Not playing by the rules: Play, problems, and human cognition

Laura Schulz
Early Childhood Cognition Lab

BAICS Talk,
April, 2020

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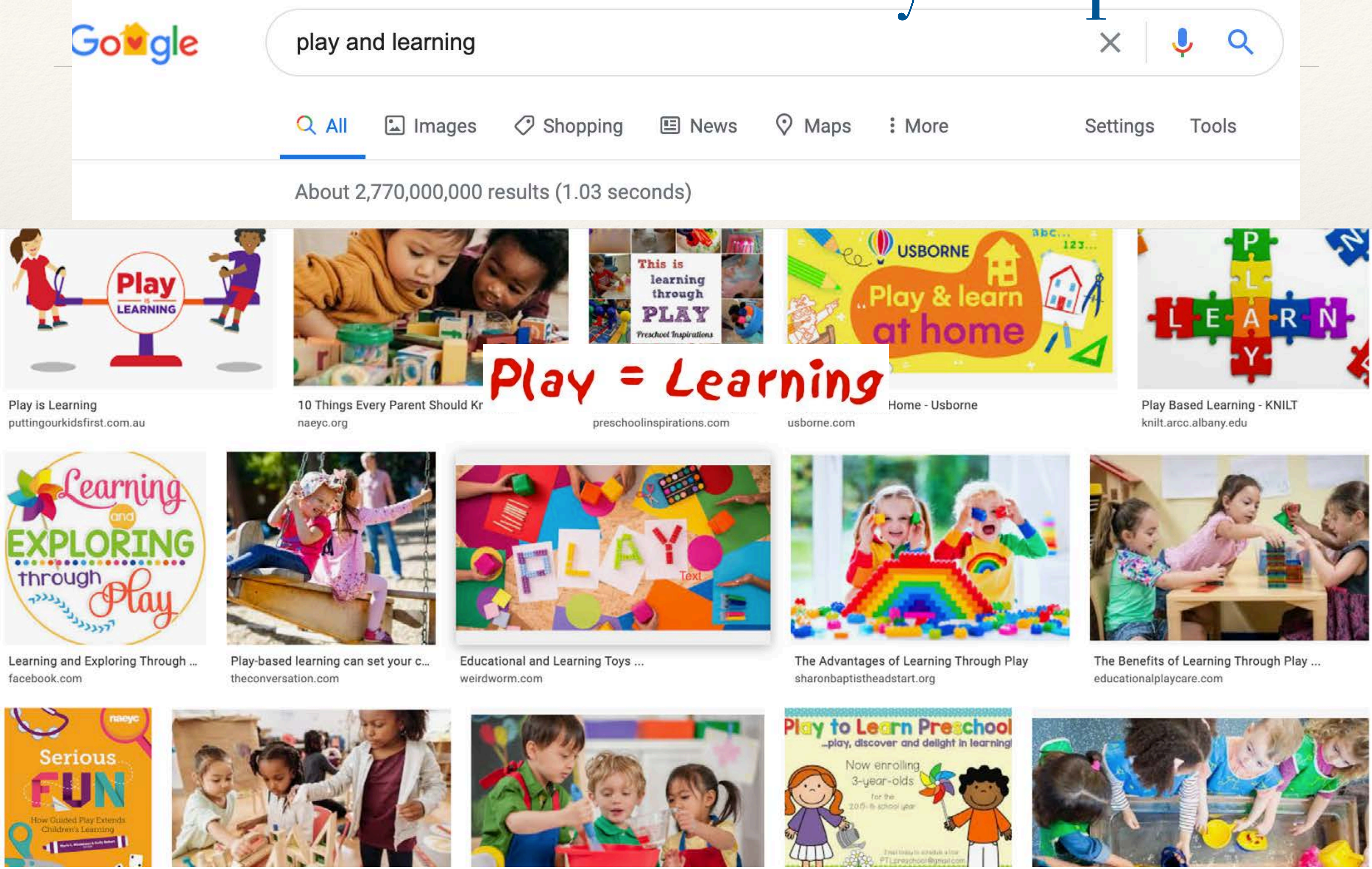
Few claims are more widely accepted …



… and so hard to substantiate

"No behavioral concept has proved more ill-defined, elusive, controversial, and even unfashionable than play" (E. O. Wilson, 1975)

"The most irritating feature of play is not the perceptual incoherence, as such, but rather, that play taunts us with inaccessibility. We feel that something is behind it all, but we do not know, or have forgotten how to see it." (Fagen, 1981 in Sutton-Smith, 1997)

What is play for?

- Non-cognitive ends
  - For pleasure (Buhler, 1935; Buytendijk, 1933; Gilmore, 1966)

(a) Common dolphins herd sardines with bubble nets. (b) A dolphin starts to release a cloud of bubbles (arrowed) from its blowhole. A moment later (c) the dolphin (1) swims on, leaving behind the expanding cloud (2). Other dolphins (incl. 3) enter the frame. (d) The sardines school within a wall of bubbles and are trapped. Images courtesy of The Blue Planet (BBC).

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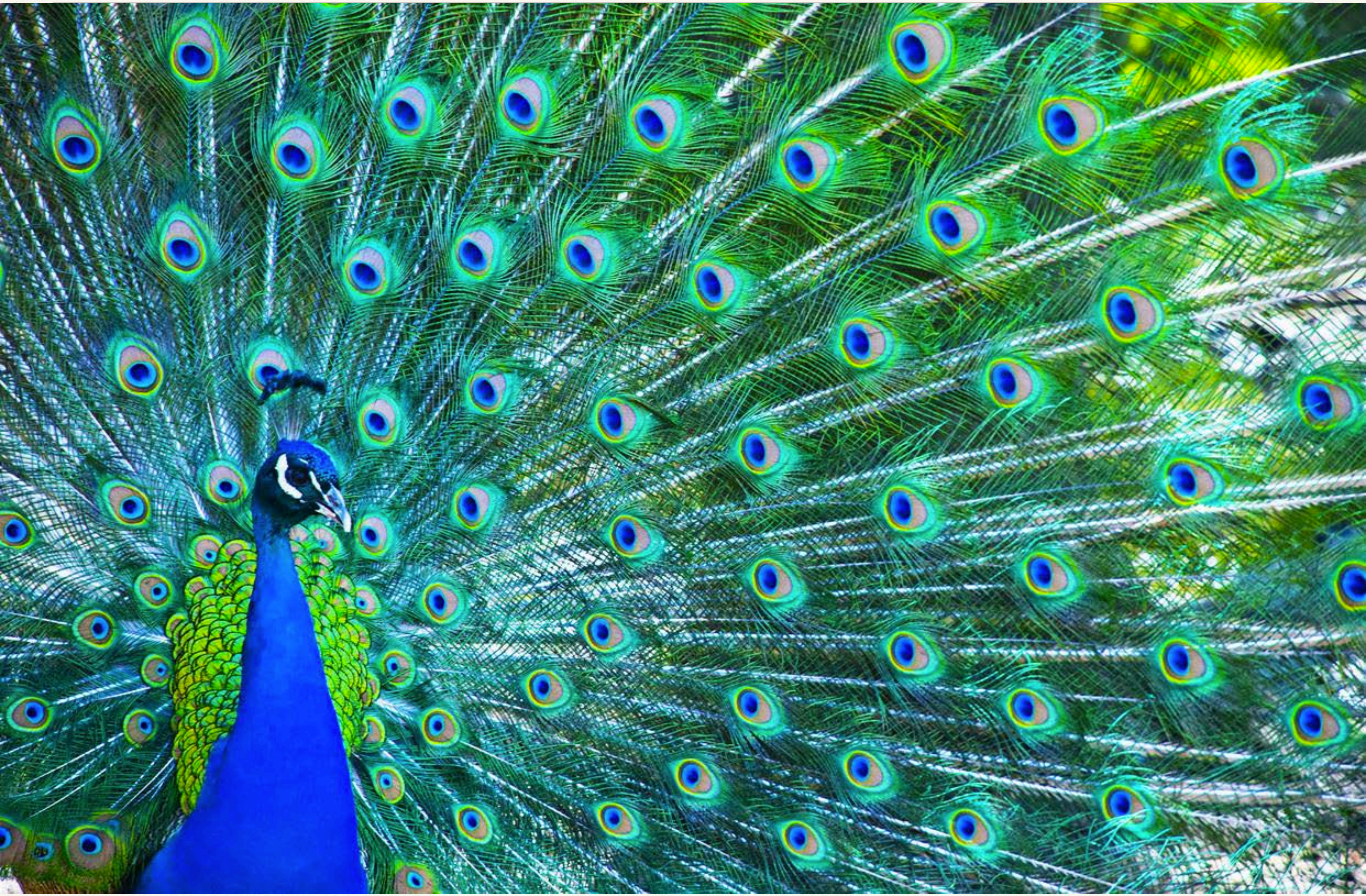

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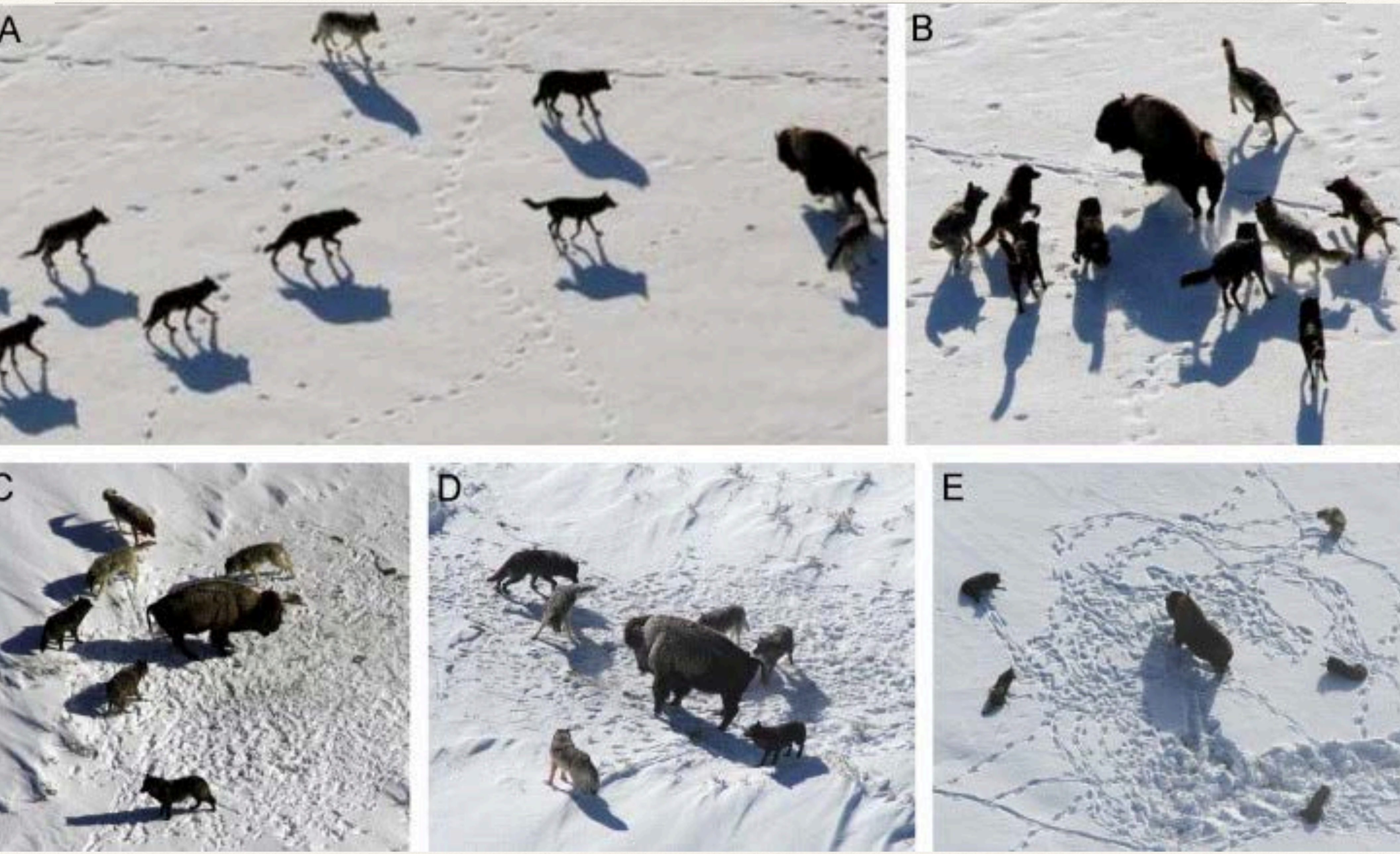
  - For performance (Hawkes. & Bird, 2002; Hingham, 2014; Smith, 1976; Zahavi & Zahavi, 1997)
  - For peace-making (Baldwin & Baldwin, 1974; Bekoff, 1974; Berman, 1982; Drea et al., 1996; Pellis & Pellis, 1992; Porier & Smith, 1974; Spinka et al., 2001; Soderquist & Serena, 2000)


A
B
C
D
E

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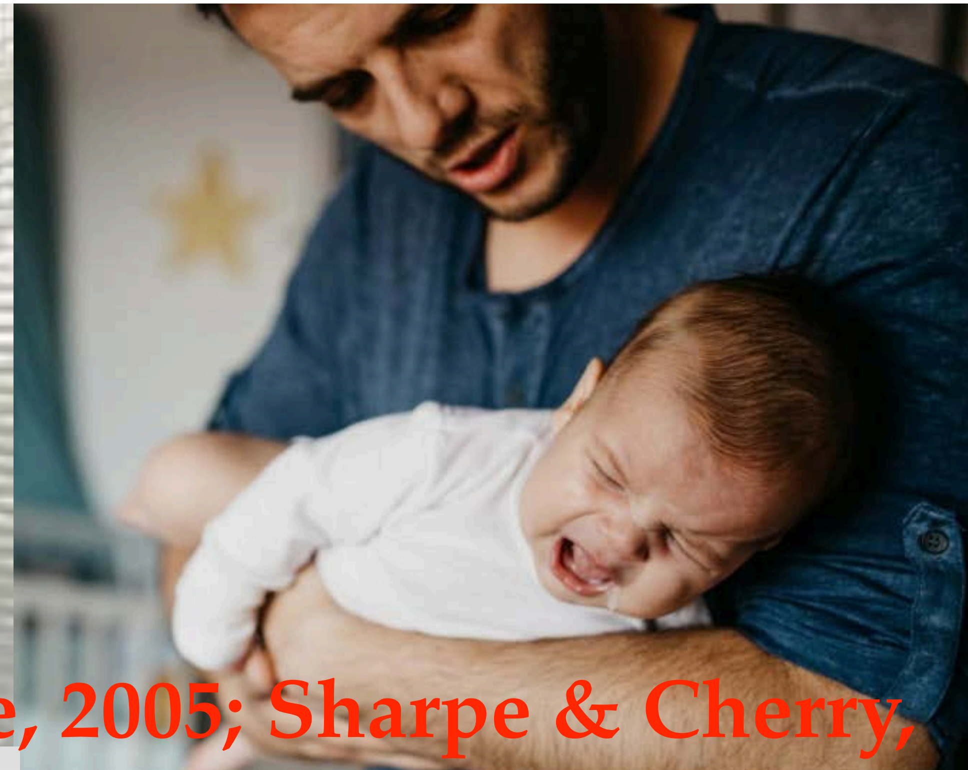

But see Caro, 1980; Sharpe, 2005; Sharpe & Cherry, 2003; Watson, 1993

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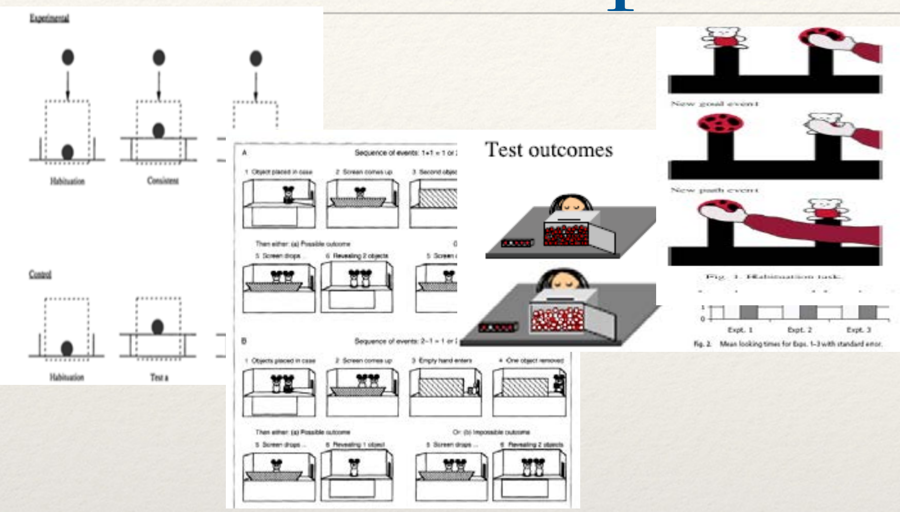
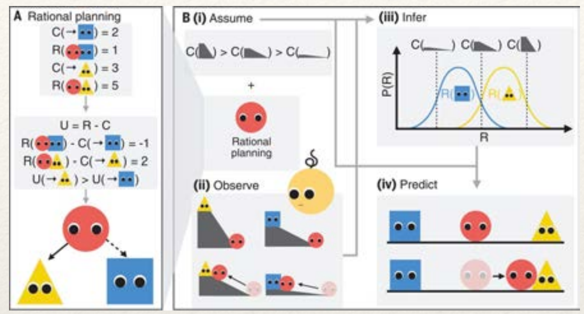
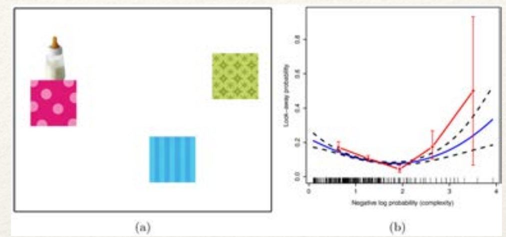
Why do we play?

- Cognitive reasons
  - For practice (Groos, 1898; see also Bekoff & Byers, 1998; Burghardt, 2005; Fagen, 1981; Pelligrini, Dupuis, & Smith, 2006)
  - For prediction (Berlyne, 1966; Bonawitz, van Schijndel, Butler & Markman, 2012; Bonawitz, et al., 2011; Buchsbaum, Bridgers, Skolnick Weisberg, & Gopnik, 2012; Chitnis, Silver, Tenenbaum, Kaelbing, & Perez, 2020; Cook, Goodman, & Schulz, 2011; Jirout & Klahr 2012; Gottleib, Oudeyer, Lopes, & Baranes, 2013; Florensa, Held, Geng, & Abbeel, 2017; Gopnik & Walker, 2013; Haber, Mrowca, Wang, Li, & Yamins, 2018; Jabria Eysenbach, Gupta, Levine, & Finn, 2019; Kang et al., 2006; Kulkarni, Narasimhan, Saeedi, & Tenenbaum, 2016; Legare, 2012; Oudeyer, Gottleib, & Lopes, 2016; Oudeyer & Smith, 2016; Pathak, Agrawal, Efros & Darrell, 2017; Schmidhuber, 2011; 2013; Schulz & Bonawitz, 2007; Schulz & Standing, 2008; Sim & Xu, 2008; Singh, Lewis, Barto, & Sorg, 2019; van Schijndel,; Visser, van Bers, & Raijmakers, 2015; Wood-Gush & Vestergaard, 1991)

Even infants explore in ways that are sensitive to expected information gain



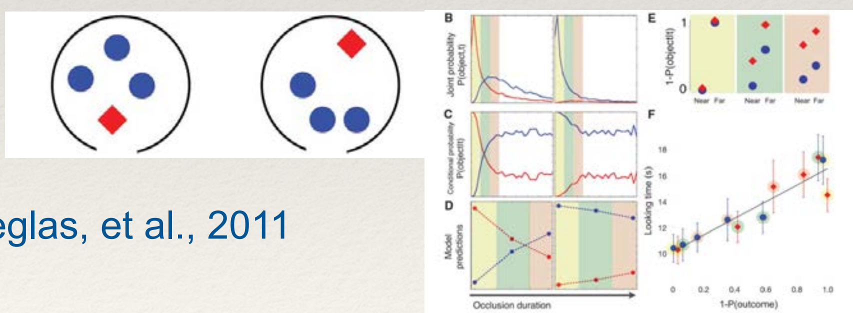


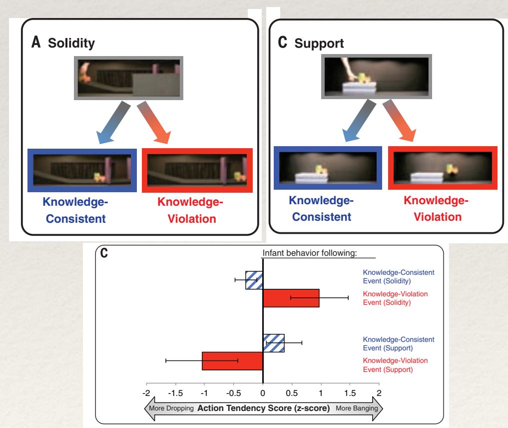


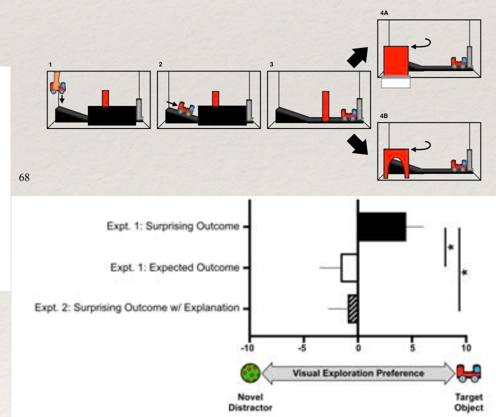
Piantidosi, Kidd, & Aslin, 2014

Liu, Ulman,Tenenbaum & Spelke, 2017

Spelke,, Wynn, Xu, Woodward, etc.







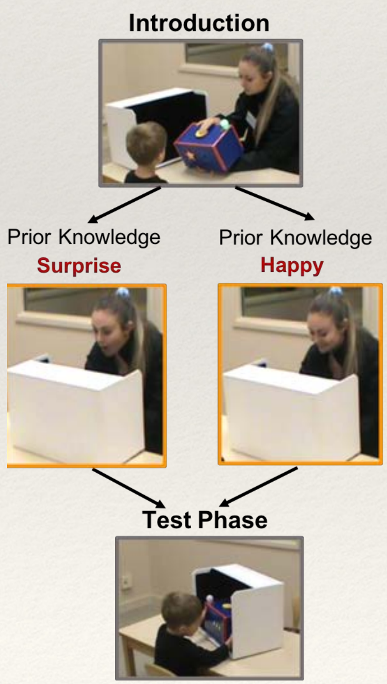
Teglas, et al., 2011

Stahl & Feigenson, 2015

Perez & Feigenson, 2020

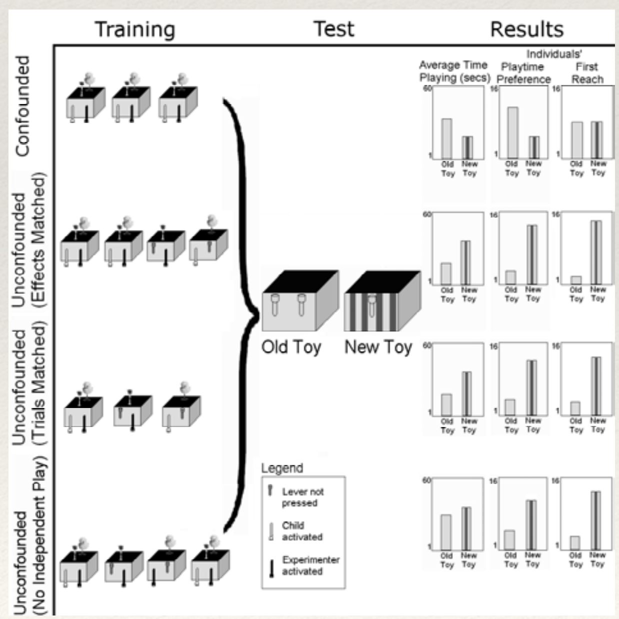
And children's exploration becomes increasingly sophisticated through early childhood

Bonawitz, Schijndel, Friel & Schulz, 2012



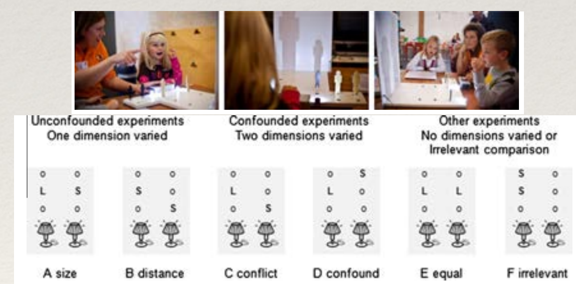
Wu & Gweon, 2019

Legare, 2012; Sobel & Legare, 2014



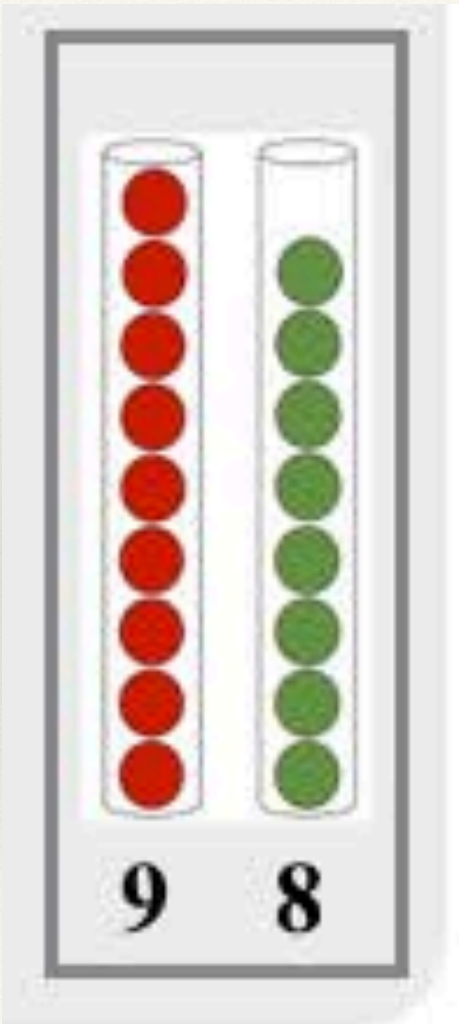
Schulz & Bonawitz, 2007

Buchsbaum, Bridgers, Weisberg & Gopnik, 2012

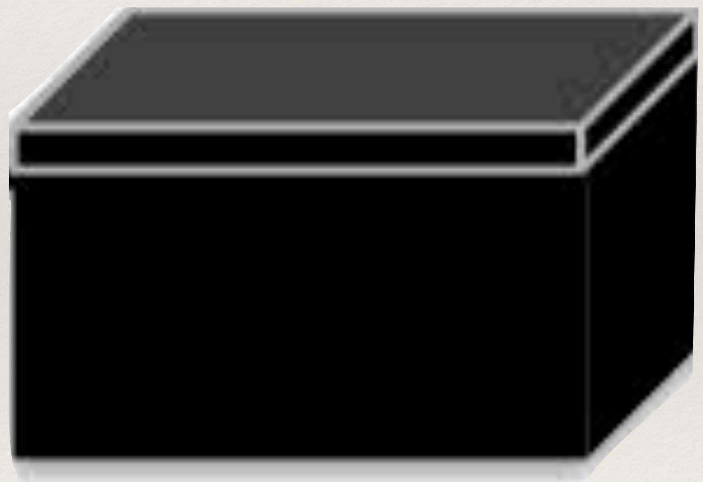


Van Shinjndel, Visser, Van Bers, Raijmakers, 2015

Uncertainty and exploratory play



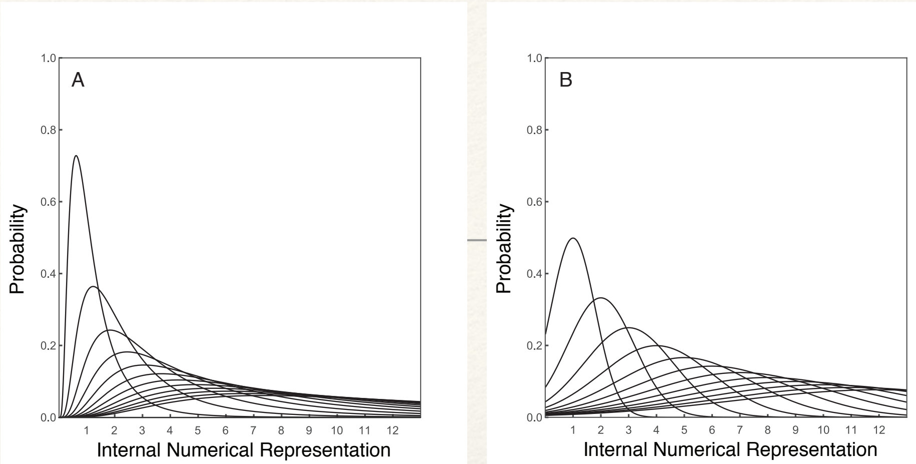
(9 marbles actually go into the box)



Max Siegel

Rachel Magid

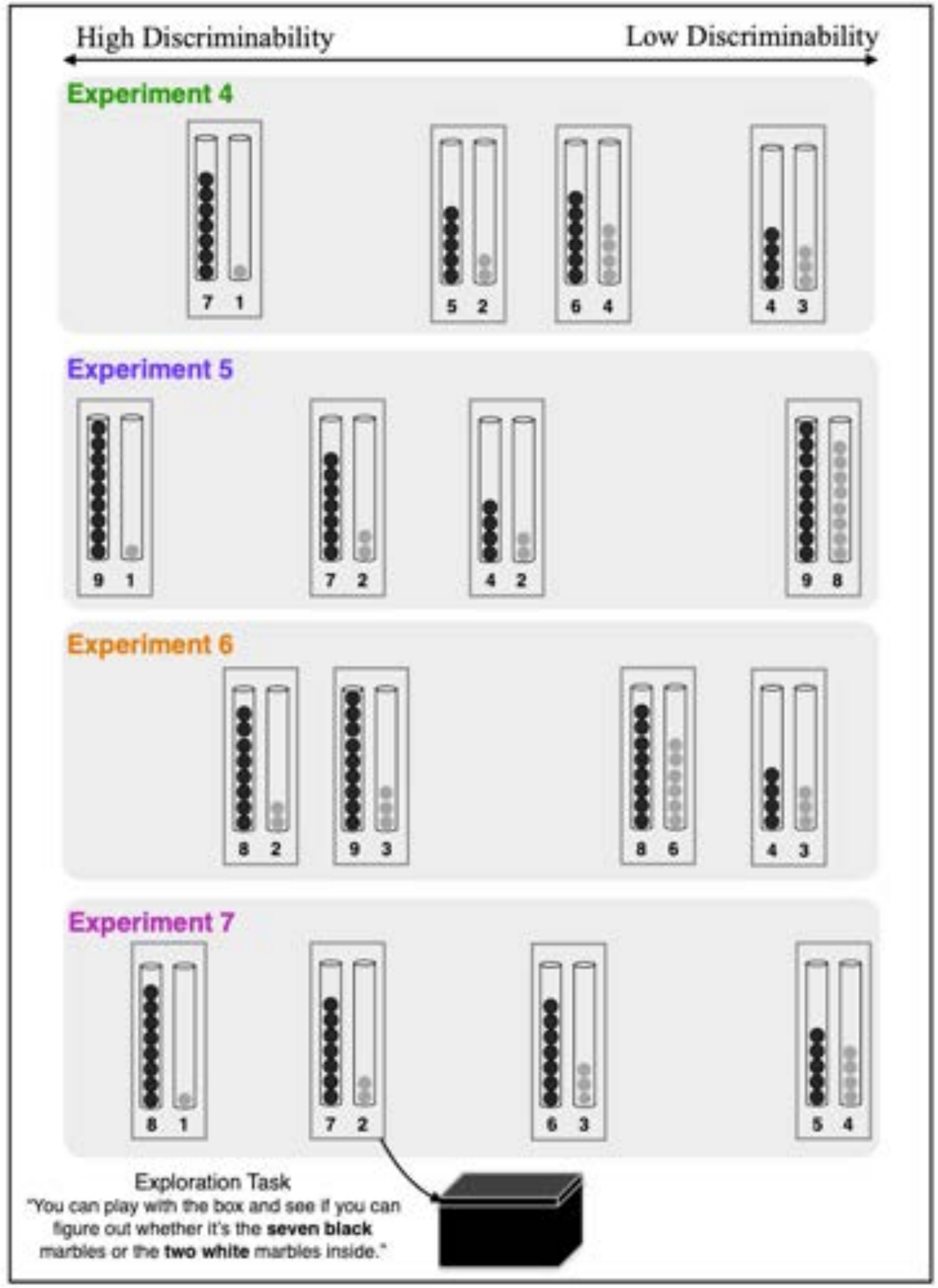
Siegel, Magid, Pelz, Tenenbaum, & Schulz, in press, *Nature Communications*



Models of children's internal representation of number, showing (A) normal distributions with fixed variance defined over logarithmic space (but visualized over linear space) and (B) normal distributions with variance proportional to mean defined over linear space.

Measure the discriminability of each contrast between l and m marbles

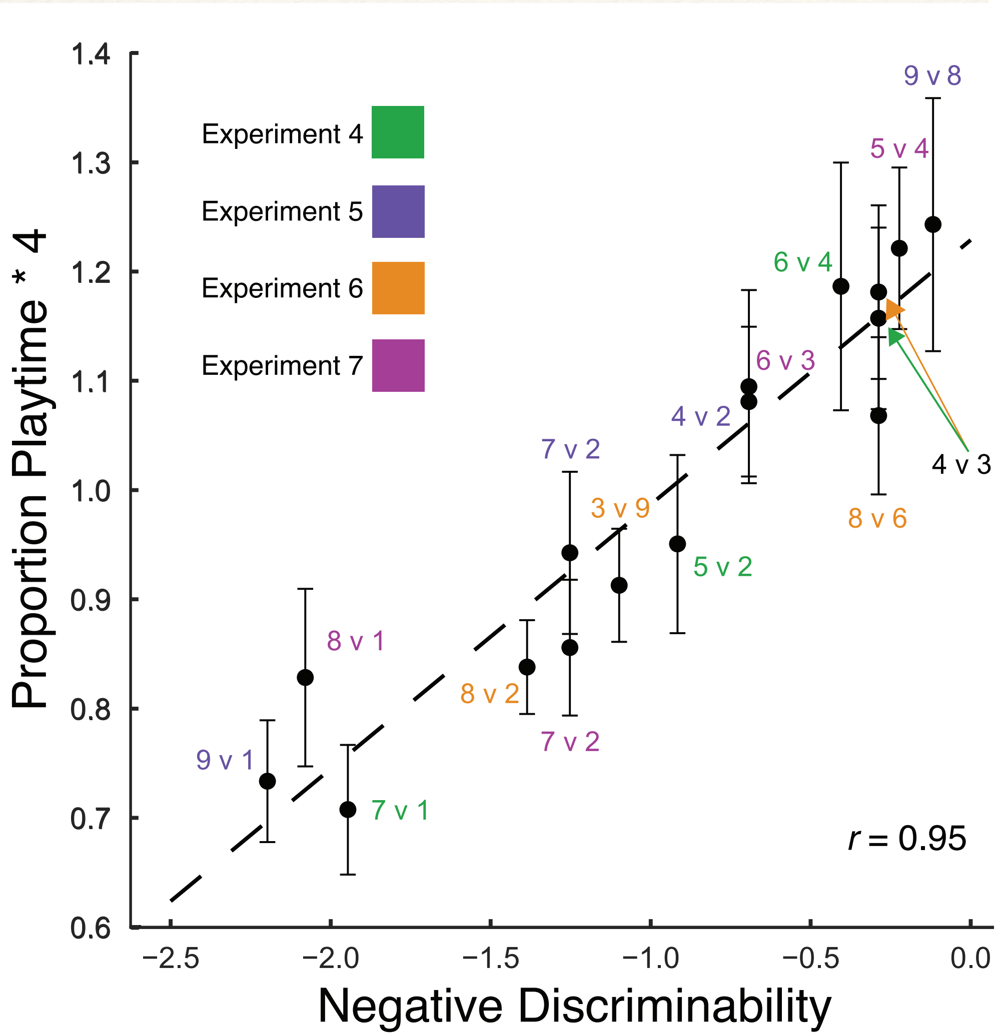
$$d' = \frac{|\mu_l - \mu_m|}{\sigma}, \text{ where } \mu_l = \log l \text{ and } \mu_m = \log m.$$



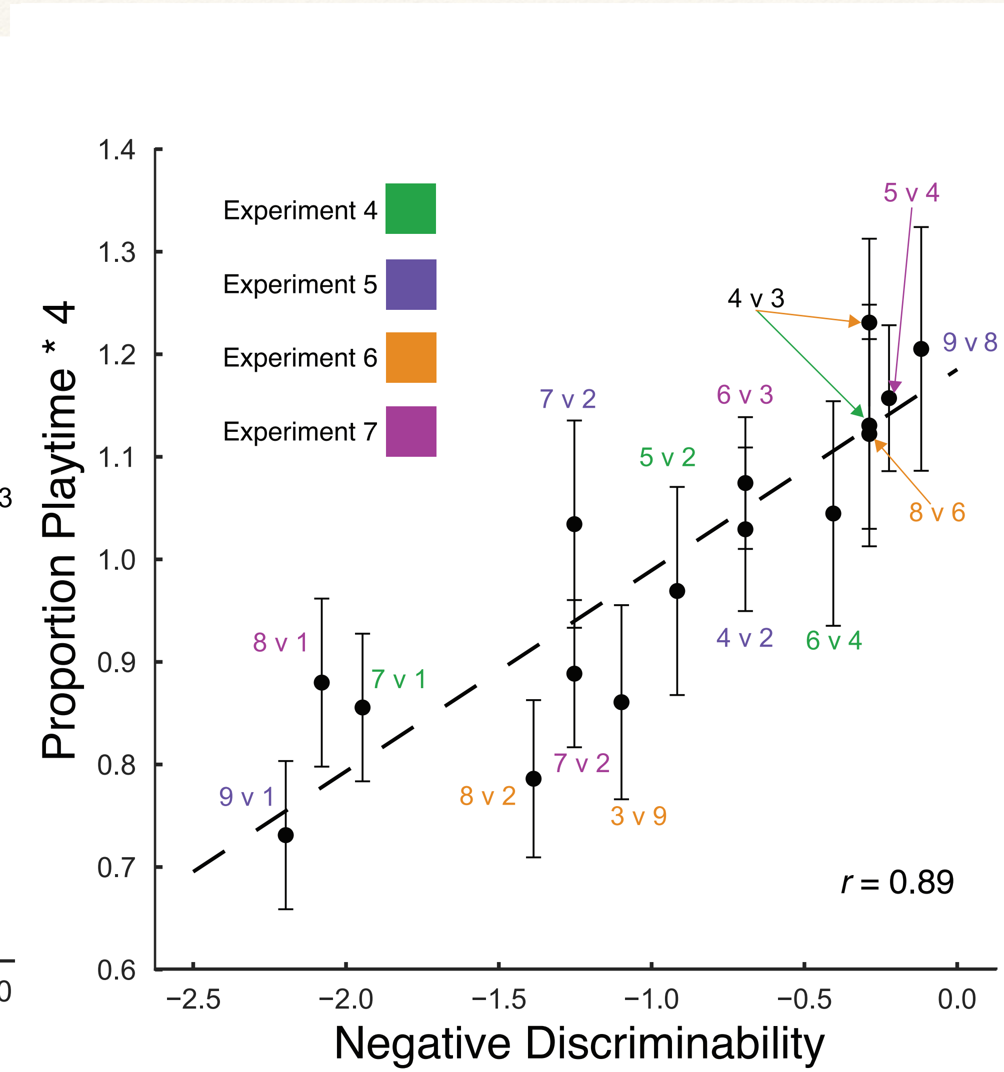
N = 96, 24 children ages 4-8 years (m_{age}= 5.83 years)

[redacted]

Children's exploration precisely tracked the discriminability of the contrast …



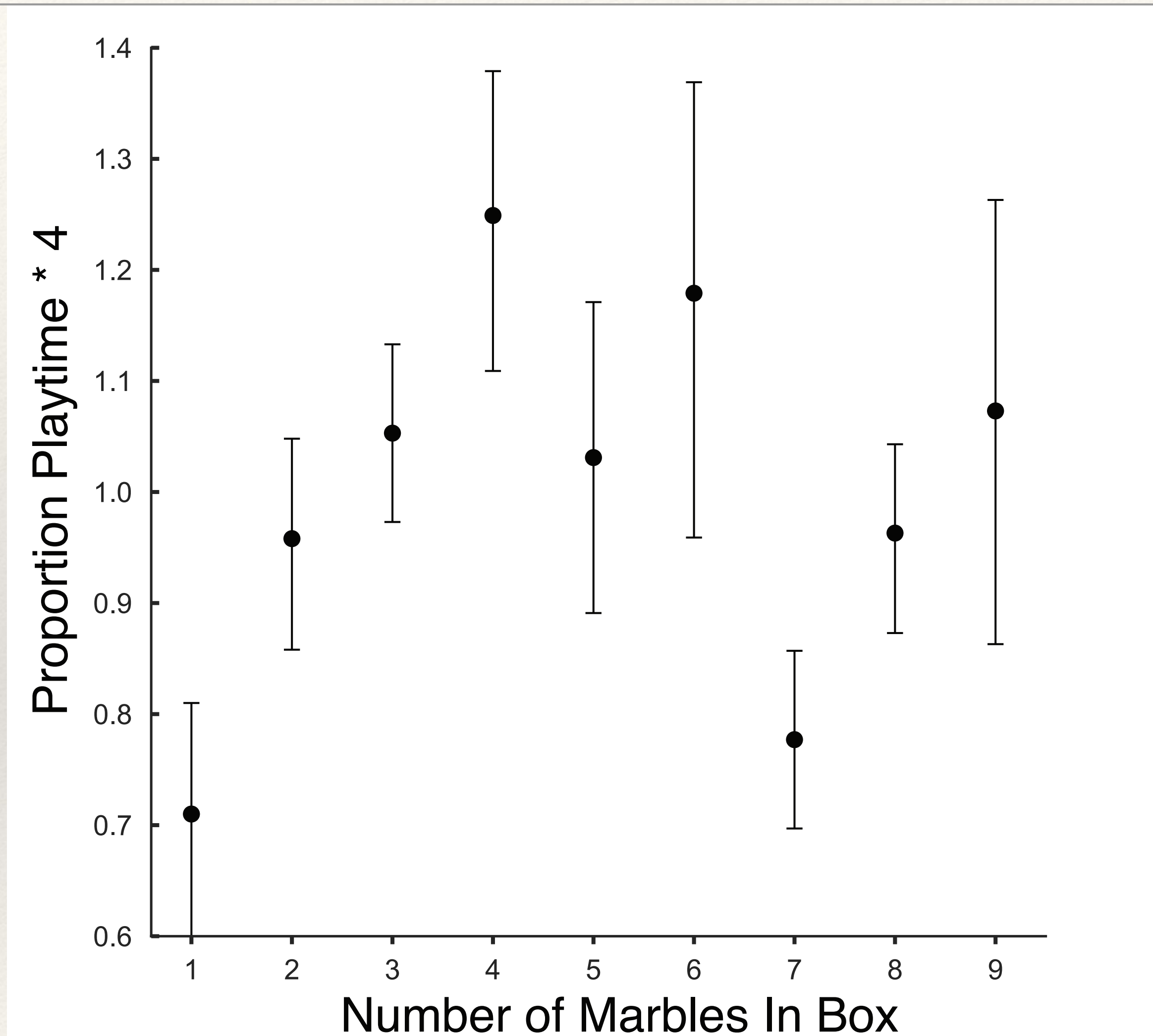
Video coded (including "thinking" time)



Arduino motion sensor

Siegel, Magid, Pelz, Tenenbaum, & Schulz, in press, *Nature Communications*

.. and was independent of the actual number of marbles in the box.



Siegel, Magid, Pelz, Tenenbaum, & Schulz, in press, *Nature Communications*

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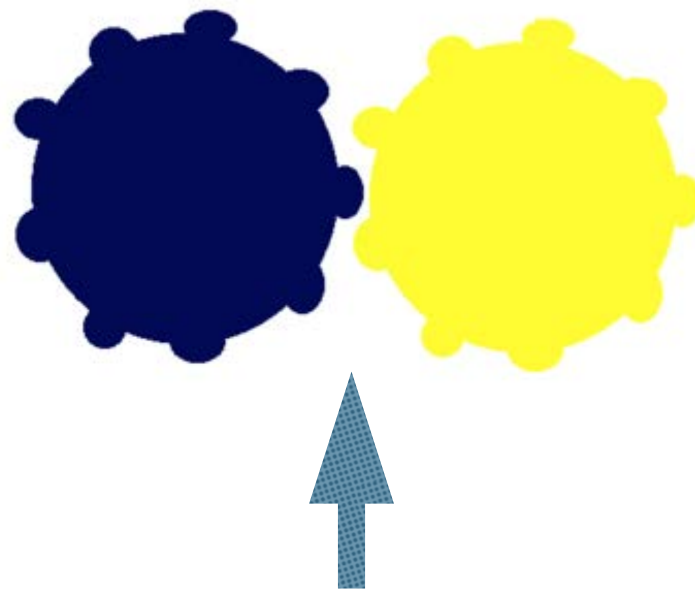
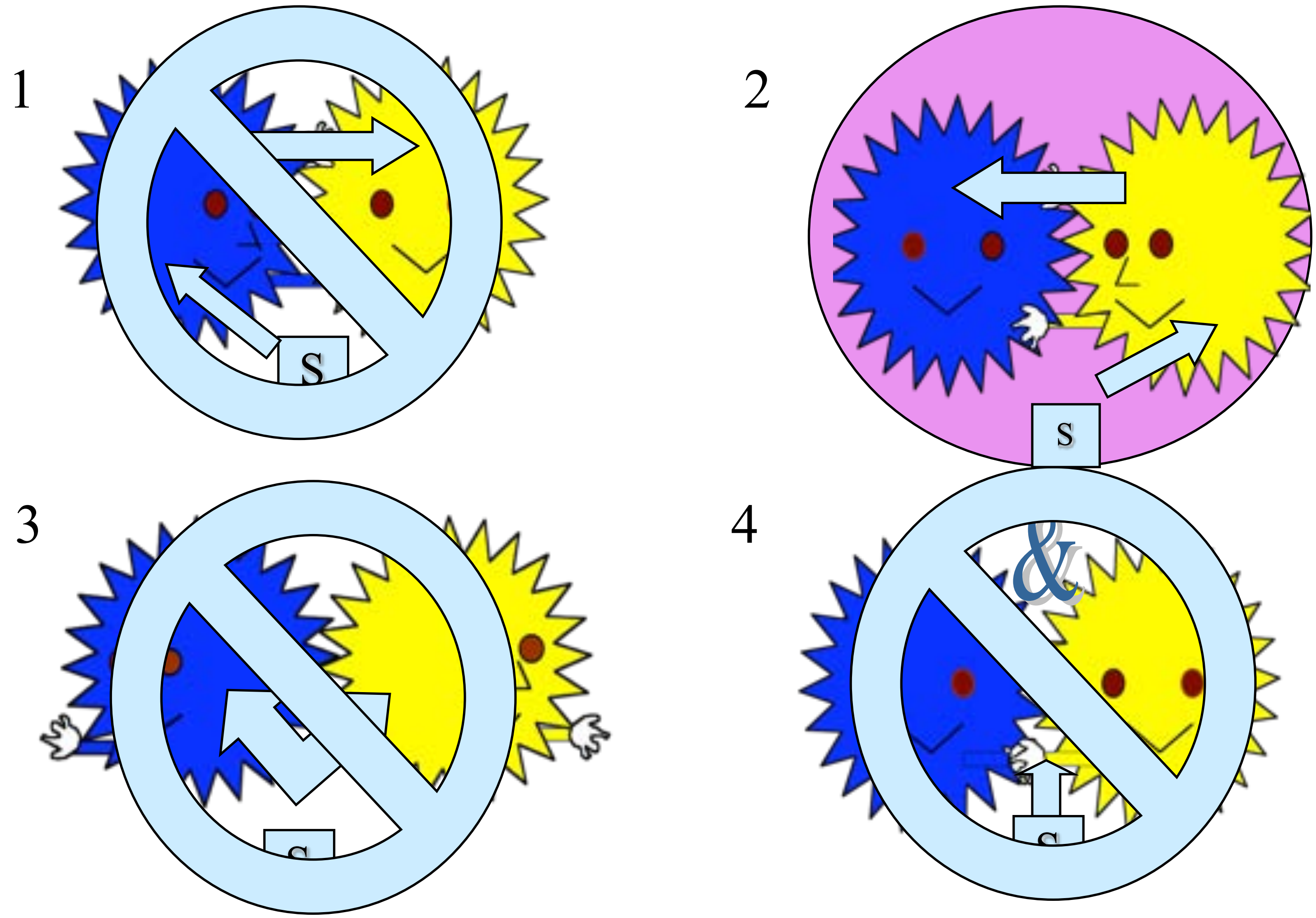


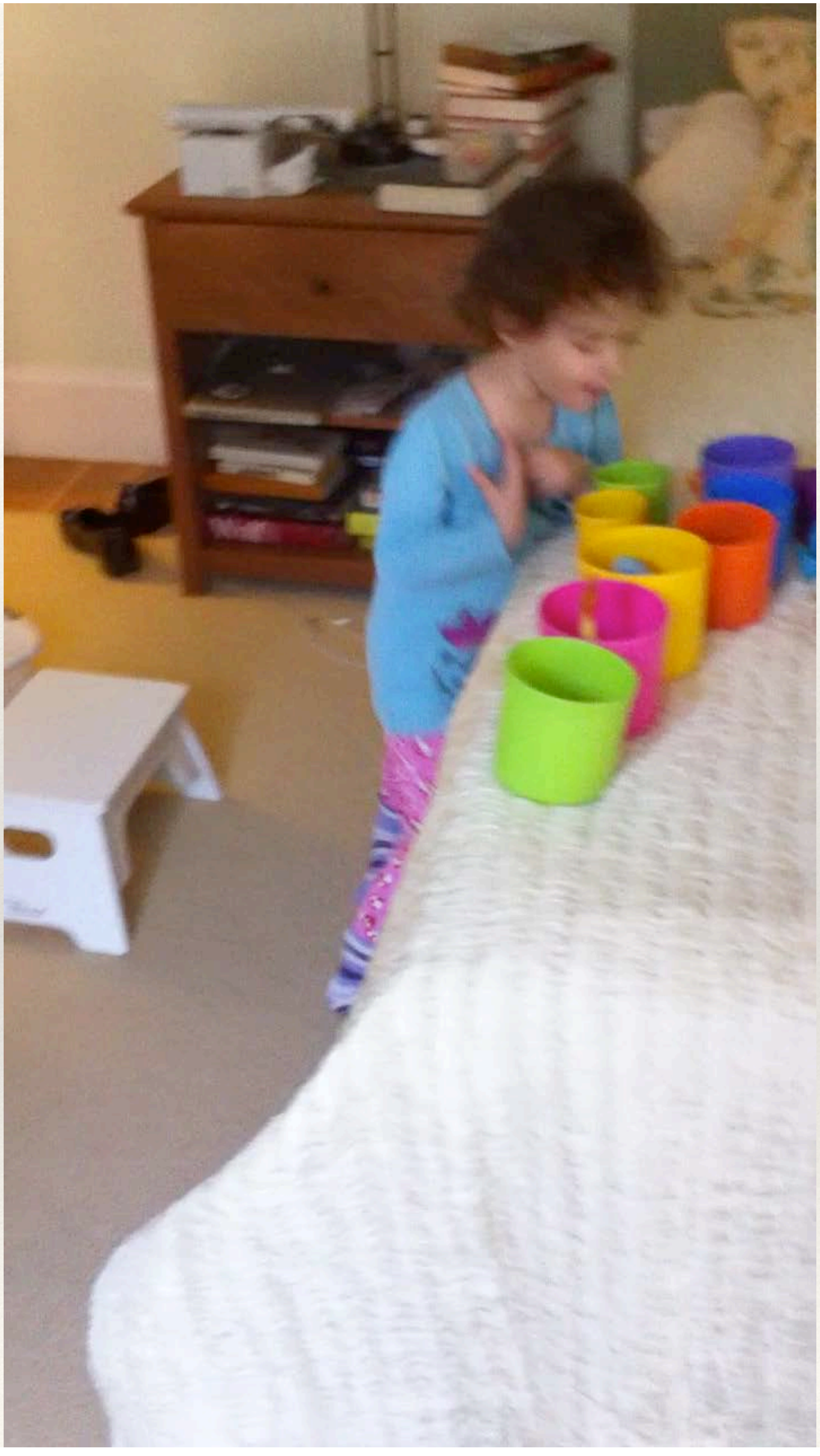
SWITCH

Schulz, Gopnik, & Glymour, 2007, *Developmental Science*

Interventions on each causal structure will produce different patterns of evidence.



Schulz, Gopnik, & Glymour, 2007, *Developmental Science*



Problems and play

- Play might be pleasurable, let us show off, help us bond, teach us real life skills, and improve our predictive models of the world …
- But when a child tries to reunite a toy octopus with his mama in a stacking cup …
- or catch a velociraptor by sticking play dough under the couch
- … these accounts don't seem very satisfying.
- *We* can use play to assess children's sensitivity to uncertainty and expected information gain but that's not necessarily the best characterization of what children use it for.

Problems and play

- However, I do think one thing is true of play — both exploratory play and pretend play
- Children make up problems, and invent plans to try solve them
  - Can I turn the gears into puppets? Can I hear inside? Can I reunite the octopus with her mom?
- The sheer arbitrariness of these problems may be the *point* …
  - the problems and solutions don't matter.
  - what matters is the ability to *invent* new problems and use them to bootstrap new plans and solutions.
- Why? Because the hard problem of cognition is not **learning** (even deep learning networks can do that ;)).
- The hard problem of cognition is **thinking**.

Program induction workshop: Cogsci 2018

“Coming up with the right hypotheses and theories in the first place is often much harder than ruling among them.”

”How do people, and how can machines, expand their hypothesis spaces to generate wholly new ideas, plans, and solutions?”

“How do people learn rich representations and action plans (expressable as programs) through observing and interacting with the world?”

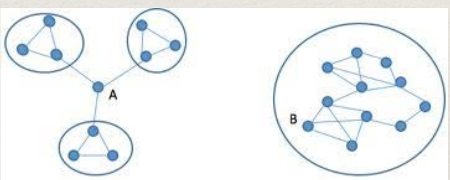
Problems and play

- So why create problems you don't have? Why set arbitrary goals?
- Because problems and goals — *all* problems and goals — support search.
- Problems impose valuable constraints on hypothesis generation and planning.

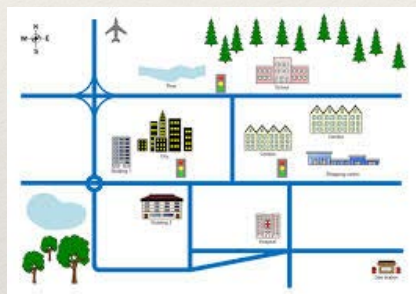
Problems are rich in all kinds of information

- Consider the information contained in question words (even before we get to the content of the questions) …

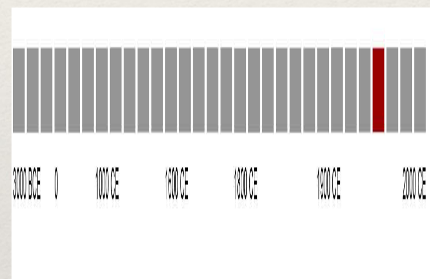
Who?



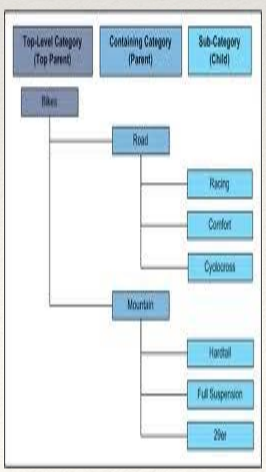
Where?



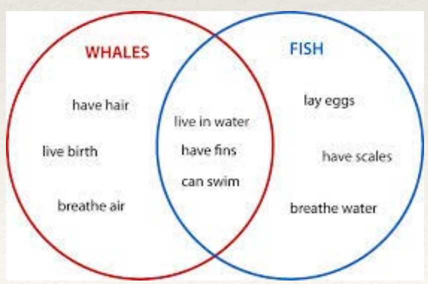
When?



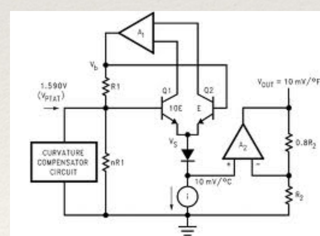
What?



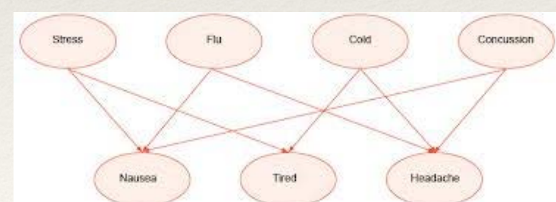
Which?

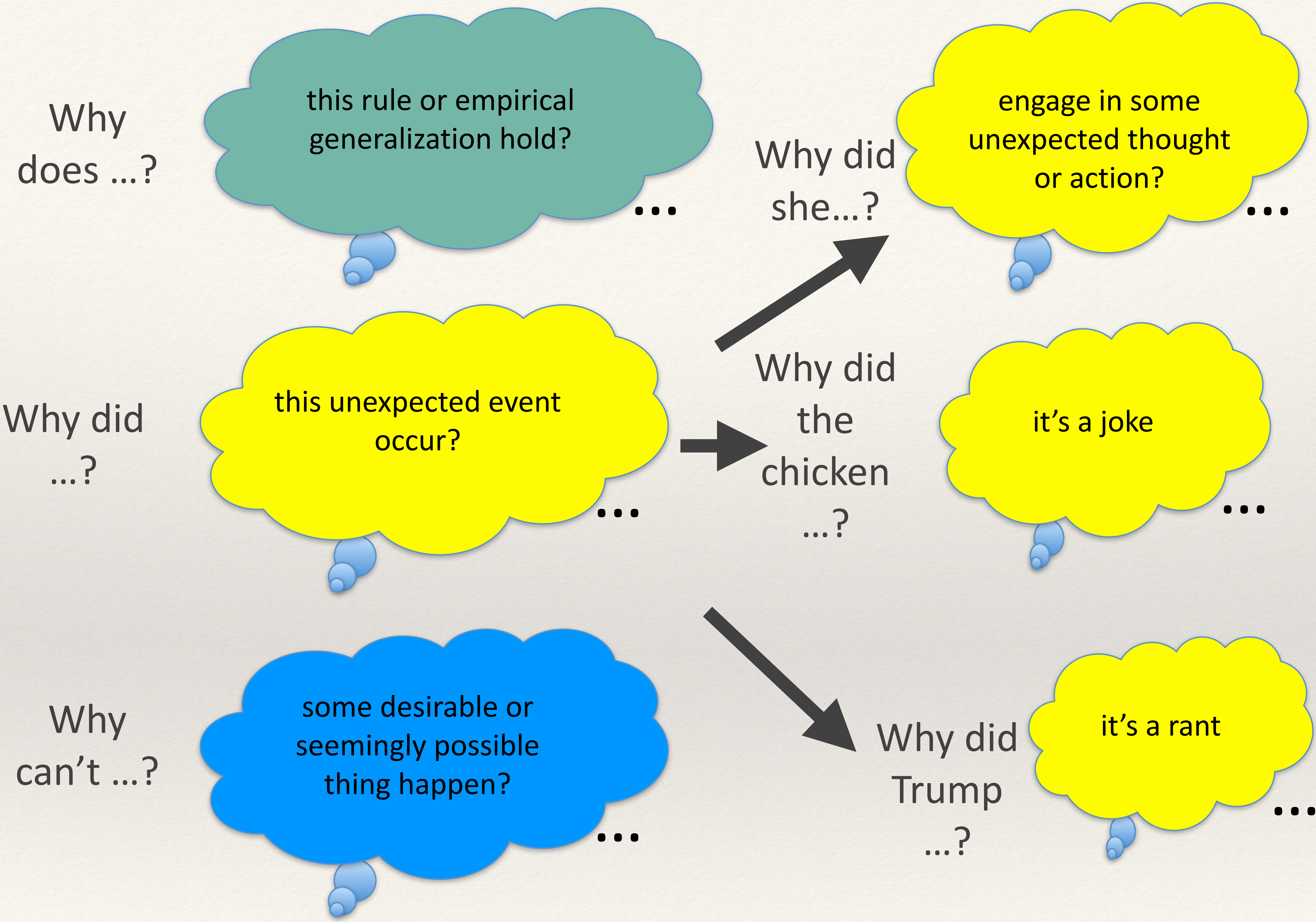


How?



Why?




Why does …?
this rule or empirical generalization hold?
…
Why did …?
this unexpected event occur?
…
Why can't …?
some desirable or seemingly possible thing happen?
…
Why did she…?
engage in some unexpected thought or action?
…
Why did the chicken …?
it's a joke
…
Why did Trump …?
it's a rant
…

Problems are rich in all kinds of information

- We know a lot about our problems before we can solve them
  - We can have a sense of being on the right track well before we can better predict or explain observed data…
  - We can think something is a "great idea" even when we know it's wrong.
- We might be able to constrain our proposals on two separate dimensions
  - How well they fit the data — "TRUTH"
  - How likely they would be to solve our problem if they were true — "TRUTHINESS"

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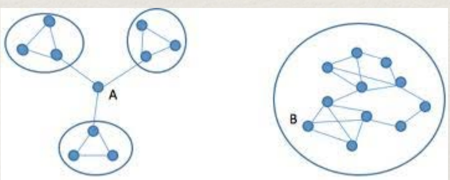
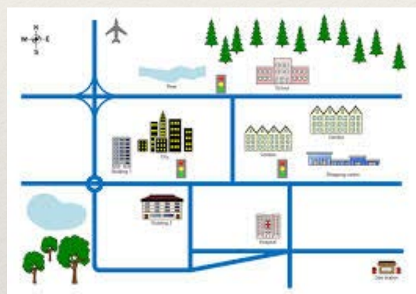
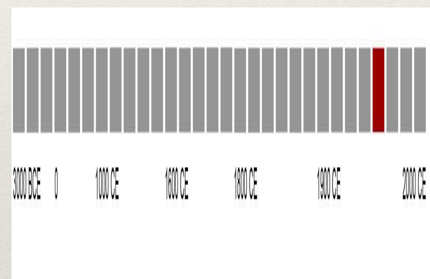
Who?



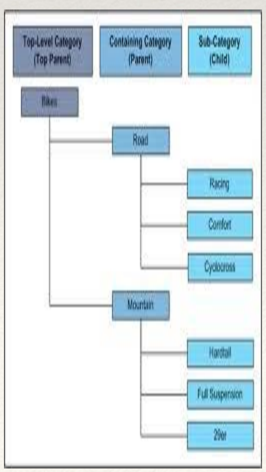
Where?



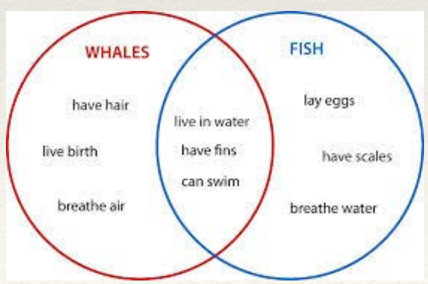
When?



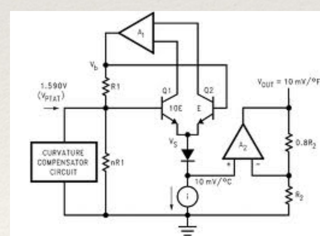
What?



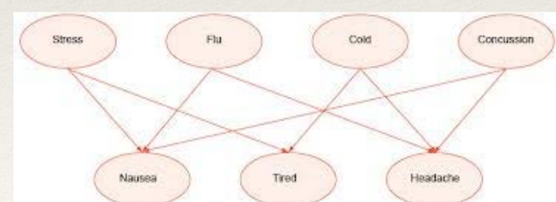
Which?



How?



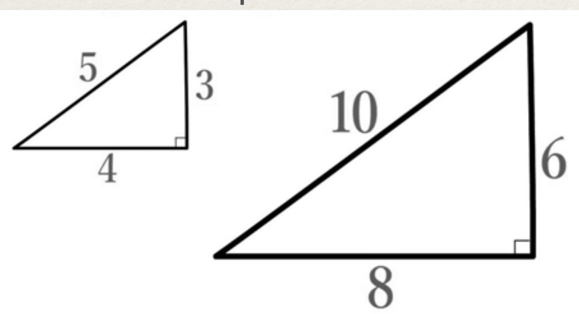
Why?



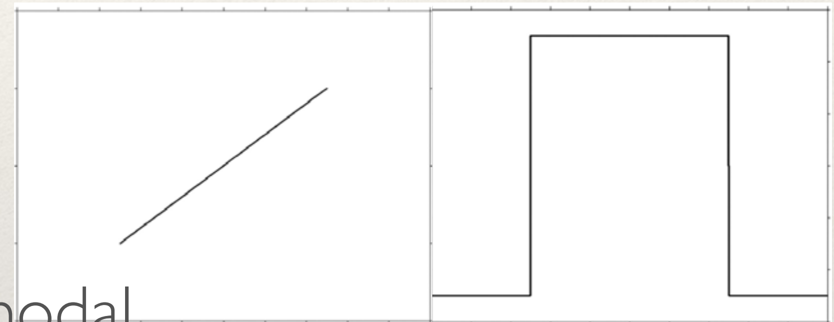
Problems are rich in all kinds of information

- Consider the information contained in ***all*** kinds of representations — independent of domain.

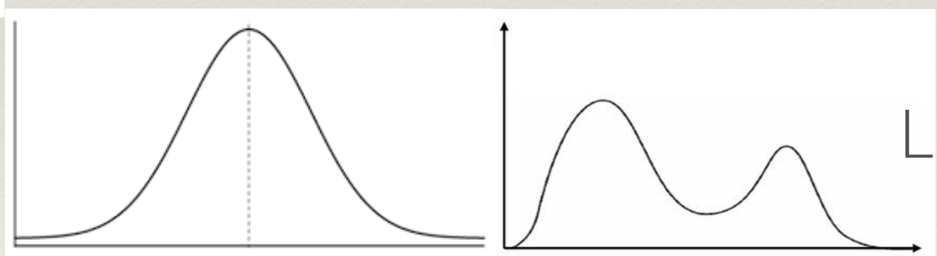
Proportion



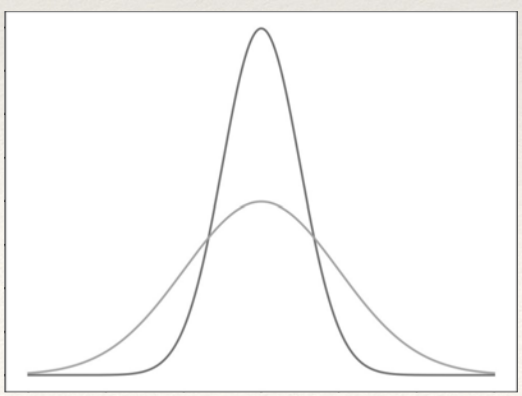
Continuous vs discrete



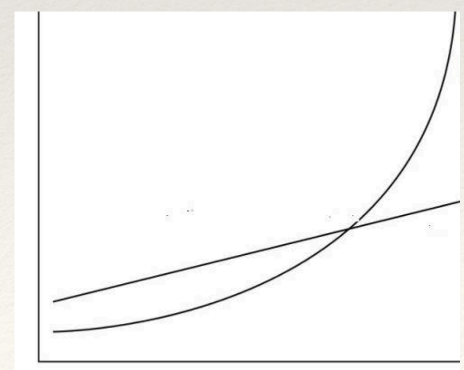
Unimodal vs bimodal



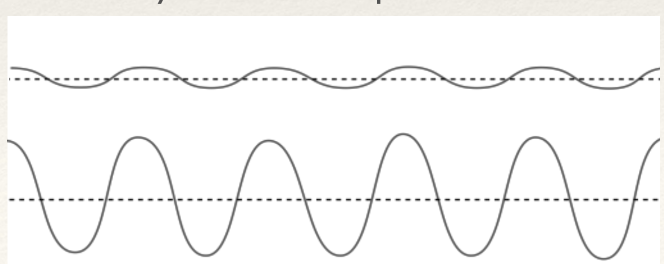
Variance



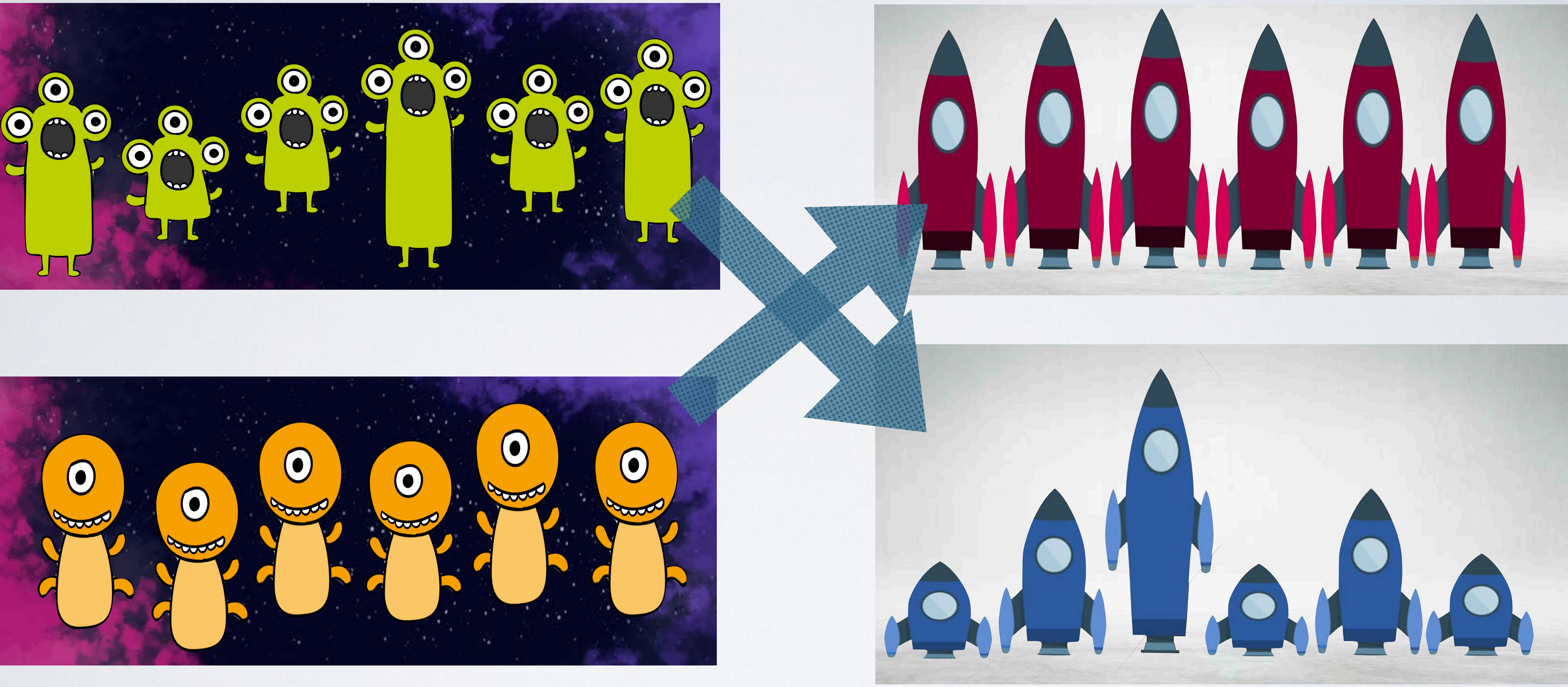
Linear vs exponential



Cyclic amplitude



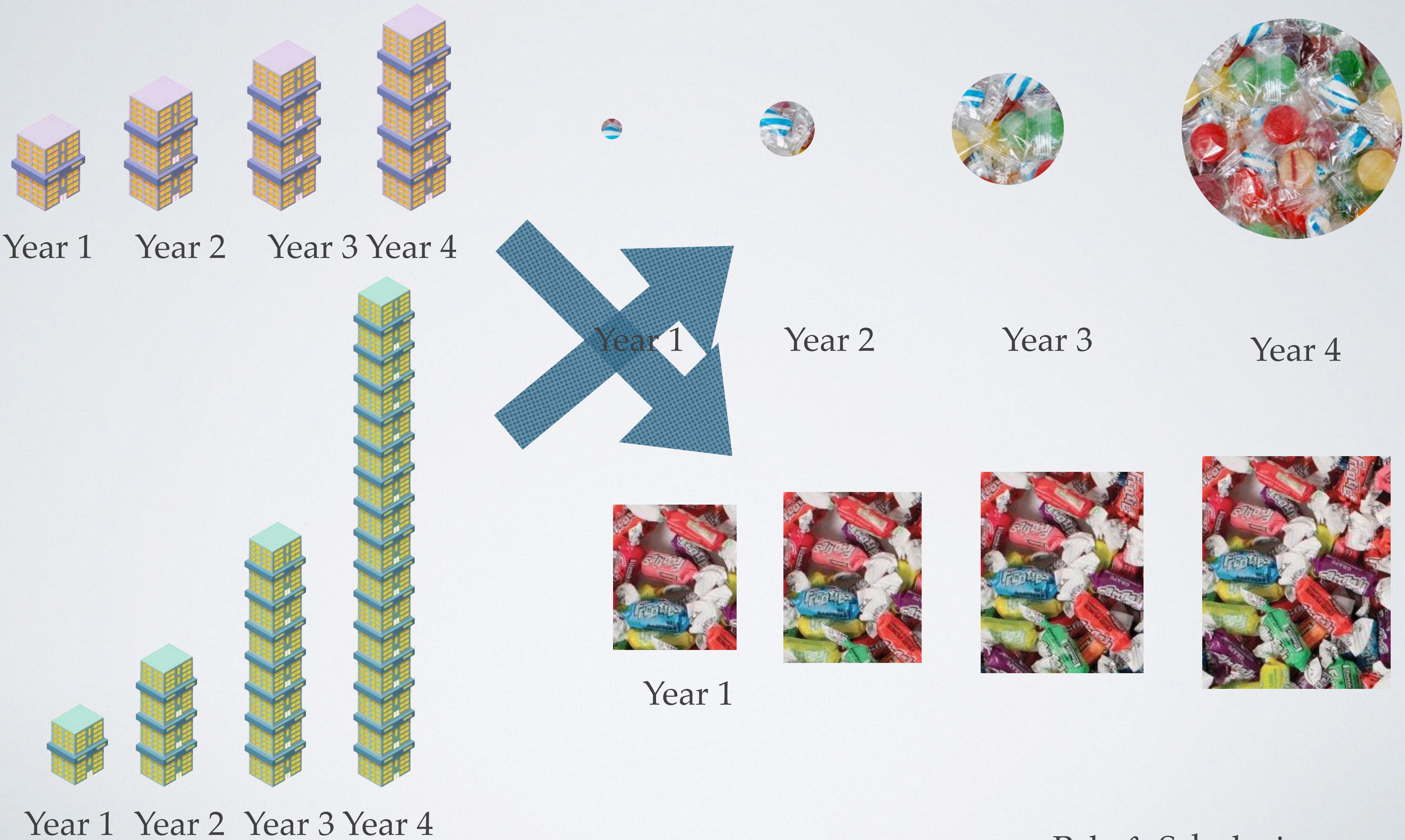
Which group of aliens bought which set of rocket ships?



Maddie Pelz

Pelz & Schulz, in prep

Which set of factories produced which set of candies?



Pelz & Schulz, in prep

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Problems and play

- Note that there is no fact of the matter … These answers are not necessarily right but at least they *could* be right.
- The structure of the problem allows children to endorse plausible hypotheses that go beyond the data.

Problems and play

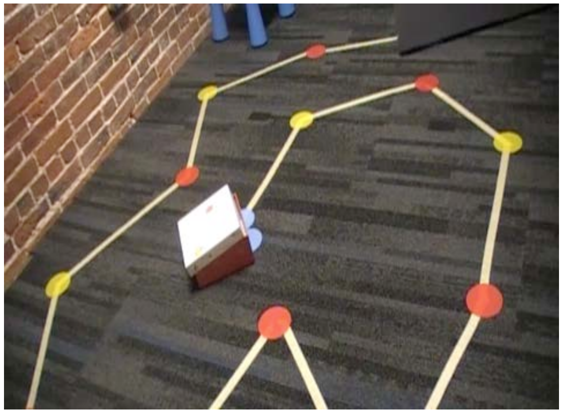
- The point of play is not that the ideas children propose in play are accurate or even verifiable or that the plans are achievable (i.e., play is not chiefly about getting the world right)
- The point of play is that it sets up problems — and gives you new things to be right (or wrong) about.
- We may be motivated to play and explore, not only by the progress we make in learning (e.g., Oudeyer, Gottleib, & Lopes, 2016) but by the progress we make in *thinking*.
- The fact that a problem contains enough information to let us generate a thought or plan might itself motivating — independent of whether those ideas are right are wrong.

Problems and play

- Finally, although my work and many other people's has been motivated by treating play as a kind of rational exploration …
- the problems we set up in play differ in critical ways from those we undertake when we are not playing.

Goal-directed action

"There are stickers in the box. Can you go in here and try to get one?"



Goal-directed play

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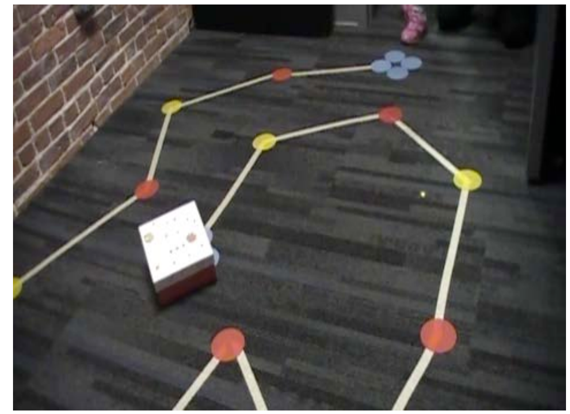

Goal-directed action

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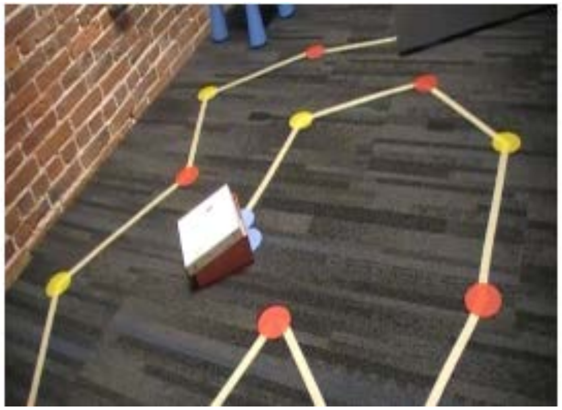
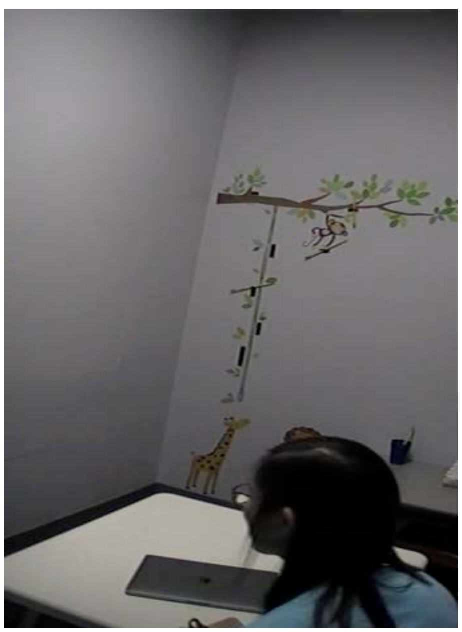
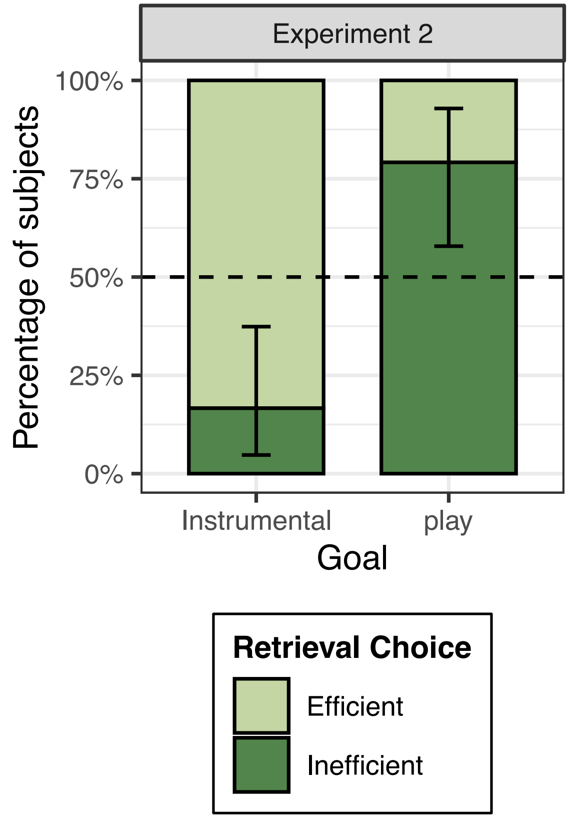


“I need a pencil to fill out th form. Can you go over ther and try to get a pencil?”





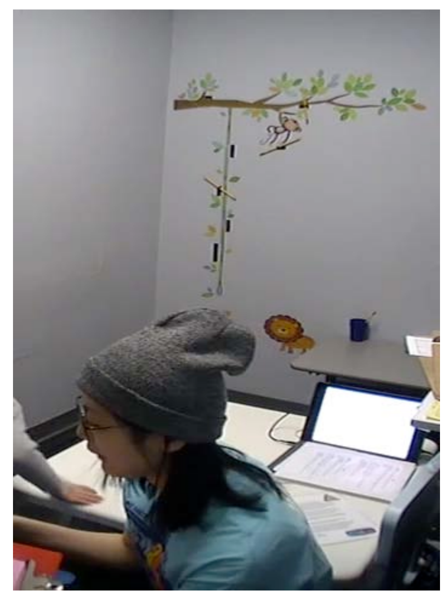
Junyi Chu

Chu & Schulz, in review

Goal-directed play

“There are stickers in the box. Can you play in here and try to get one?”

“I need to fill out this form. While I’m doing that can you play over there and try to get a pencil?”



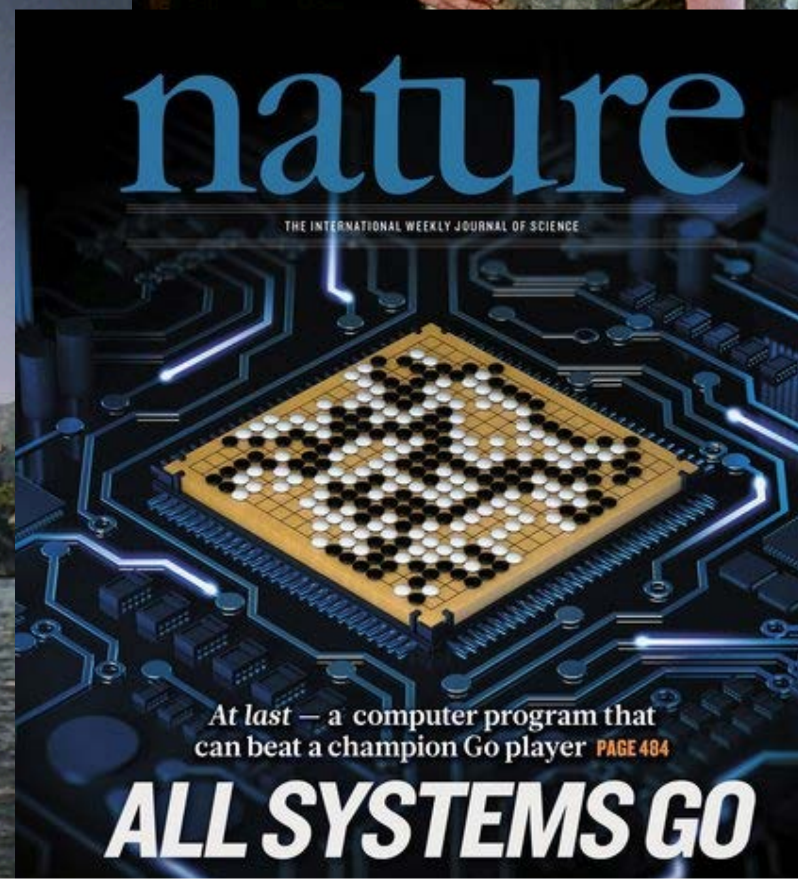
Problems and play

- Children violate principles of rational action in play, but they do not act either randomly or irrationally
  - Even when children opt for the harder task, they behave efficiently with respect to that task (adhering close to the twirly path, jumping directly towards the pencils …)
- Behavior in play is *conditionally* rational …rational with respect to a manipulated utility function.

Problems and play

- In play, neither the costs nor the reward are real; If they are, you are no longer playing.
- In this sense, *all* play is pretend play.
- In play, we “hack” our own utility function to create novel goals.
- And as a species, this allows us to take on innumerable goals.

We populate the world with problems of our own making— we want to end poverty, cure cancer, write the Great American novel, achieve enlightenment, eat more hot dogs than anyone else …


nature
THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE
At last — a computer program that
can beat a champion Go player PAGE 484
ALL SYSTEMS GO

Problems and play

- One reason our motivational system may be as rich as it is, is because the diversity of goals confer an advantage for learning
- As humans, we can endogenously fix our utilities on anything.
- Epistemic goals are not the only — or necessarily even the best —
- Being able to want anything at all (as a species) might let us explore a vast space of possible plans and ideas.

Problems and play

- The world is full of unknown unknowns — as great as our uncertainty about the world is, there are even more things we don’t even know we don’t know.
- If we only explored in ways that tried to maximize expected information gain — we would miss the chance to gain unexpected information.
- Creating new problems with no obvious utility in themselves may be the best way to discover (genuinely) new things

What is play for?

- **For pleasure**
- **For performance**
- **For peacemaking**
- **For practice**
- **For prediction**
- **For posing new problems**

Massachusetts Institute of Technology

brain+cognitive sciences

Thanks!

A B C M I T E C C L


Max Siegel


Rachel Magid


Maddie Pelz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BOSTON CHILDREN'S MUSEUM

MIT EARLY CHILDHOOD COGNITION LAB PlayLab AT BOSTON CHILDREN'S MUSEUM

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