Ecological Active learning Across development

Trajectories, Mechanisms, and Opportunities for Intervention

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University of Gothenburg, 9.12.2025

Expected observation ≠ Actual observation

Wait, what?

search, learn, test, explore, change, reorganize, adapt

Child as scientist

- Infants prefer informative and **knowledgeable social partners** (see Bazhydai et al., 2020; Csibra & Gergely, 2009) and are more likely to attend, explore, and solicit information when their **expectations are violated** (e.g., Dunn & Bremner, 2017; Stahl & Feigenson, 2015)
- Preschoolers are more likely to explore when presented with **confounded evidence** (e.g., Bonawitz et al., 2012; Schulz & Bonawitz, 2007)
- The **ability to make informative interventions** become more sophisticated in the preschool years (Cook et al., 2011; McCormack et al., 2016)
- Toddlers prefer to query and **trust the most reliable** and knowledgeable sources of information (see Mills, 2013)

- Preschoolers ask questions that are **domain appropriate and informative** (see Greif et al., 2006; Legare et al., 2013).

Child as (bad) scientist

- Children do not not demonstrate robust adult-like inquiry patterns until closer to age 10 (see Ruggeri & Feufel, 2015)
- Children's predecisional information search is exhaustive, unfocused, and unsystematic until age 10 (see Davidson, 1991; Betsch, 2014)
- Even 12-years-olds often fail to demonstrate mastery of the most basic scientific inquiry skills (e.g., Klahr et al., 1993)

Ecological Active Learning

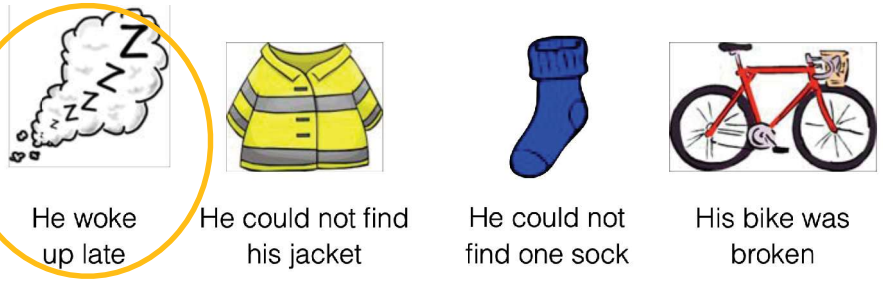
Ruggeri, *Current Directions in Psychological Science*, 2022
Stanciu, Török, & Ruggeri, *Child Development Perspectives,* 2024

How children explore and learn by:

- Recognizing the potentially ever-changing characteristics of their **environments**,
- Monitoring their **own competences**
- Considering internal/external **goals**
- Maximize effectiveness

Uniform distribution

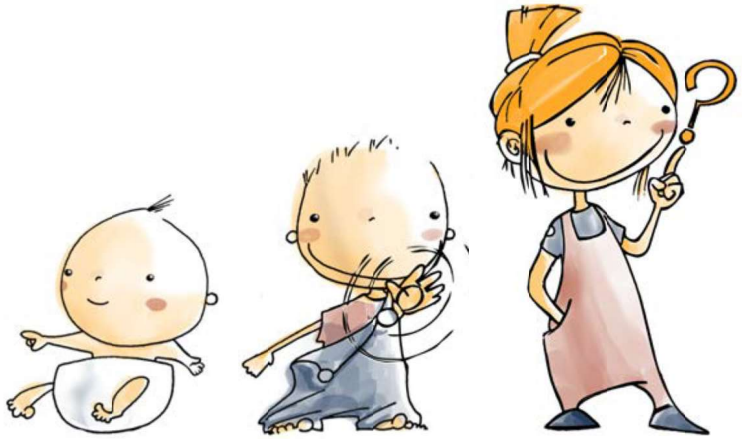
Skewed distribution



CONSTRAINT SEEKING
"Is it because he couldn't find something?"

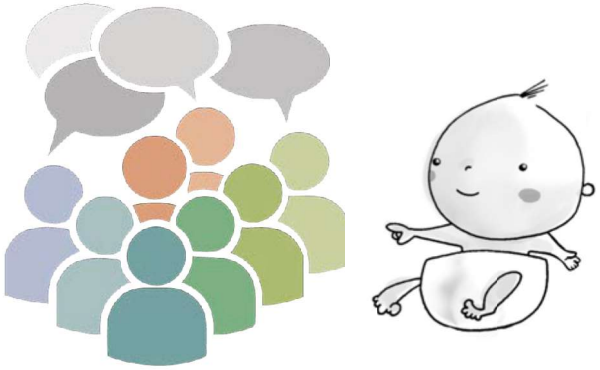
HYPOTHESIS SCANNING
"Is it because he woke up late?"

- Different kinds of questions are **differently informative depending on the likelihood distribution** across the given hypotheses



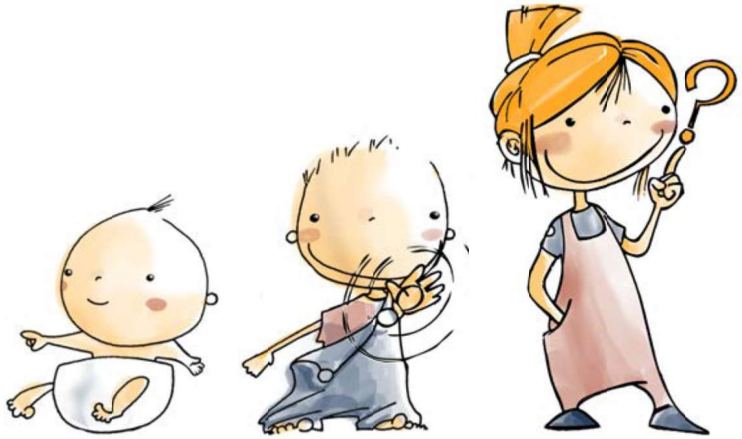
Developmental trajectory

Underlying Dynamics of Exploration



Navigating the social world

Interventions to support learning



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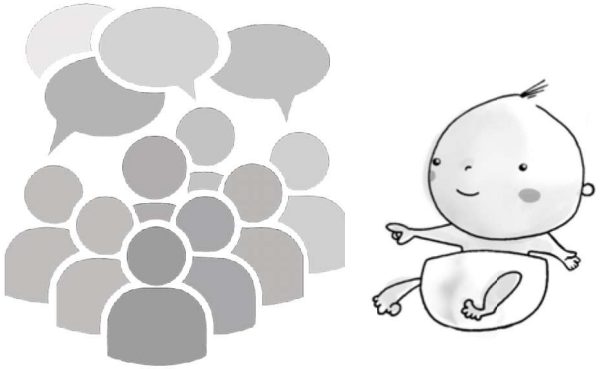


Navigating the social world

Interventions to support learning

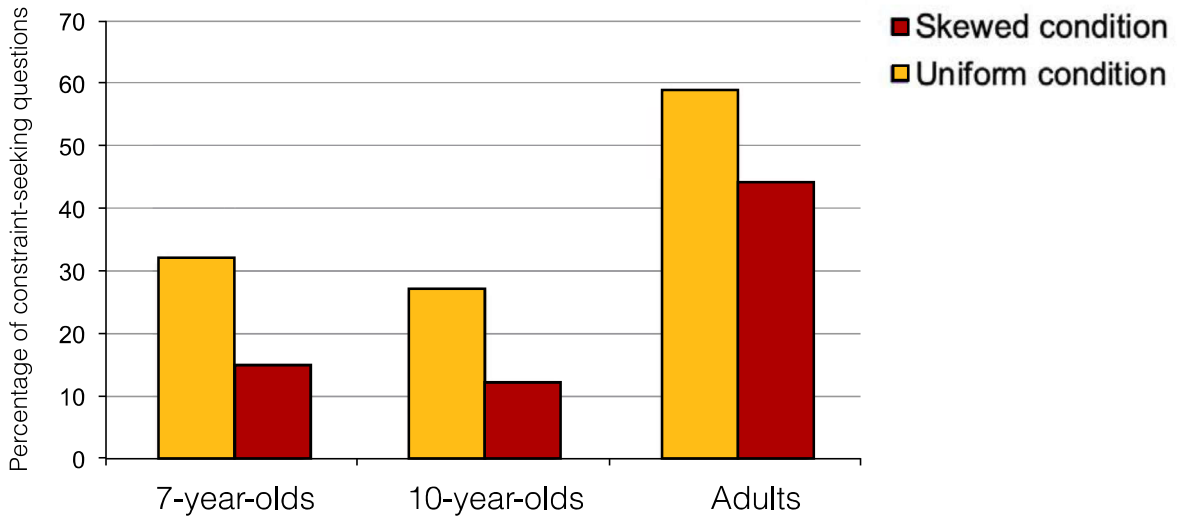
Children are adaptive learners

Ruggeri & Lombrozo, *Cognition*, 2015

Uniform
He forgot something at home and had to return for it
His alarm went off late so he overslept
His alarm did not go off so he overslept
He forgot something in his car and had to go get it
He could not find the keys to the car and had to search for them
He could not find his wallet and had to search for it
He had an errand to run on the way to work
He had a phone call to make before work
He was not feeling well when he woke up
He was not feeling well during the night

Skewed	
High	He forgot something at home and had to return for it
High	His alarm went off late so he overslept
Medium	He had to drop off his children at school that morning
Medium	He had to drop his wife at work that morning
Medium	The main street leading to his office was closed
Medium	The police stopped his car for a control
Low	He got robbed on the street on the way to the bus
Low	He got robbed on the bus
Low	A dog bit him in his front yard
Low	A dog was chasing him on the street

Children are **adaptive learners**



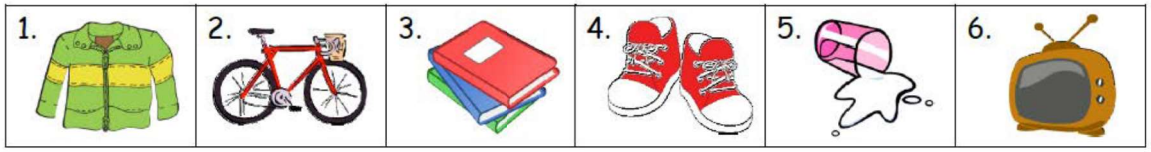
- Children are ecological active learners by age 7: they **dynamically adapt** the types of questions asked to improve efficiency.

Preschoolers **identify** the most informative questions

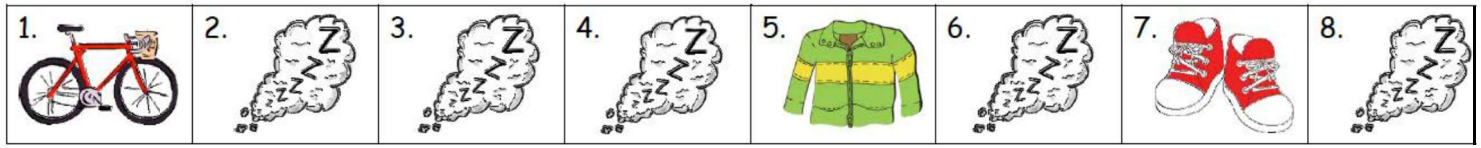
Zi Lin Sim

Ruggeri, Sim, & Xu, *Developmental Psychology*, 2017

Uniform condition



Skewed condition



Preschoolers **identify** the most informative questions

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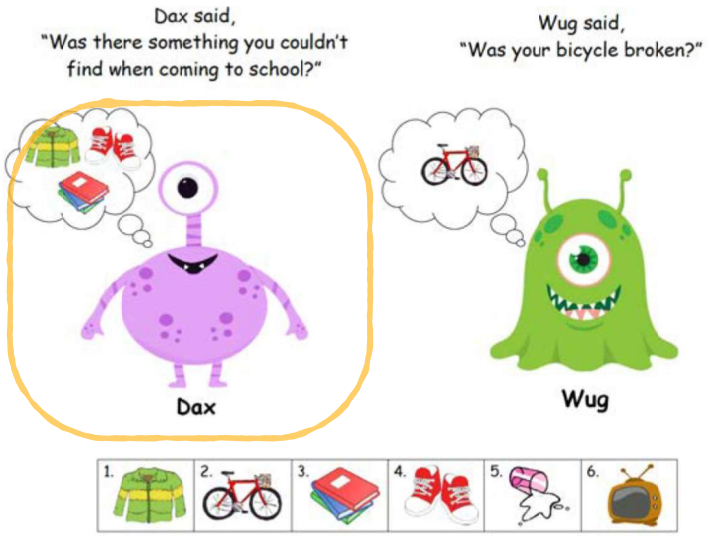
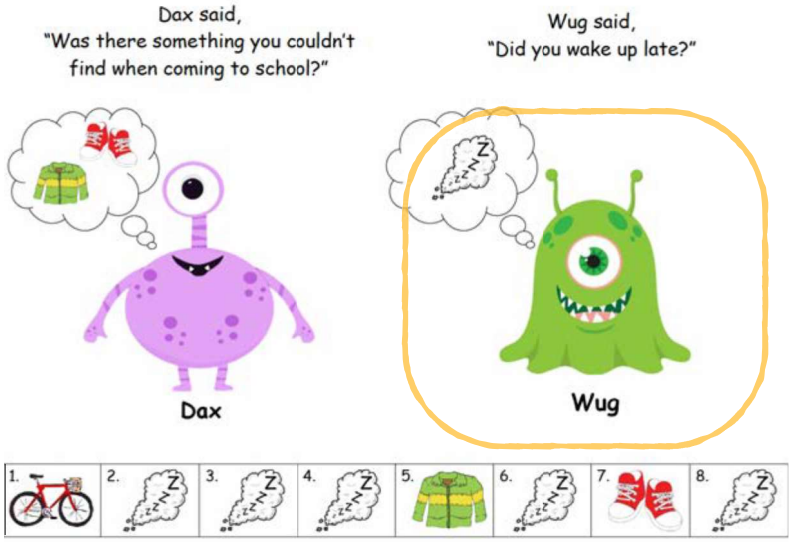


Skewed condition



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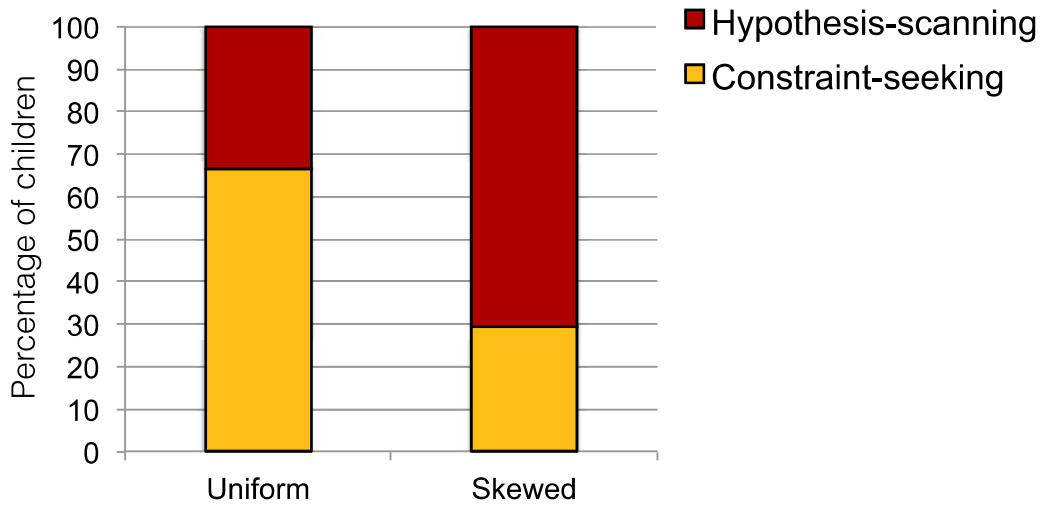


- Five-year-olds are ecological learners: They **adapt** their reliance on different kinds of questions based on the situation at hand.

Shake it baby, but **only when needed**

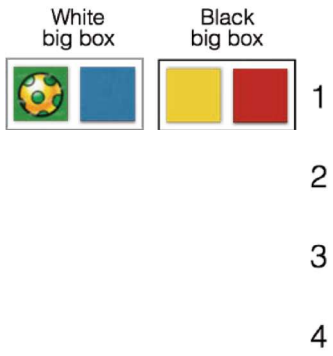
Nora Swaboda

Ruggeri, Swaboda, Sim, & Gopnik, *Cognition*, 2019

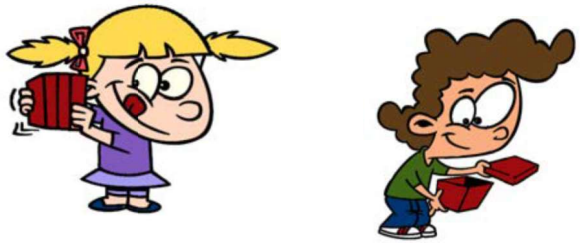
Shake it baby,
but **only when needed**

Distribution training

Uniform condition



Actions training



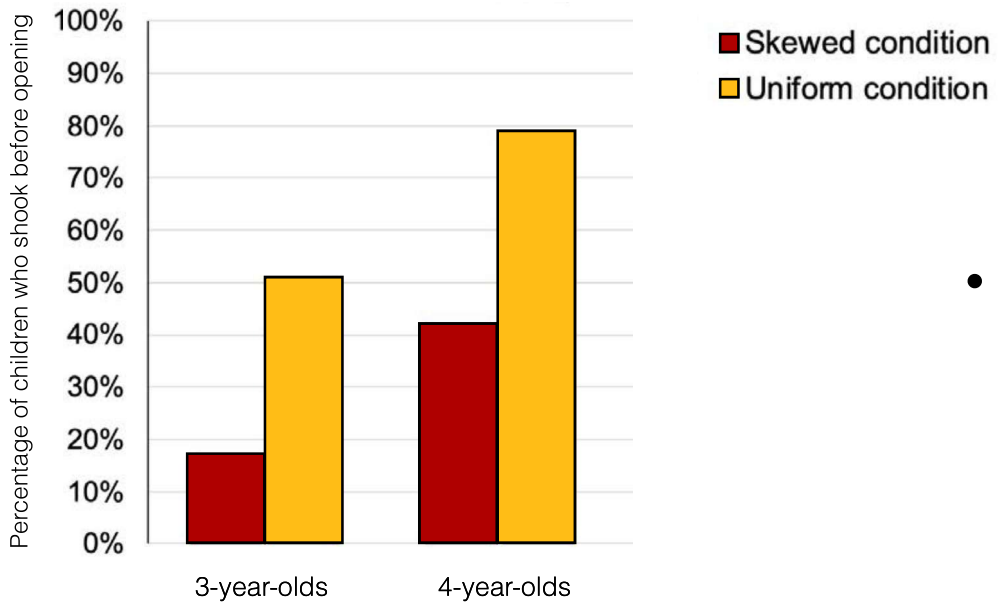
Shake

Open

Constraint seeking

Hypothesis Scanning

Shake it baby, but **only when needed**



- Three- and 4-year-olds are ecological active learners: They use **different exploratory actions** depending on the information structure of the task at hand.

Poli, Li, Naidu, Mars, Hunnius, & Ruggeri, *Nature Communication, 2024*

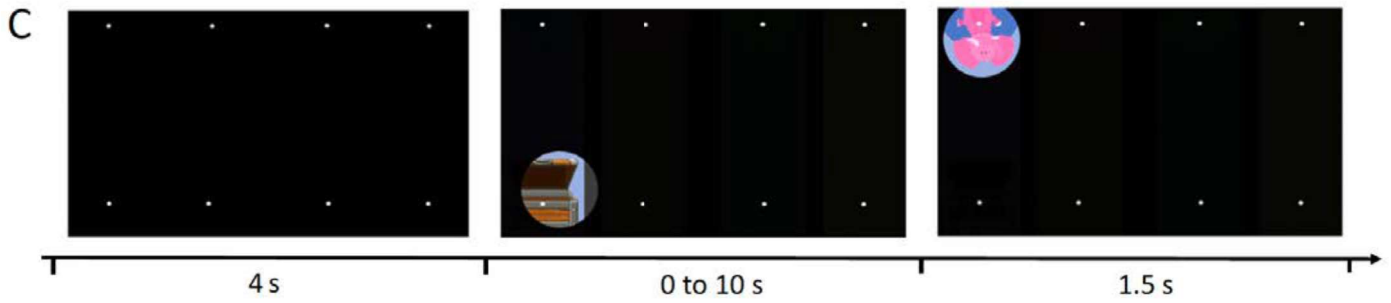
Toddlers' ecological active learning

Francesco Poli

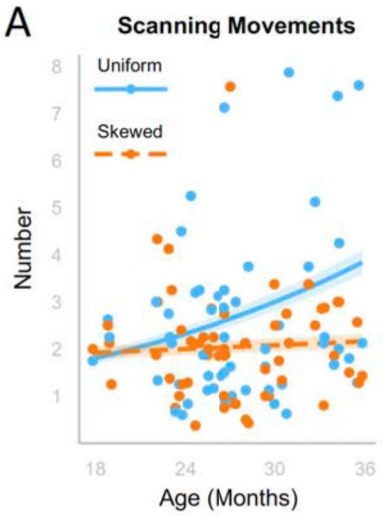
Poli, Li, Naidu, Mars, Hunnius, & Ruggeri, *Nature Communication, 2024*

A

Toddlers’
ecological active learning



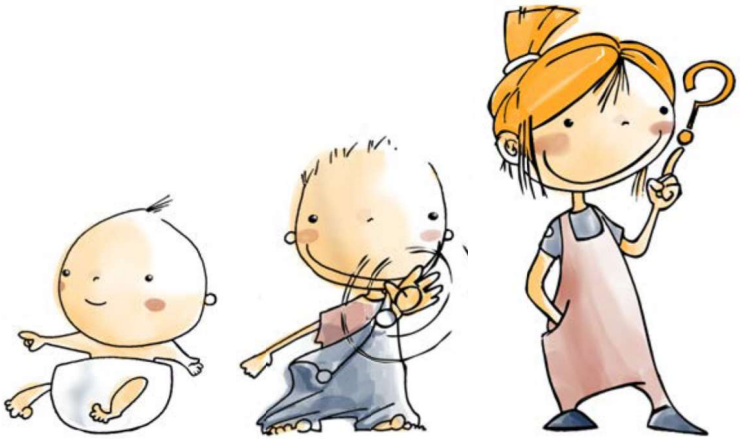
Toddlers'
ecological active learning



- Eye-movement data show that, from 24 months of age, toddlers start adapting their exploratory strategies to the information structure of the task.

How children explore and learn by:

- Recognizing the potentially ever-changing characteristics of their **environments**,
- Monitoring their own **competences**
- Considering internal/external **goals**



Developmental trajectory

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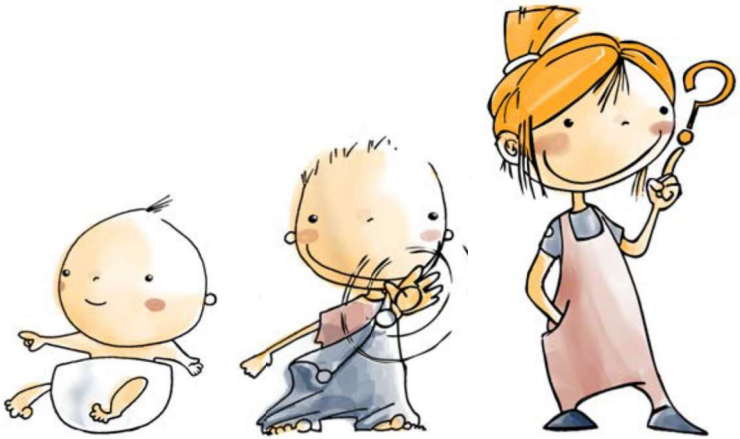


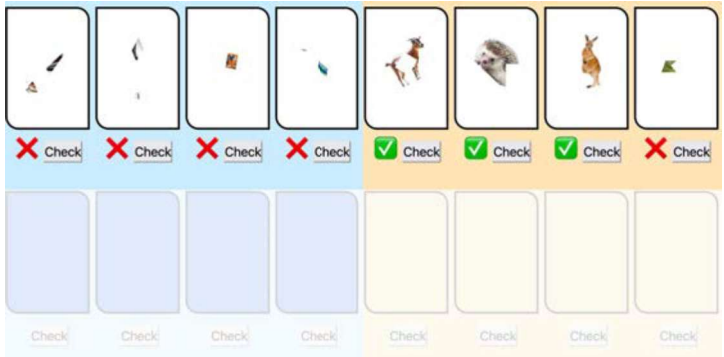
Developmental trajectory

Children strategically decide **what to practice**

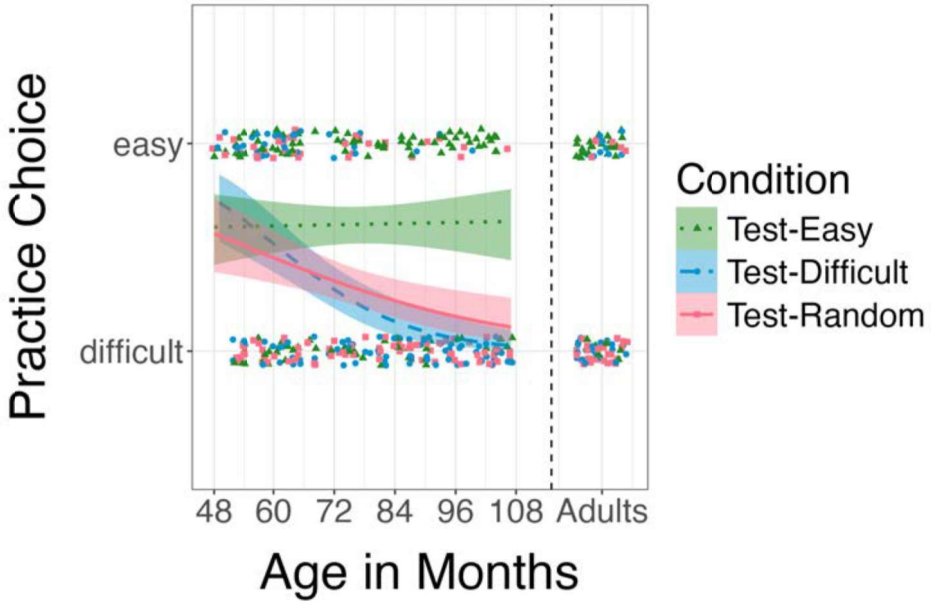
Daniil Serko

Serko, Leonard, & Ruggeri, *Child Development,* 2025

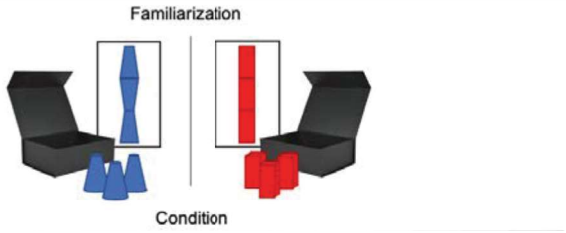
- **Ecological Active Practice:** the strategic choices students make regarding how to invest their time and effort in preparing for the future.

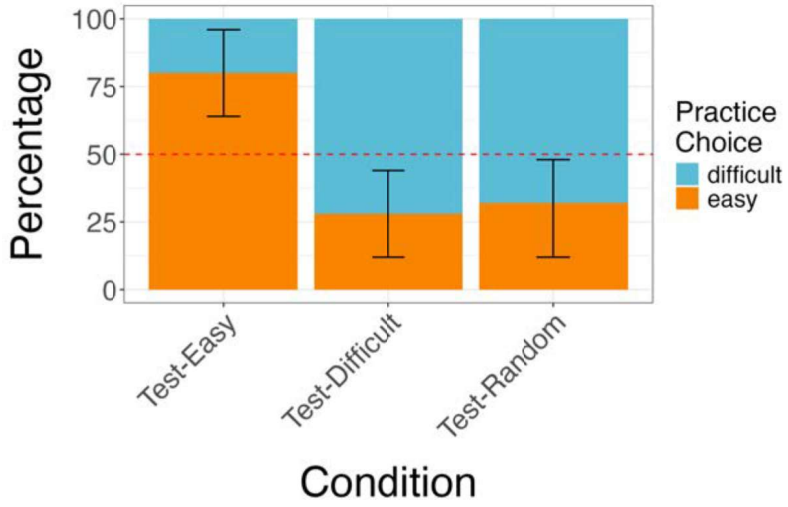


- Conditions:
  - Easy
  - Difficult
  - Random



Children strategically decide **what to practice**



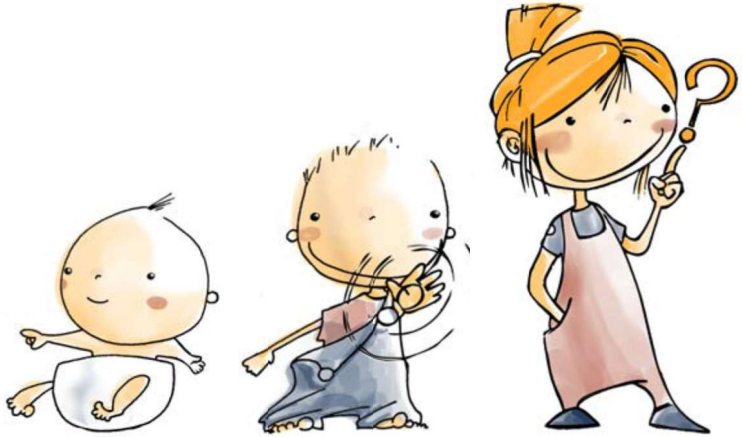


- **Ecological Active Practice** develops from age 4 to 6.

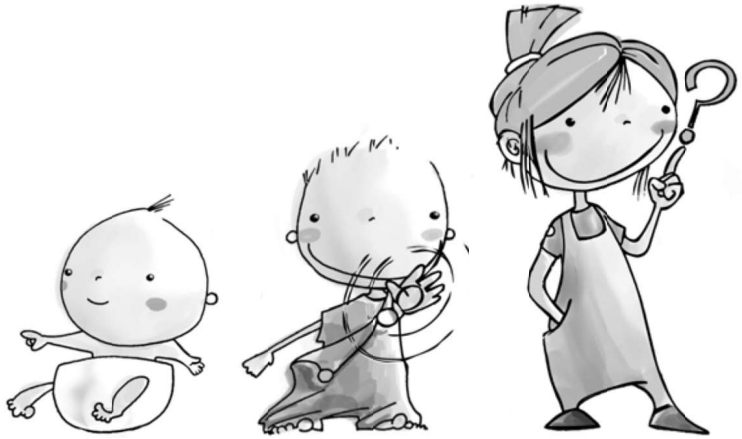
How children explore and learn by:

- Recognizing the potentially ever-changing characteristics of their **environments**,
- Monitoring their own **competences**
- Considering internal/external **goals**

(Bramley & Ruggeri, 2022, *Dev. Psych.;* Török, Domberg, & Ruggeri, 2024, *Dev. Psych.;* Lapidow, Walker, & Ruggeri, *under review*; Walker & Ruggeri, *in revision*, *Dev. Science*)

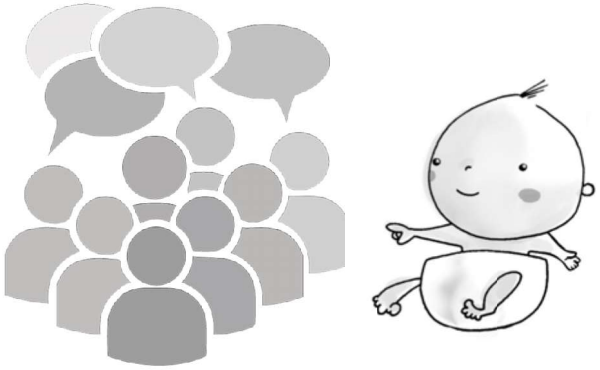


Developmental trajectory



Developmental trajectory

Underlying Dynamics of Exploration



Navigating the social world

Interventions to support learning

- **Mechanisms** of developmental change
- **Triggers** of active learning
- **Factors** modulating active learning efficiency

Underlying Dynamics of Exploration

- **Mechanisms** of developmental change
- **Triggers** of active learning
- **Factors** modulating active learning efficiency

Underlying Dynamics of Exploration

Curiosity as Engine

- AI struggles to learn when rewards are sparse
- Children thrive in exactly those messy conditions
- Loewenstein's "information-gap" - the itch to close what we don't know

Children's Curiosity

- Even infants attend longer to surprising events, seeking to reduce uncertainty (Stahl & Feigenson 2015; Kidd et al. 2012).
- Preschoolers explore more when evidence is confounded or unexpected (Schulz & Bonawitz 2007; Bonawitz et al. 2012).
- Young children actively choose actions with higher potential information gain (Jirout & Klahr 2012; Ruggeri et al. 2017, 2019).
- Persistence—staying with a single challenge—predicts later achievement and is shaped by both task features and social cues (Duckworth et al. 2007; Leonard et al. 2017).

Toddlers **search longer** when there is **more to gain**

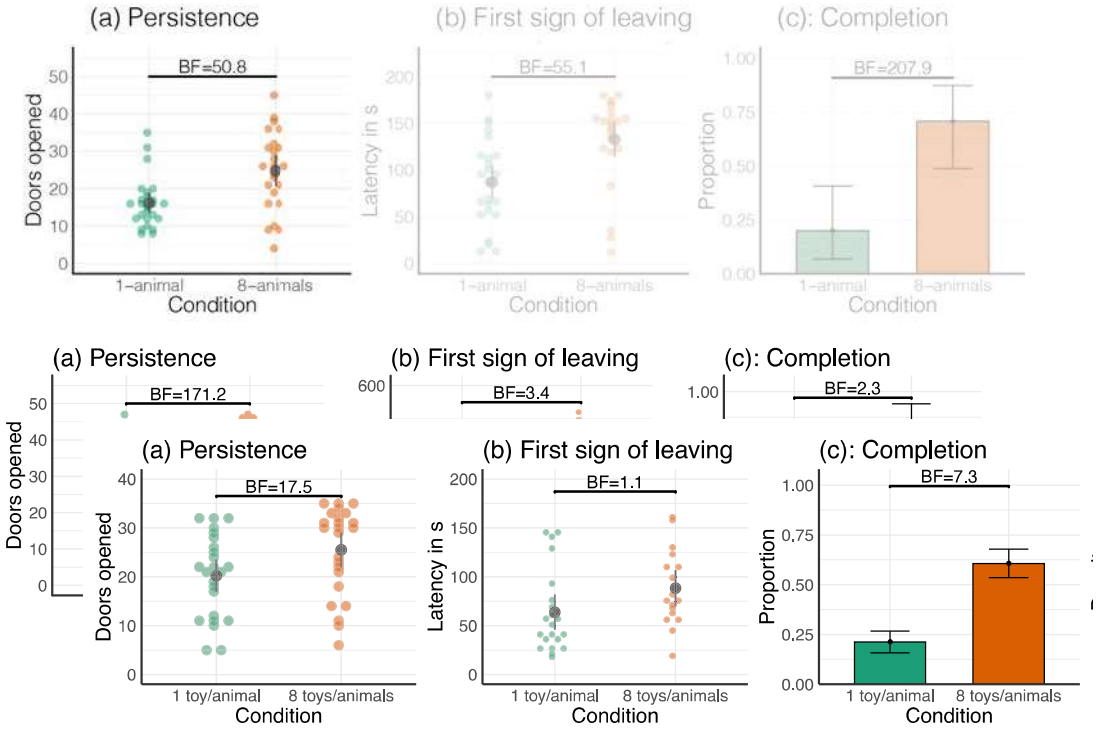
Eric Schulz

Ruggeri, Stanciu, Pelz, Gopnik, & Schulz, *Dev. Science 2023*

1-animal

8-animals

Toddlers **search longer** when there is **more to gain**



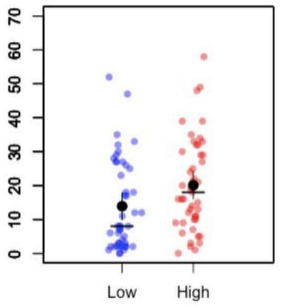
- We replicated these results when manipulating the *amount* of additional information gained (Study 2)…
- …and when conditions were manipulated within subjects (Study 3)
- In the absence of any rewards, preschoolers' search is **motivated by the expected informativeness** of the actions available

Children **search longer** when there is **more to gain**

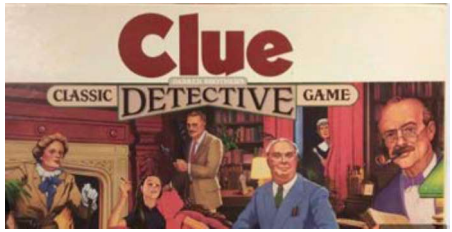
Oana Stanciu

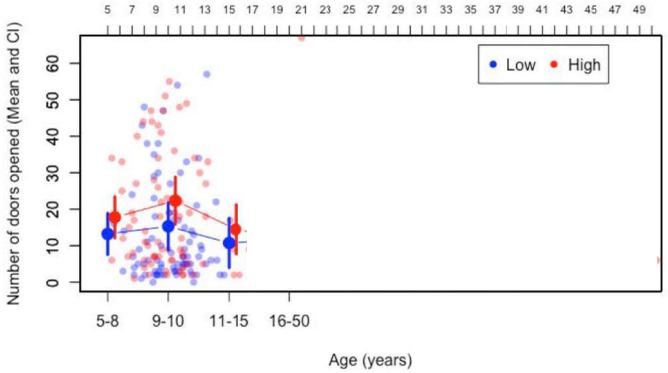
Stanciu & Ruggeri, *in prep.*

3-5 years

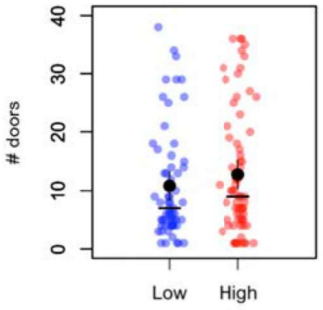


5 years to adults





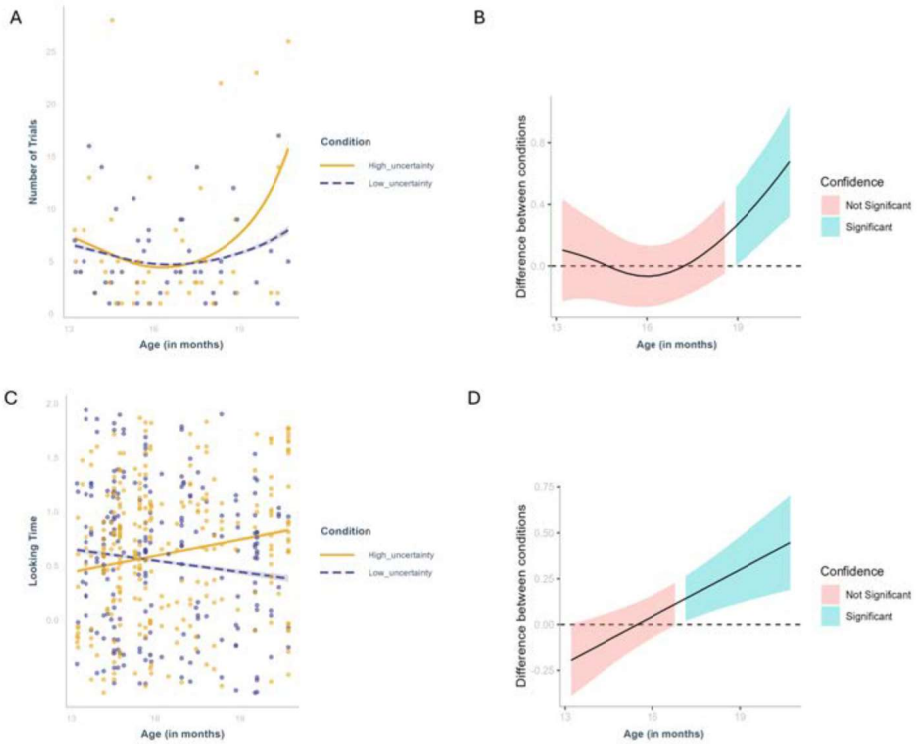
Adults

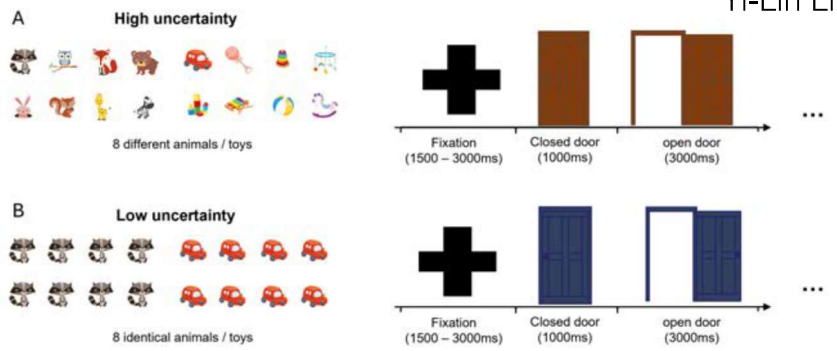


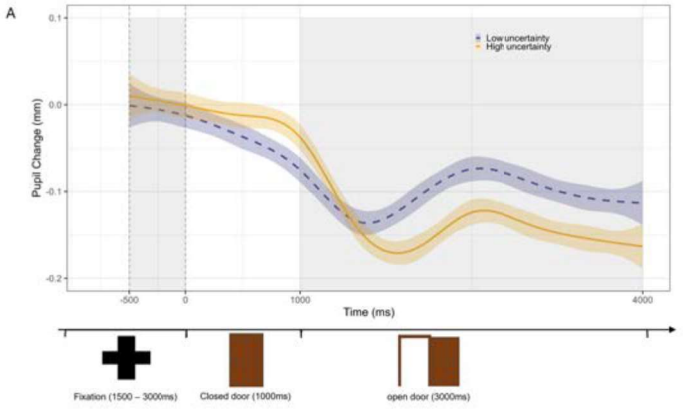
Infants **search longer** when there is **more to gain**

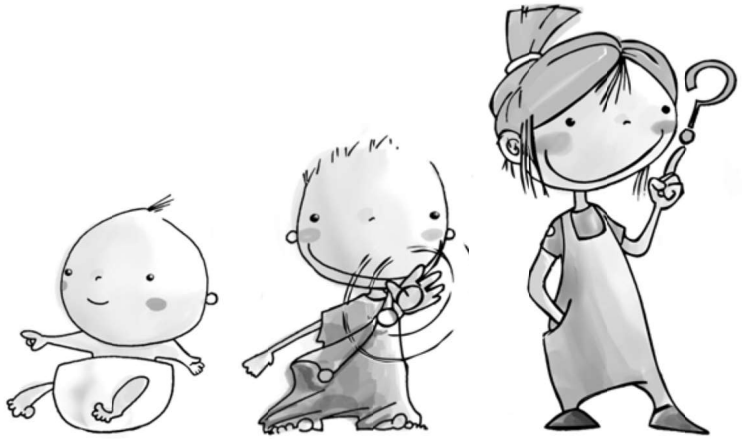
Li, Poli, & Ruggeri, *under review*

Yi-Lin Li



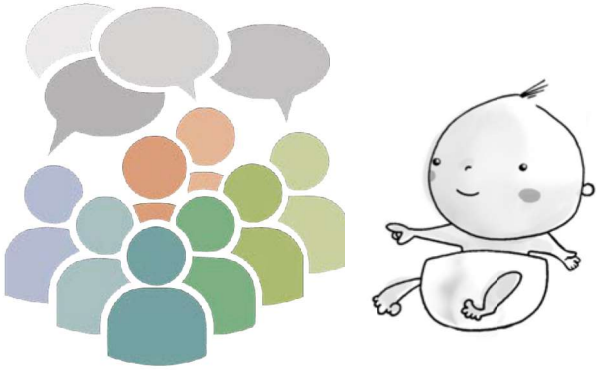






Developmental trajectory

Underlying Dynamics of Exploration



Navigating the social world

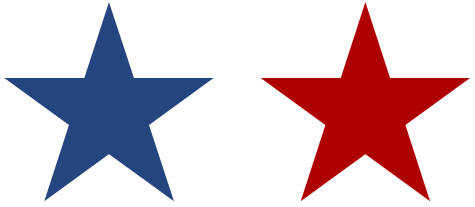
Interventions to support learning

Rule communication is context dependent

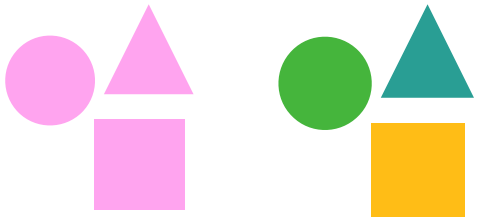
Paula Fischer

- 8-year-old children create rules to guide their behavior in a social-dilemma game (Grueneisen, 2019)
- 5-year-olds maintain previously learnt norms by communicating them to new peers in group activities (Göckeritz,2014)
- In cooperative contexts, children support one another by offering reminders and clarifications (Koymen et al., 2016)
- How someone communicates in a cooperative/competitive context, influences partner choice (Dunfield, 2013)

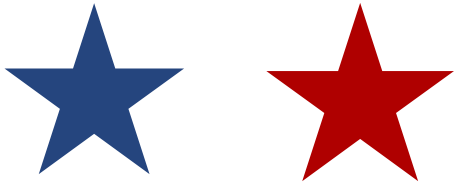
Rule communication is context dependent



Familiarisation

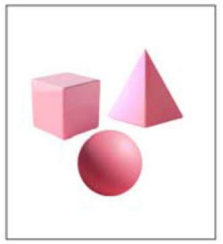


Manipulation



Same team Opposite team

Test



Fidi likes pink objects

Correct

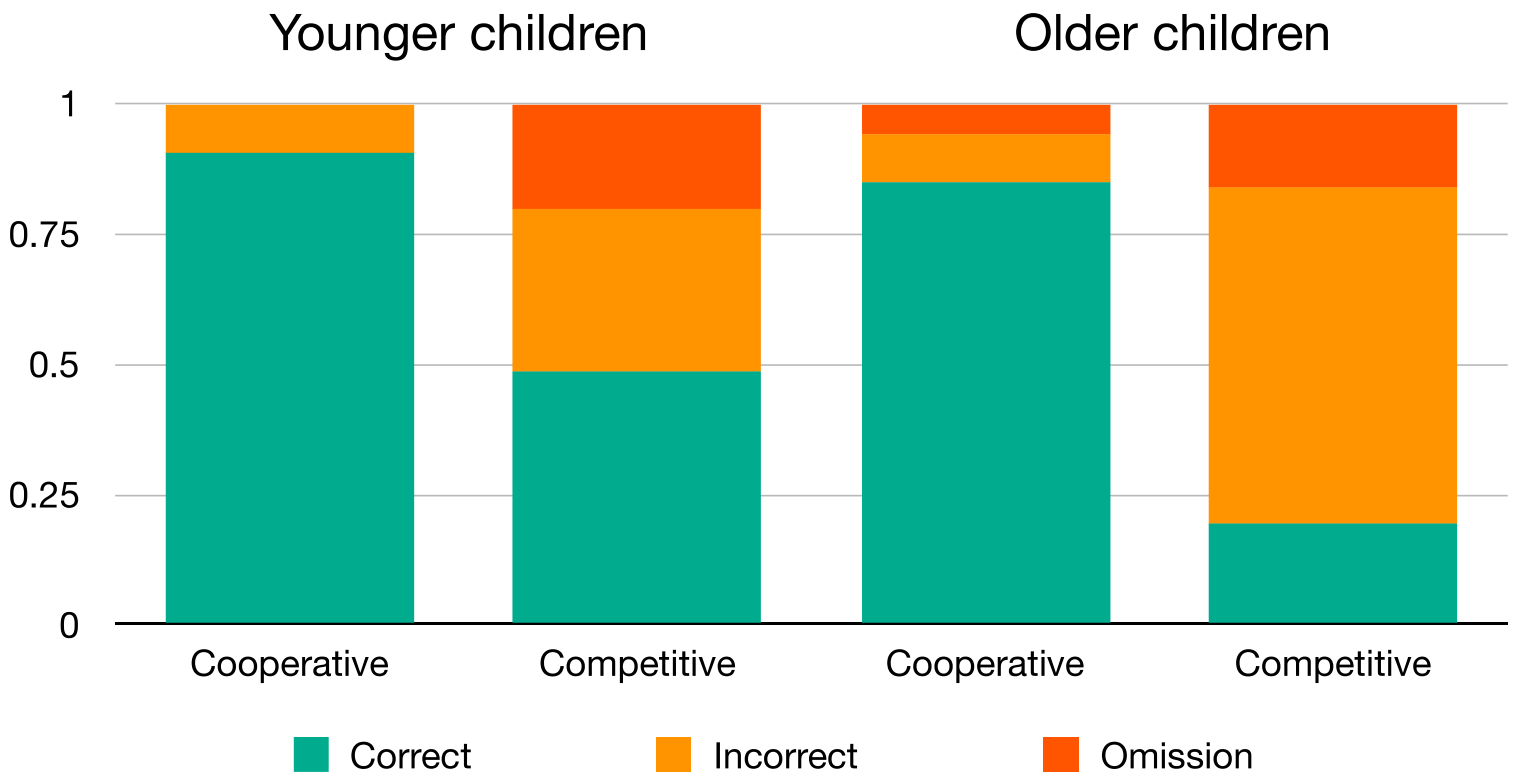
Fidi likes green objects

Incorrect

I am not sure what Fidi likes

Omission

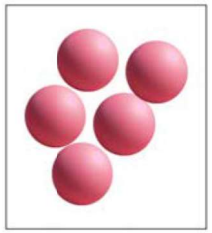
Rule communication is context dependent



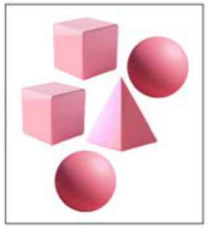
Rule communication is context dependent

Test

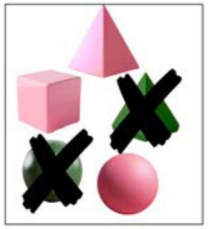
Fidi doesn't like green



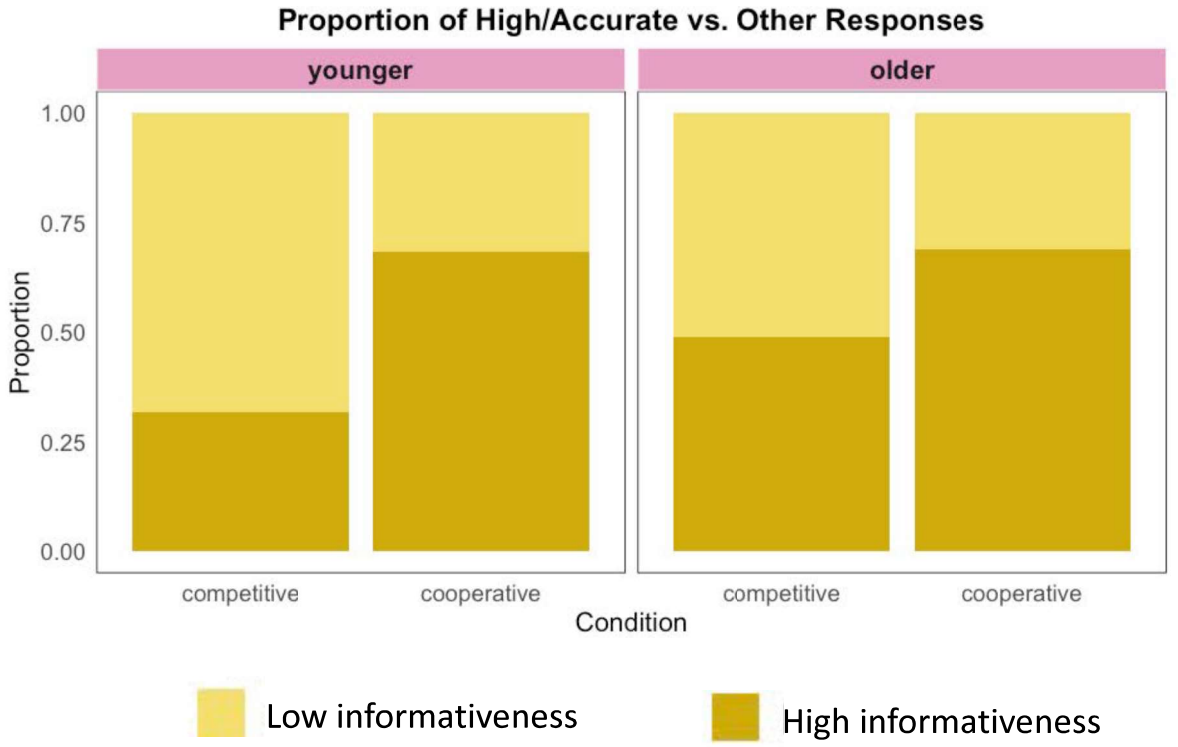
Fidi likes



Fidi likes pink objects

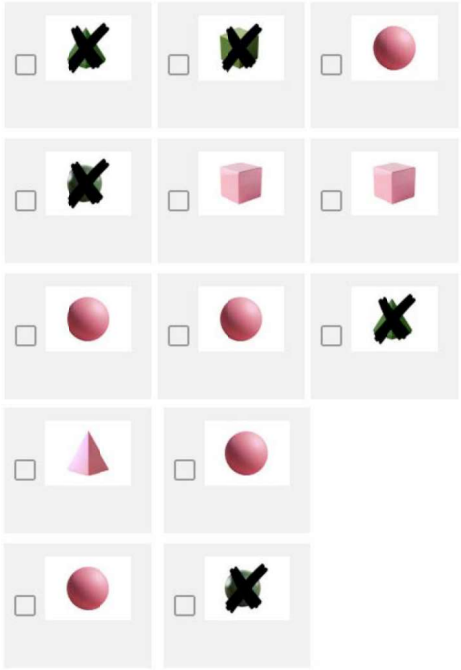


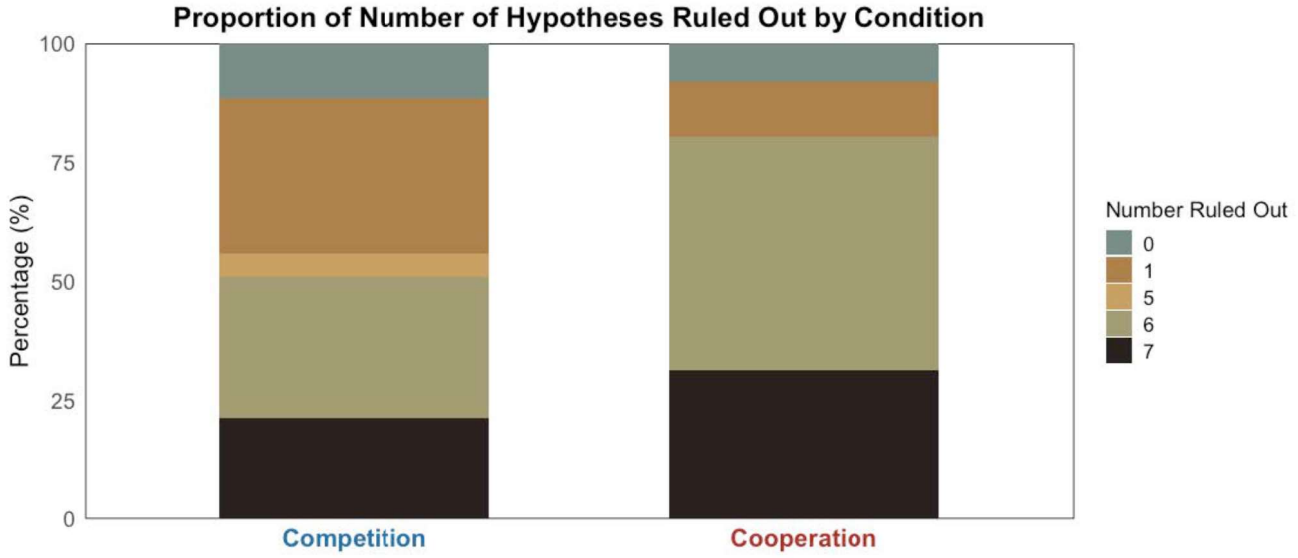
Fidi only likes pink

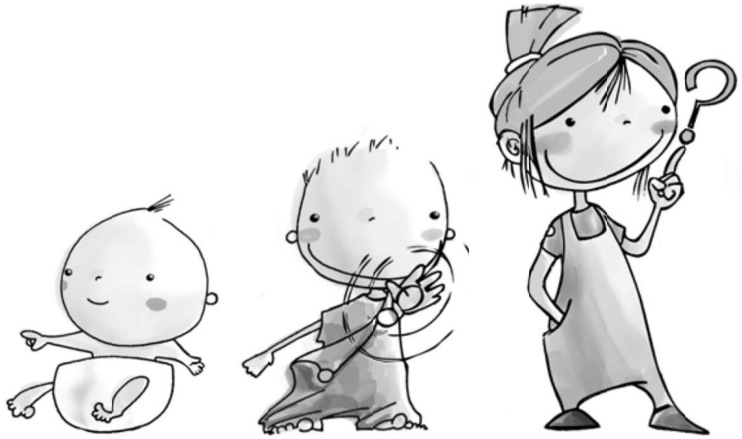


Rule communication is context dependent

Test

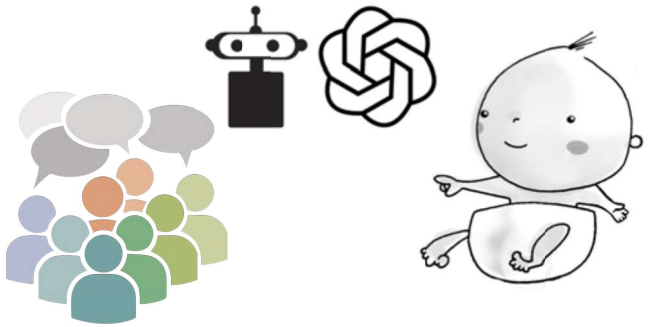






Developmental trajectory

Underlying Dynamics of Exploration



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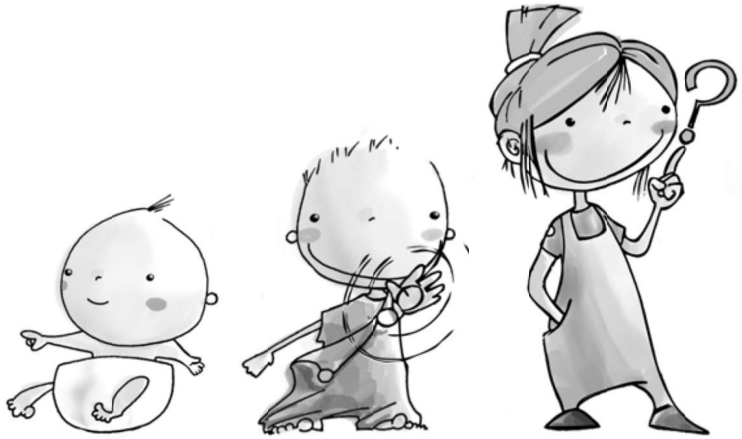
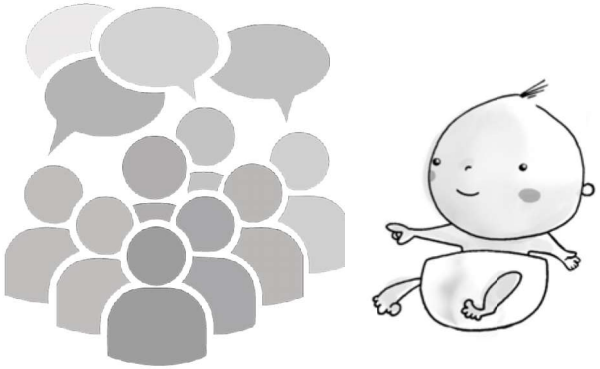
Interventions to support learning



Developmental trajectory

Underlying Dynamics of Exploration



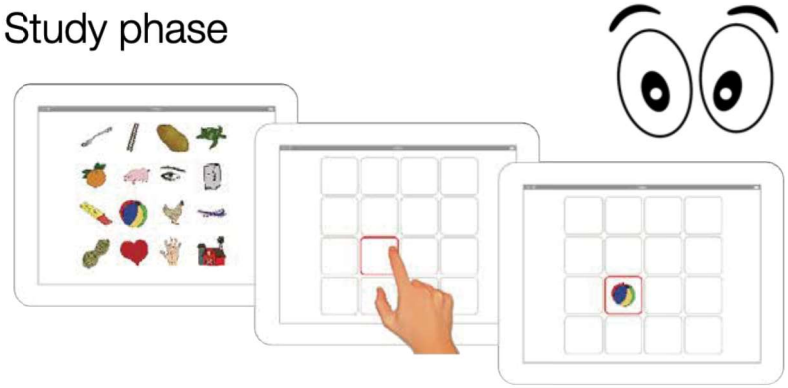
Navigating the social world

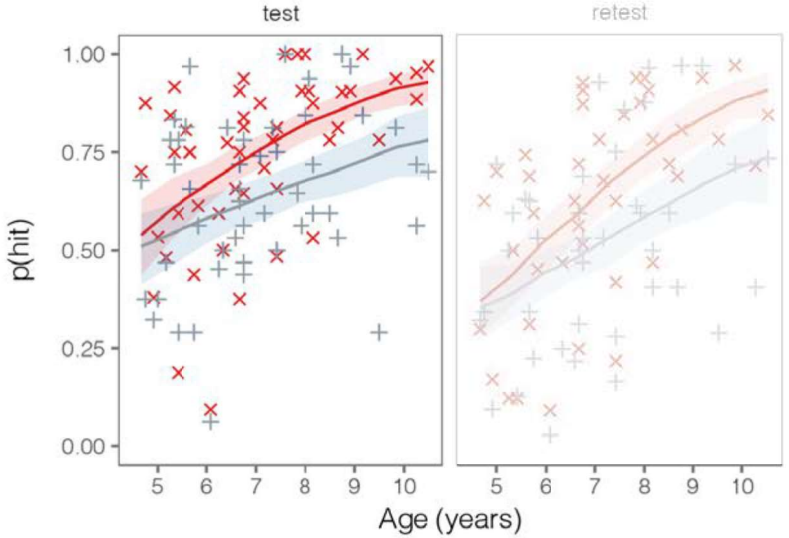
Interventions to support learning

Benefits of active control of study

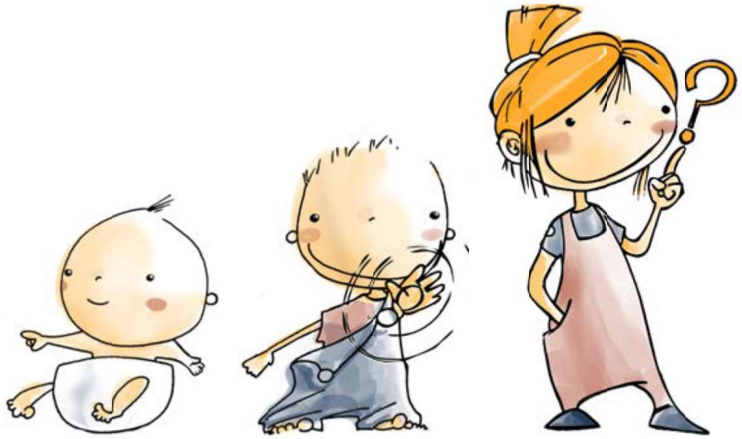
Doug Markant

Ruggeri, Li, & Markant, *in revision*; Optiz & Ruggeri, *Lernen und Lernstörungen*, 2022; Fantasia, Markant, Valeri, Perri, & Ruggeri, *Autism*, 2020; Ruggeri, Markant, Gureckis, & Xu, *Cognition,* 2019



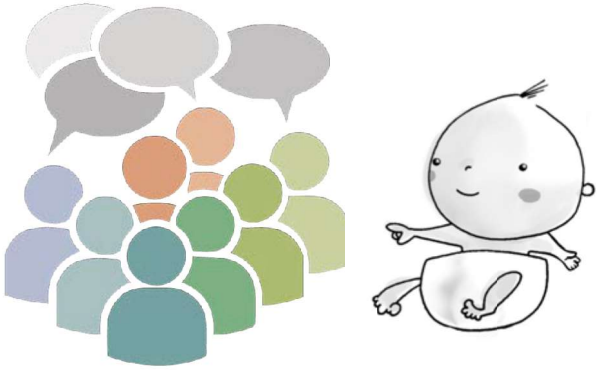


- Recognition memory **more accurate in the active condition**.
- **Robust** across different versions, countries, and replicated with children affected by autism



Developmental trajectory

Mechanisms of developmental change



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Interventions to support learning

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