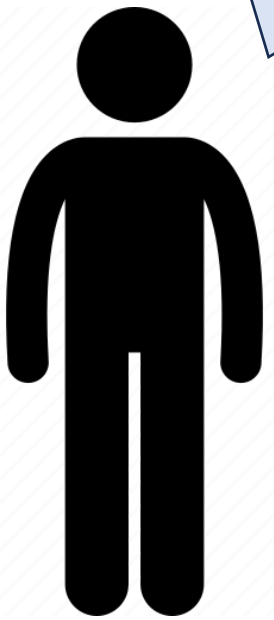

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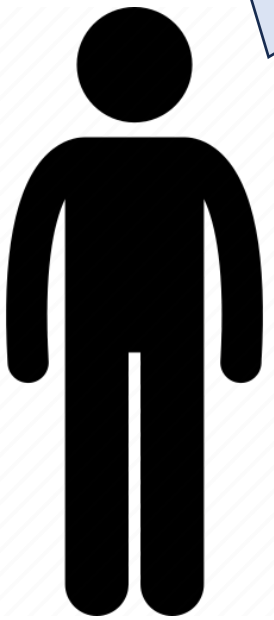

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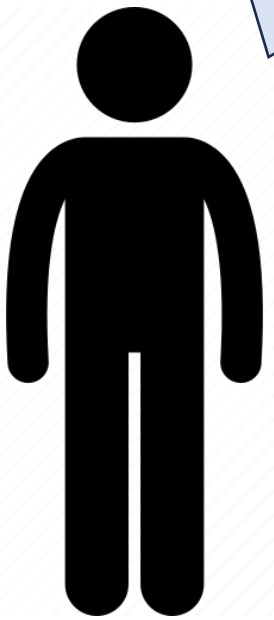

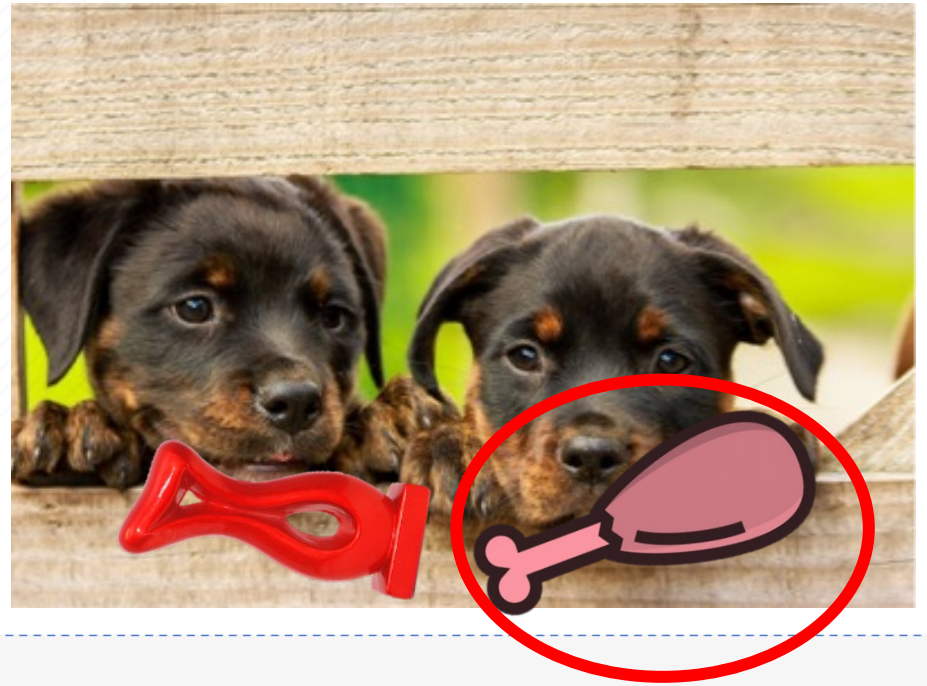

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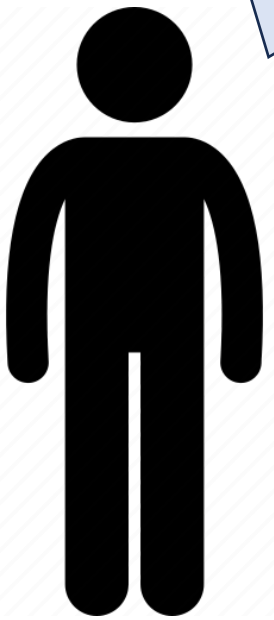

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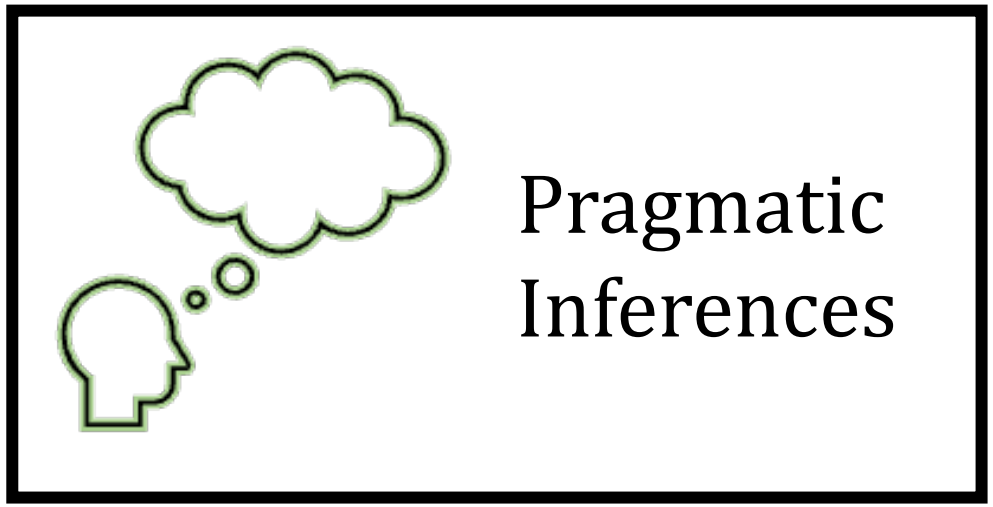

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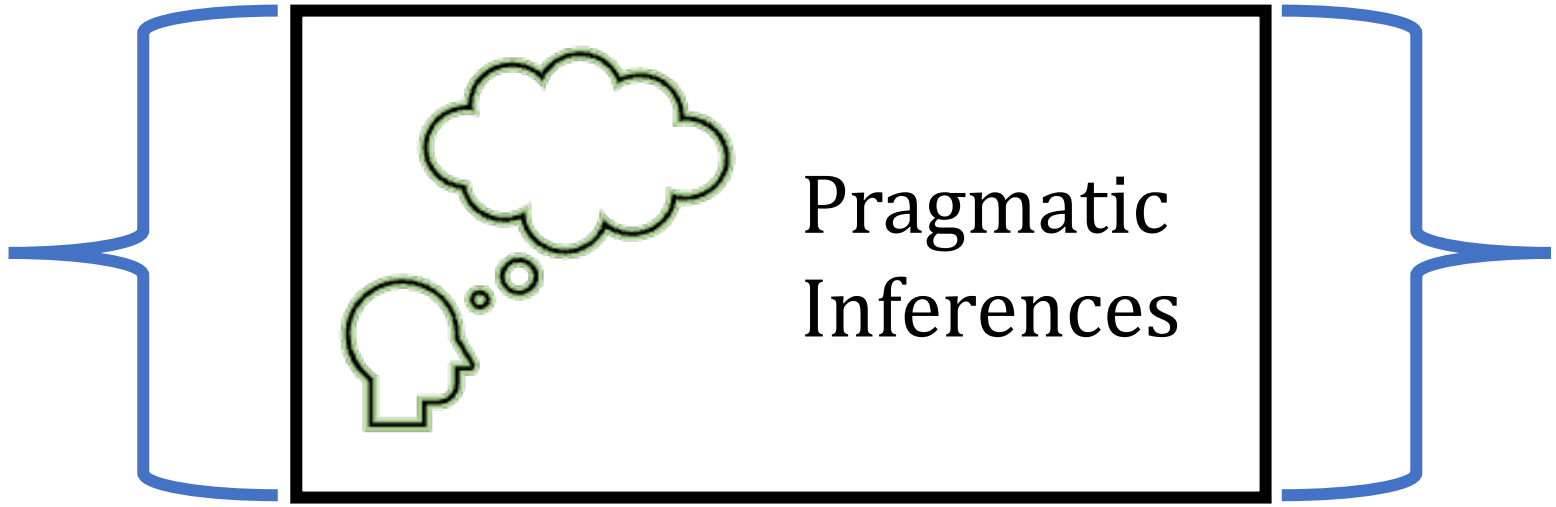

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Pragmatic Inference

What is Said

Pragmatic Inferences

What is Meant

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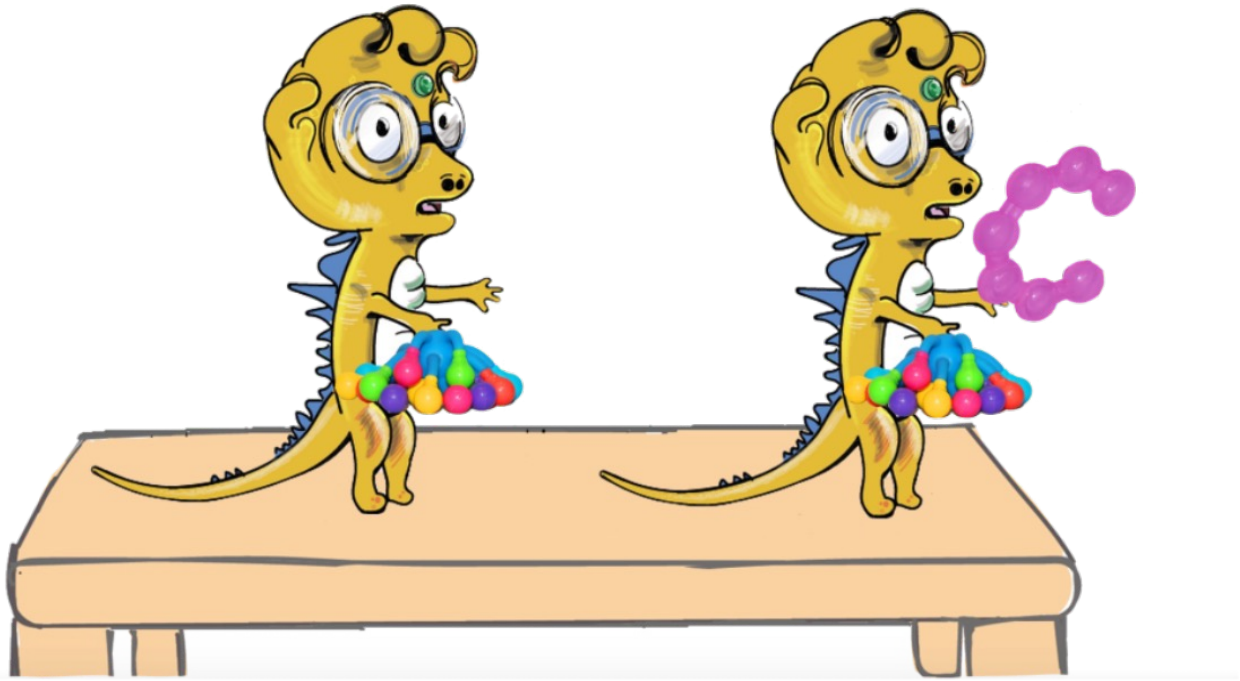

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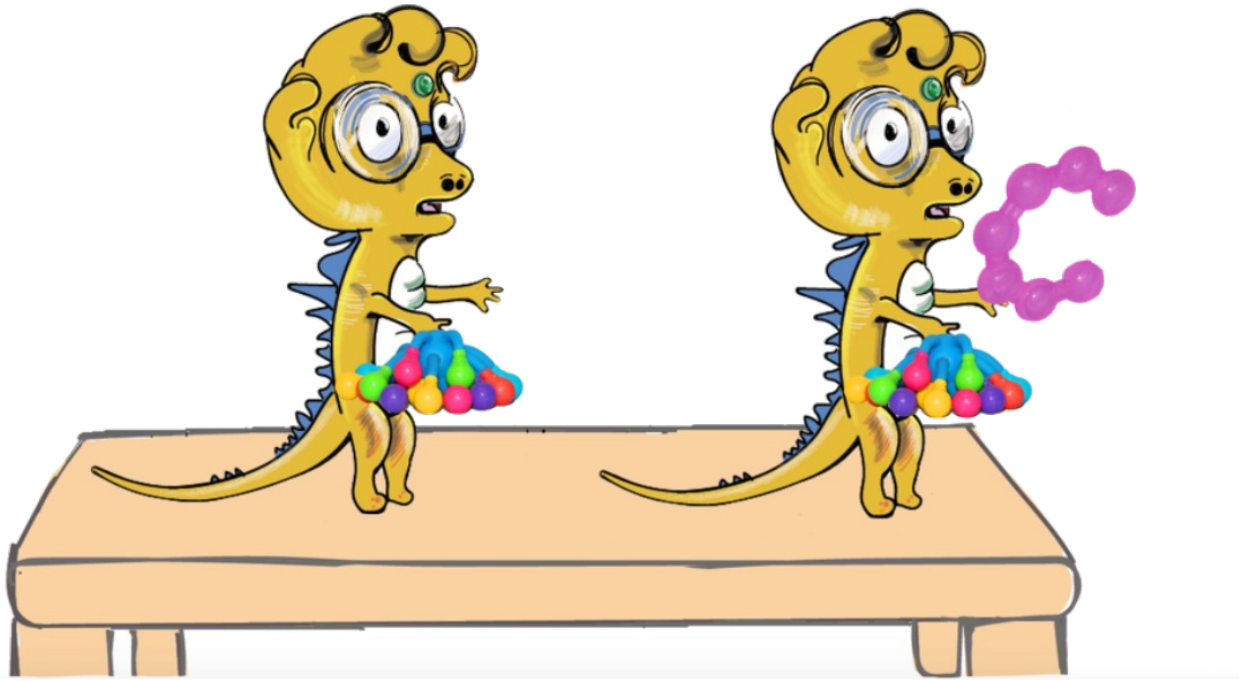

"Look! I like this dinosaur! It is holding a **MEL**!"

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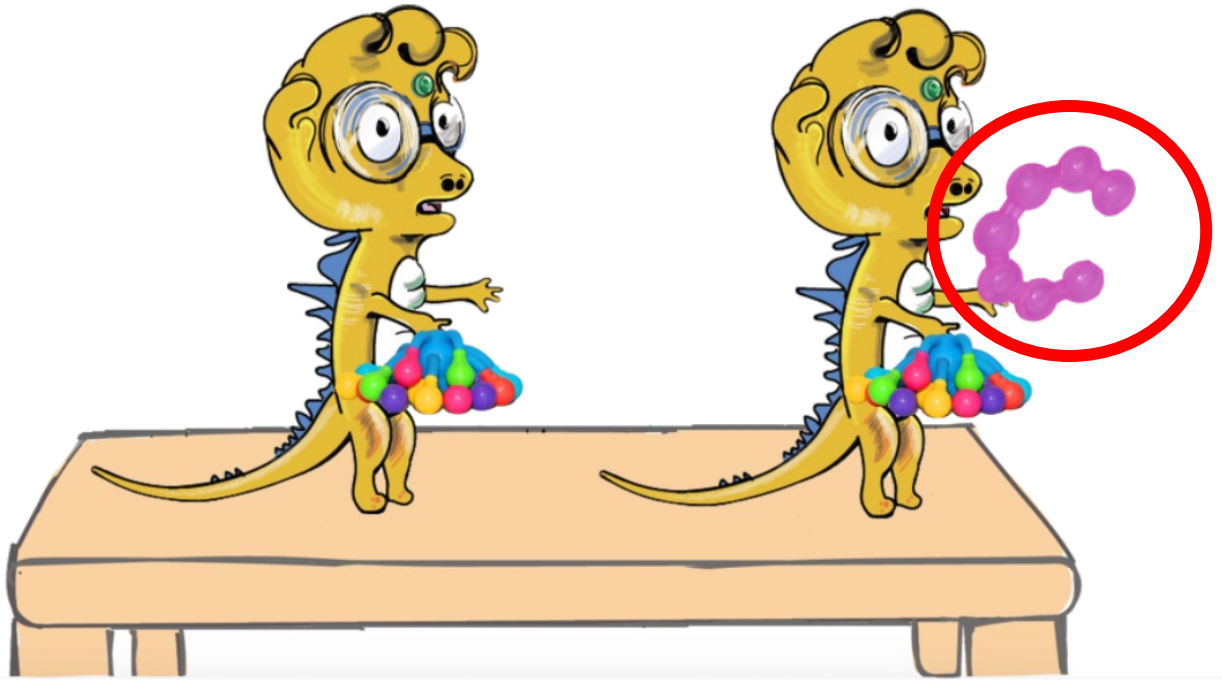

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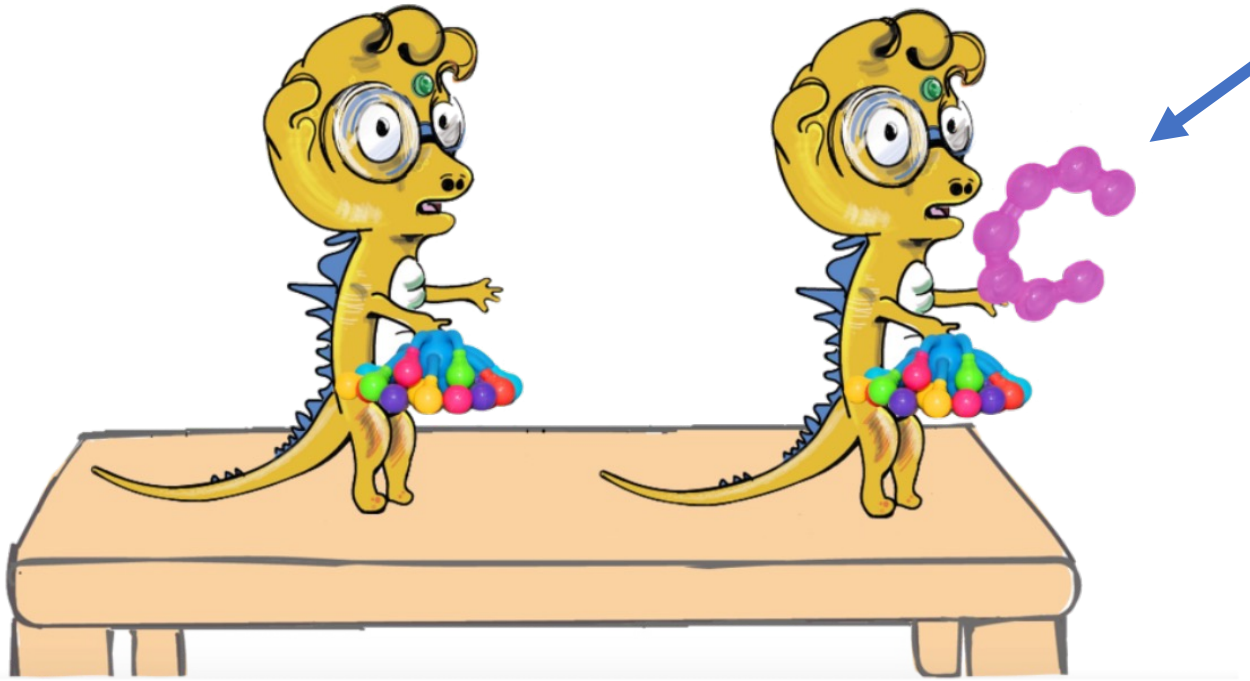
Disambiguating object = **MEL**!



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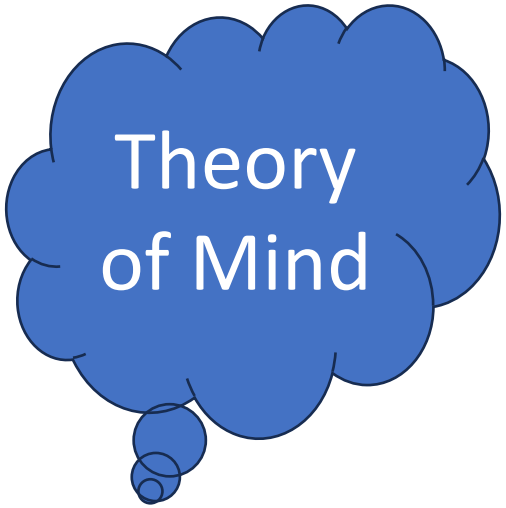

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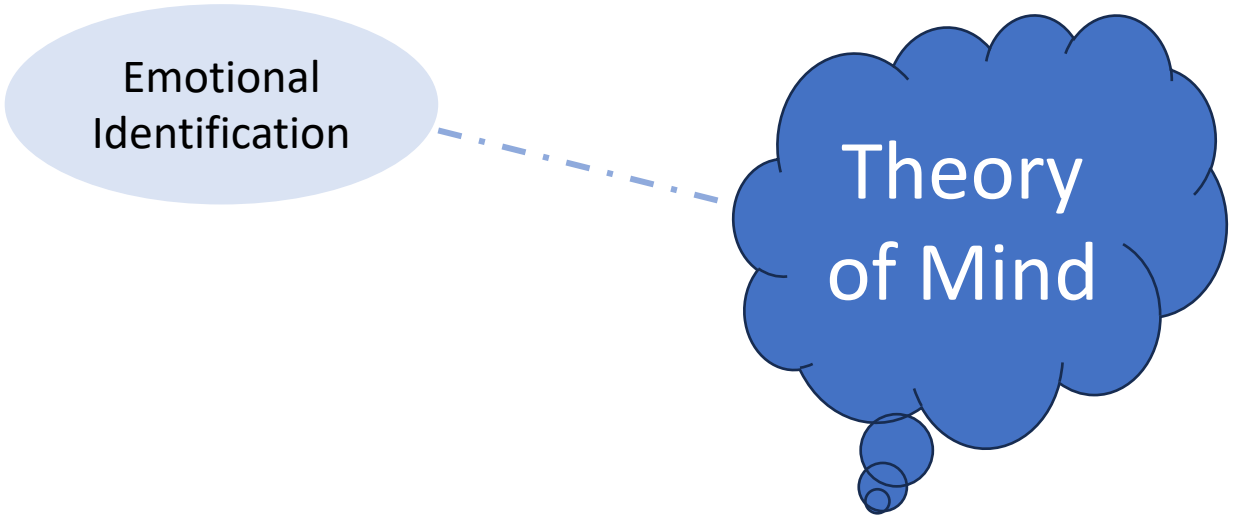

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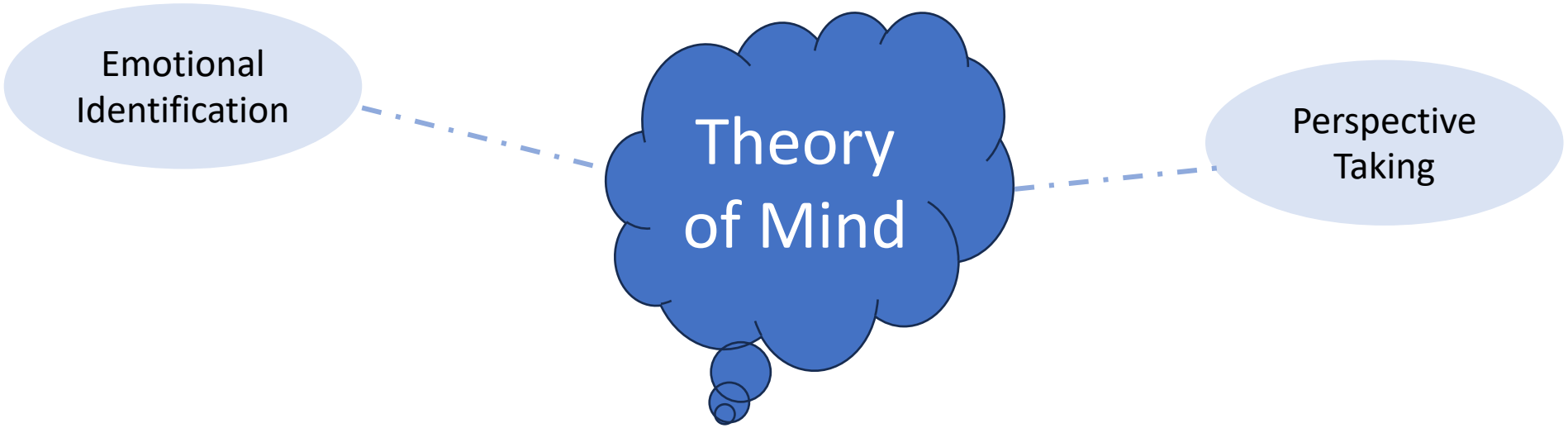

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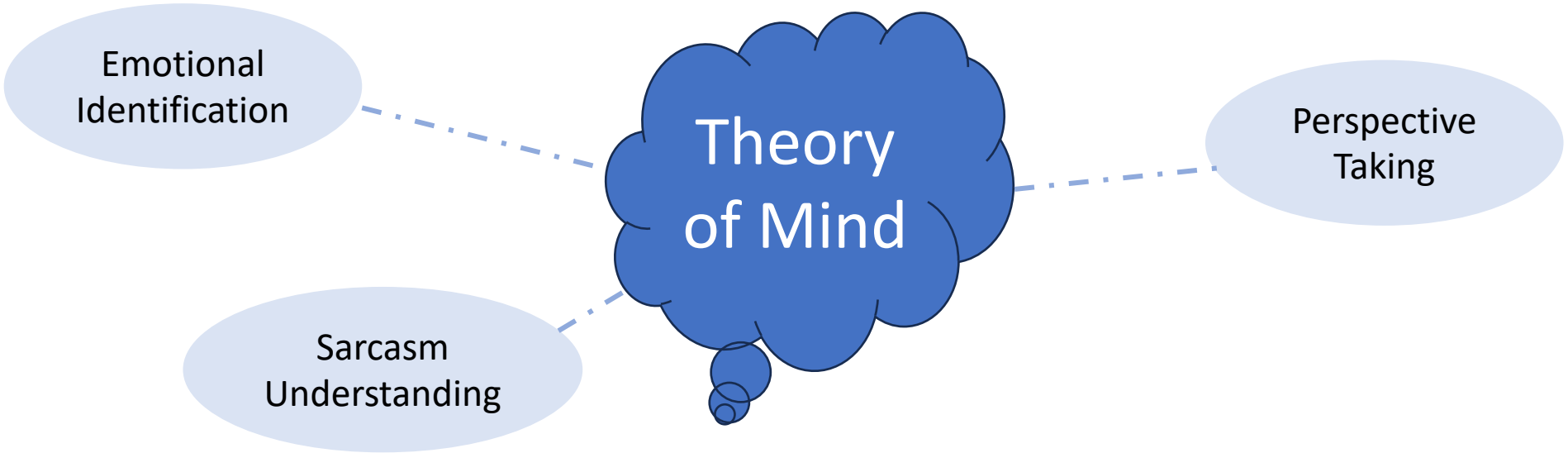

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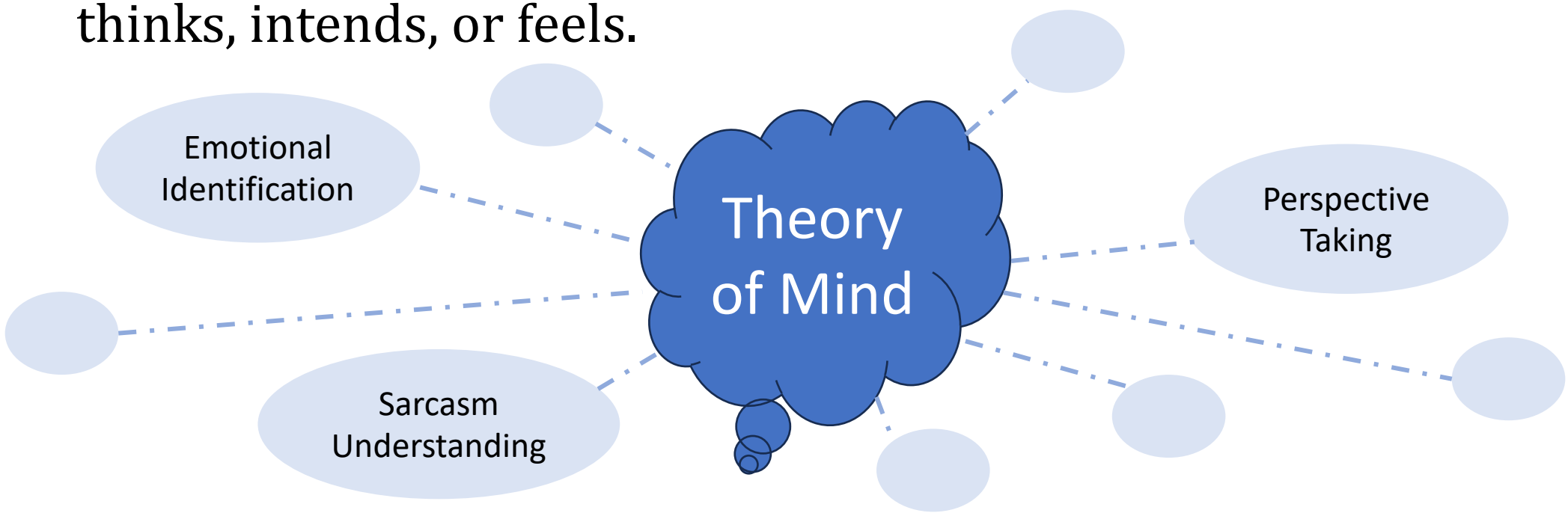

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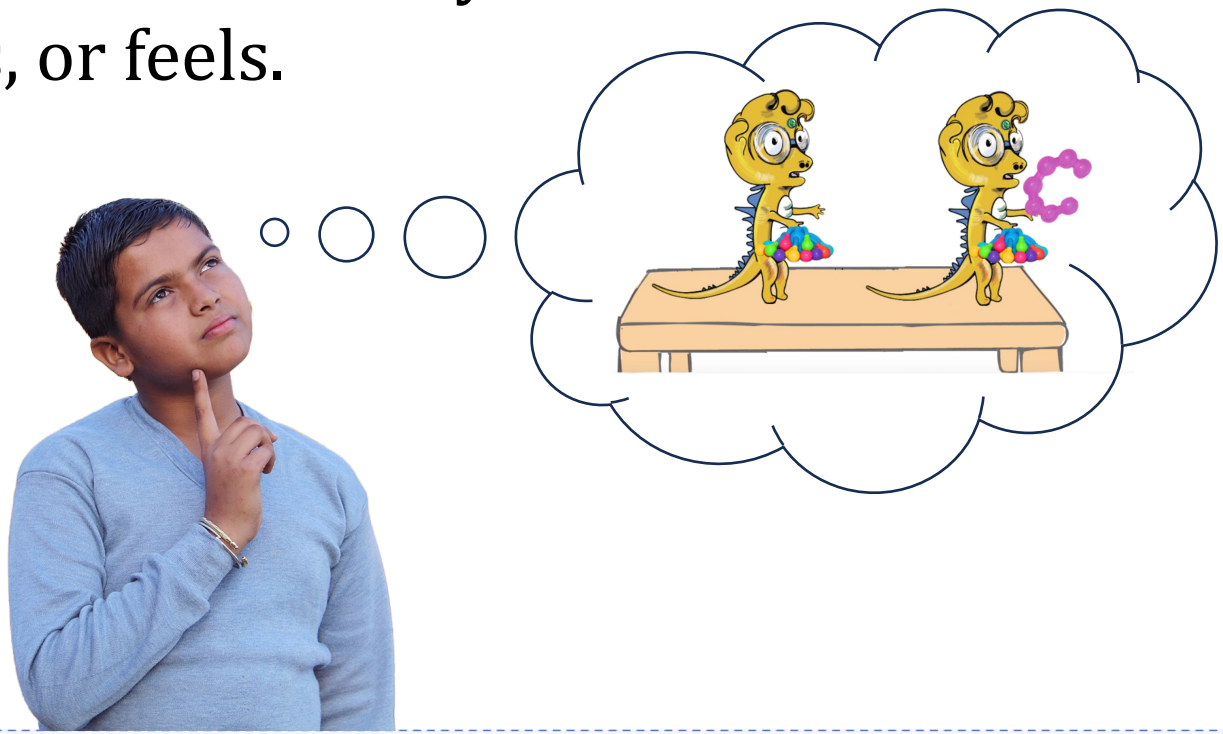

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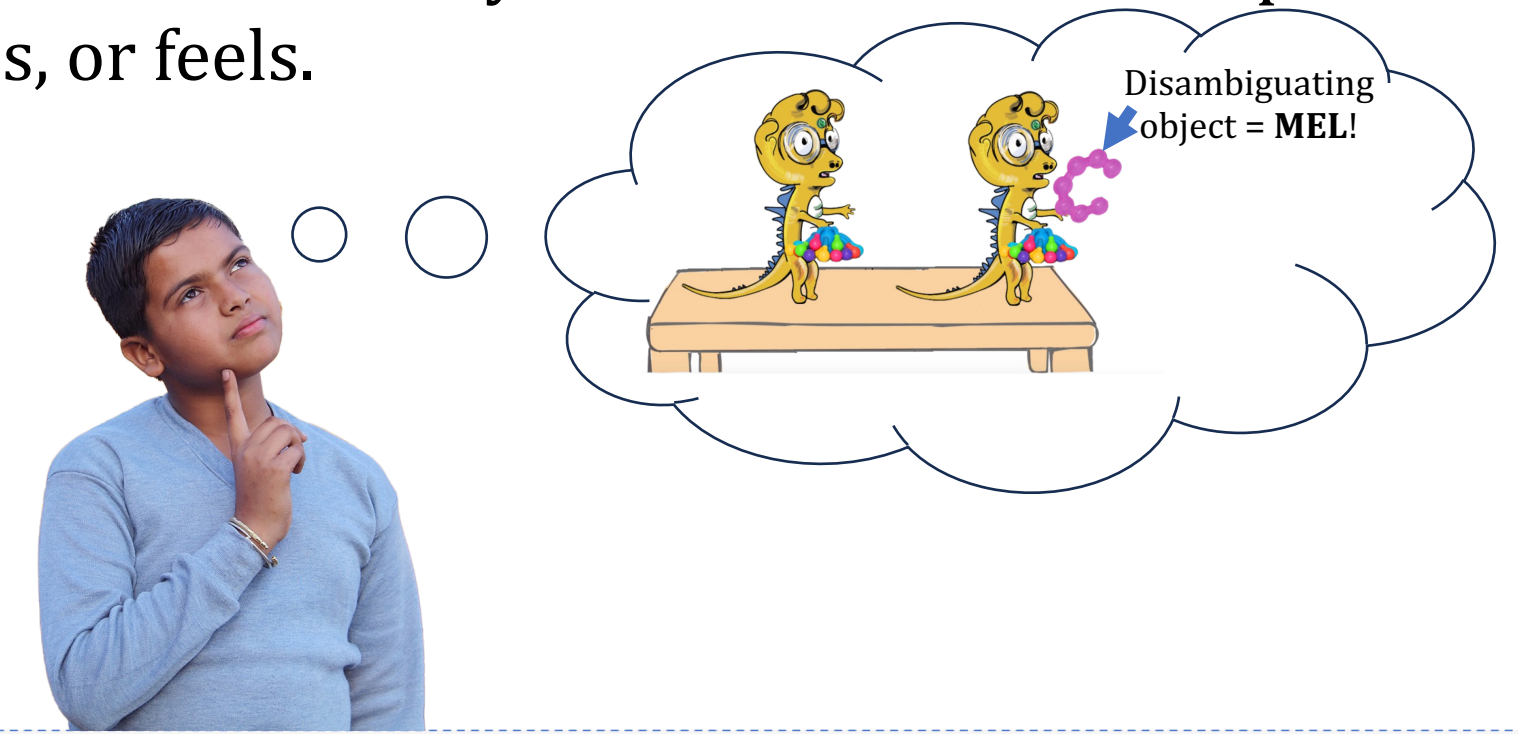

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Prior Research

Those that can **map** words via pragmatic inference include –

- ✓ Neurotypical children ages 4-6
- ✓ Neurotypical children ages 6-9
- ✓ Neurotypical adults

Adult Pre-Print:

QLAB

+

Dionysia Saratsli

+

Anna Papafragou

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Those that have a **memory advantage** for pragmatically inferred words –

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Retention of pragmatically inferred words is modulated by **theory of mind** skills –

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Autistic Children

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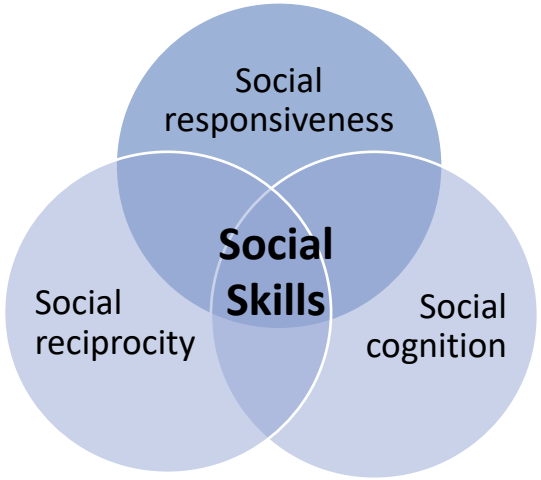
- Theory of mind difficulties are central to autistic symptomology
  - Intertwined with DSM-V diagnostic criteria



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Autistic Children

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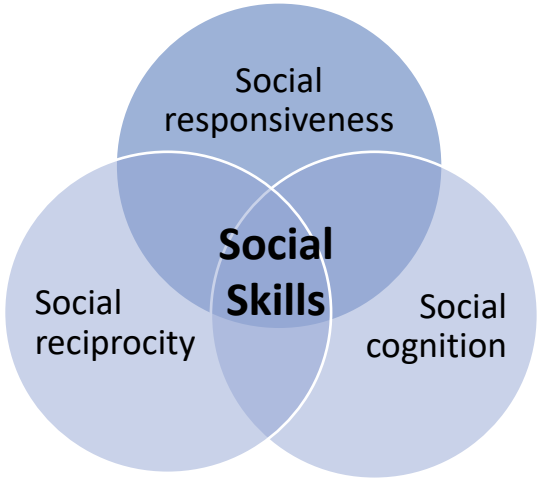

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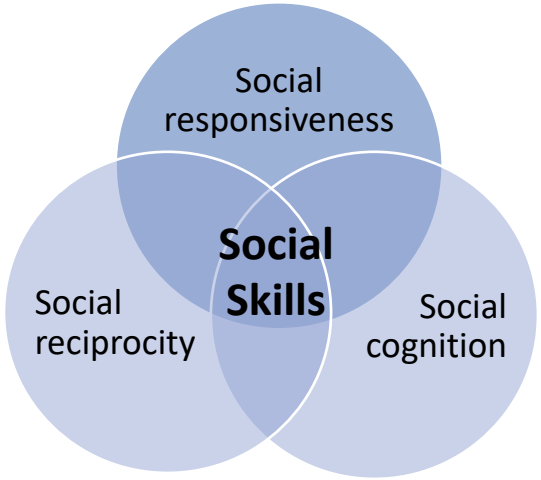
Autistic Children

- Theory of mind difficulties are central to autistic symptomology
  - Intertwined with DSM-V diagnostic criteria
  - Research on word learning interface has focused on basic social cues
- Understanding of informativity may not develop until teenage years



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Autistic Children

- 60% of autistic children present with co-occurring language impairment, including vocabulary

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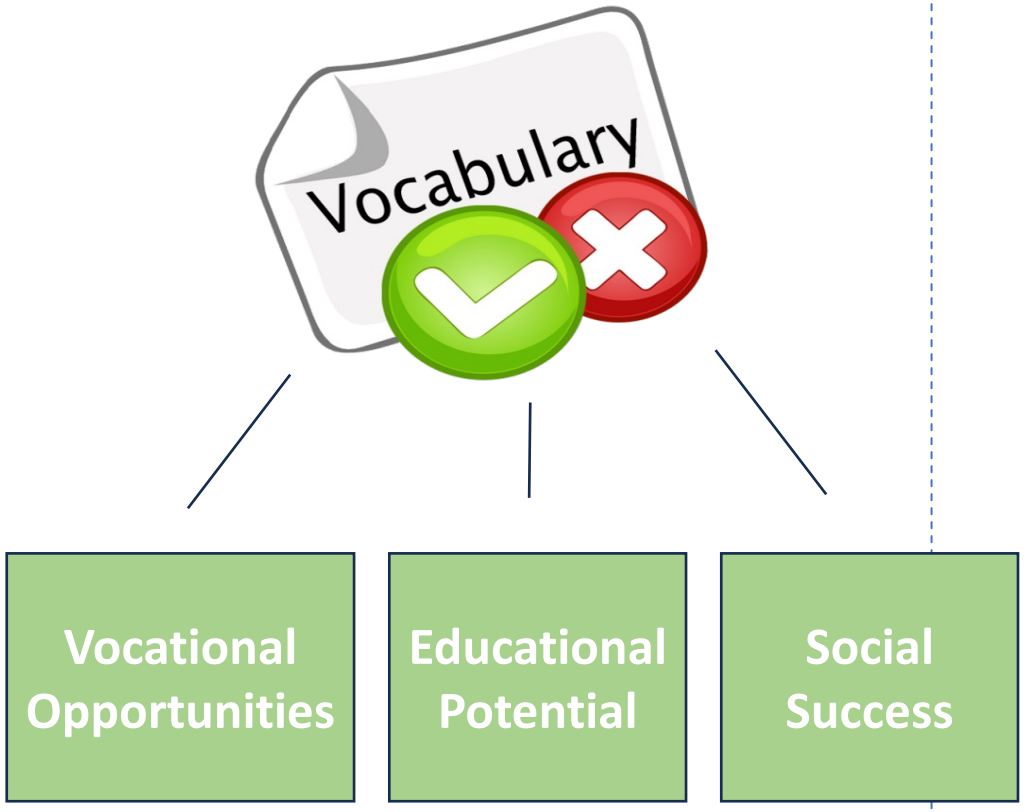
Autistic Children

- 60% of autistic children present with co-occurring language impairment, including vocabulary
  - Difficulties do not resolve with age
- Language skills and vocabulary correlate with long term vocational, educational, and social success.



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Research Questions

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- How do autistic children (6-9 years old) learn and retain novel words in an inferential context vs a direct mapping context?
  - Is there a memory advantage for pragmatically inferred words?
- What individual difference measures – theory of mind skills, language skills, non-verbal intelligence, etc – relate to better pragmatic inference learning and retention?

Participants

- Recruited from SPARK Database
  - Professionally diagnosed with autism

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- Recruited from SPARK Database
- ✓ - Professionally diagnosed with autism

SPARK

Simons Powering Autism Research

Participants

- Recruited from SPARK Database
- ✓ - Professionally diagnosed with autism
- ✓ - Speak at least three-word sentences

SPARK

Simons Powering Autism Research

Participants

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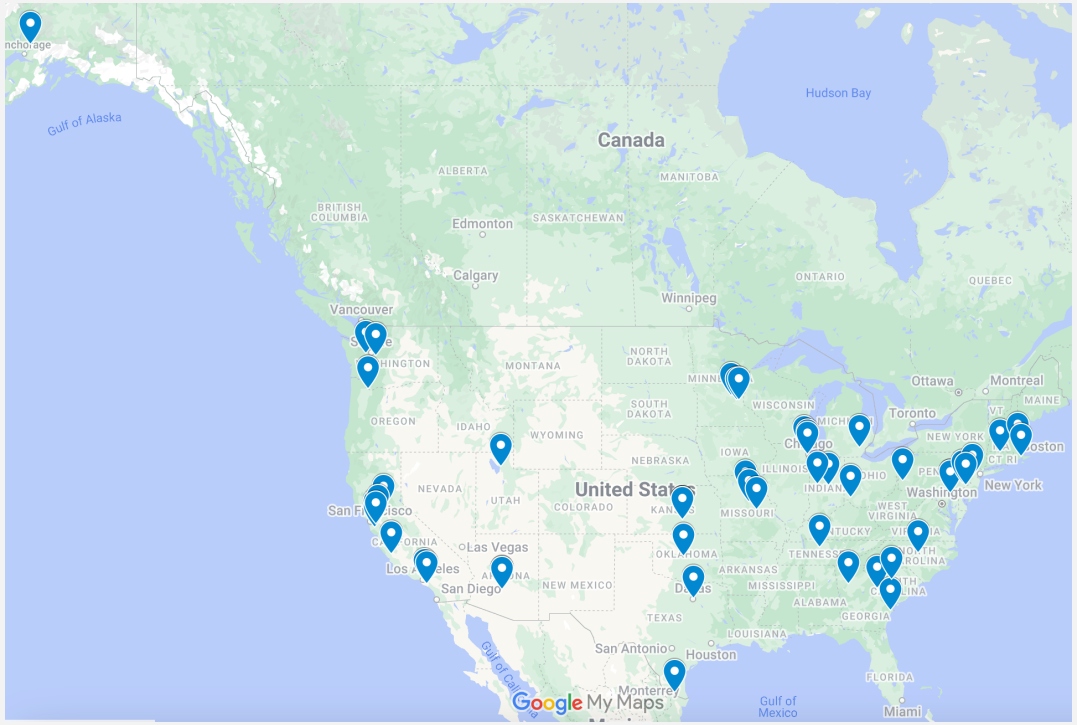
- ✓ - Professionally diagnosed with autism
- ✓ - Speak at least three-word sentences
- ✓ - Excluded if Social Communication Questionnaire below autism cutoff and were marked as diagnosis validity in question on SPARK Database



Participants

- 49 autistic children
  - Between the ages of 6 and 9

Demographics (n=49)		Count	%	Mean	Standard Deviation	Range
Age (years)				7;7	0;11	6;0 – 8;10
Gender	Male	35	71%			
	Female	14	29%			
Race/Ethnicity	White	32	65%			
	Black	6	12%			
	Asian	2	4%			
	Hispanic/Latino	4	8%			
	Multiracial	5	10%			
Area Deprivation Index				36.1	23.9	1-98
SCQ				18	6.3	5-30

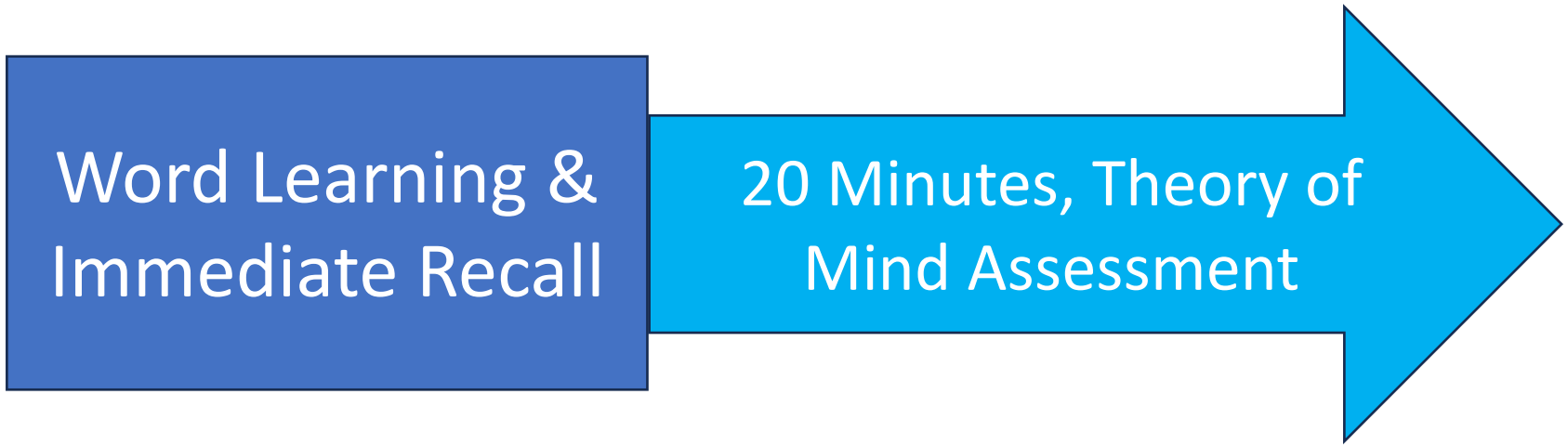
- Tested on Gorilla Experimental Builder via Zoom

Main Experiment

Main Experiment

Word Learning & Immediate Recall

Main Experiment



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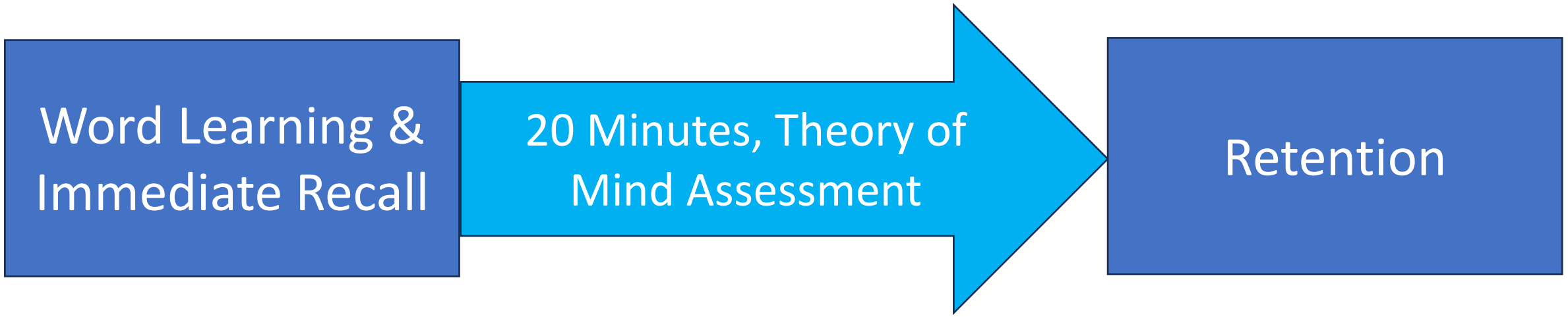


Main Experiment

Word Learning & Immediate Recall

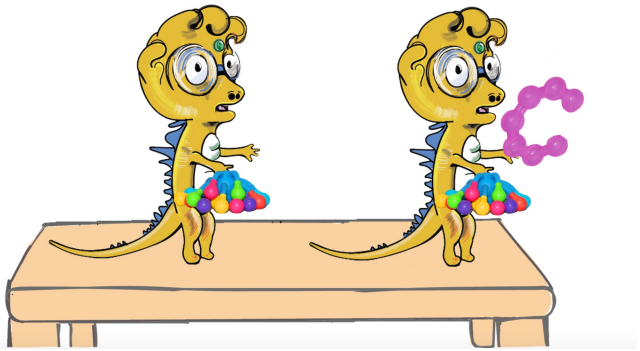
20 Minutes, Theory of Mind Assessment

Retention

Learning

1) Learning 2) Immediate Recall 3) Retention

Inference



"Look! I like this dinosaur! It is holding a **MEL**!"

- Four words per condition
- Two trials per word
- Blocked design

Learning

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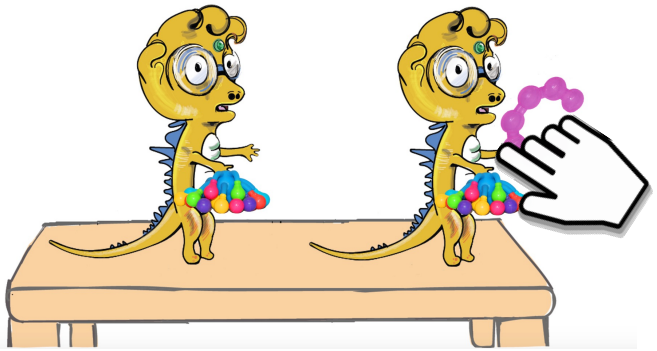
Inference



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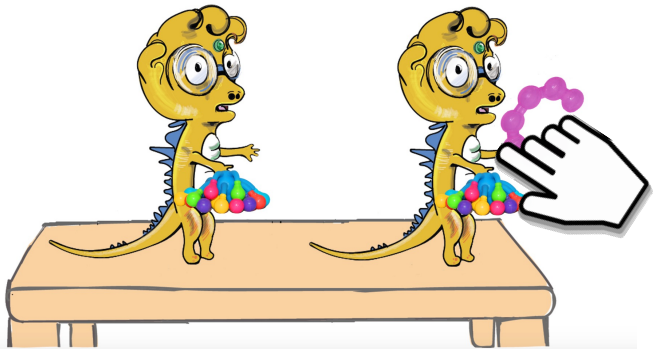

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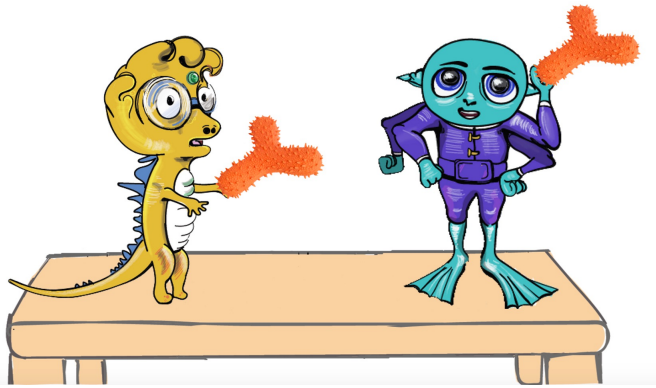
Direct Mapping



"Look! I like this **BINK**! It is on the alien!"

- Four words per condition
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Learning

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2) Immediate Recall

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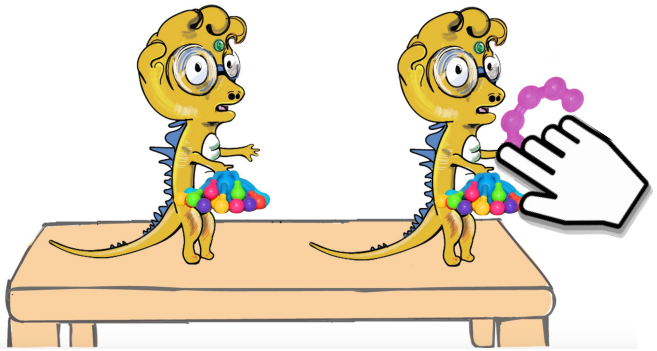
Inference



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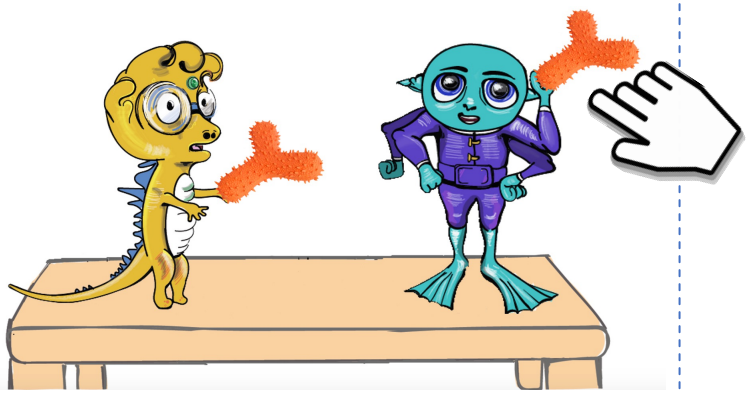

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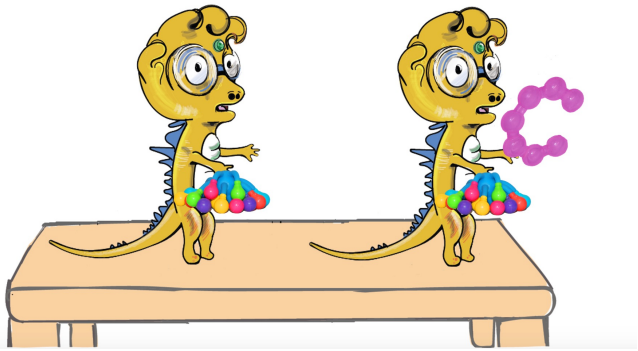

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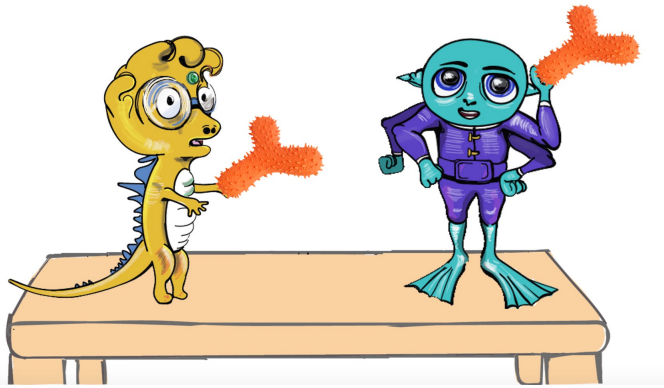

"Look! I like this **BINK**! It is on the alien!"

- Coded for looks to target vs competitor vs away

Learning

1) Learning

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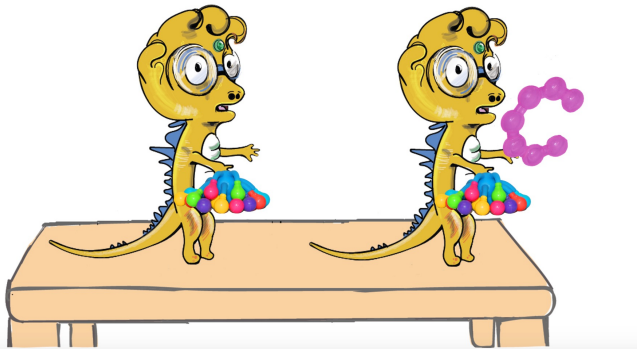
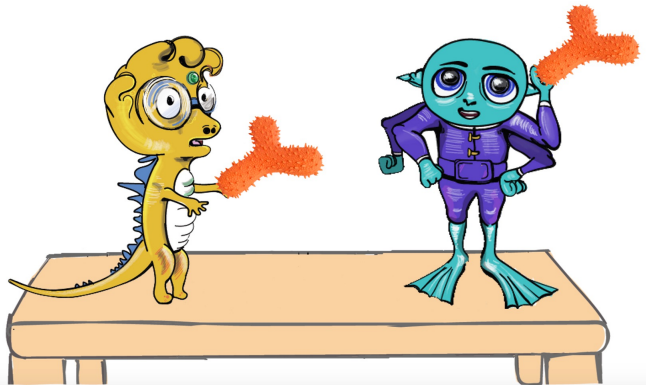
Inference



"…ing a **MEL**!"

Direct Mapping



"…the alien!"

- Coded for looks to target vs competitor vs away
- 200 ms before – 1800 ms after final word onset

Recall & Retention

1) Learning

Inference

Which one is a MEL?

2) Immediate Recall

3) Retention

Direct Mapping

Which one is a BINK?

Recall & Retention

1) Learning

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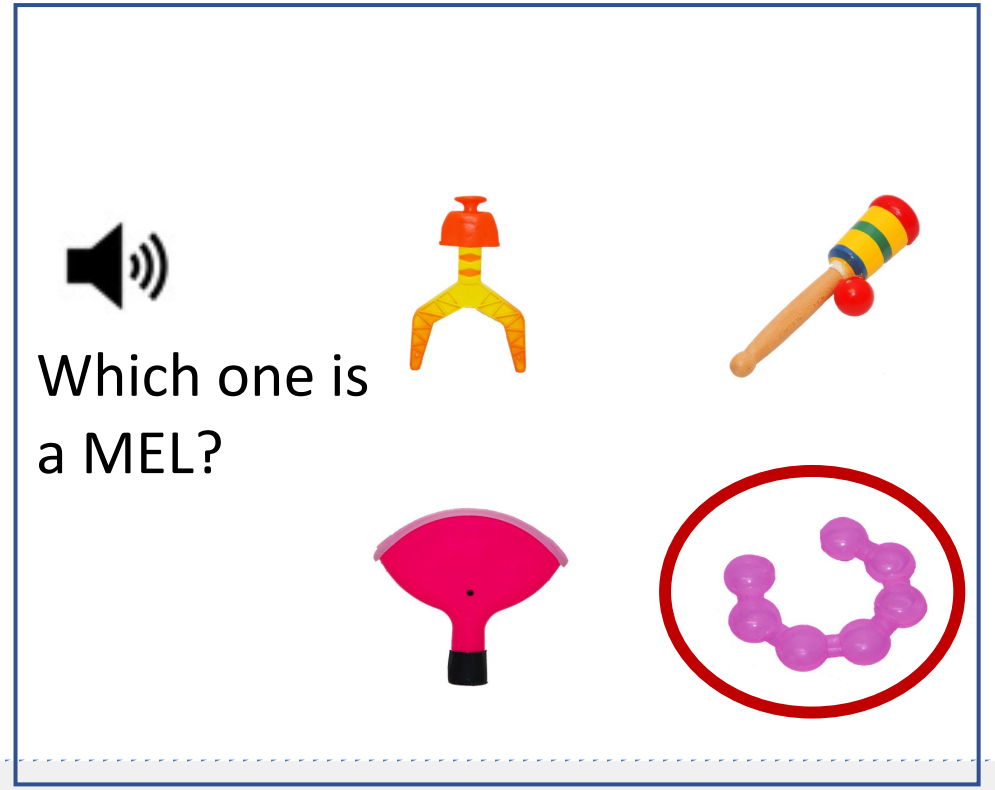

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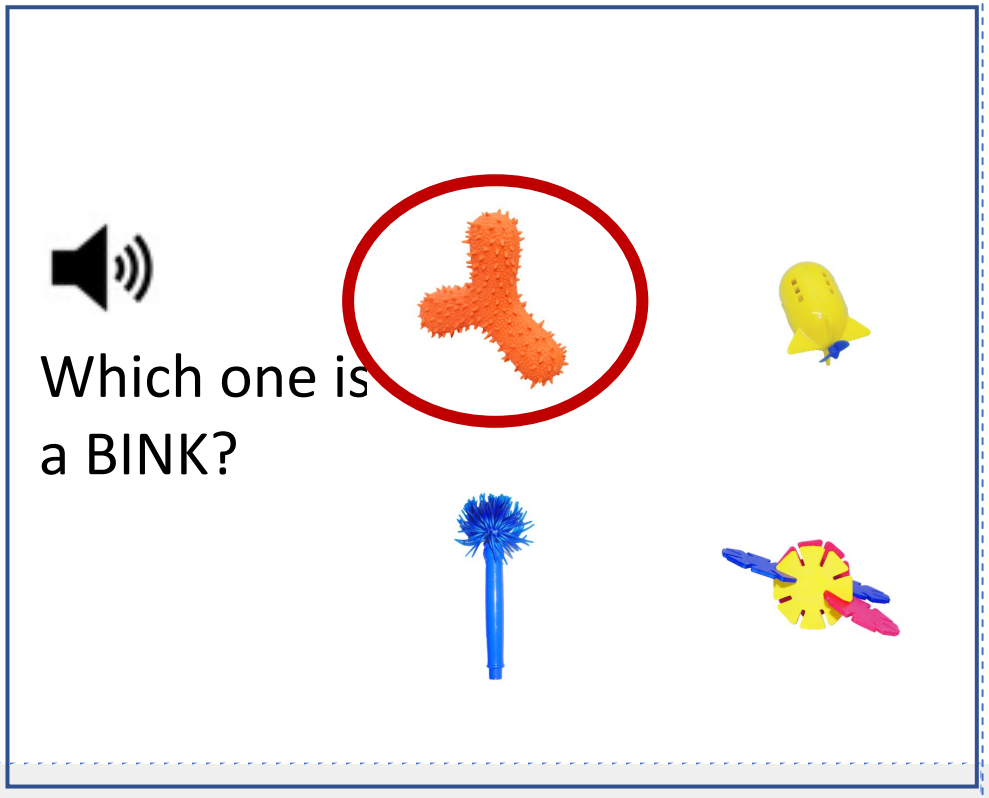
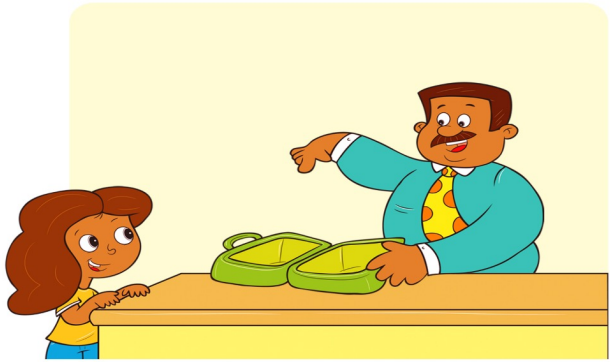
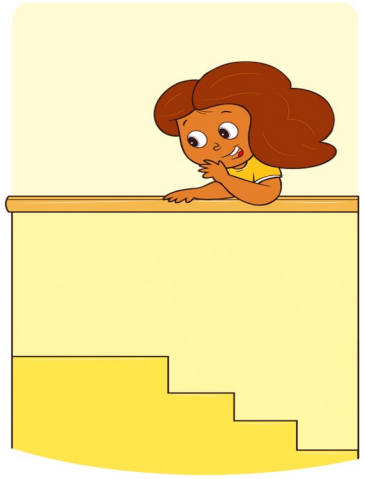
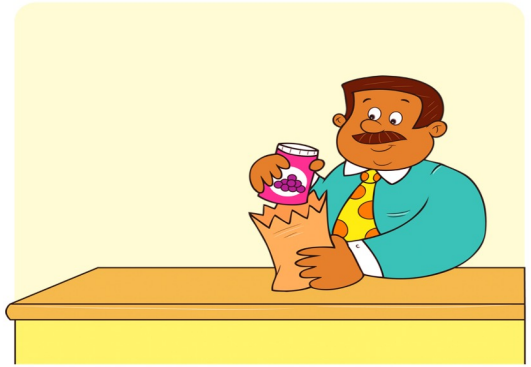
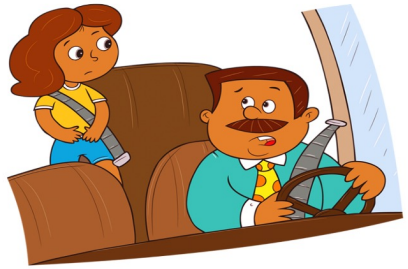


Theory of Mind Booklet Task









Theory of Mind Question Example: Why is Emma surprised?

Richardson, H. et. al. (2018). Development of the social brain from age three to twelve years. *Nature Communications, 9*, 1027.

Other Individual Difference Measures

- Theory of Mind
  - Theory of Mind Booklet

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- Theory of Mind
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  - Autism Behavioral Inventory – Short
    - Social Communication Sub-score

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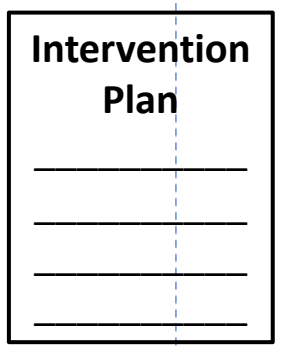
- Interventions
  - Autism Services
  - Individualized Education Plan
    - With or without language services



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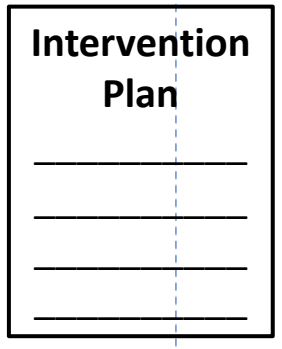


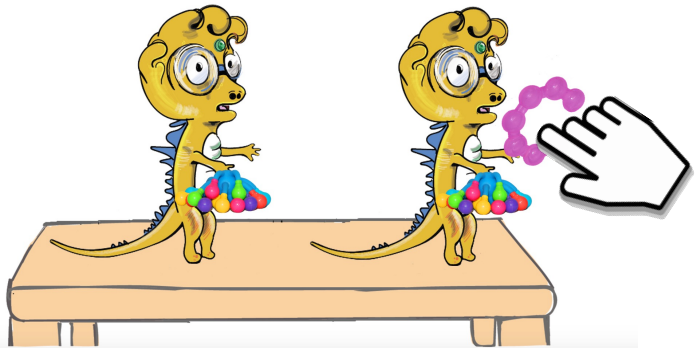
- Cognition & Demographics
  - Kaufman Brief Intelligence Test
    - Non-Verbal
  - Current Age
  - Age at Diagnosis
  - Gender

Results

Autistic children can map words via pragmatic inference

- Pragmatic Inference
  - 0.62 ± 0.05

Inference



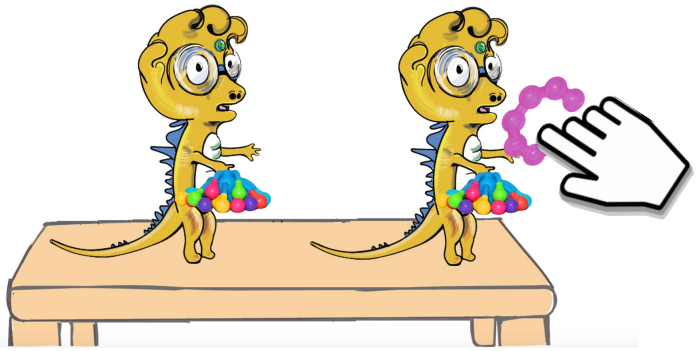
"Look! I like this dinosaur! It is holding a **MEL**!"

Error values represent 95% confidence intervals

Autistic children can map words via pragmatic inference

- Pragmatic Inference
  - 0.62 ± 0.05
- Direct Mapping
  - 0.93 ± 0.03

Inference



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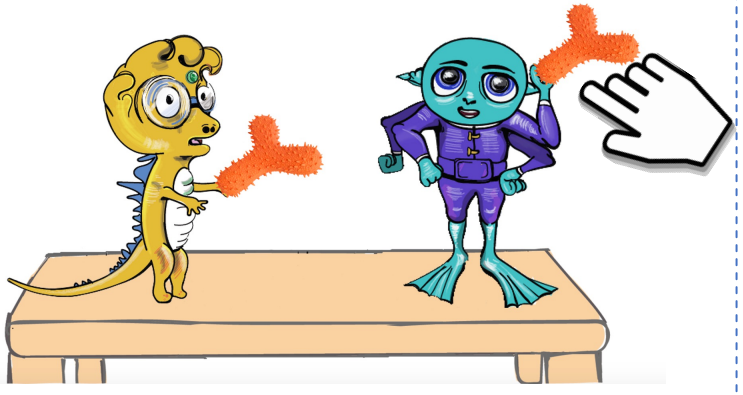
Direct Mapping



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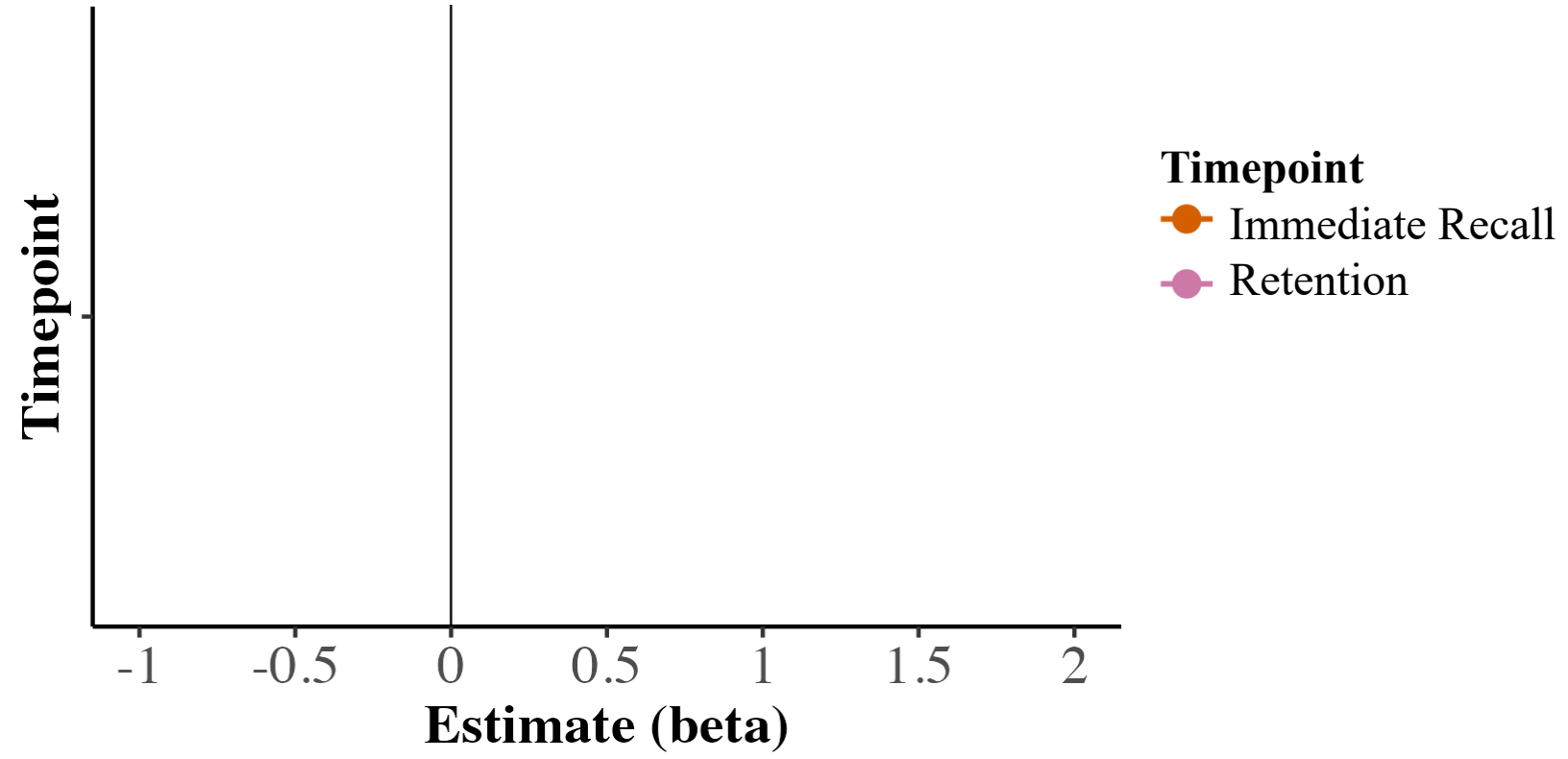
Error values represent 95% confidence intervals

Difference Between Conditions

Direct Mapping > Pragmatic Inference

Pragmatic Inference > Direct Mapping



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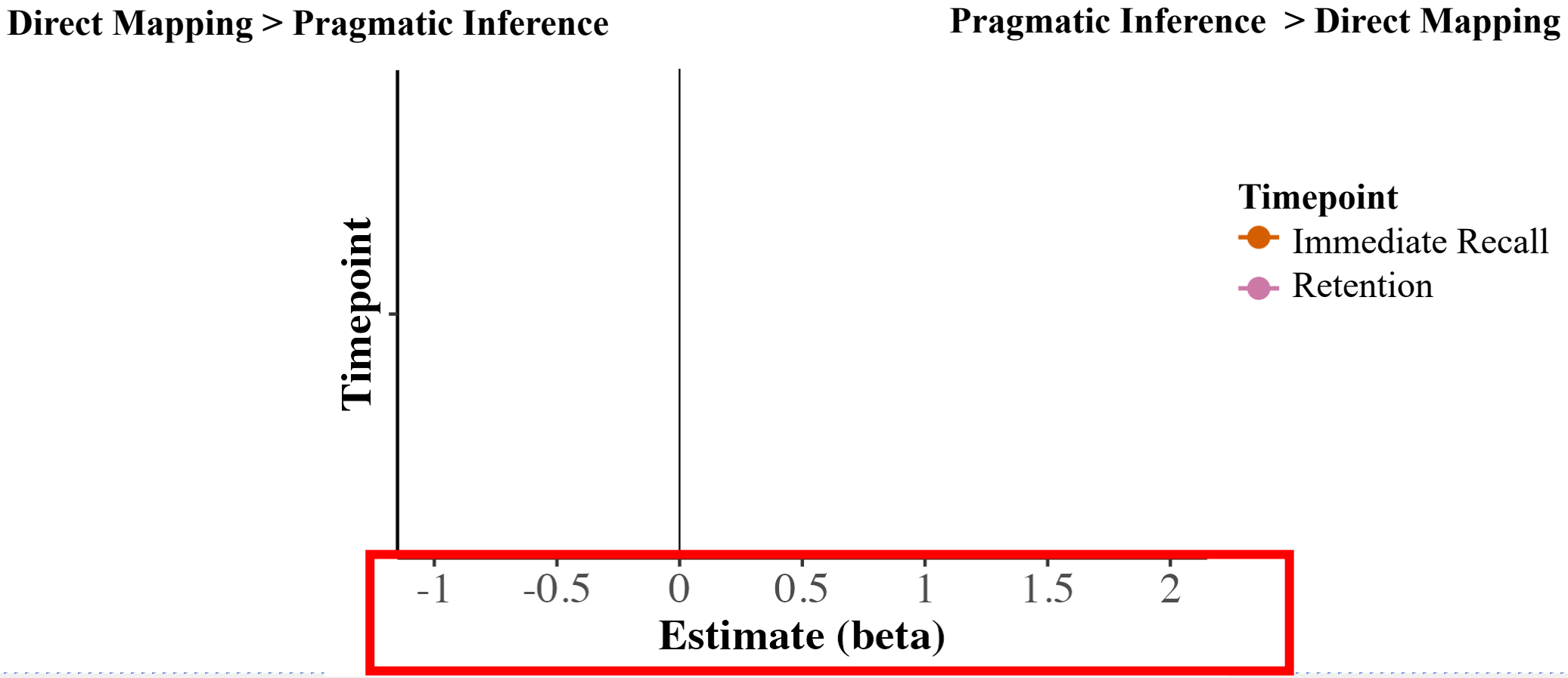

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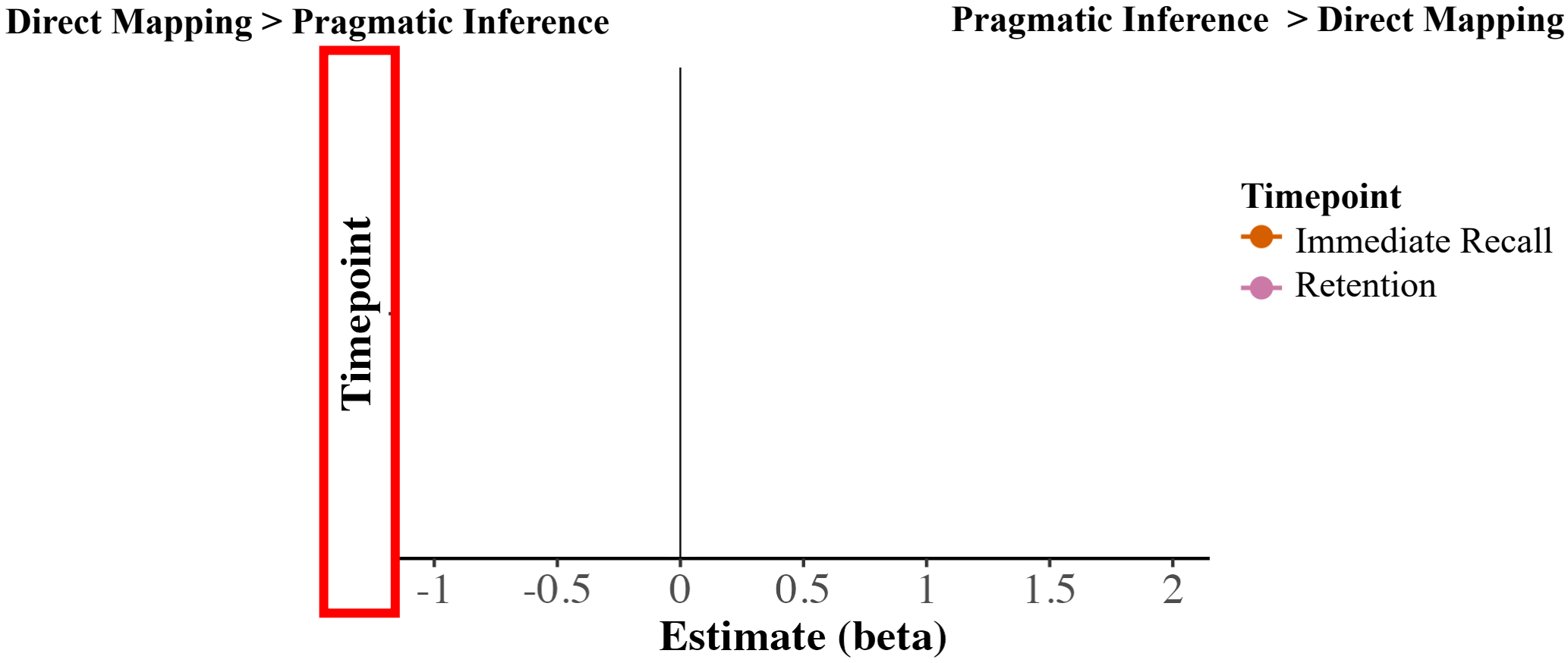
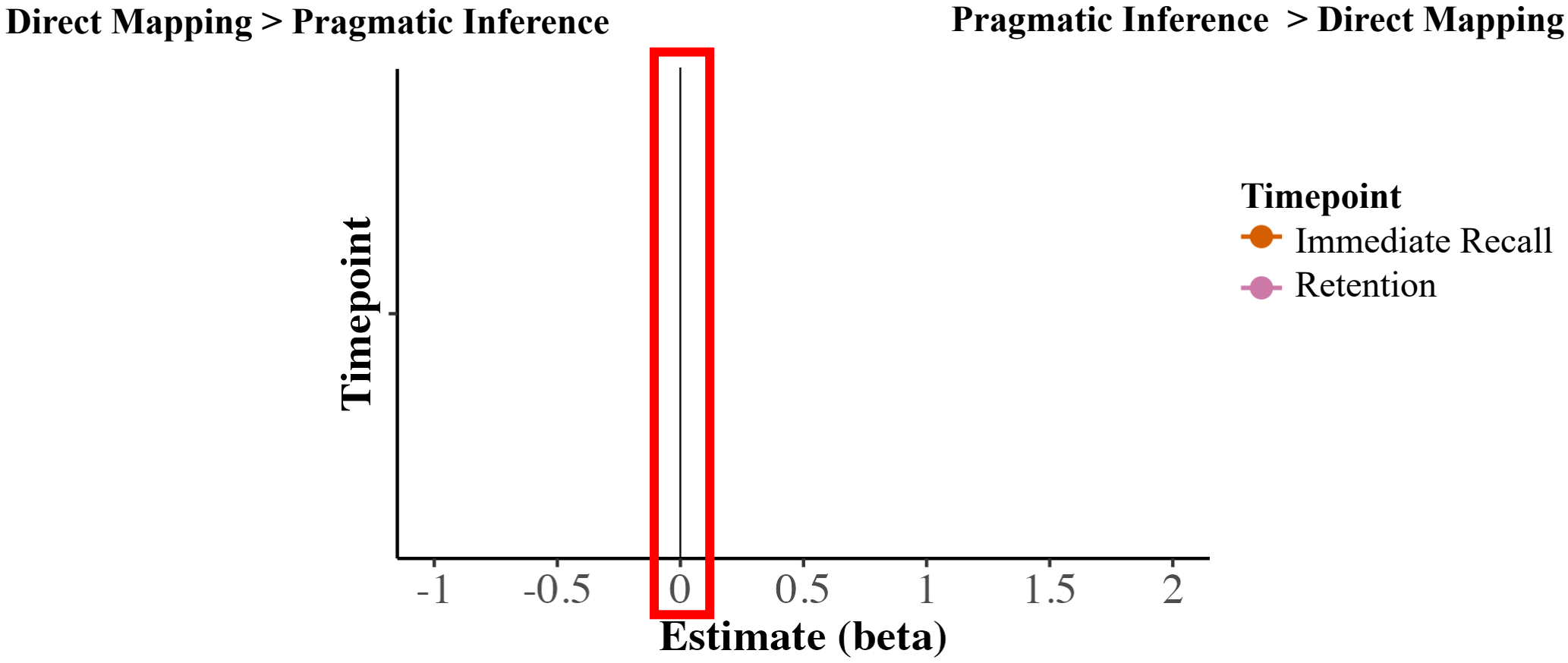


Difference Between Conditions



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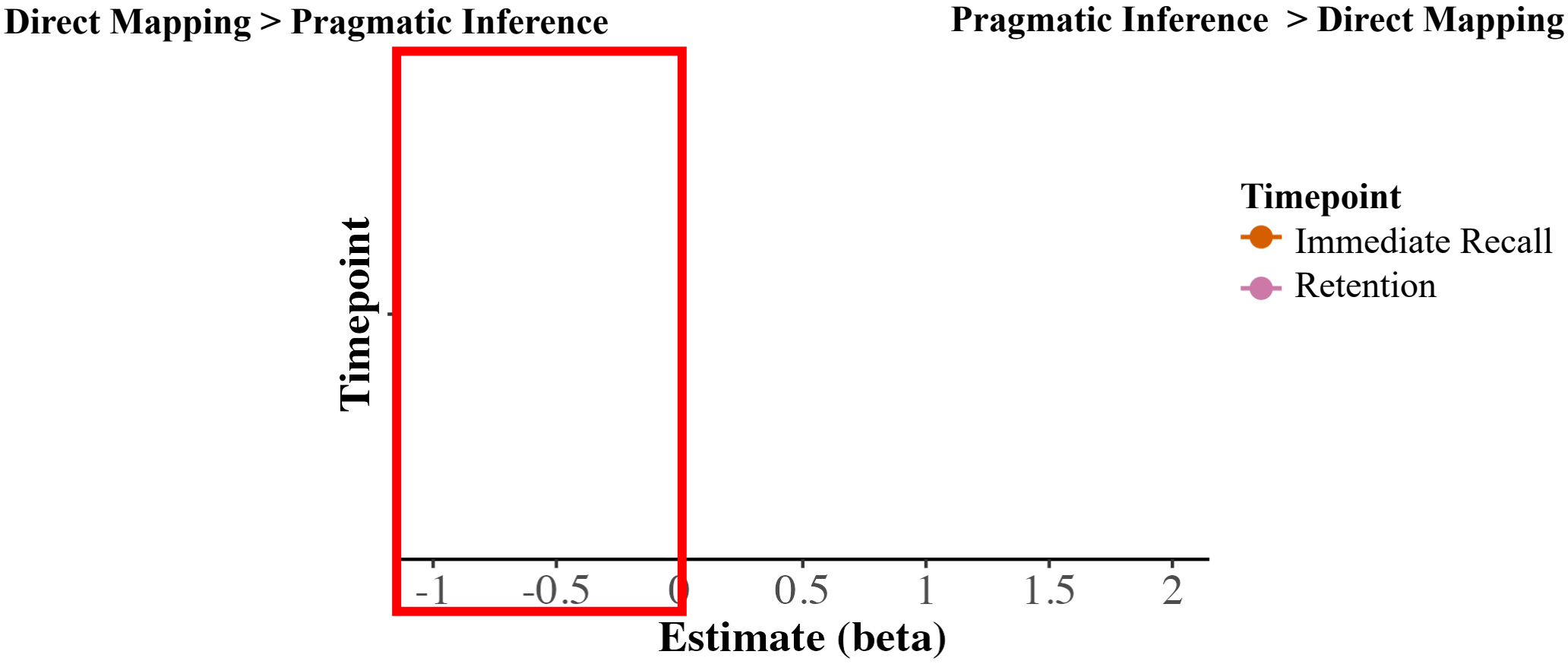

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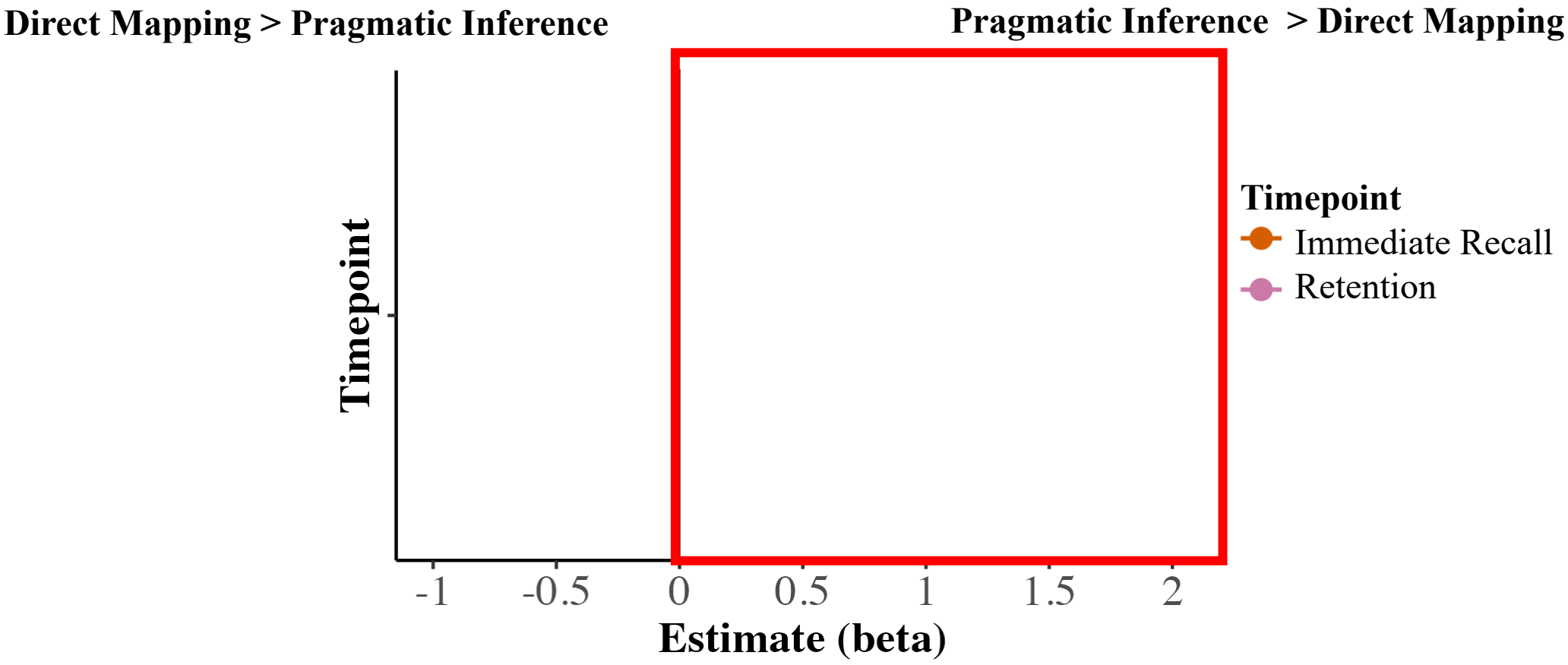
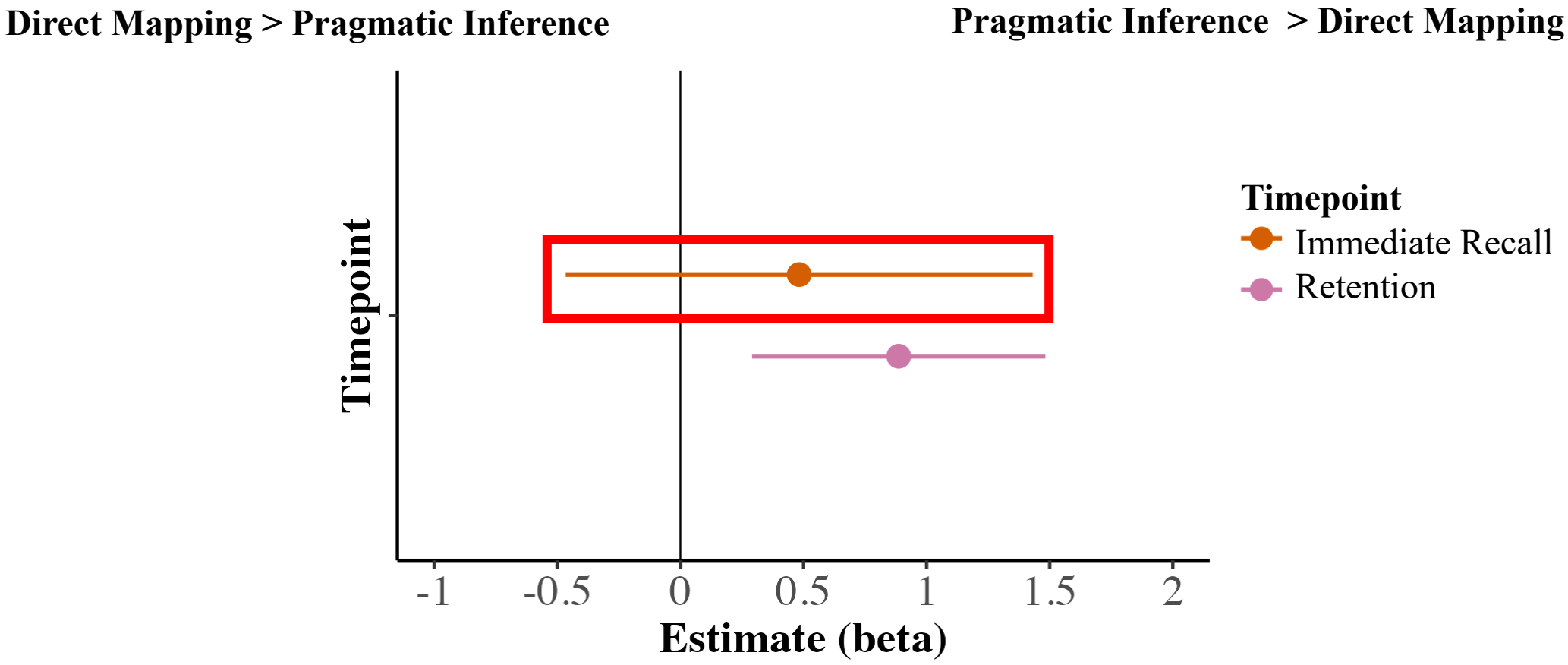
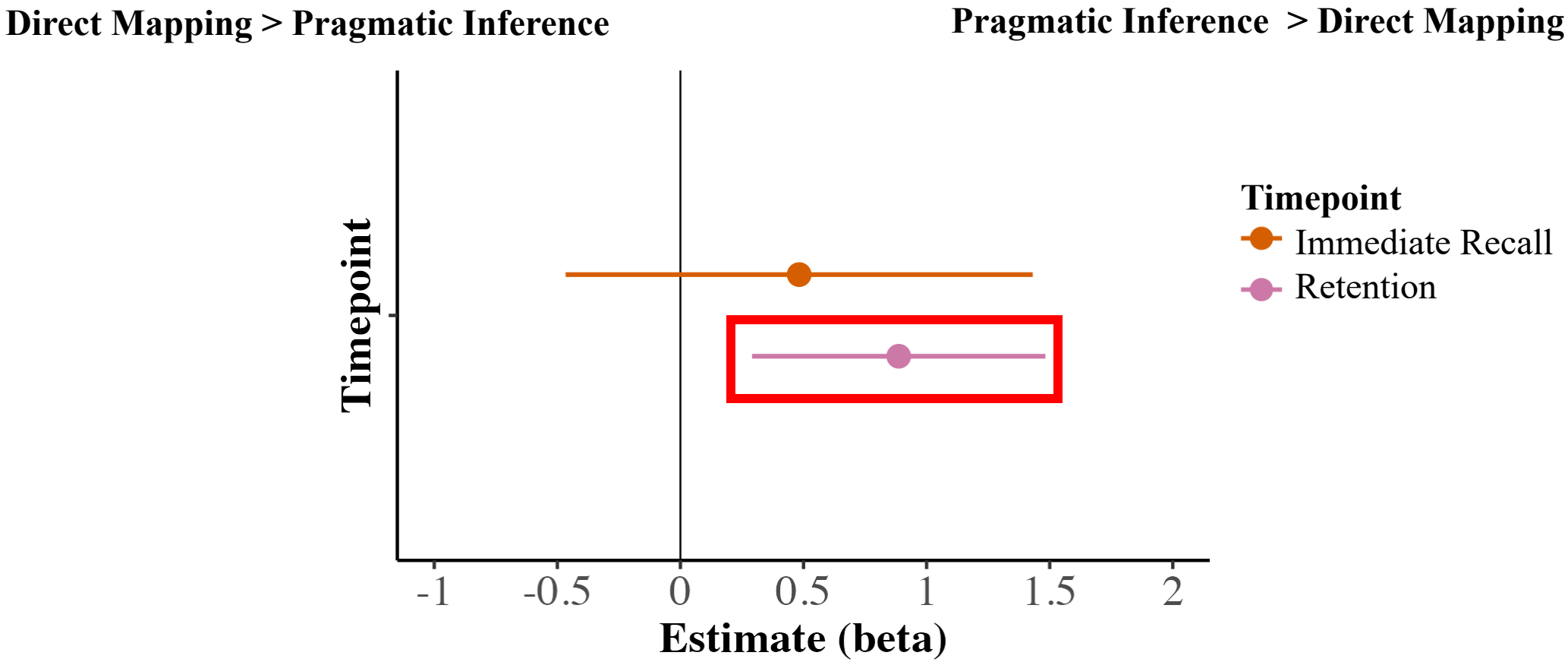


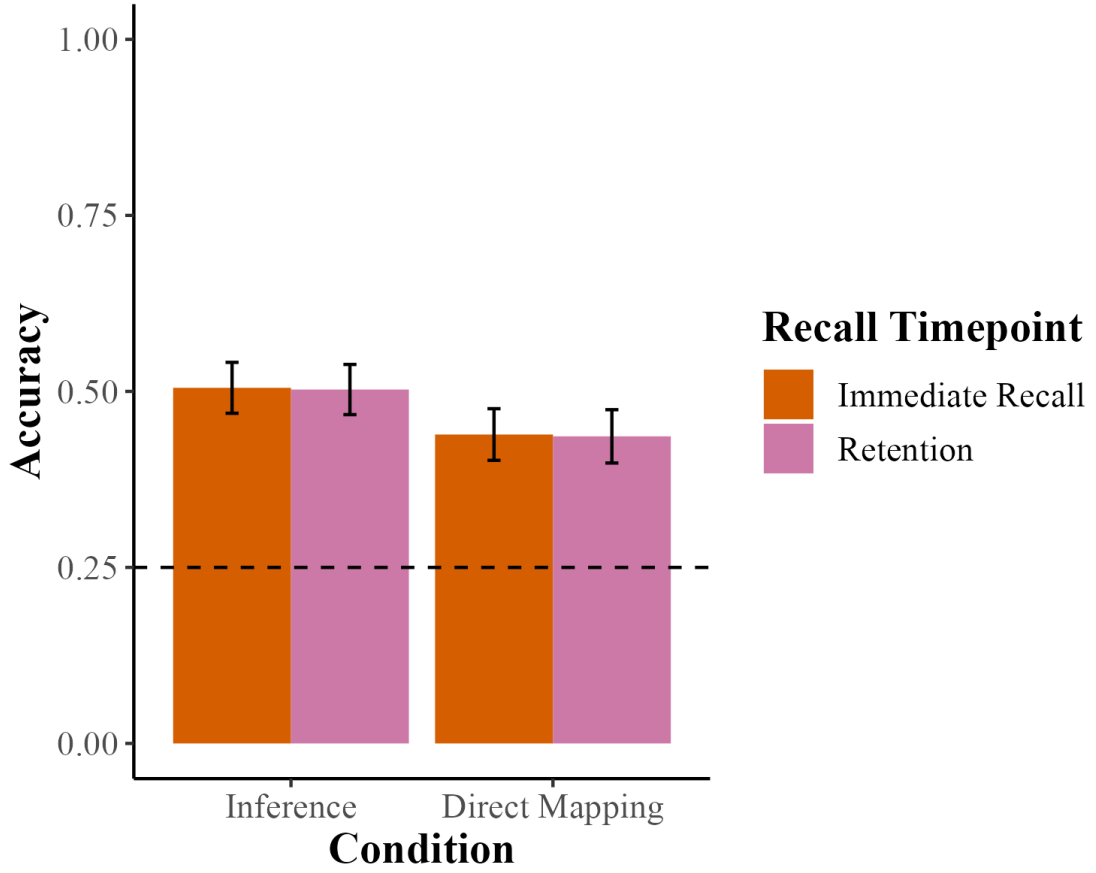
No Difference in Conditions During Immediate Recall



Pragmatic Inference Advantage During Retention



Memory Stable Across Conditions



Interim Summary

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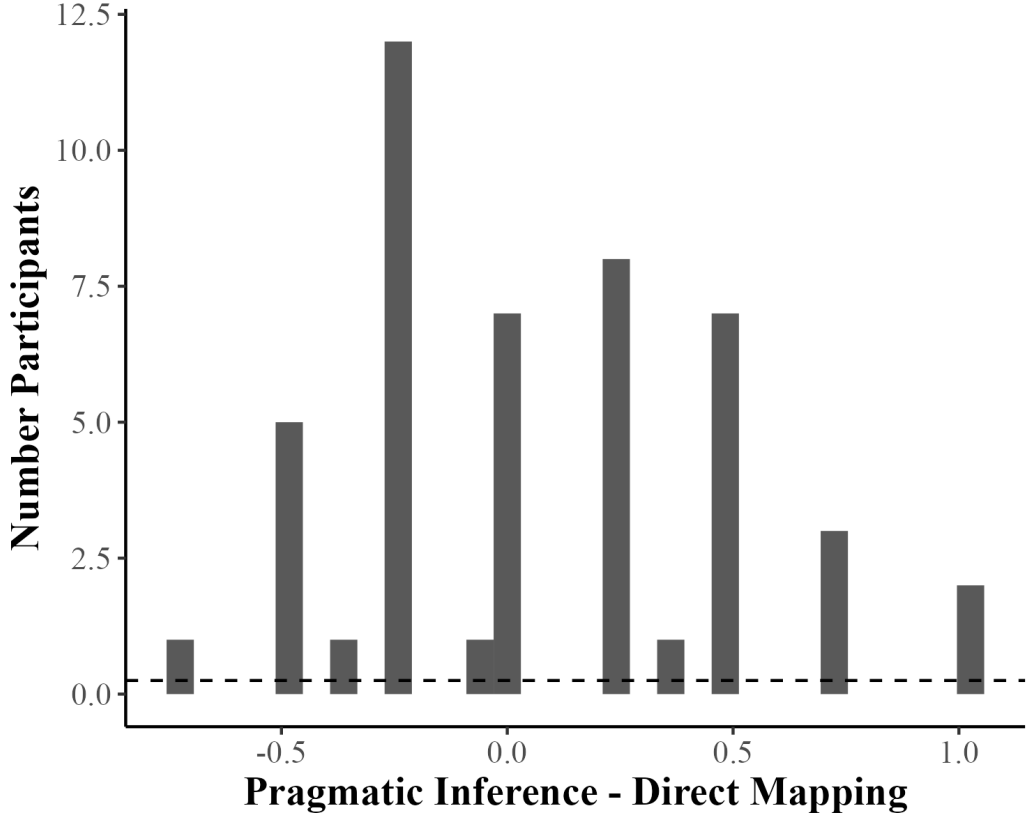
But!

Pragmatic Inference Advantage is not Universal



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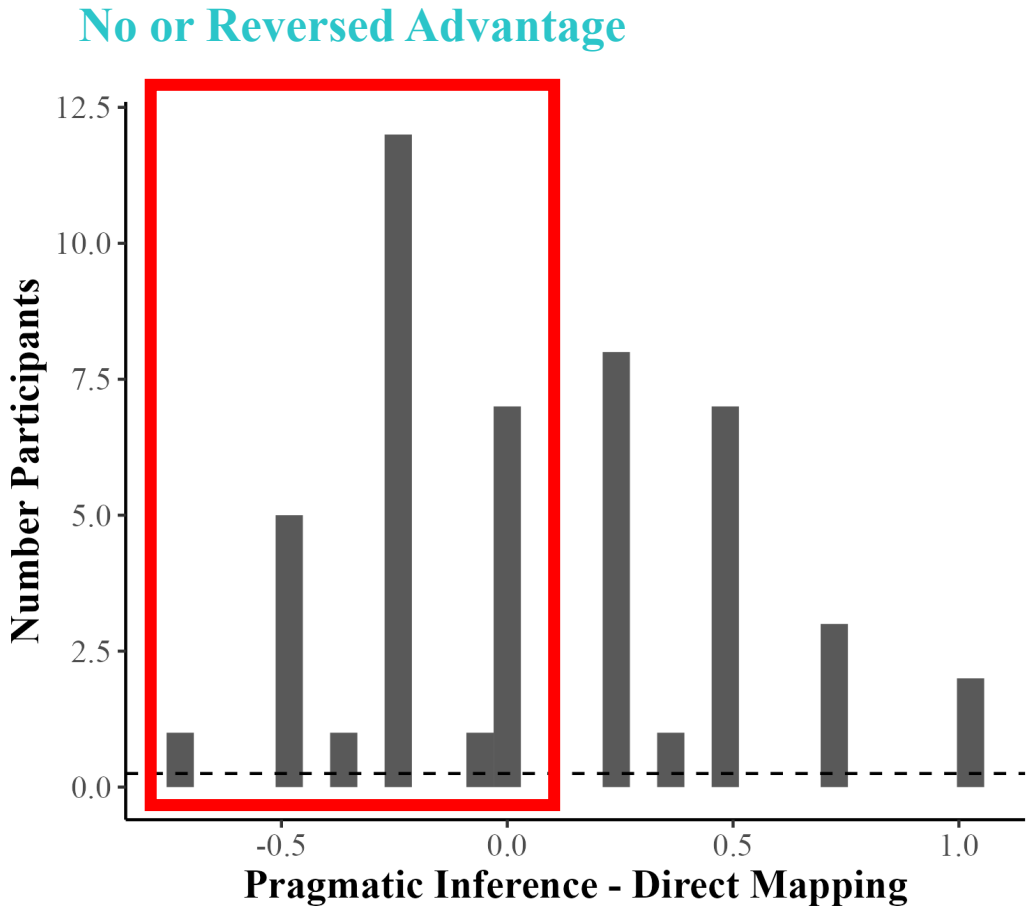

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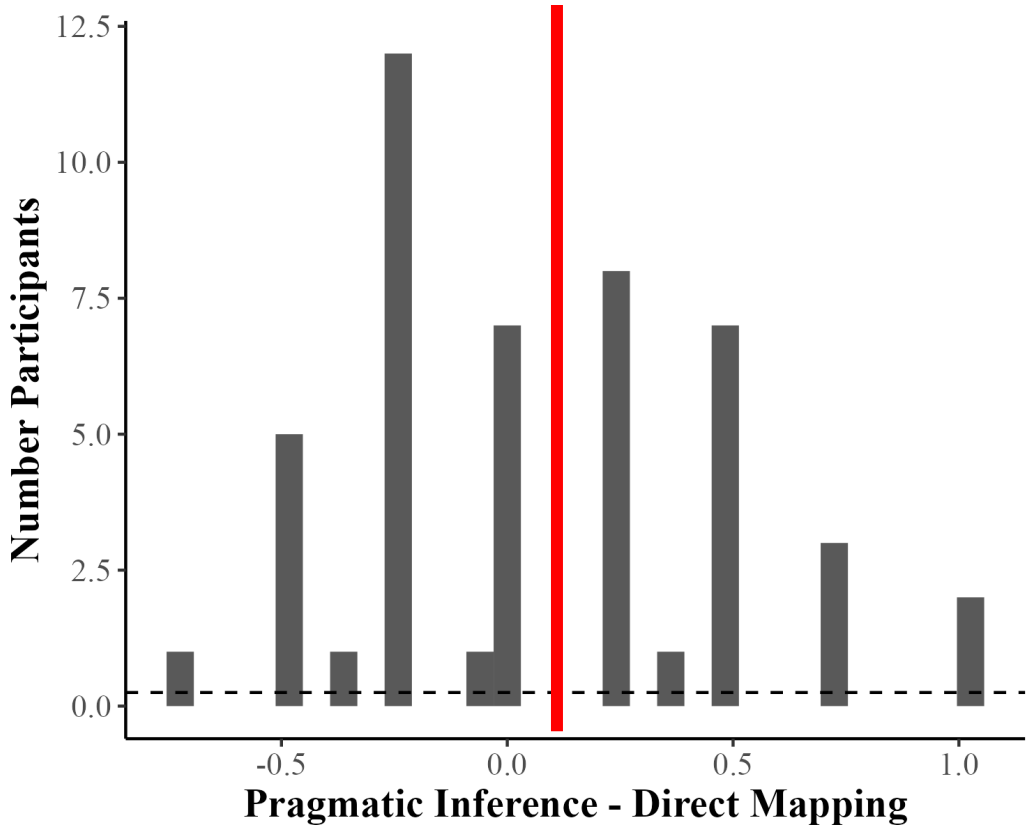

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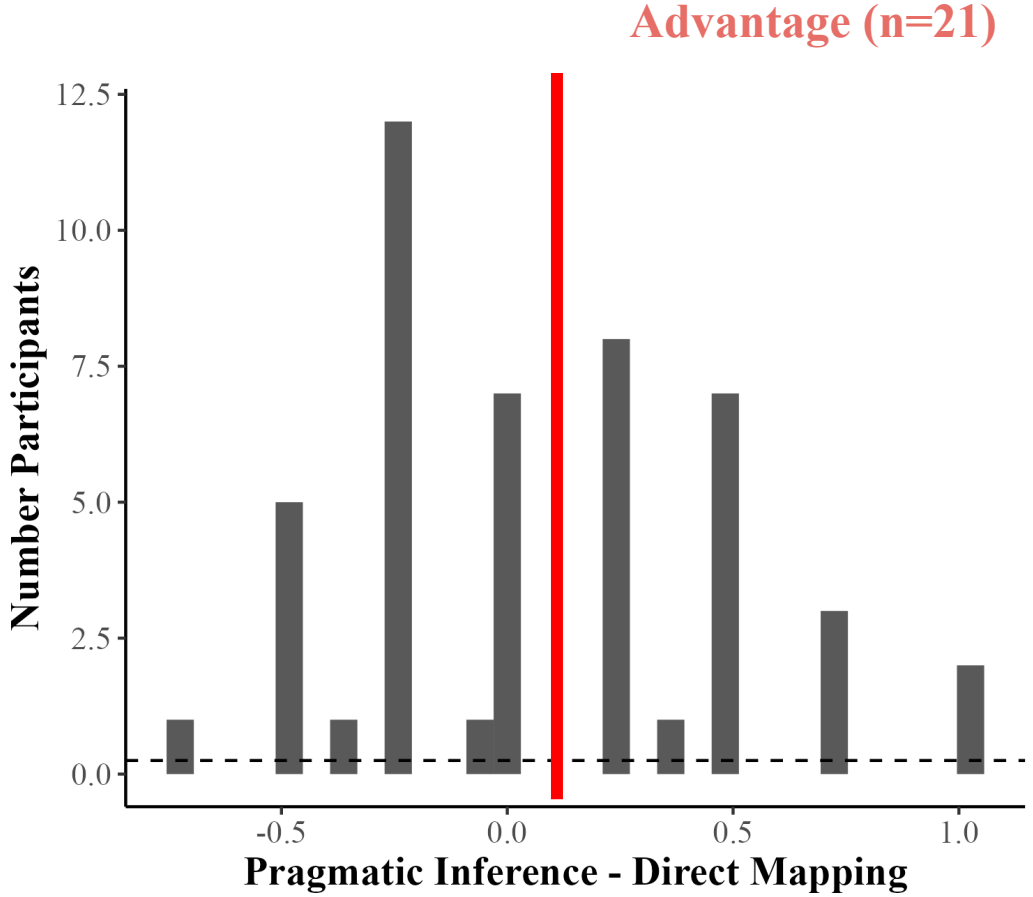

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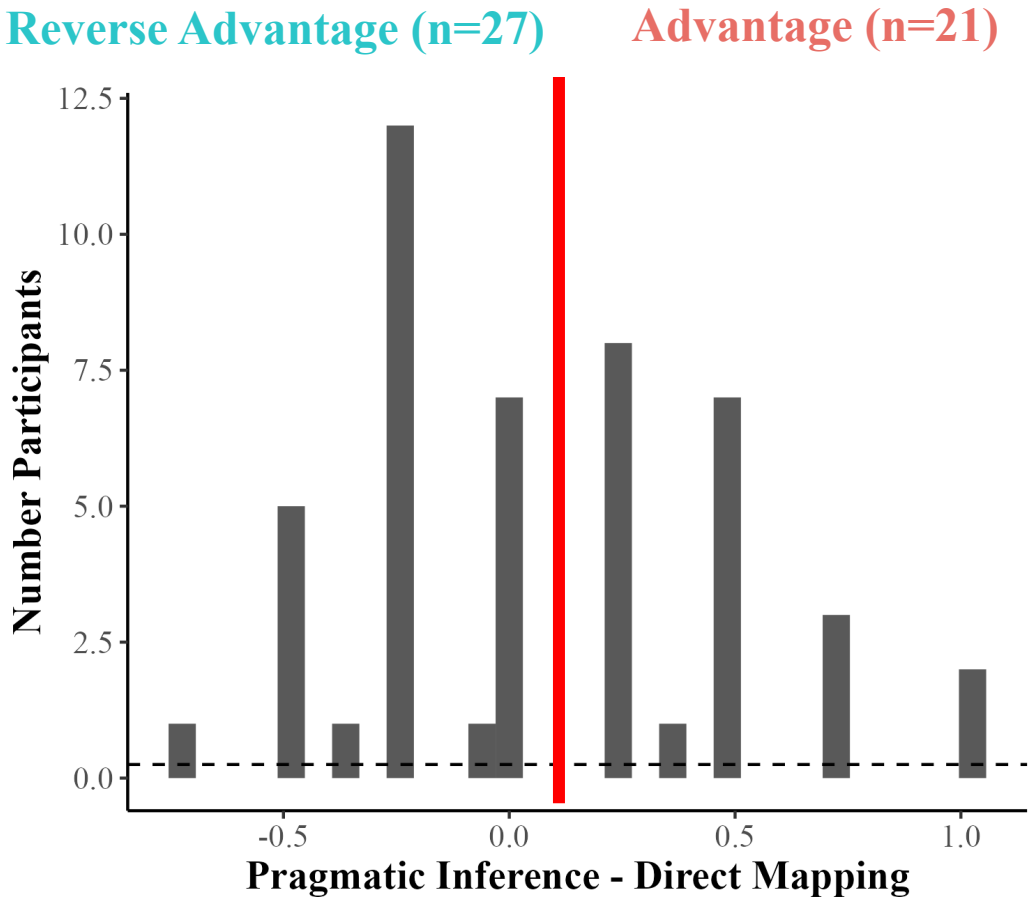

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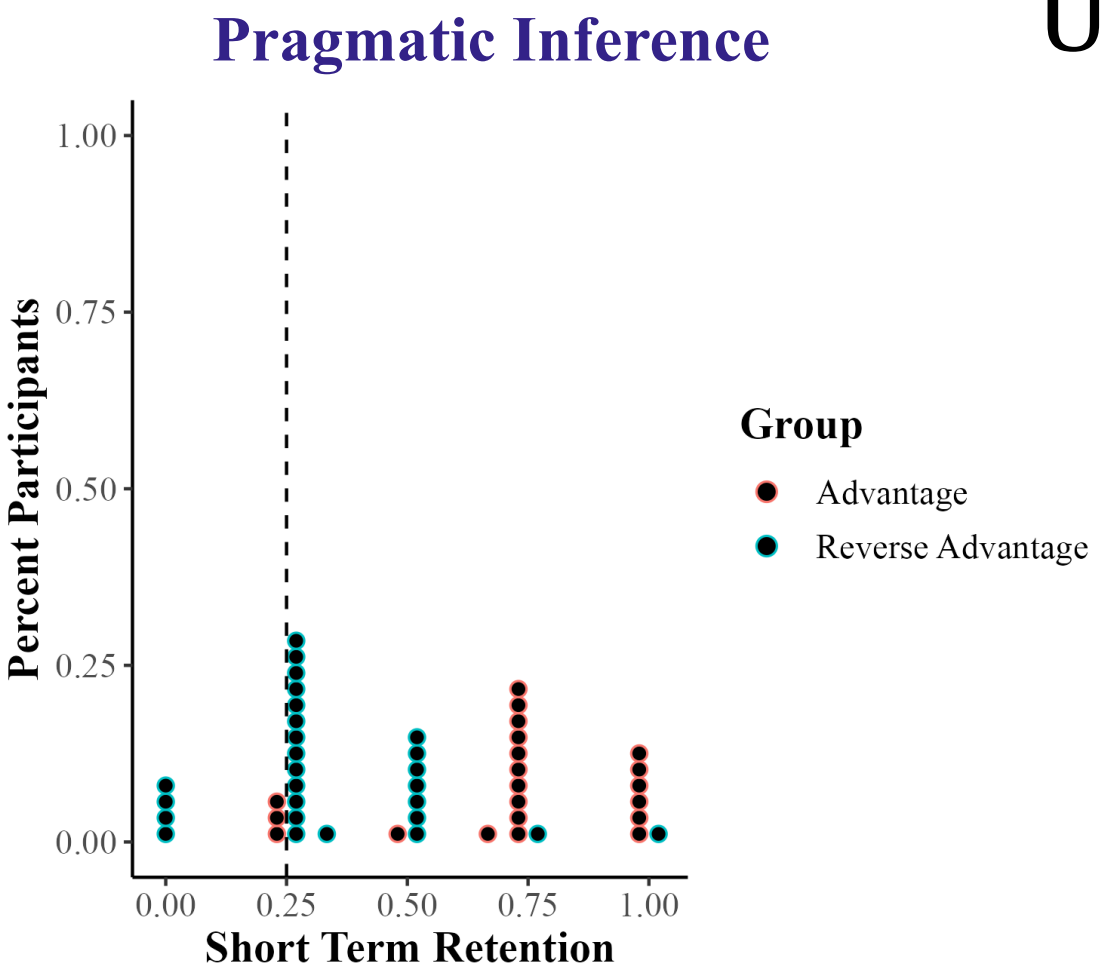

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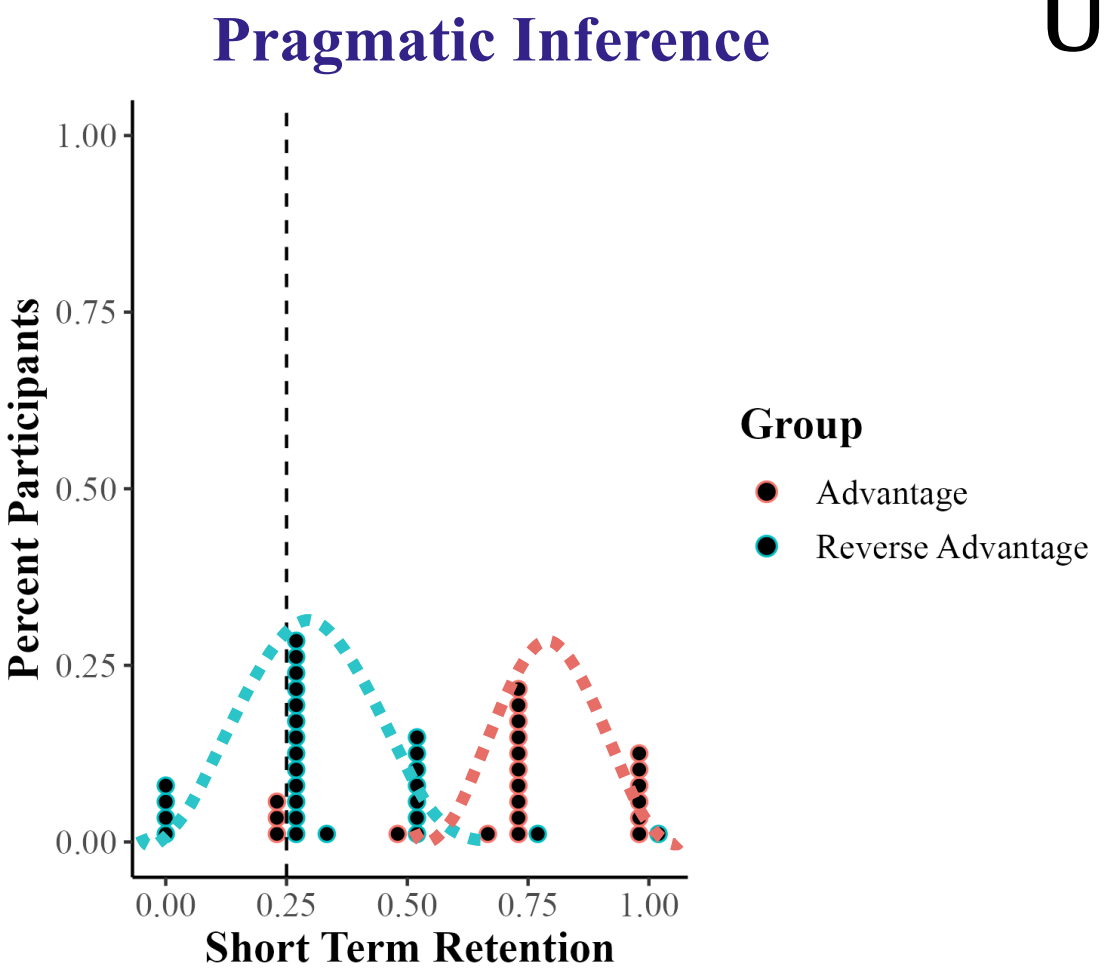

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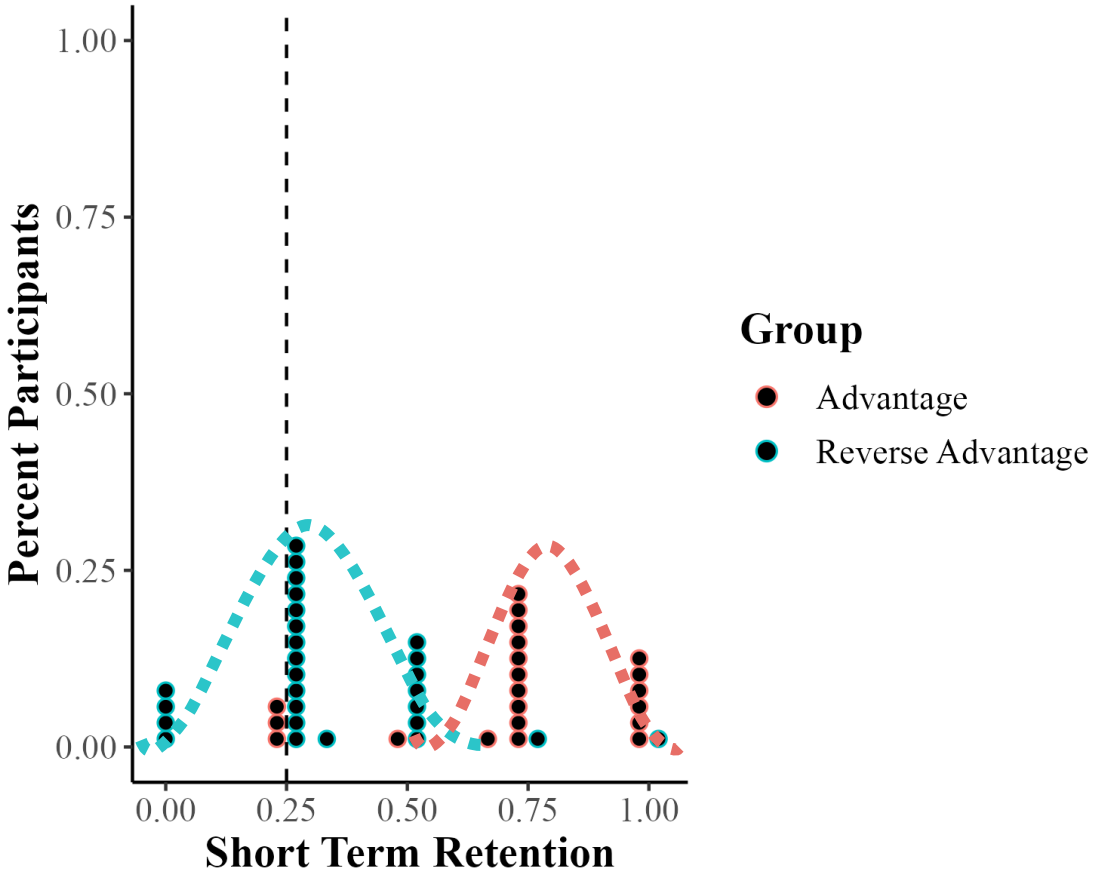
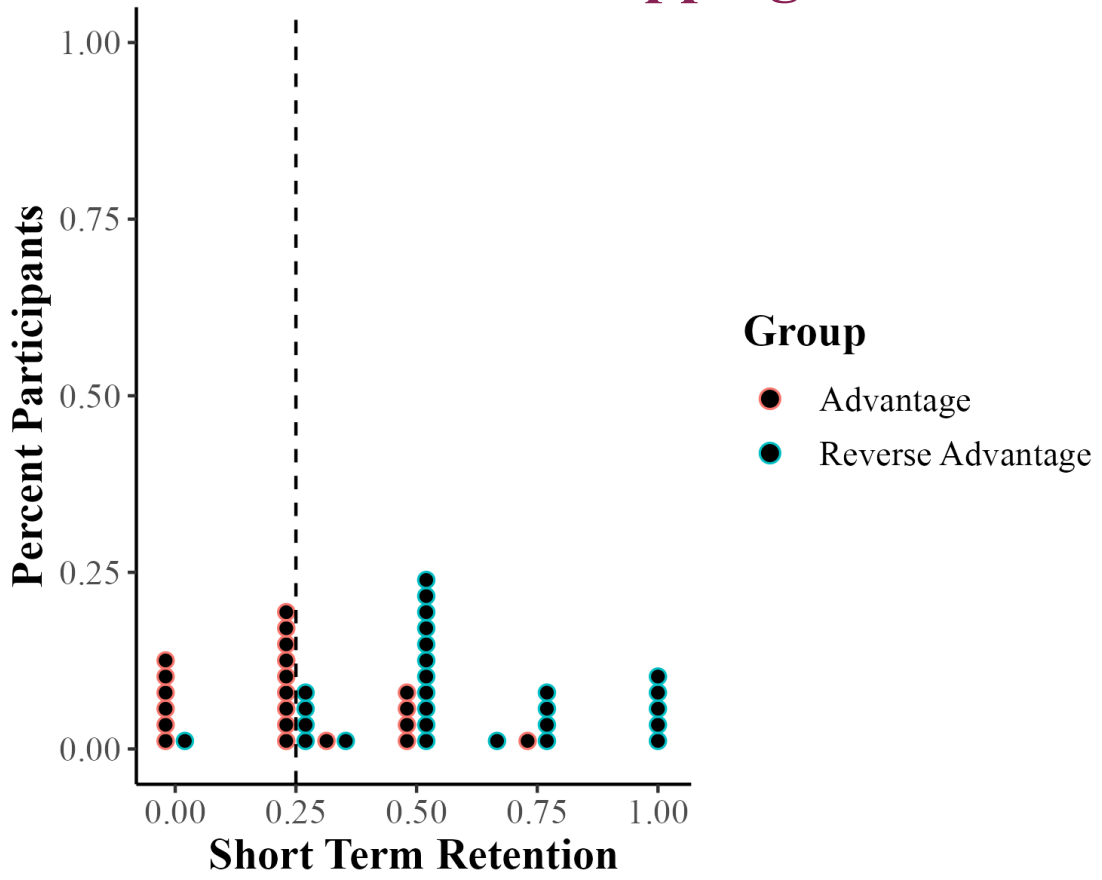
Pragmatic Inference



Direct Mapping



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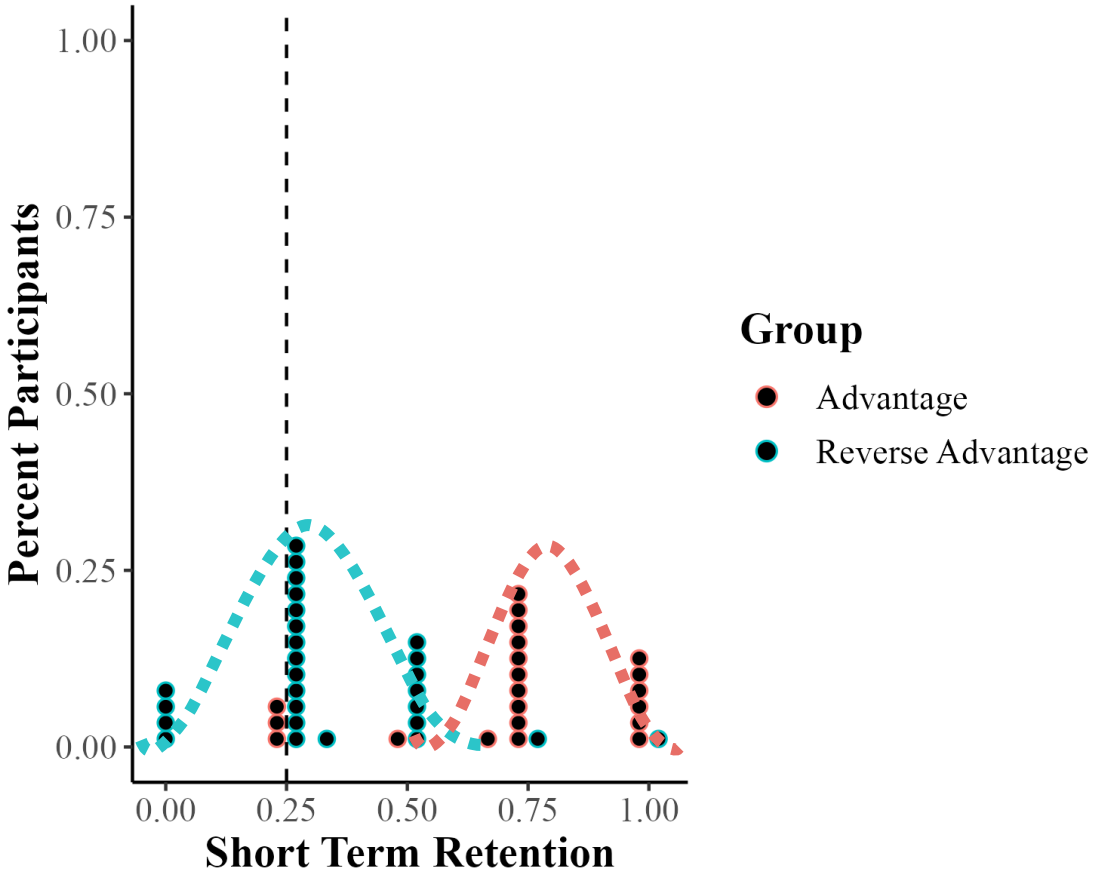

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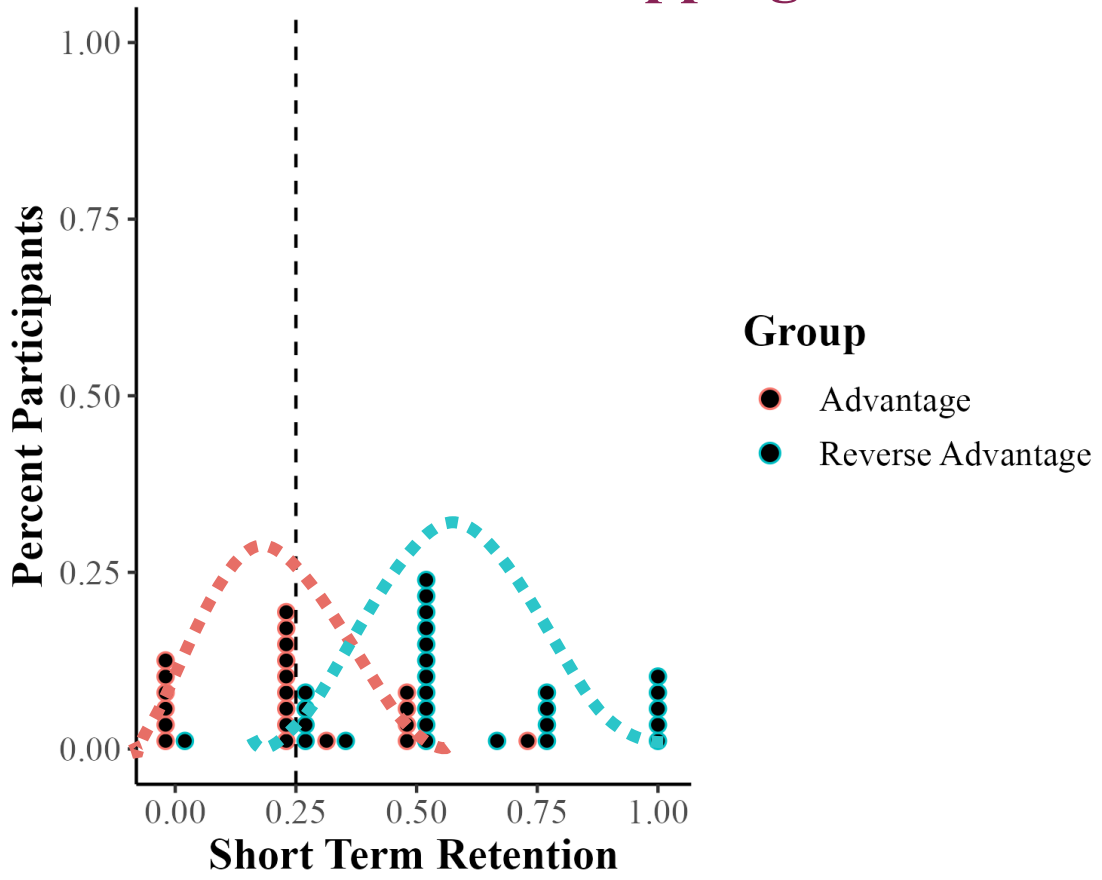
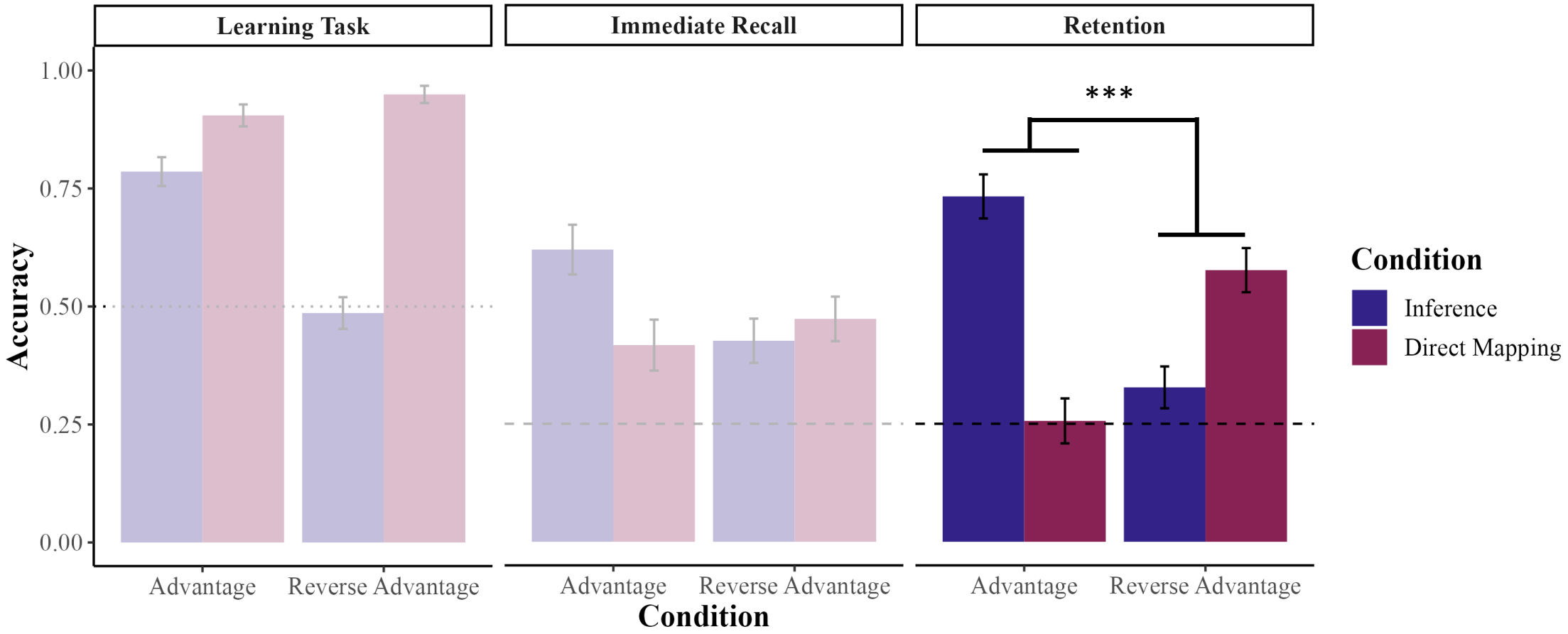
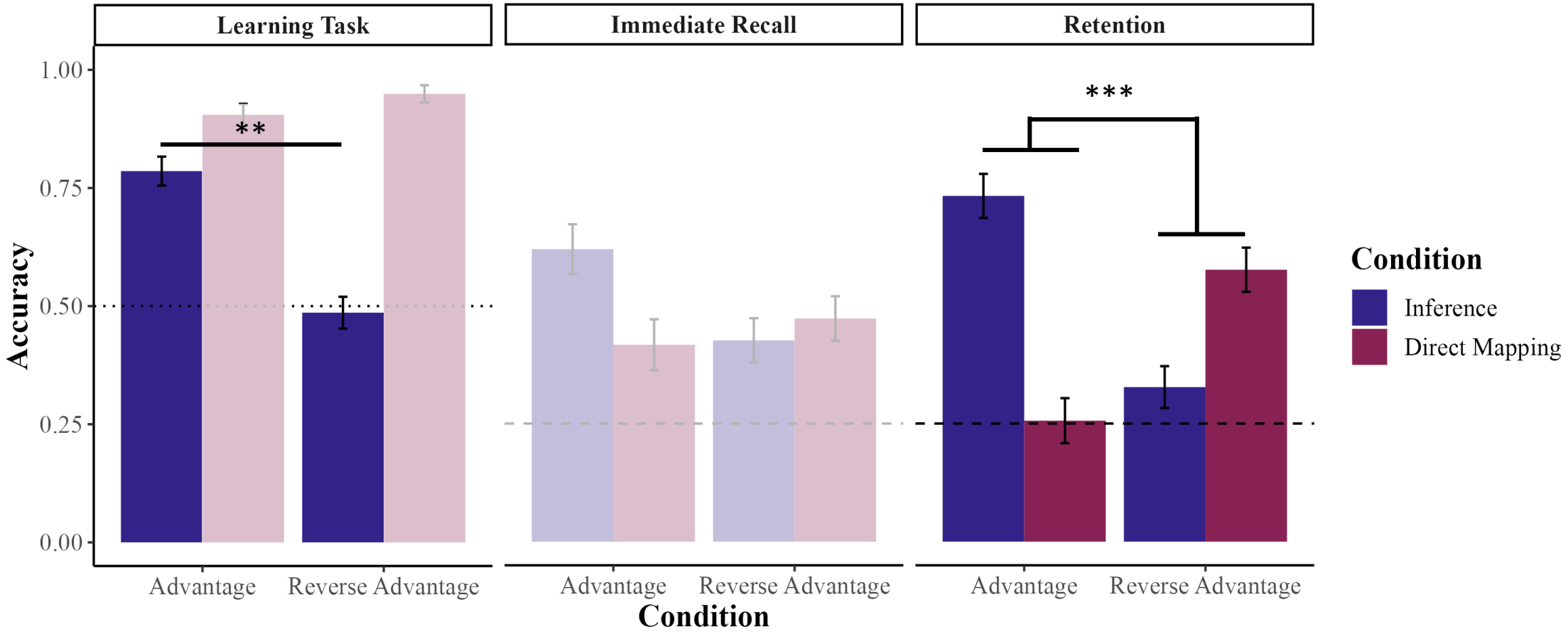


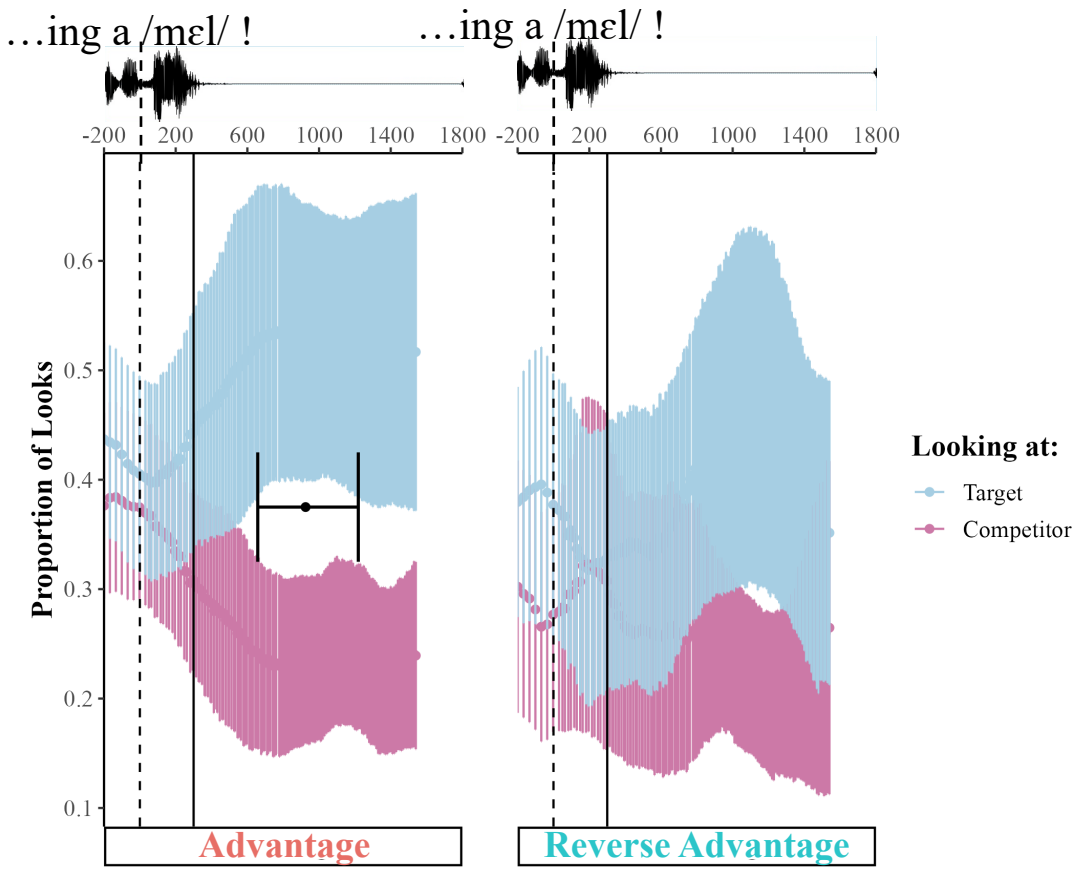
And Represents Two Different Retention Profiles



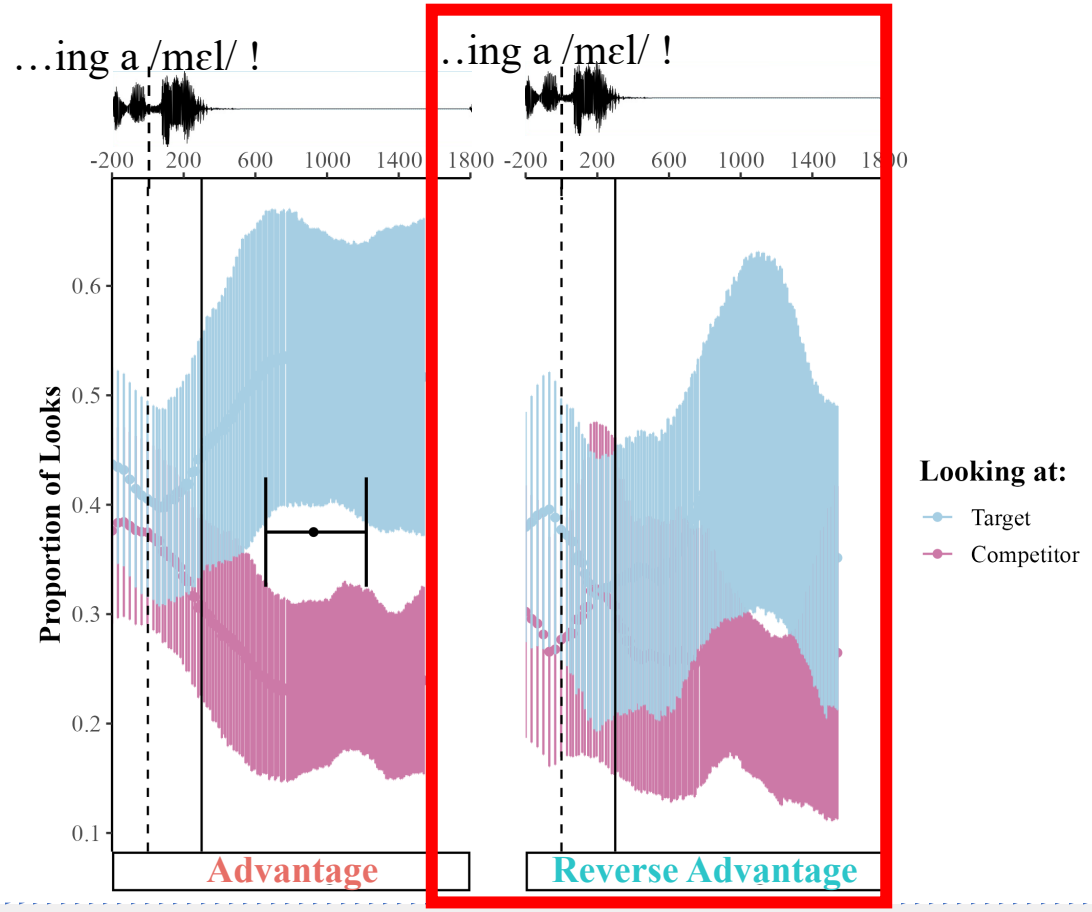
Pragmatic Inference Mapping for Non-Advantage is at Chance



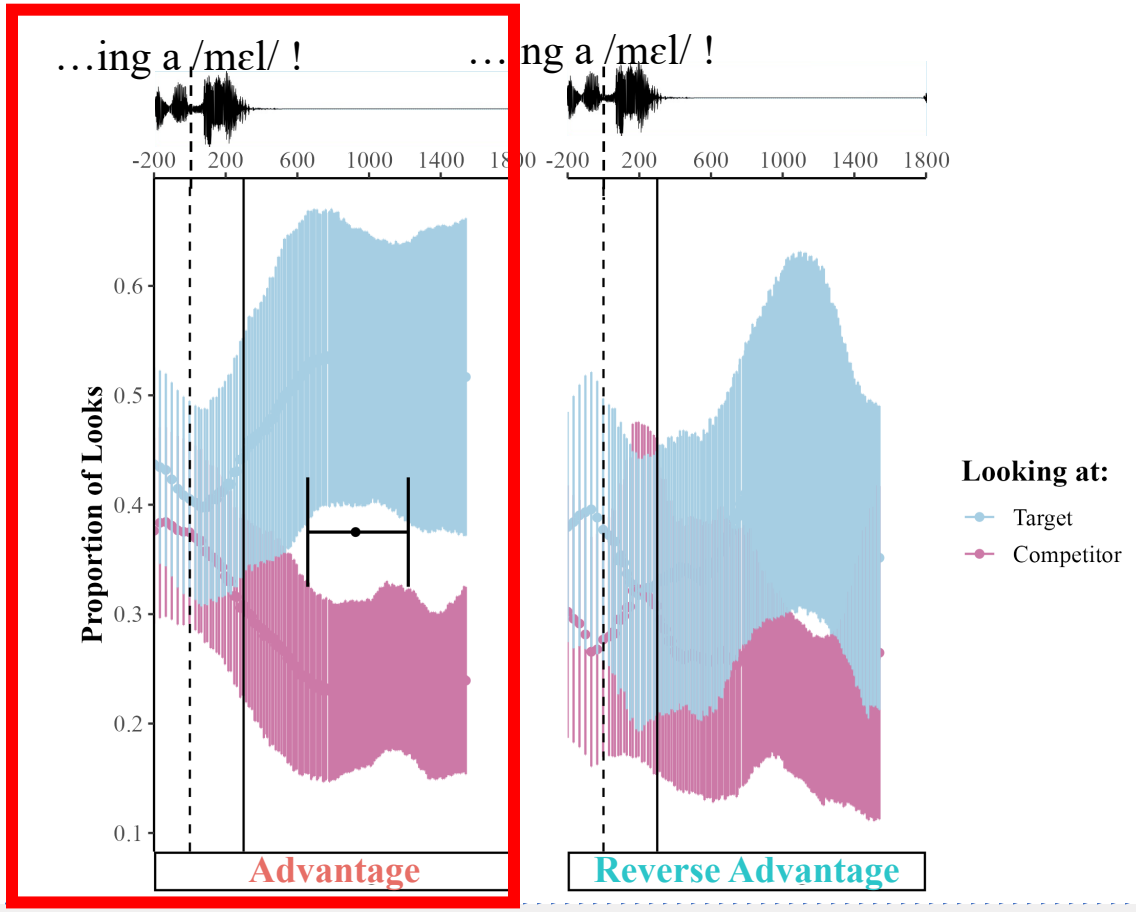
Eye Gaze During Pragmatic Inference…



…Does Not Diverge for Reverse Advantage



…Does Diverge for Advantage



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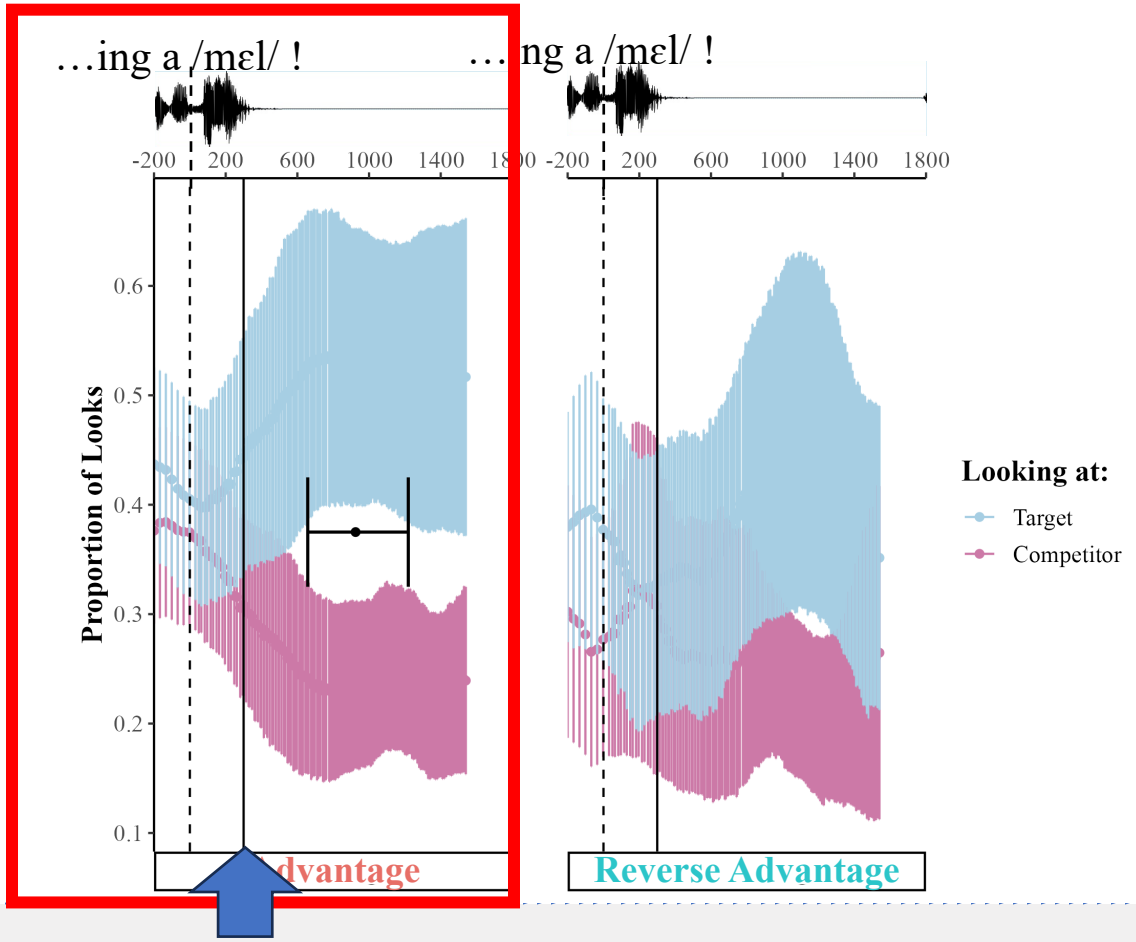
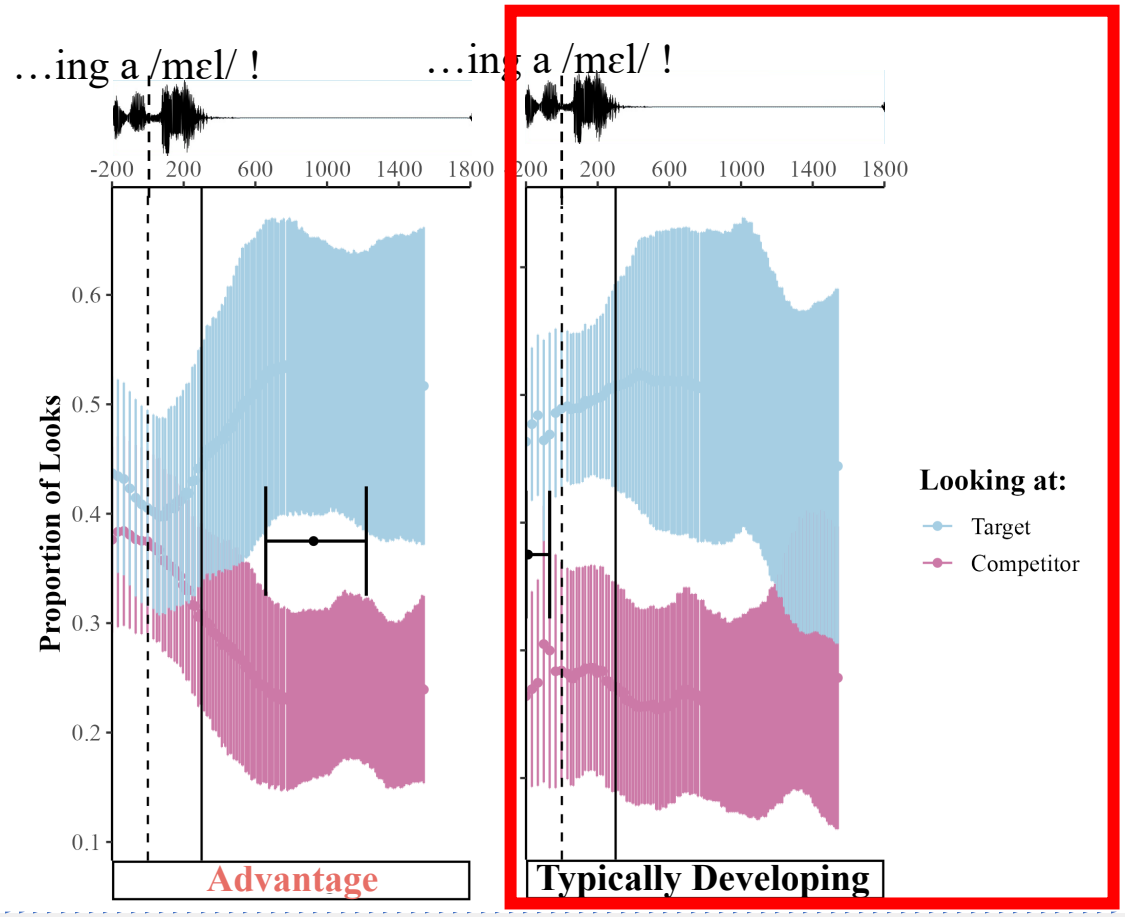


End of Saccade if Triggered by Novel Word

But Diverges Later than Typically Developing Peers



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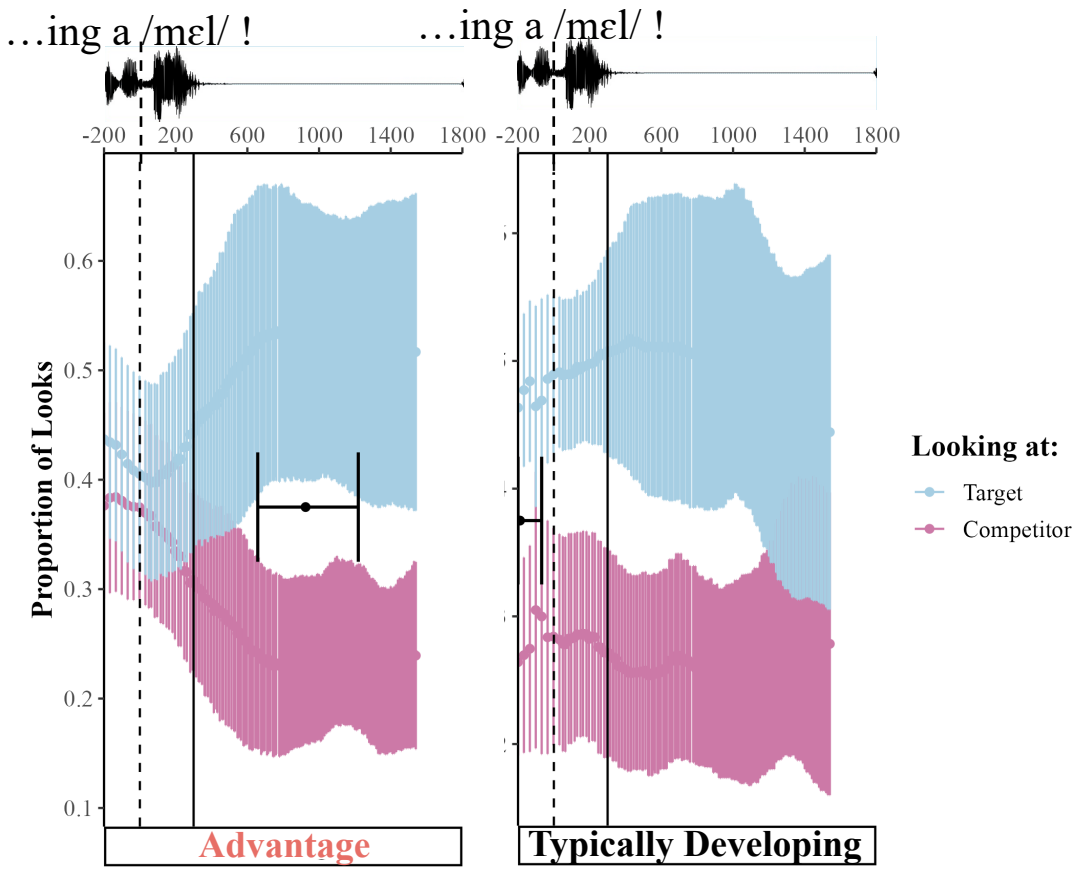

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Group Profiles?

Group Profiles

	Advantage				Reverse Advantage				
	Mean	SD	Count	%	Mean	SD	Count	%	*p*

Group Profiles

		Advantage				Reverse Advantage				
		Mean	SD	Count	%	Mean	SD	Count	%	*p*
Language	PVT Standard Score	100.55	17.65			105.83	19.67			> 0.1
	ORR Standard Score	101.25	12.56			110.00	17.85			> 0.1
	RSR Standard Score	88.42	20.01			85.35	25.95			> 0.1
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Group Profiles

Intervention Plan

_____
_____
_____
_____

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Services	ASD Services									> 0.1
	Yes			13	72.22			20	74.07	
	No			5	27.78			7	25.93	
	IEP Services									> 0.1
	Yes, Including Language			7	38.89			11	40.74	
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Intervention Plan

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General	KBIT Score	104.45	28.46			109.84	26.60			> 0.1
	Gender									> 0.1
	Boy			14	66.67			20	74.07	
	Girl			7	33.33			7	25.93	
	Currrent Age	7.65	0.92			7.52	0.86			> 0.1
	Diagnosis Age	3.59	1.07			3.48	1.00			> 0.1

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Summary

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  - Reliably resolve pragmatic inferences
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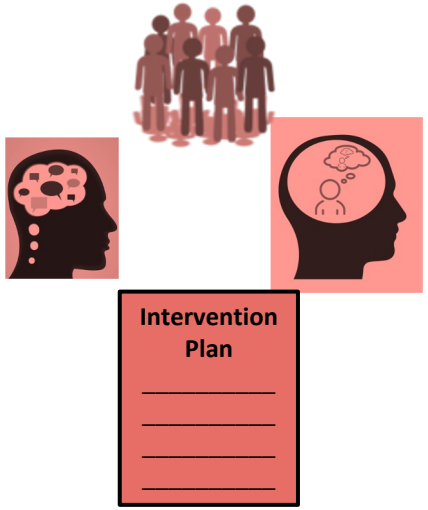
Summary

- There are no significant individual difference measure group differences between our sub-groups



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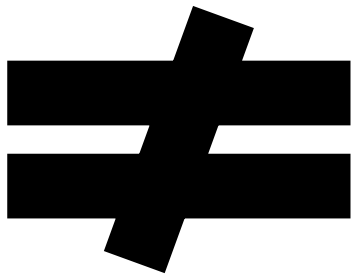
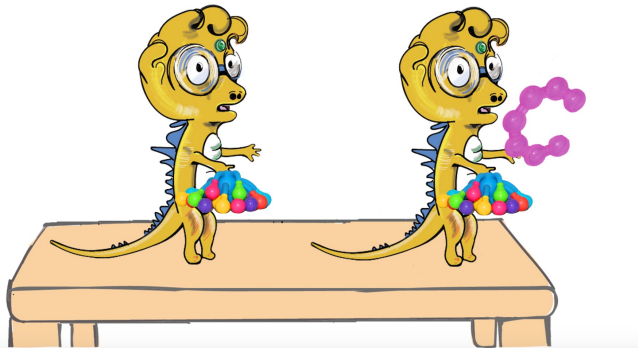
Summary

- There are no significant individual difference measure group differences between our sub-groups
  - Including theory of mind skills
- Unlike in neurotypical individuals, theory of mind may not be driving pragmatic inference resolution and retention

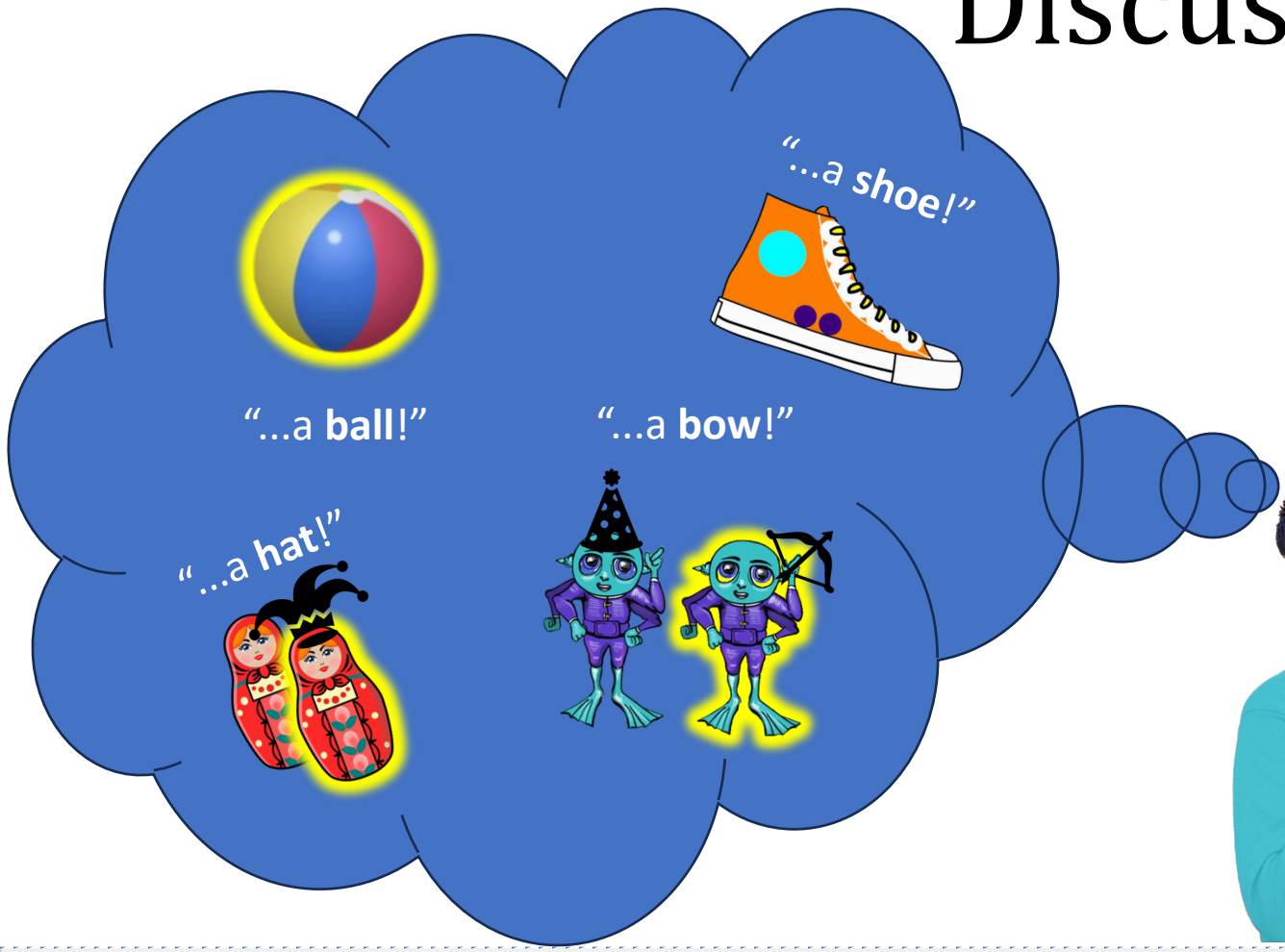




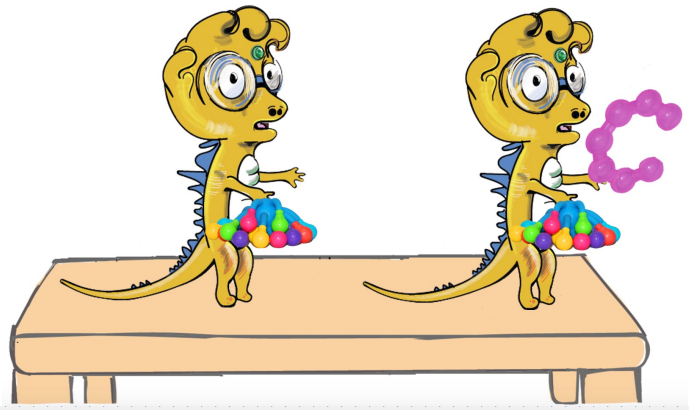
Discussion

Why might some autistic children incorrectly resolve pragmatic inferences?

Discussion

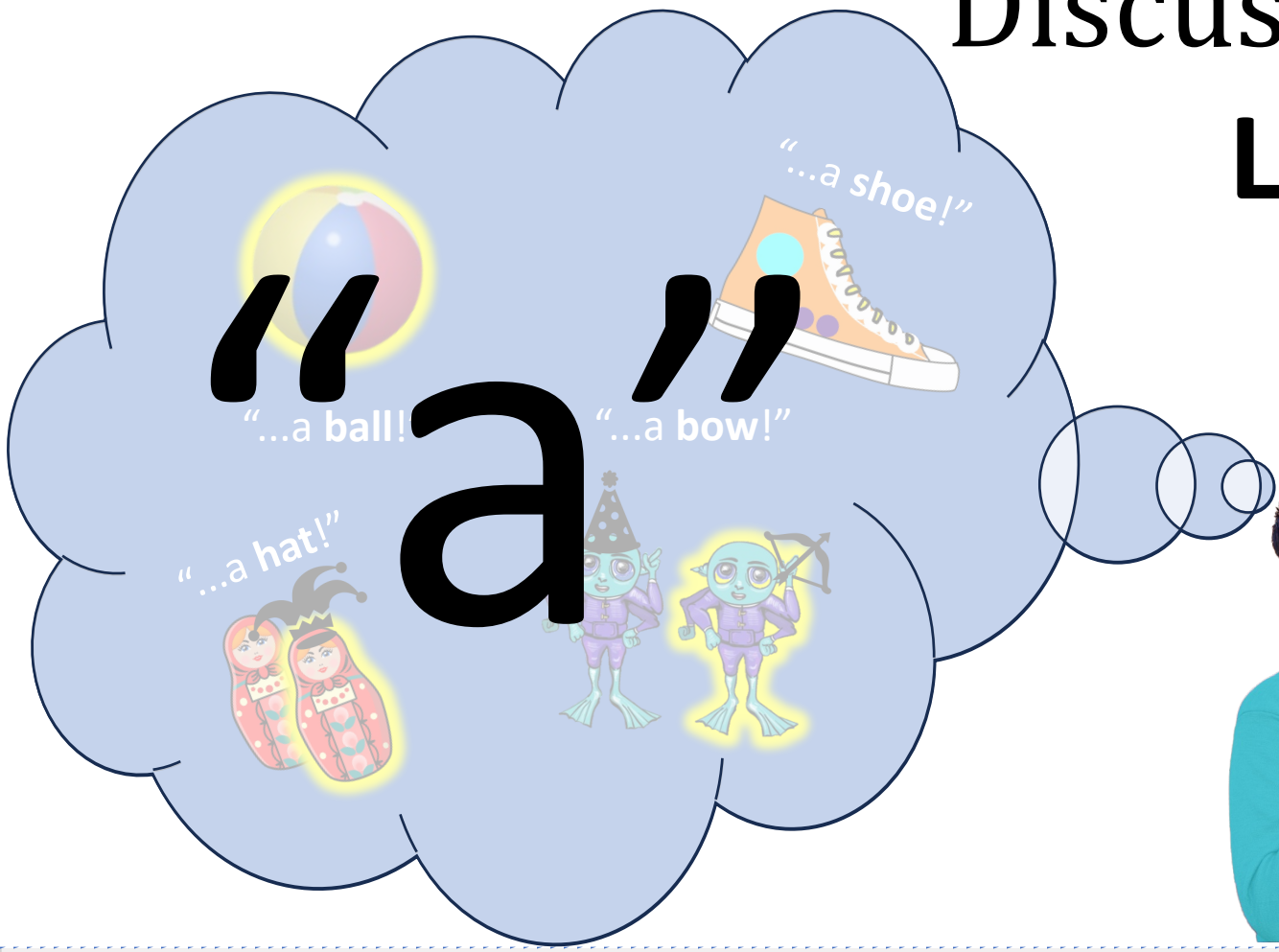


"...a **MEL**!"



Discussion

Learned Linguistic Pattern



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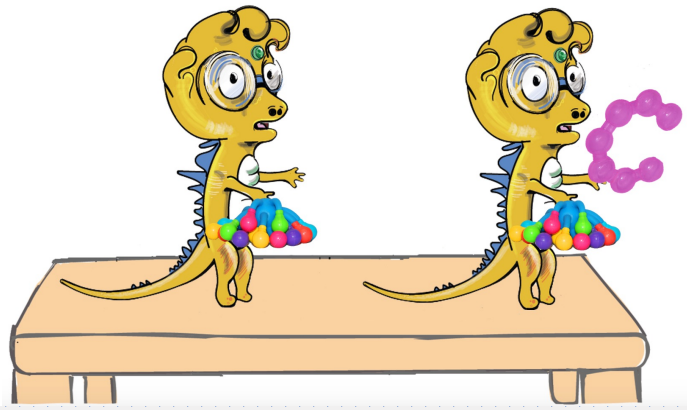

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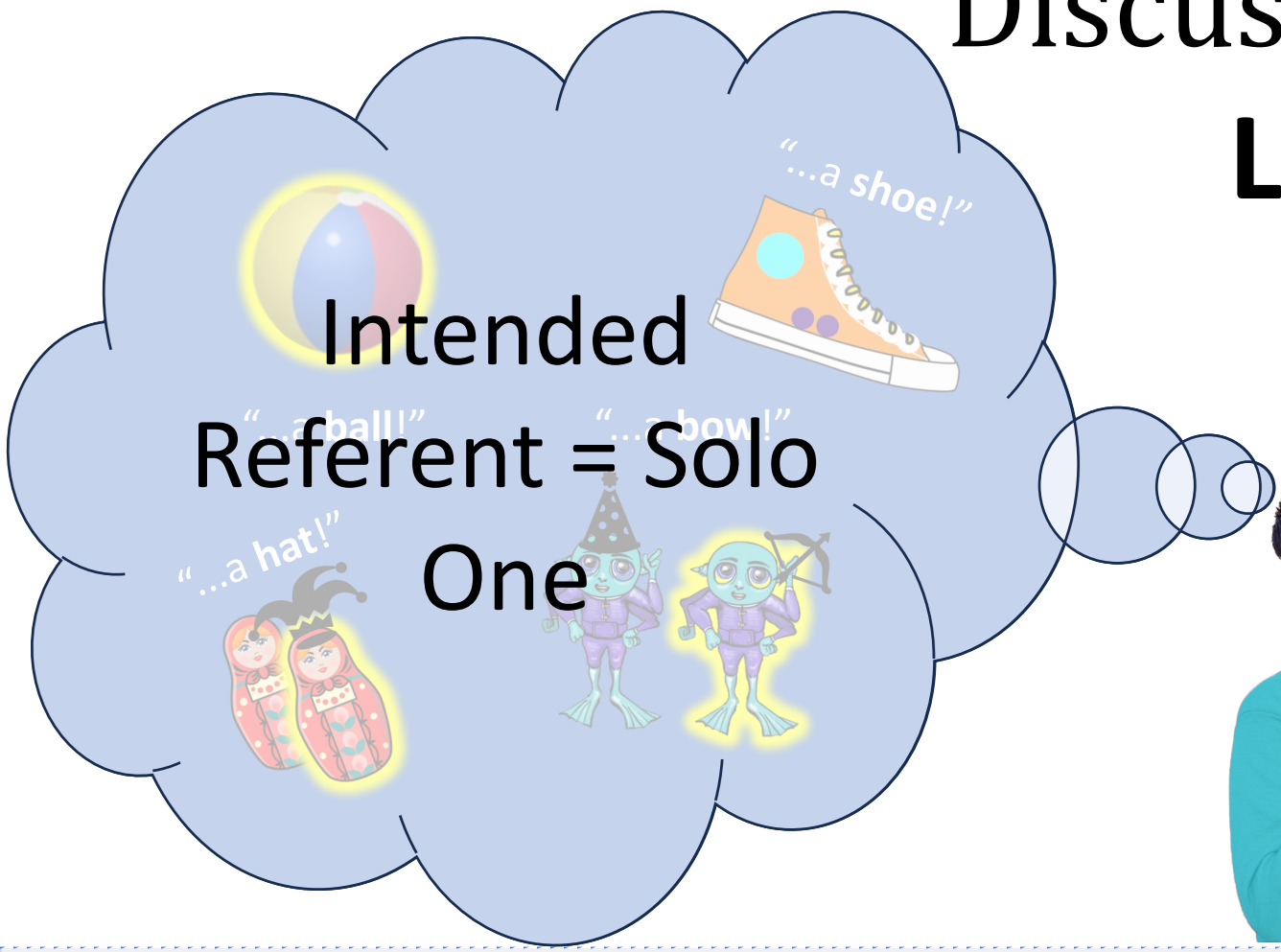

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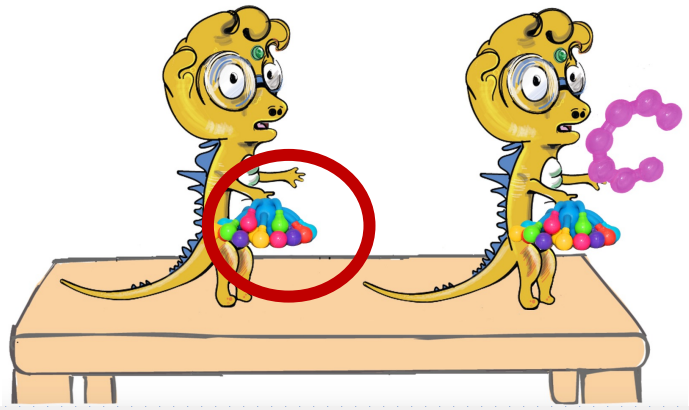

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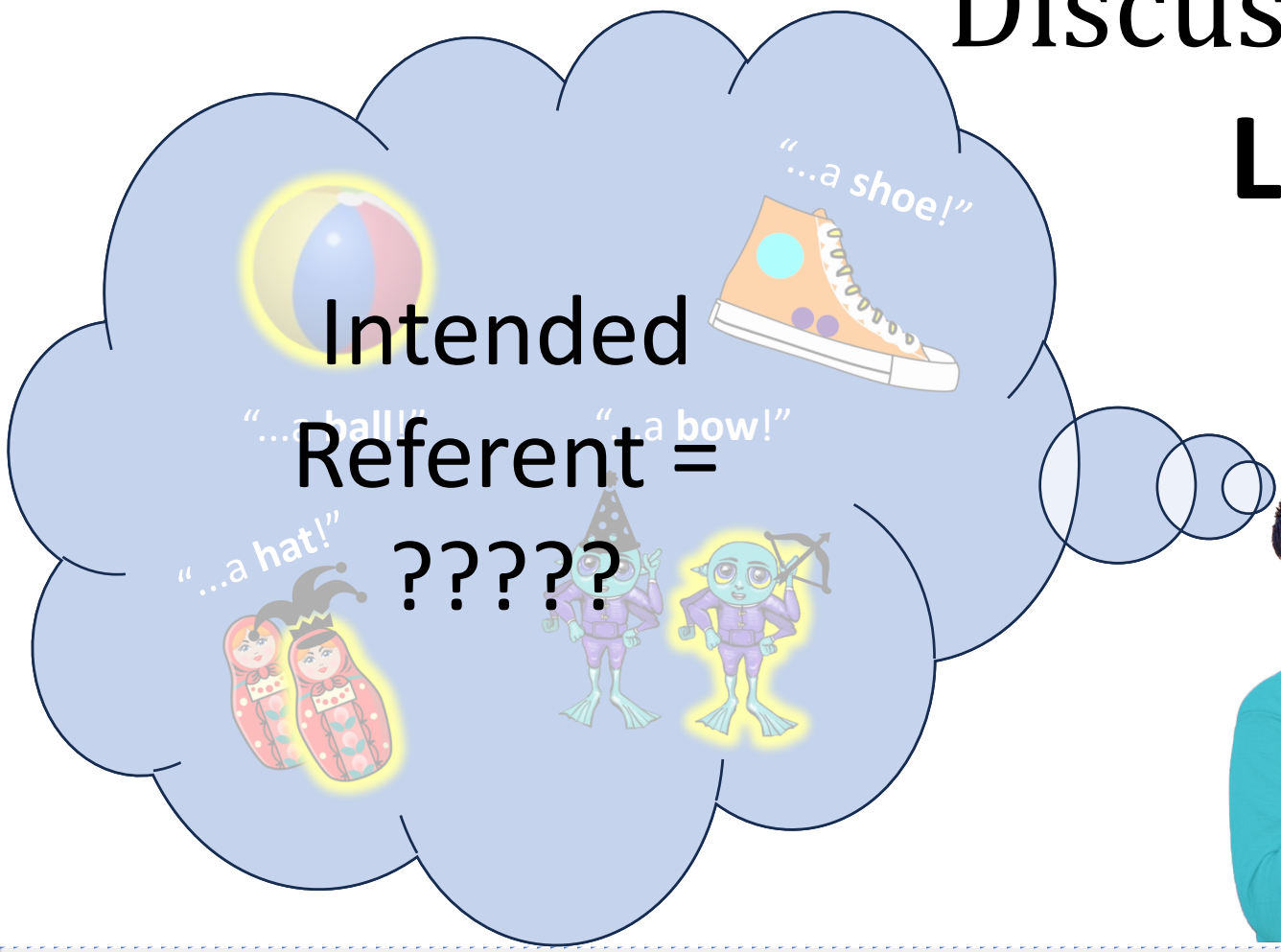

Intended Referent = ?????

Learned Linguistic Pattern

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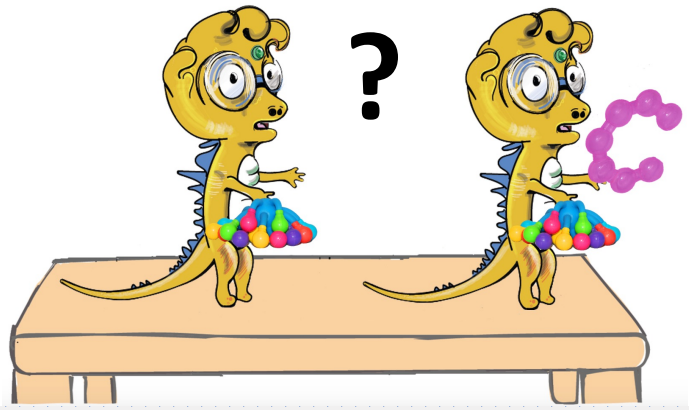

Discussion

Why might some autistic children incorrectly resolve pragmatic inferences?

Do we know autistic children are not using theory of mind?

Discussion

- Current theory of mind assessments occur offline

Discussion

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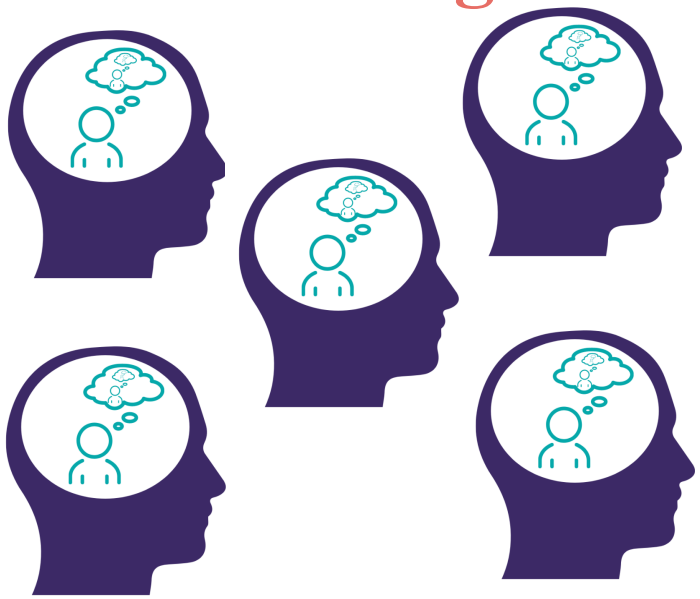
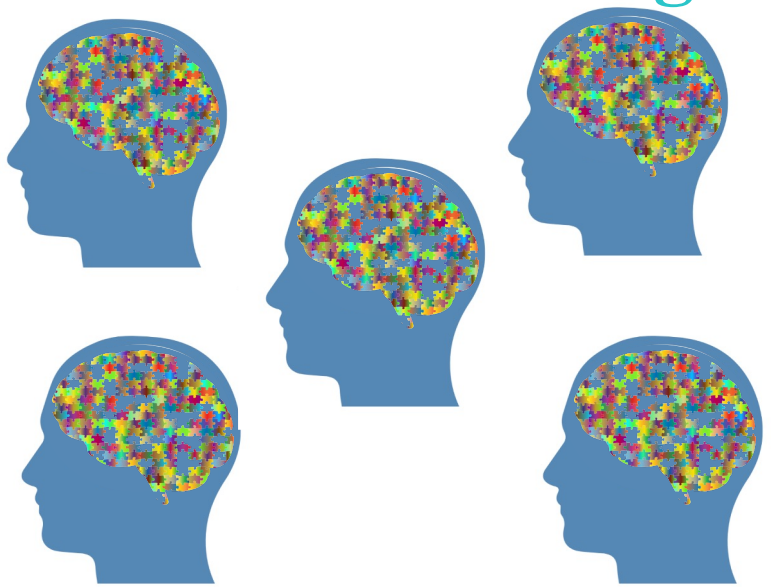
Advantage



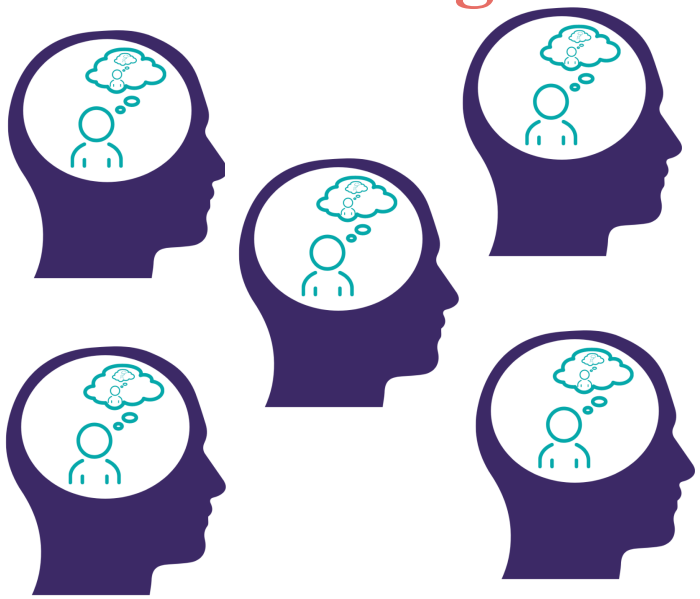
Reverse Advantage

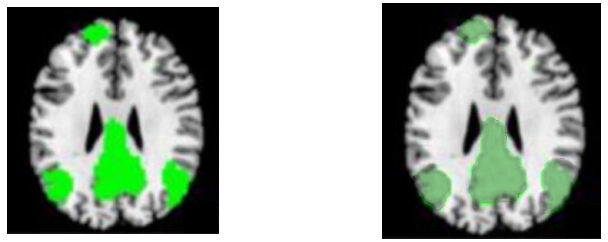


Discussion

- Current theory of mind assessments occur offline
- Online metrics of theory of mind may tease these aspects apart

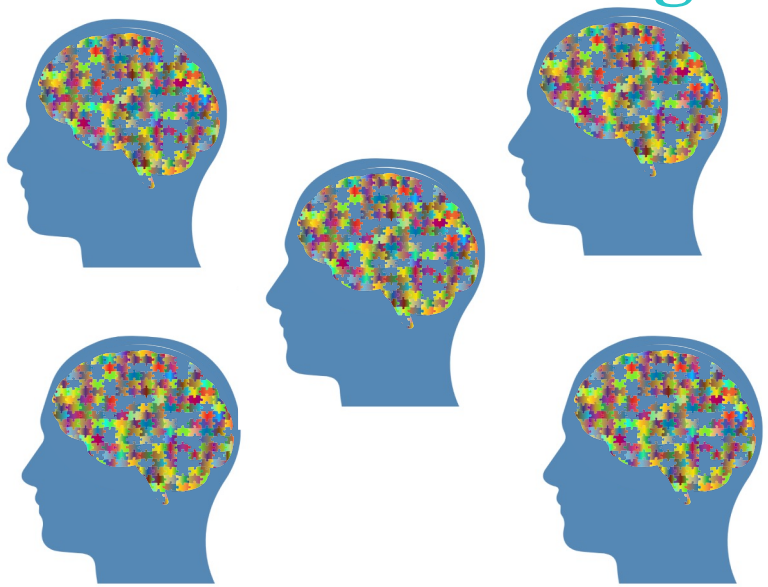
Advantage





Theory of Mind Network

Reverse Advantage



Discussion

What is causing the pragmatic inference advantage?

Discussion

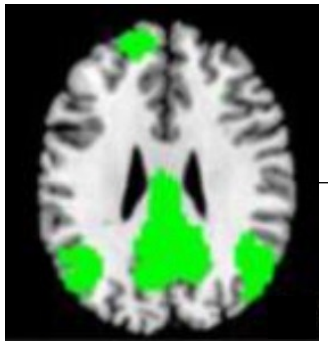
Pragmatic Inferences

Discussion

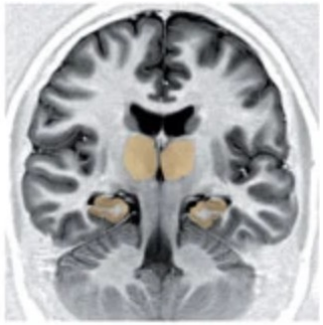
Pragmatic ~~Inferences~~

Discussion

- Privileging of information processed by theory of mind system in memory
  - More accessible
  - Greater precision



Theory of Mind Network



Semantic Memory Network

Lin, H., Li, W. P., & Carlson, S. (2019). A Privileged Working Memory State and Potential Top-Down Modulation for Faces, Not Scenes. *Frontiers in human neuroscience*, *13*, 2.

Discussion

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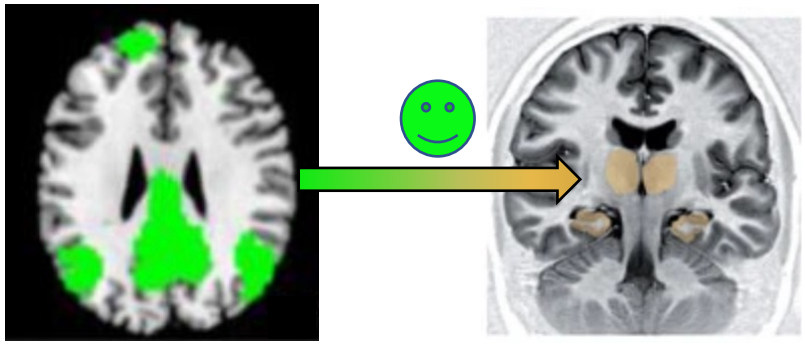

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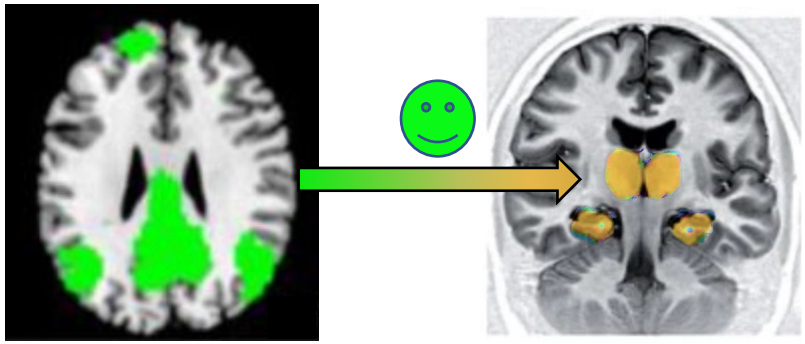

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Discussion

Pragmatic Inferences

Discussion

~~Pragmatic~~ Inferences

Discussion

- Active learning and encoding

Ruggeri, A., Markant, D. B,. Gureckis, T. M., Bretzke, M., & Xu, F. (2019). Memory enhancements from active control of learning emerge across development. *Cognition, 186,* 82-94.

Discussion

- Active learning and encoding
  - Involves learner control

Ruggeri, A., Markant, D. B,. Gureckis, T. M., Bretzke, M., & Xu, F. (2019). Memory enhancements from active control of learning emerge across development. *Cognition, 186,* 82-94.

Discussion

- Active learning and encoding
  - Involves learner control
  - Advantage on word retention emerges between the ages 5 and 8

Ruggeri, A., Markant, D. B,. Gureckis, T. M., Bretzke, M., & Xu, F. (2019). Memory enhancements from active control of learning emerge across development. *Cognition, 186,* 82-94.

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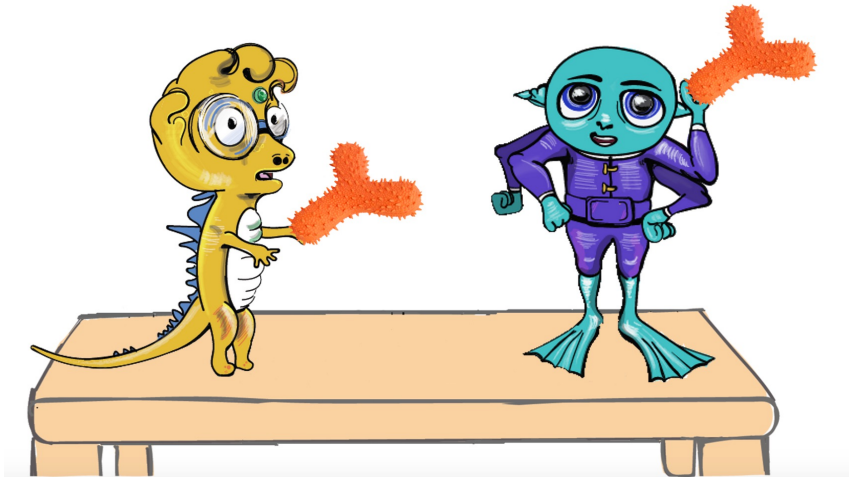

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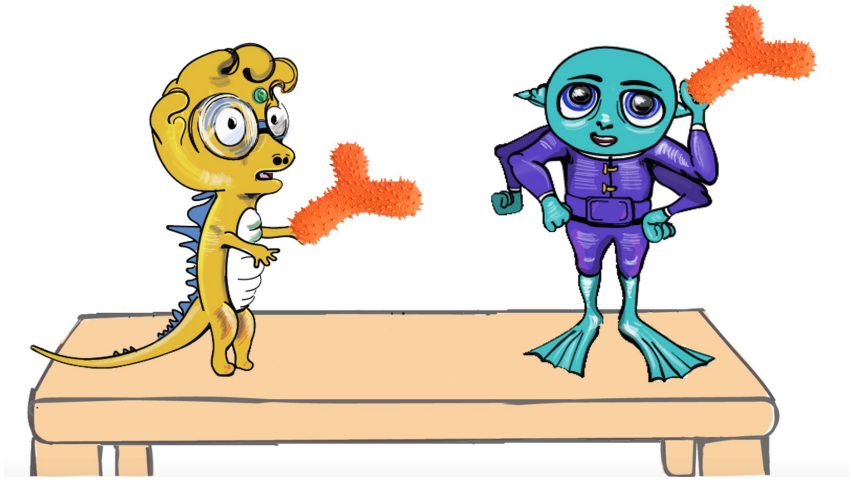

- Limited effort

Ruggeri, A., Markant, D. B,. Gureckis, T. M., Bretzke, M., & Xu, F. (2019). Memory enhancements from active control of learning emerge across development. *Cognition, 186,* 82-94.

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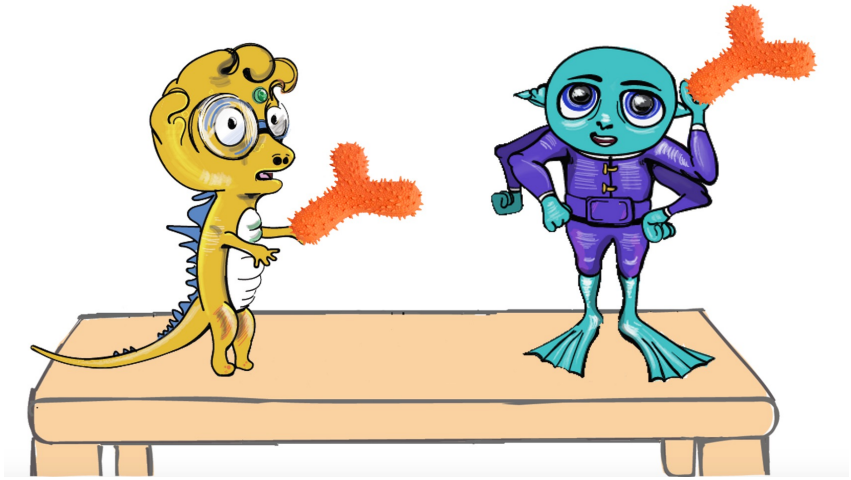

- Limited effort
- Limited computation

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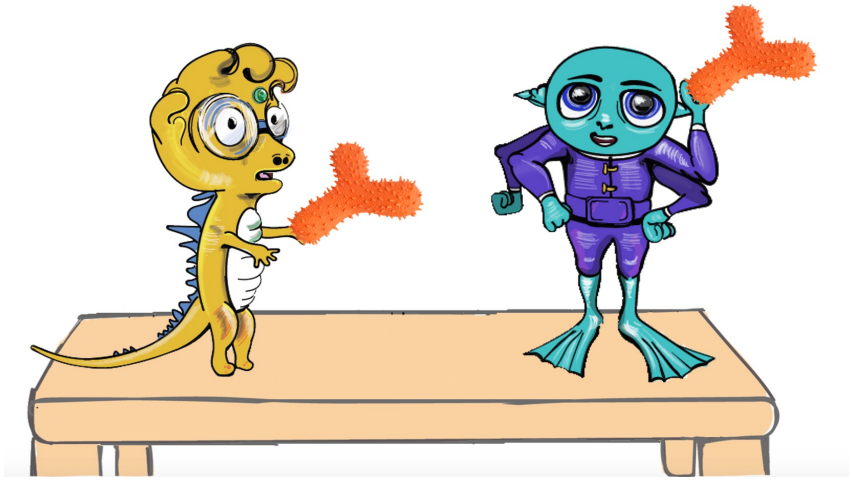

- Limited effort
- Limited computation
- Little role of control

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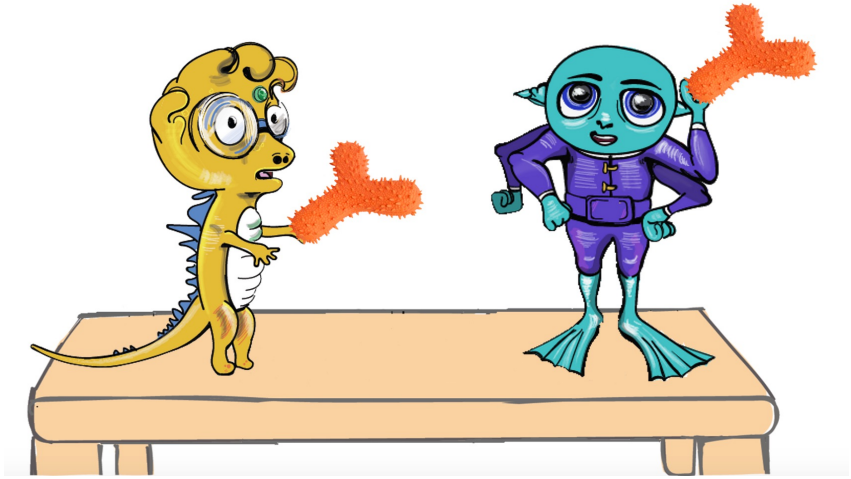

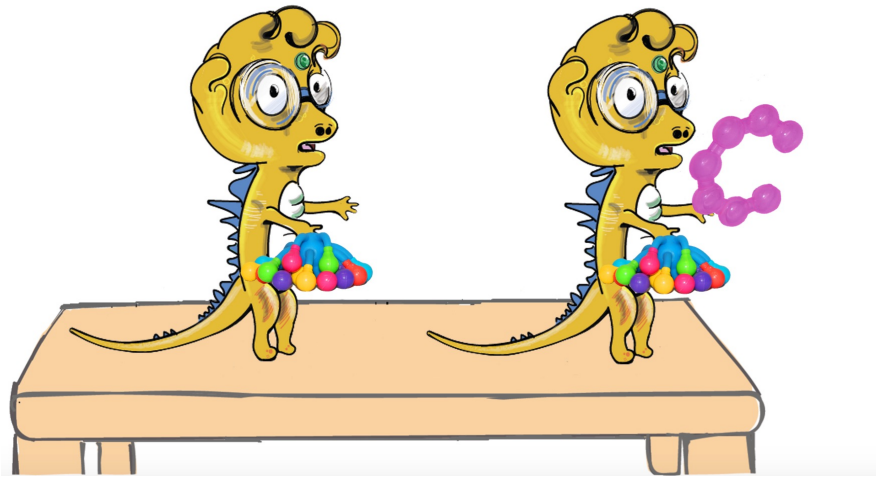

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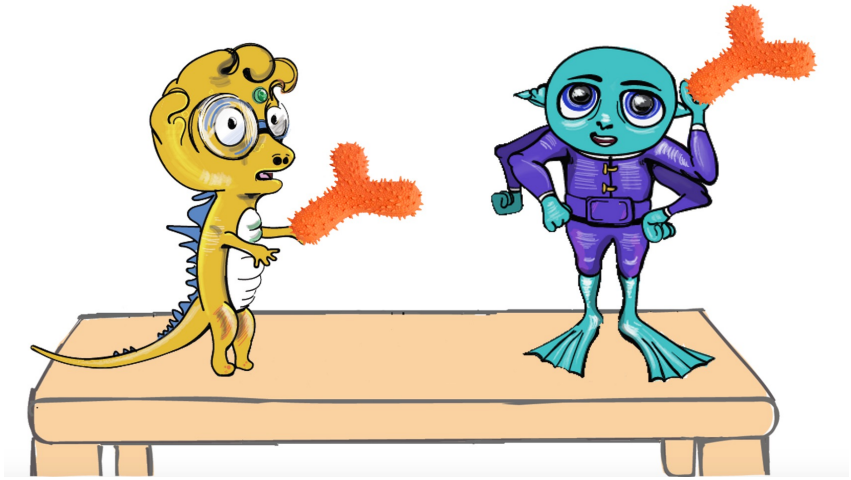

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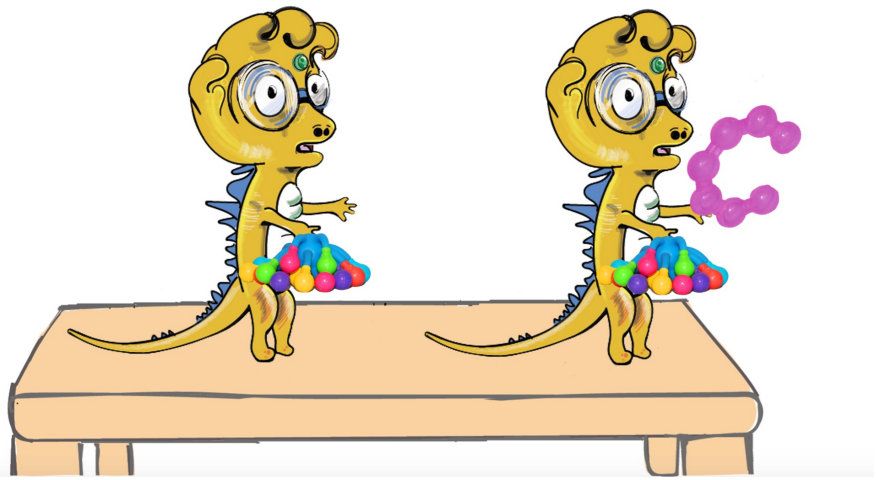

- Active engagement

Ruggeri, A., Markant, D. B,. Gureckis, T. M., Bretzke, M., & Xu, F. (2019). Memory enhancements from active control of learning emerge across development. *Cognition, 186,* 82-94.

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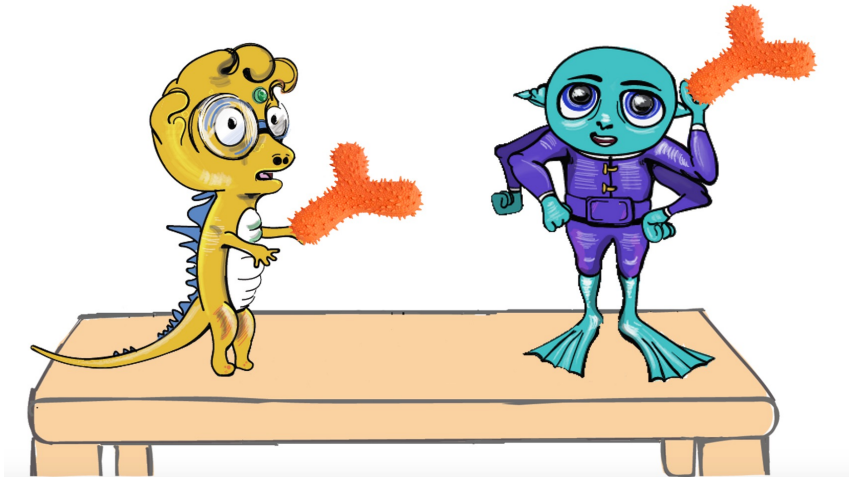

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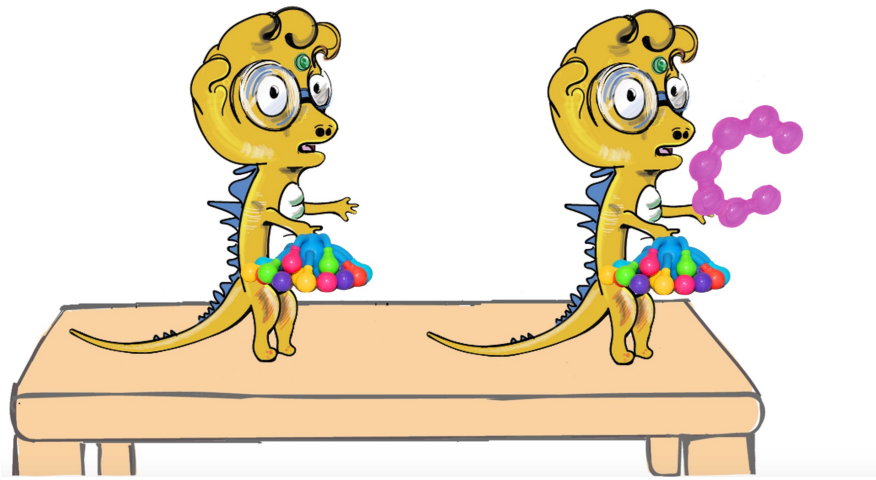

- Active engagement
- Internal computation/judgement

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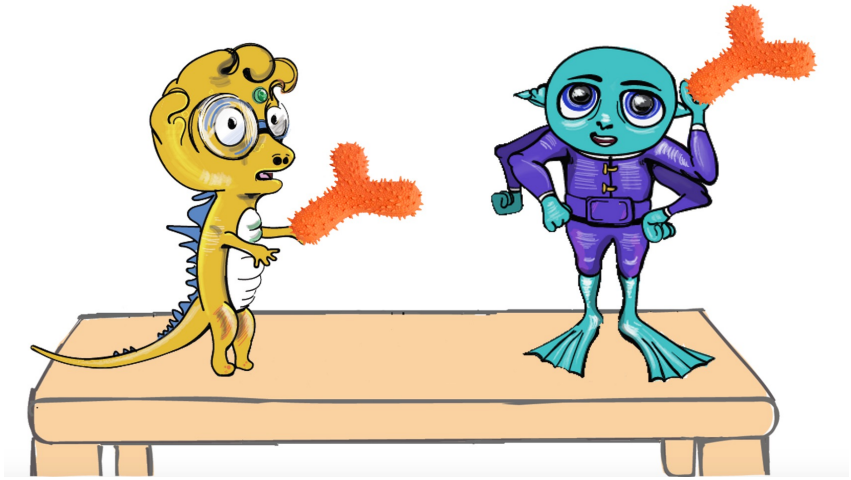

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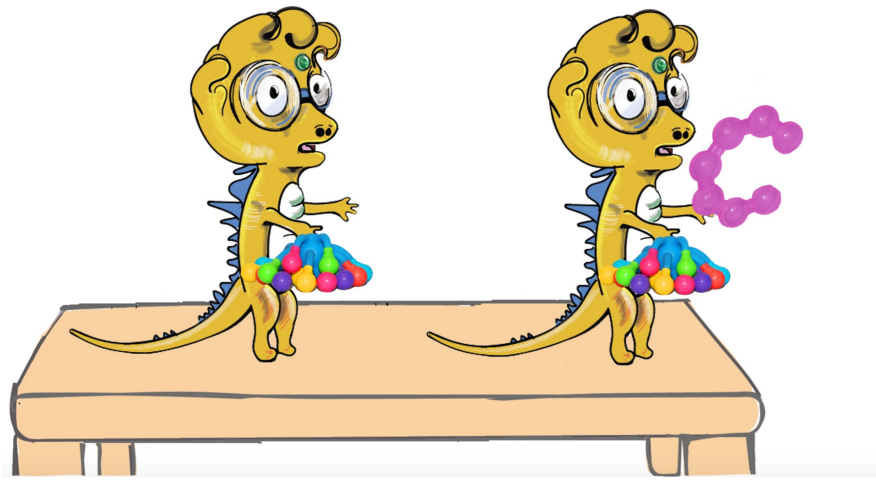

- Active engagement
- Internal computation/judgement
- Control over cognitive processes

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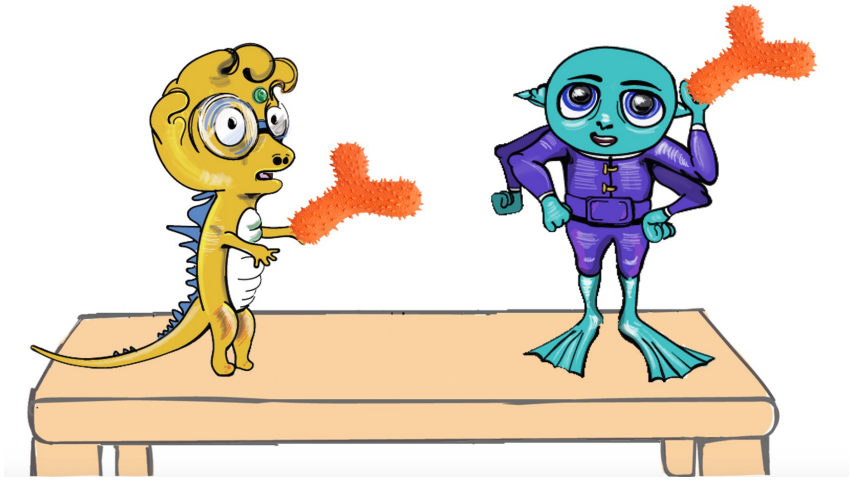

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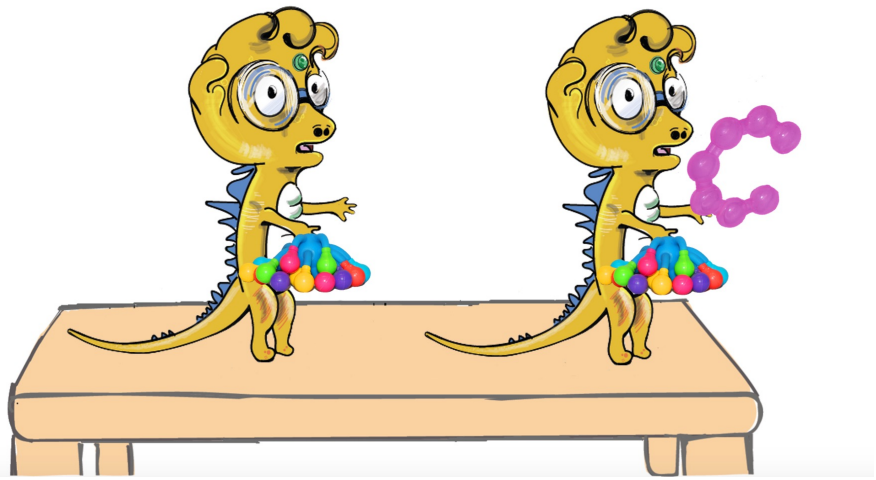

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Discussion

- Study word mapping and retention in other linguistic inferences
  - Syntactic
  - Semantic
  - Lexical

Wrap-Up

- Many paths through word learning

Wrap-Up

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- Distinctive strategies for learning in autistic children not characterized by common metrics

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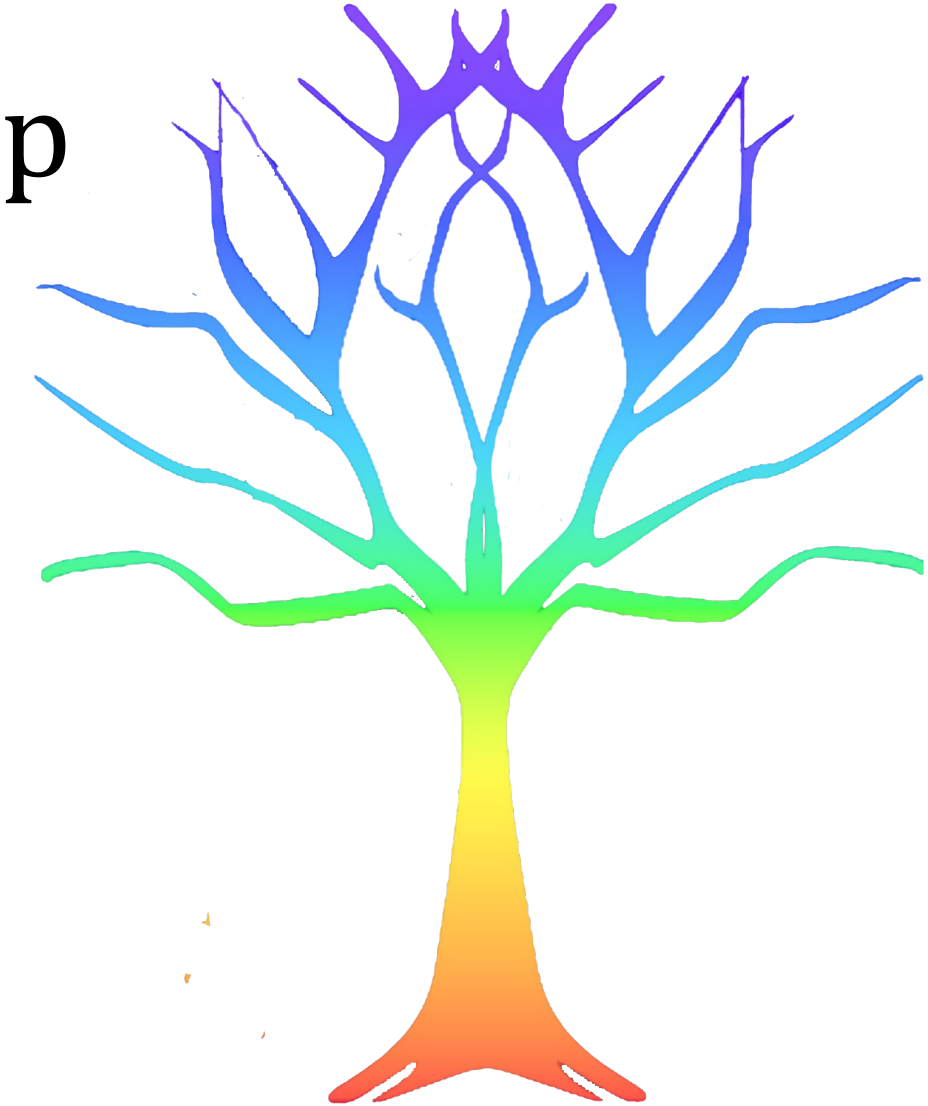
- Future research:

Wrap-Up

- Many paths through word learning
- Distinctive strategies for learning in autistic children not characterized by common metrics

- Future research:
  - What drives different learning preferences and strategies in autistic children?



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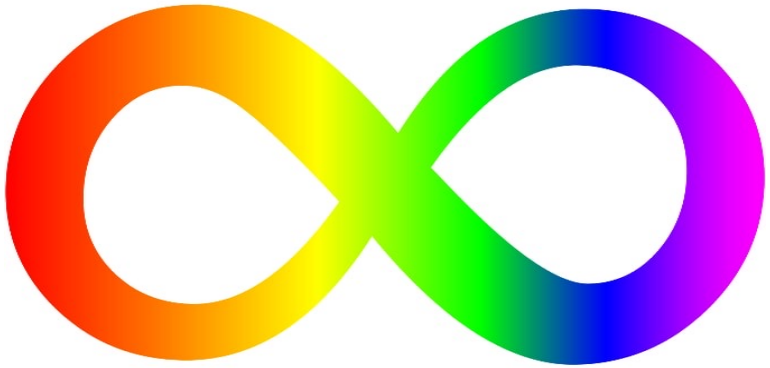

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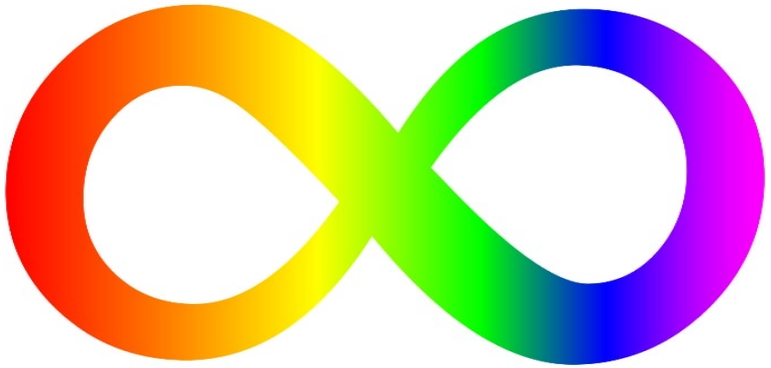

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Dionysia Saratsli

Anna Papafragou

Questions?

Adult Pre-Print:

Neurotypical Child Pre-Print:

Available soon!

Email trice.k@northeastern.edu

For access

Autistic Child Pre-Print:

Available soon!

Email trice.k@northeastern.edu

For access

Or!

Contact me on Bluesky:

@ktrice.bsky.social