9.85 Cognition in Infancy and Early Childhood

Causal knowledge in infancy and early childhood

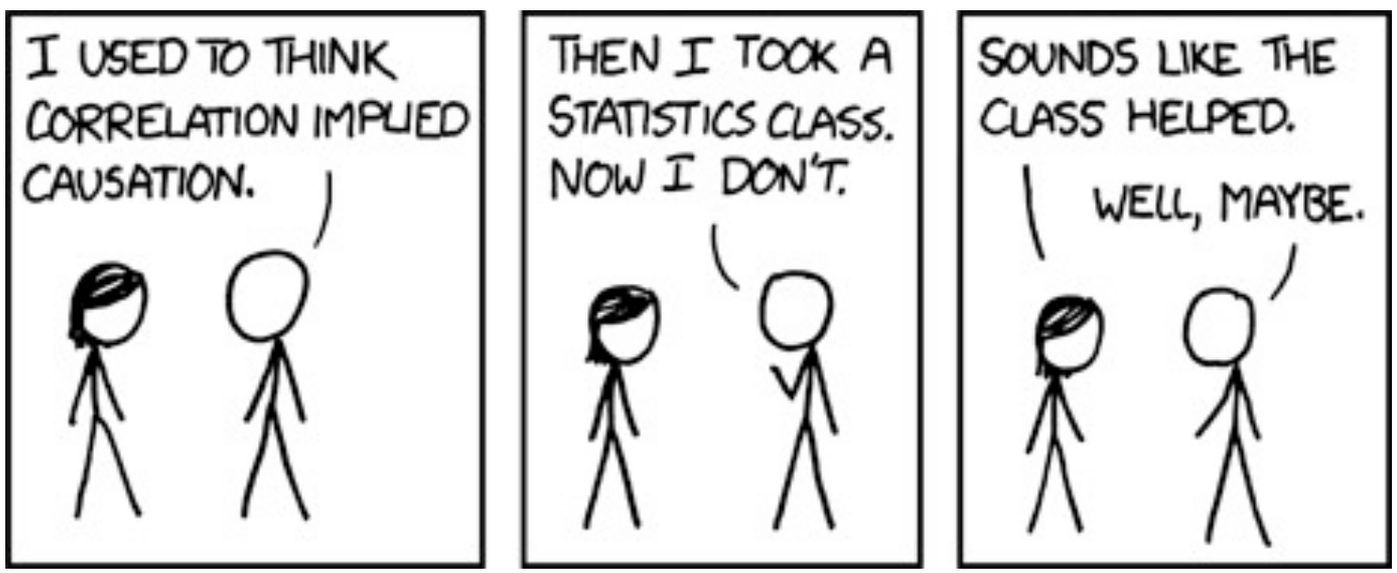

Image: xkcd CC BY-NC. http://xkcd.com/552/

Why care about causality?

- Allows us to:
  - Predict the future
  - Explain the past
  - Intervene in the present
- Pervades daily life.
  - Naive physics: building things, fixing things
  - Naive biology: growing things, cooking things
  - Naive psychology: influencing, crediting, blaming

Causality as an easy problem?

"Great interactive features stimulate motor skill development and **increase cause-effect understanding.**"

Causality as an easy problem?

"Each toy is unique, easy-to-grasp, and includes several activities for developing the senses and skills such as eye-hand coordination, fine motor skills, **or learning about cause and effect.**"

Causality as an easy problem?

"The new Gymini features the one-of-a-kind Lights & Music Touch Pad -- which baby activates all on her own producing immediate feedback, **sparking development of cause and effect learning.**"

Causality as a hard problem

- “Where we have observed a particular event to follow upon another, we are not entitled to form a general rule, or foretell what will happen in like cases; it being justly esteemed an unpardonable temerity . . . and there is nothing in a number of instances different from any single instance.” David Hume

Image: Wikimedia. Public Domain.

Causality as a hard problem -- in particular because it cannot be directly perceived

- “The impulse of one billiard-ball is attended with motion in the second. This is the whole that appears to the outward senses ... there is not, in any single, particular instance of cause and effect, any thing which can suggest the idea of power or necessary connexion.” David Hume

Image: Wikimedia. Public Domain.

Causal reasoning in infancy and early childhood

- In 1960 infants and young children were "precausal". Why?
  - "confusion between psychological activity and physical mechanism"
- By 1990 infants and young children were much smarter. Why? (not because toy manufacturers rediscovered operant learning ...)
  - infants and children do understand domain-specific causal mechanisms.
  - "see" causality in the world

Piaget and causality

- Piaget believed infants started only with an undifferentiated feeling of effort …
- “Nursling at the age of one or two months … must experience …without his knowing how a certain action leads to a result, that a certain complex of efforts, tension, expectation, desire, etc. is charged with **efficacy**.” (1954)
- No separation of action and outcome.

Piaget and causality

- Differentiation resulted in **phenomenalism**
- Whenever infants experience efficacy, they infer that they a causal relationship between their action and the subsequent (or simultaneous) phenomena.
- Like operant learning except for emphasis on internal experience -- sensation of doing something.

Piaget and causality: Domain-specific theories

- Precausal reasoning characterized by “a confusion between psychological activity and physical mechanism.”
- **Artificialistic**: river moves because of boats
- **Animistic**: string unwinds because it wants to.

Piaget and causality

- Piaget described a total of 17 stages in the development of causal reasoning.
- Believed children were “precausal” for years.

But are preschoolers really confused about the boundary between physical and psychological causality?

- Max wants to throw a rock in the water and make a big splash. Can he?

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Gelman & Wellman, *Foundational theories in Core Domains*

Domain-specific theories

- Max wants to jump in the air and stay up forever. Can he?

Image: Flickr. David Olivari. CC BY-NC-SA.

Domain-specific theories

- Max wants to drink cider instead of milk. Can he?

Domain-specific theories

- Max wants to stop growing. He wants to stay small forever. Can he?

Toddlers' domain-appropriate explanations

- It breaked because it was glass.
- She's scared because she doesn't want to be in the dark.
- My tummy hurts because I'm sick.

- ~It breaked because it's sick.
- ~ She's scared because she was glass.
- ~ My tummy hurts because it is in the dark.

Domain-specific theories even in infancy

Even infants distinguish physical and psychological causality …

- Reach for objects
- Coo at agents

- Expect physical objects to move if and only if contacted
- Agents can move (or not) as they like

- As we'll see soon, objects (mechanical claws) do not have goals
- Agents do

Causality as a hard problem -- in particular because it cannot be directly perceived

- “The impulse of one billiard-ball is attended with motion in the second. This is the whole that appears to the outward senses ... there is not, in any single, particular instance of cause and effect, any thing which can suggest the idea of power or necessary connexion.”

Image: Wikimedia. Public Domain.

Infant causal perception

- Infants form causal representations of motion events:
  - discriminate causal and noncausal motion events between 6- and 12-months
  - assign causal roles of "agent" and "patient"
  - are sensitive to contact relation in causal events

(Leslie, 1982, 1984a, 1984b; Cohen & Oakes, 1990; Oakes & Cohen, 1993; Oakes, 1994; Cohen & Amsel, 1998; Leslie & Keeble, 1987; Ball, 1973; Kotovsky & Baillargeon, 2000)

Spatiotemporal regularity and causality

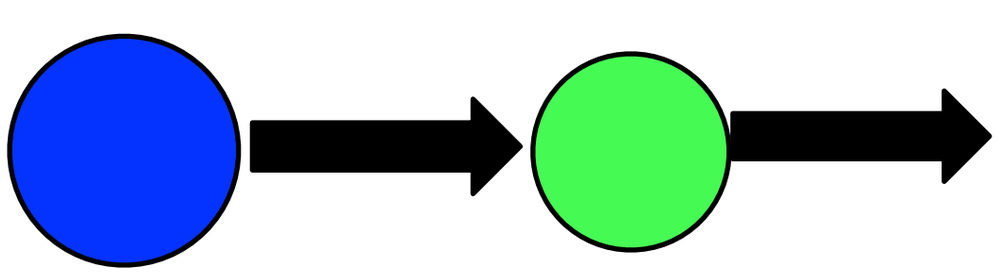
- Note that a strict Humean would argue that all of these:

- Direct launching
- Delayed launching
- Launching without collision
- Delayed reaction without collision

- are all instances of regularity and therefore equally good/ bad evidence for causality.
- However infants, like adults, perceive only the first as causal

Origins of causal reasoning in infancy: Three possibilities

Contact causality (modular?) and other domain-specific theories about causal mechanisms



Sensitivity to agency

Sensitivity to predictive relations

- Domain-general mechanism that tracks conditional probabilities in events
  - Saffran; Aslin; Sobel; Kirkham

In adulthood, the idea of causation includes all of these: 1) relationships between interventions and outcomes 2) predictive relationships and 3) intuitive (or even scientific) theories of plausible mechanisms.

How about infants? What is the developmental trajectory of causal reasoning?

Rational inference in infancy?

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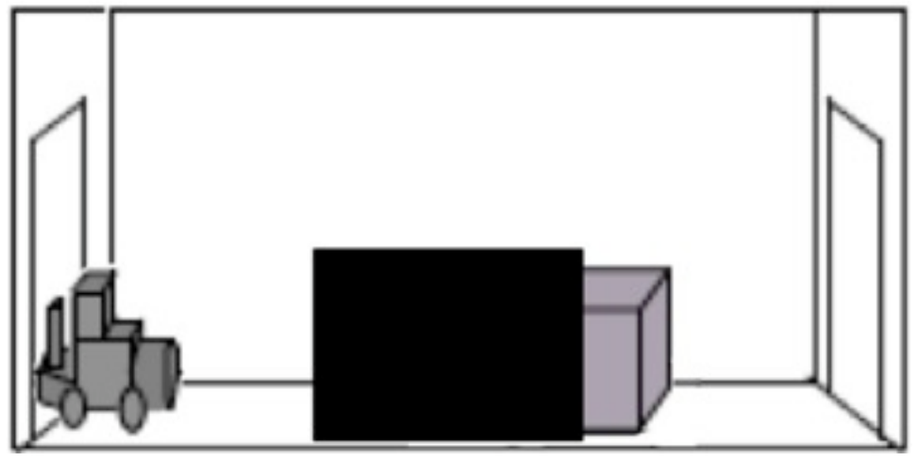
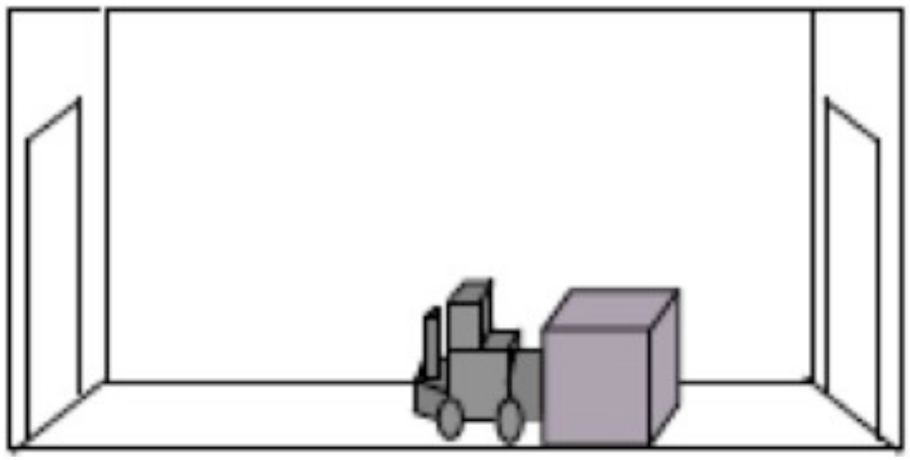
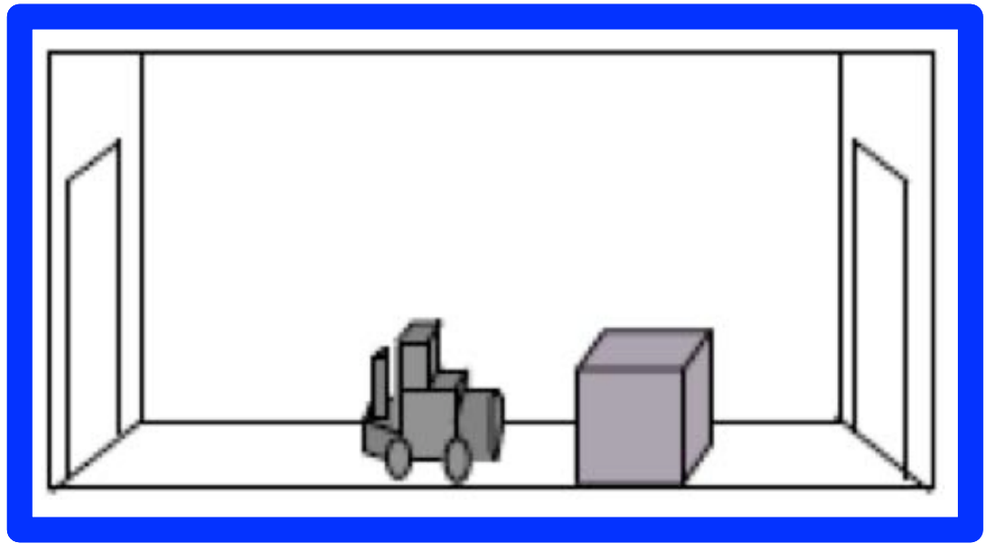
Contact sensitivity for motion events







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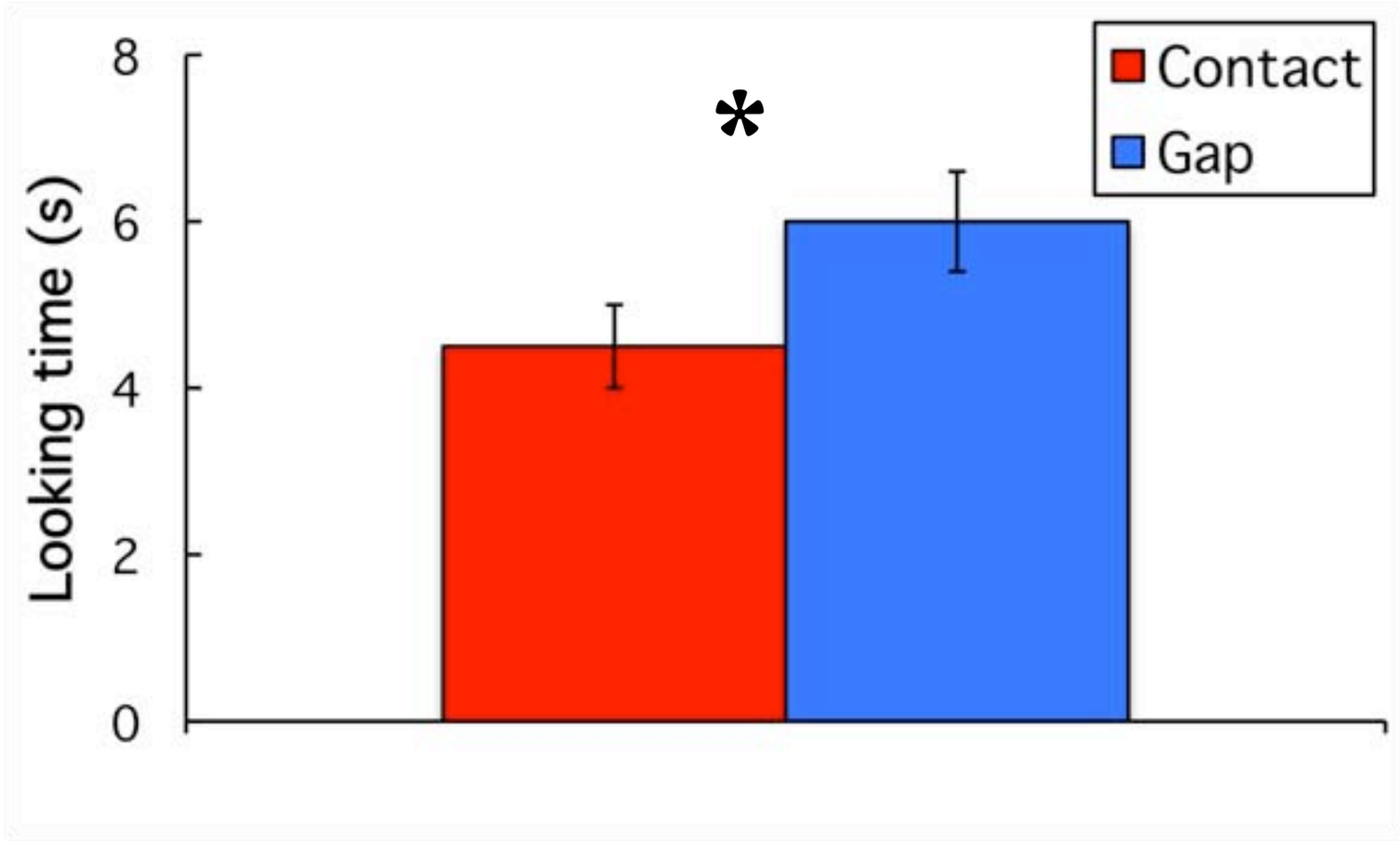
*adapted from Ball (1973)

Contact sensitivity for causal events



* $p < .05$

15/20 infants

Muentener & Carey (2010, *Cognitive Psychology)*

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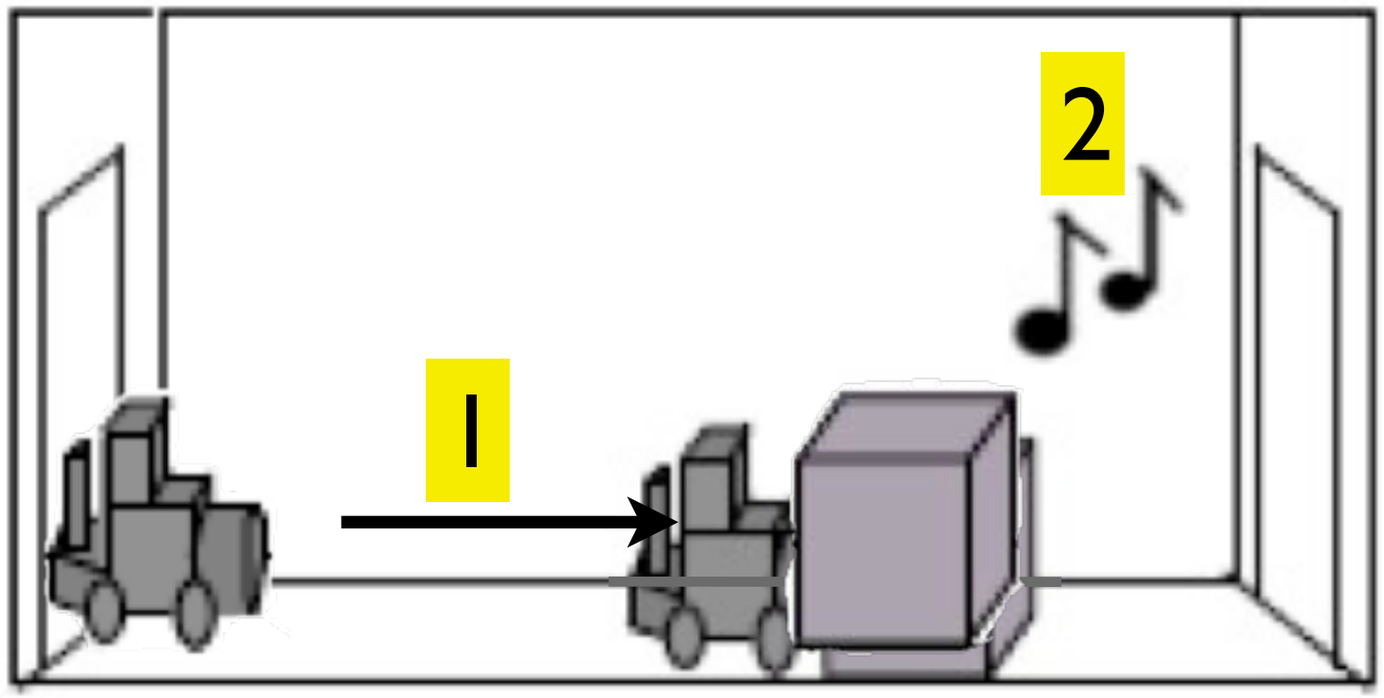
State change events?



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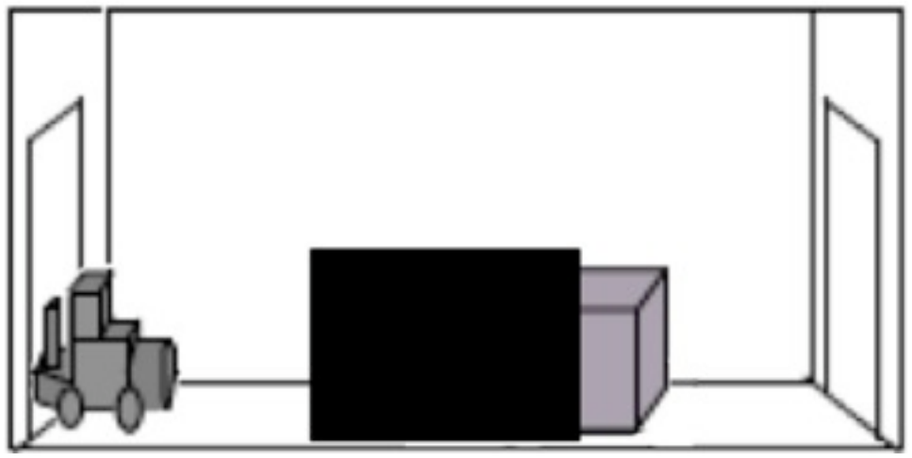
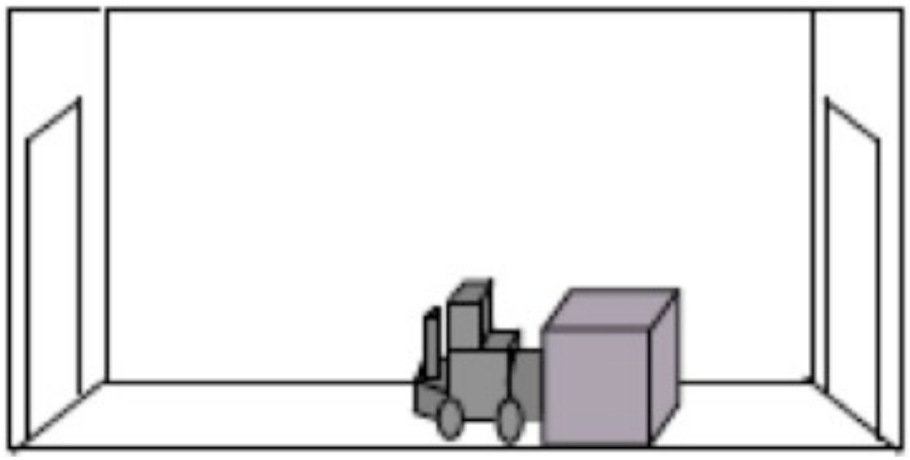
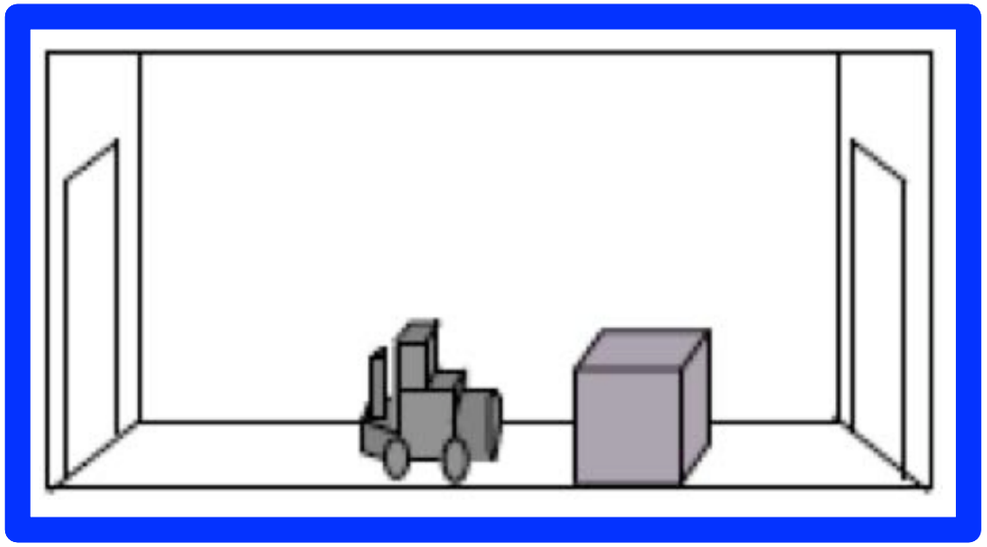
Contact sensitivity for change of state events?

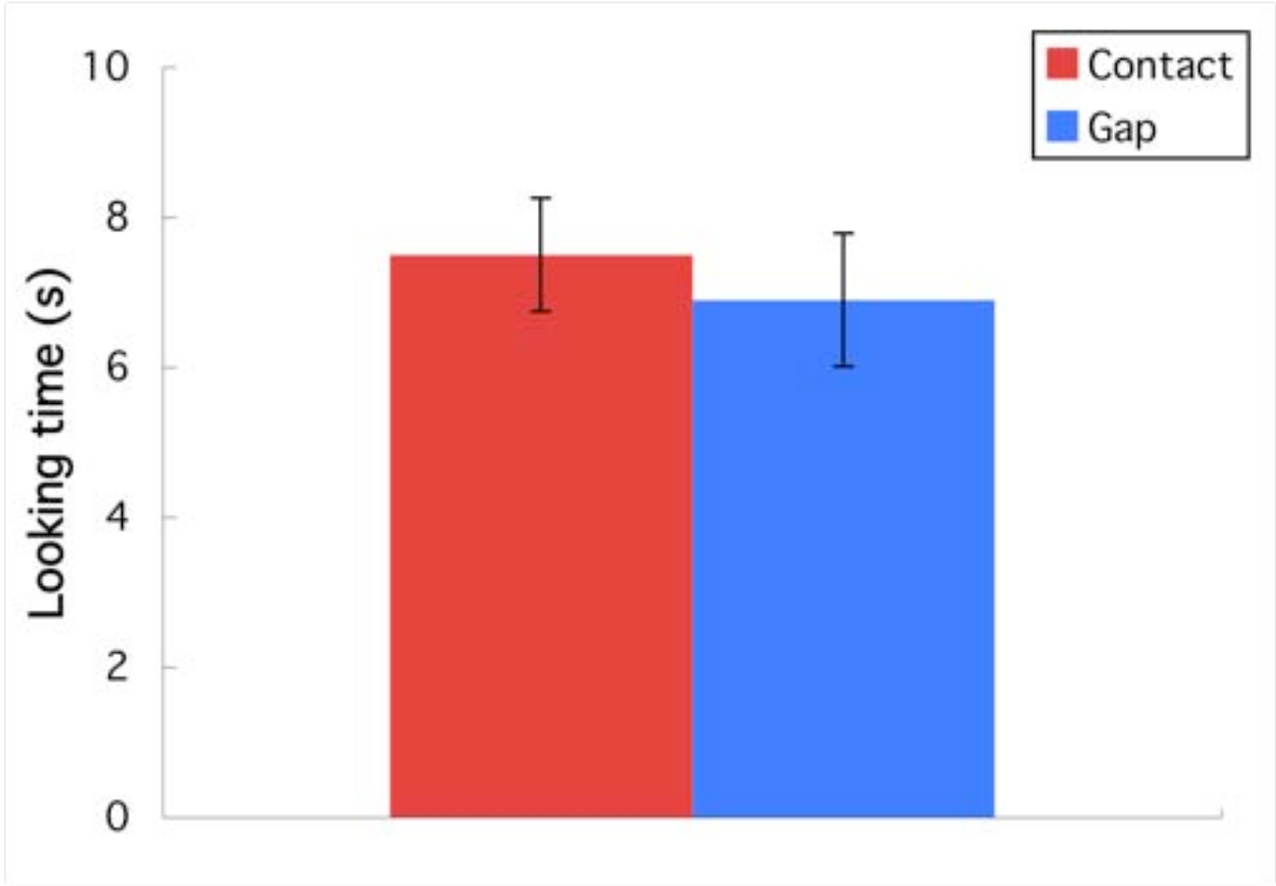






*adapted from Ball (1973)

State change events?



Muentener & Carey (2010, *Cognitive Psychology)*

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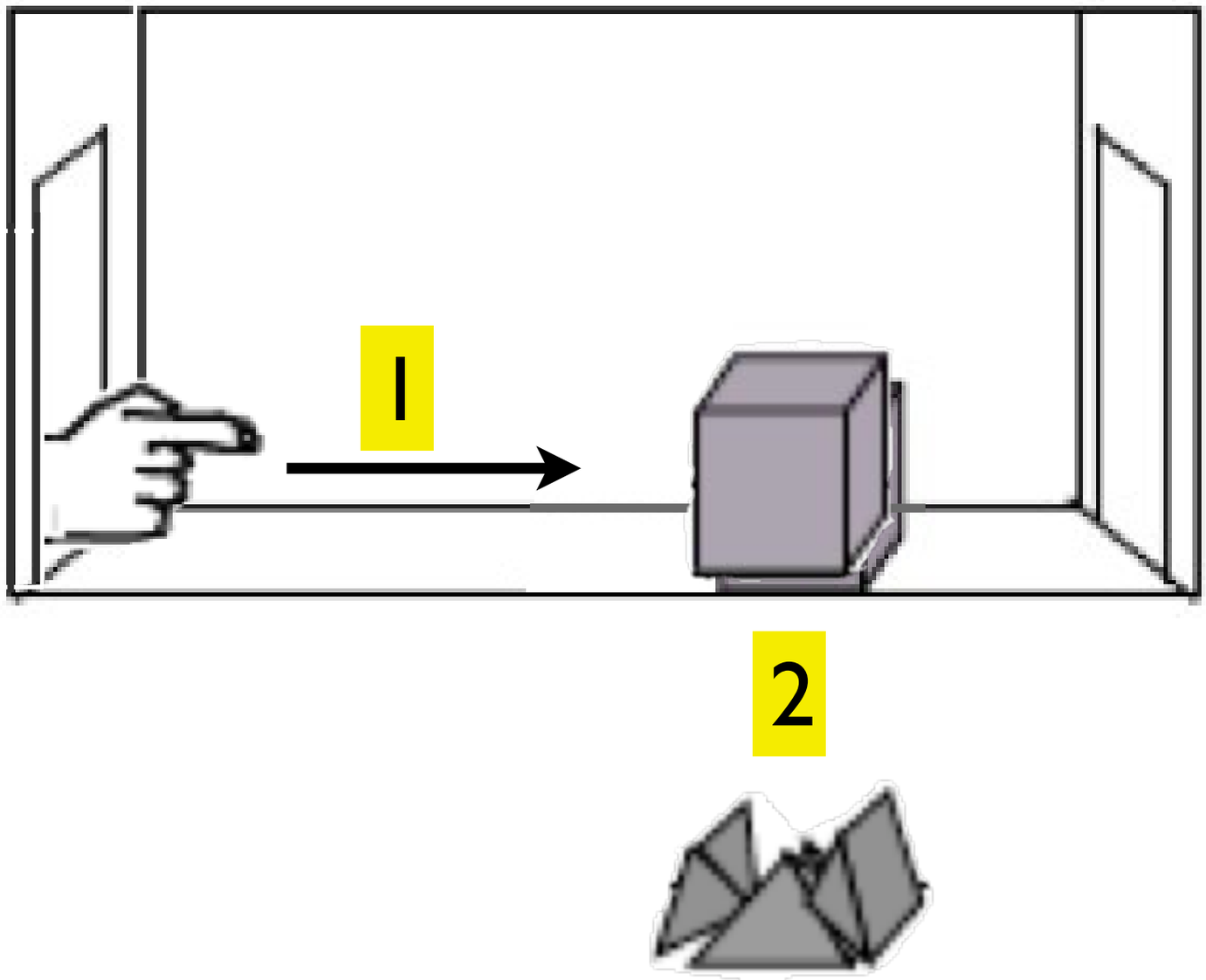
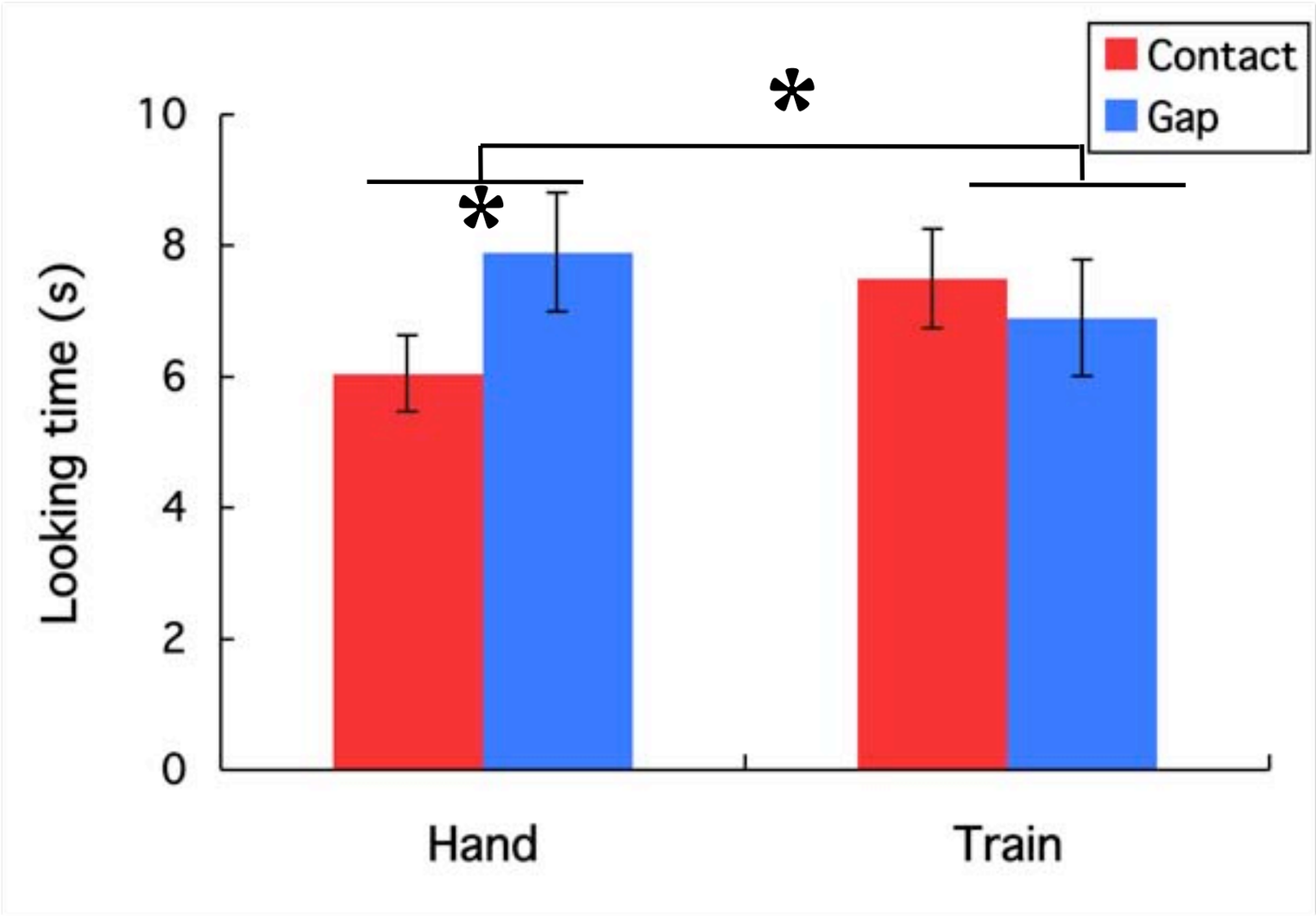
Can agency act as input to causal reasoning?



Type of agent?



* $p < .05$

Muentener & Carey (2010, *Cognitive Psychology)*

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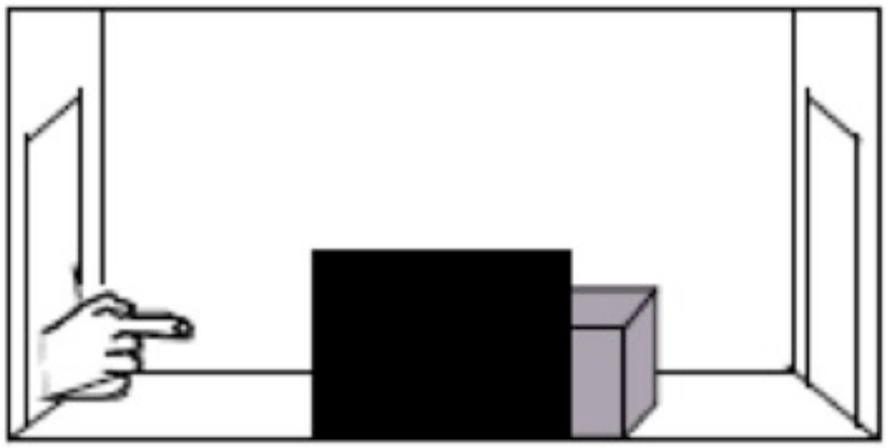

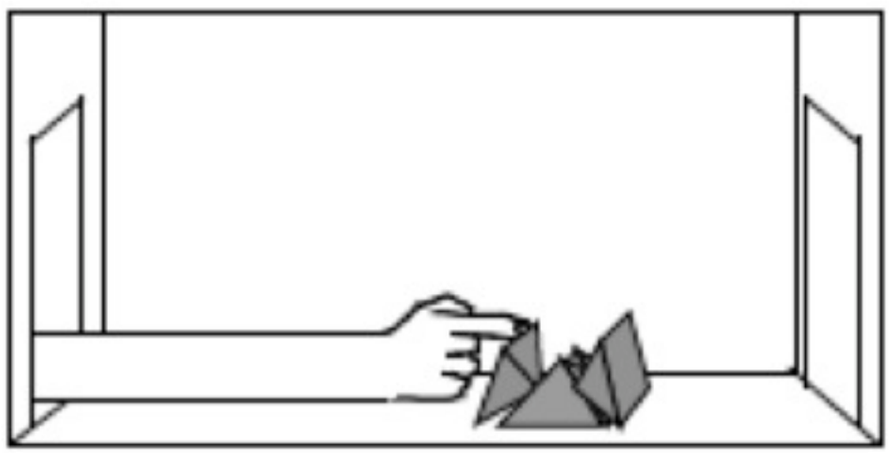

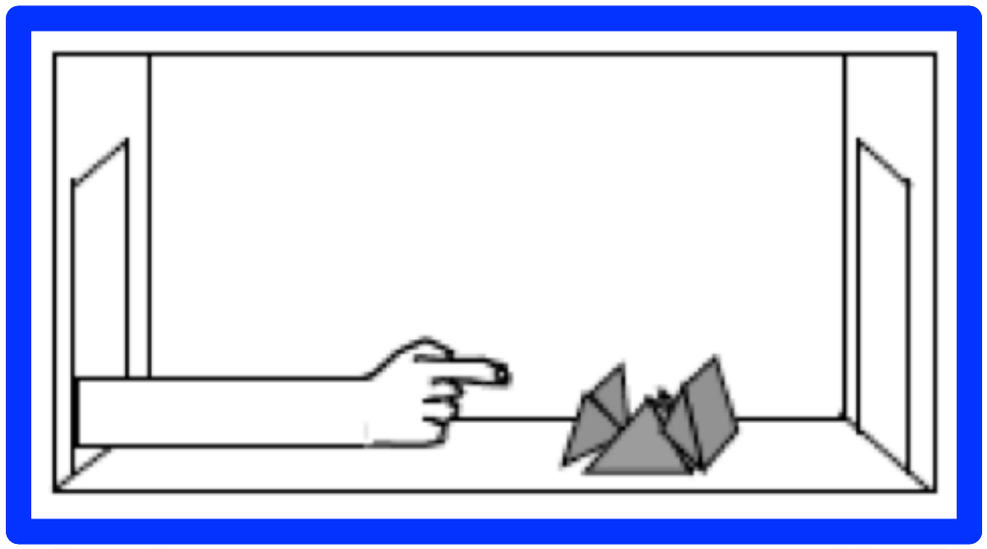

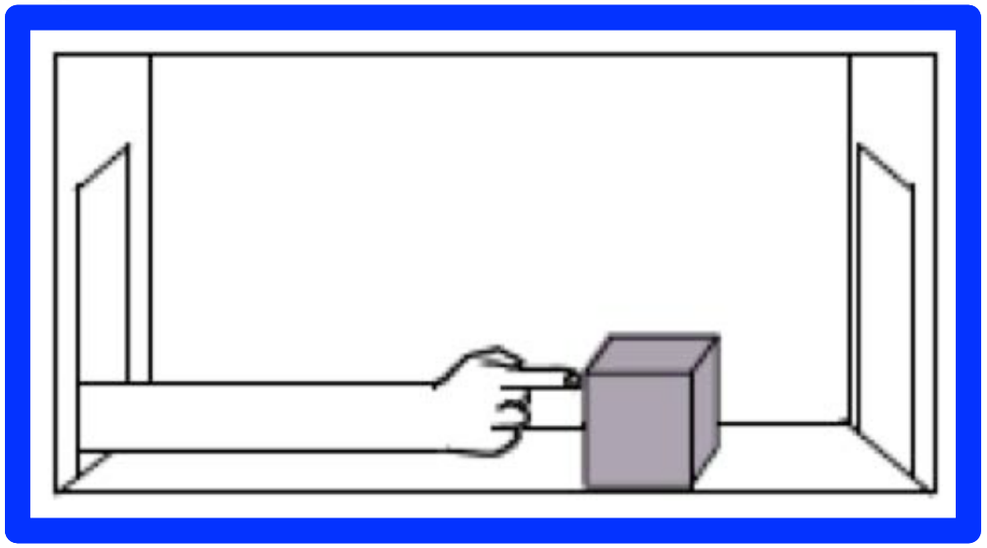

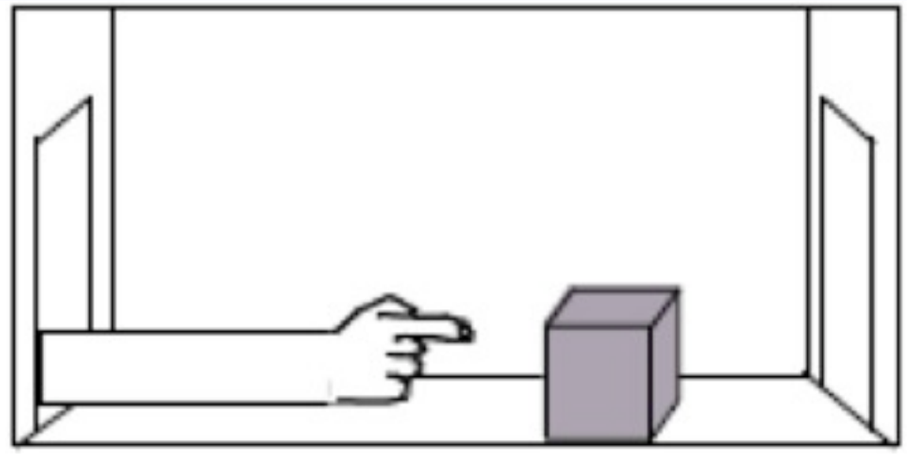

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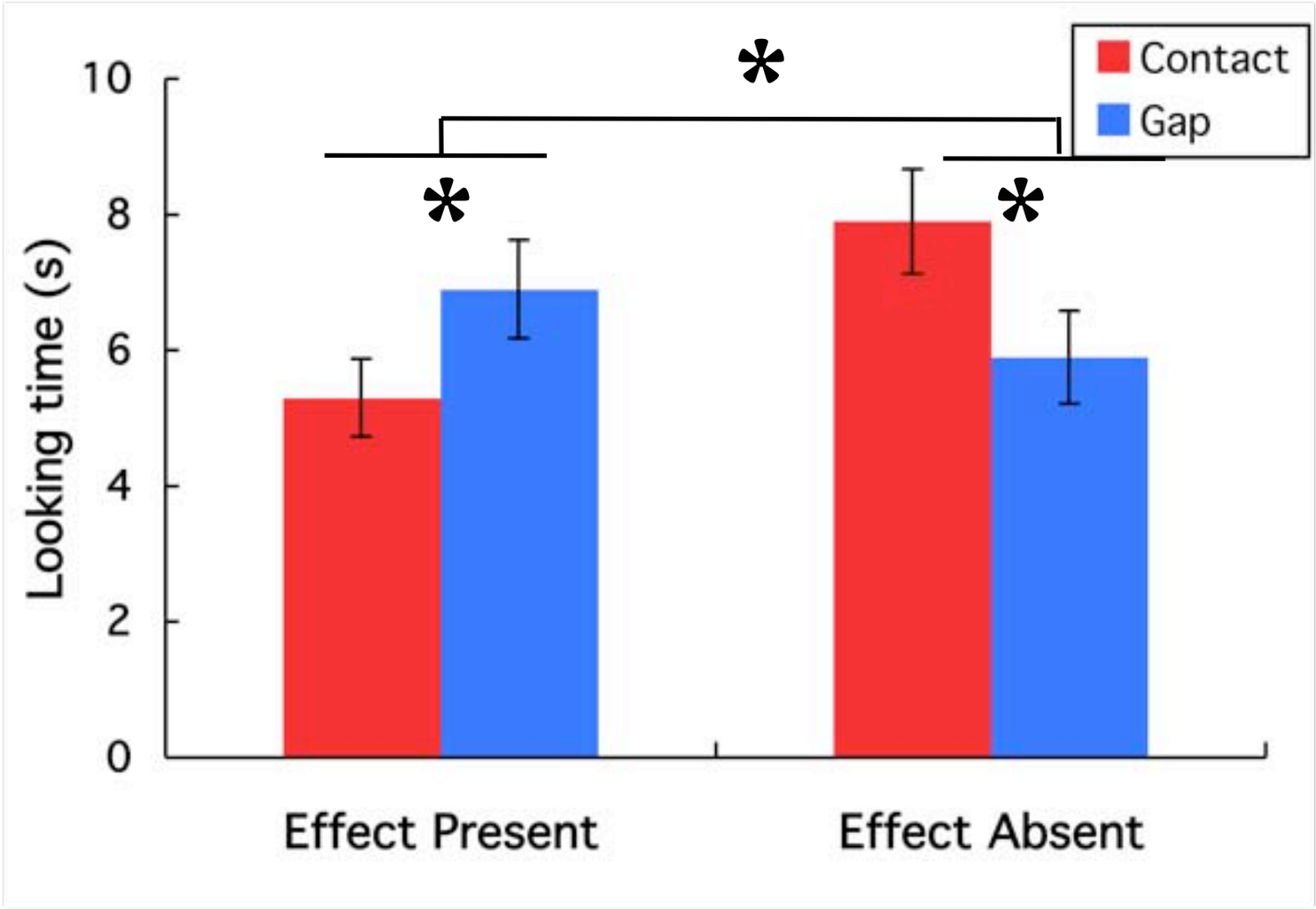

Muentener & Carey (2010, *Cognitive Psychology)*

$* p < .05$

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Part 1: Infant causal reasoning

- Infants are sensitive to contact relations for motion events, regardless of whether the causal agent is a dispositional agent or an object.
- Infants are sensitive to contact relations for state change events only when the causal agent is also a dispositional agent.

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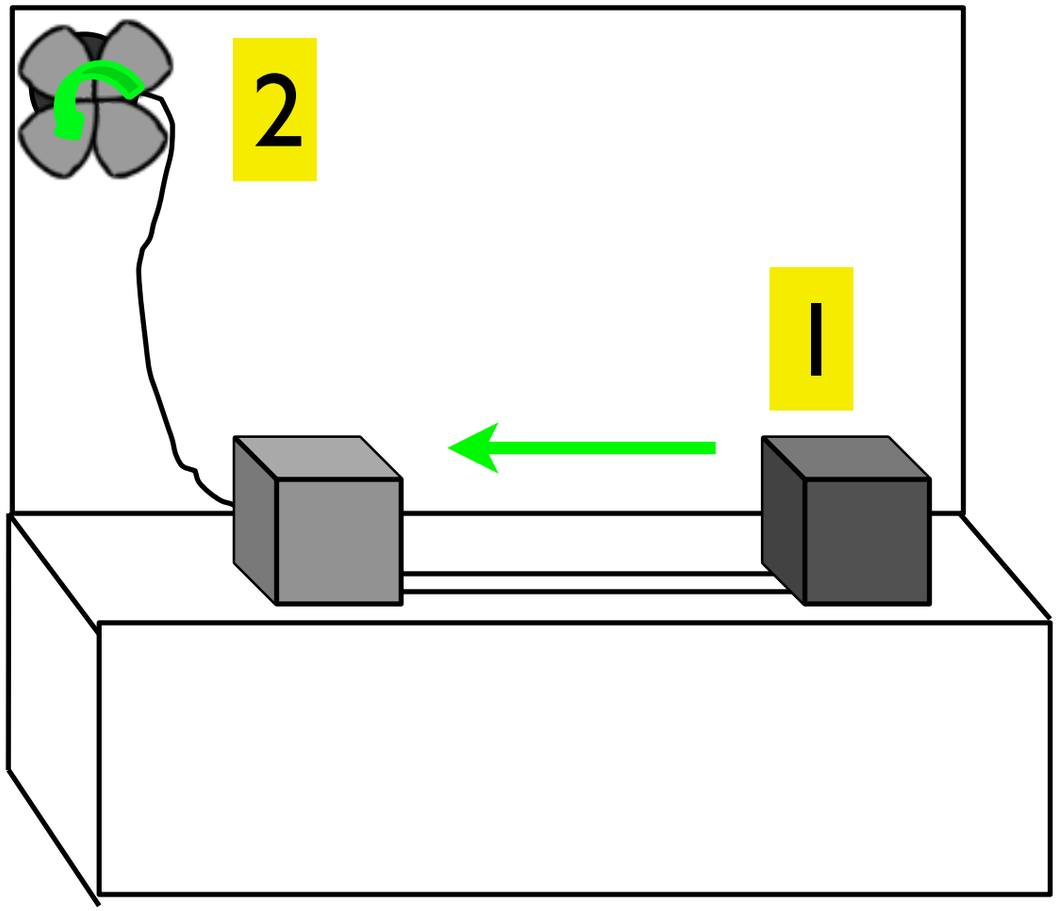
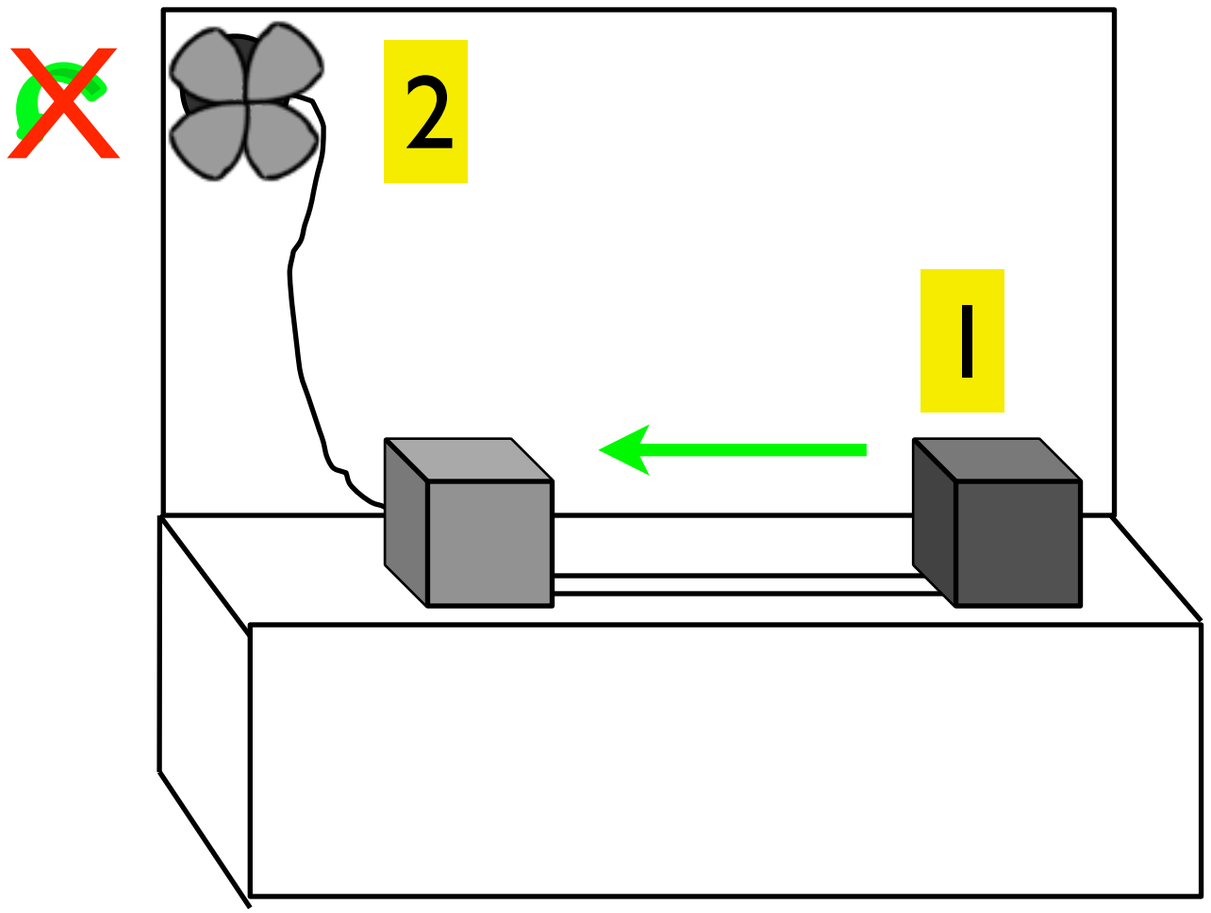
Part II: Toddler causal reasoning



Bonawitz et al (2010) *Cognition*

Part II: Toddler causal reasoning



Source: Muentener, Paul, Elizabeth Bonawitz, Alexandra Horowitz, and Laura Schulz. "Mind the gap: Investigating toddlers' sensitivity to contact relations in predictive events." *PLoS One* 7, no. 4 (2012). License CC BY.

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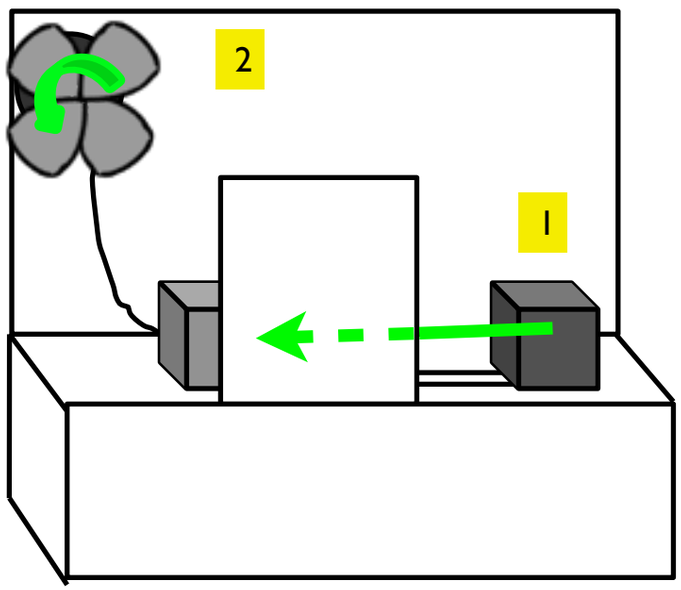
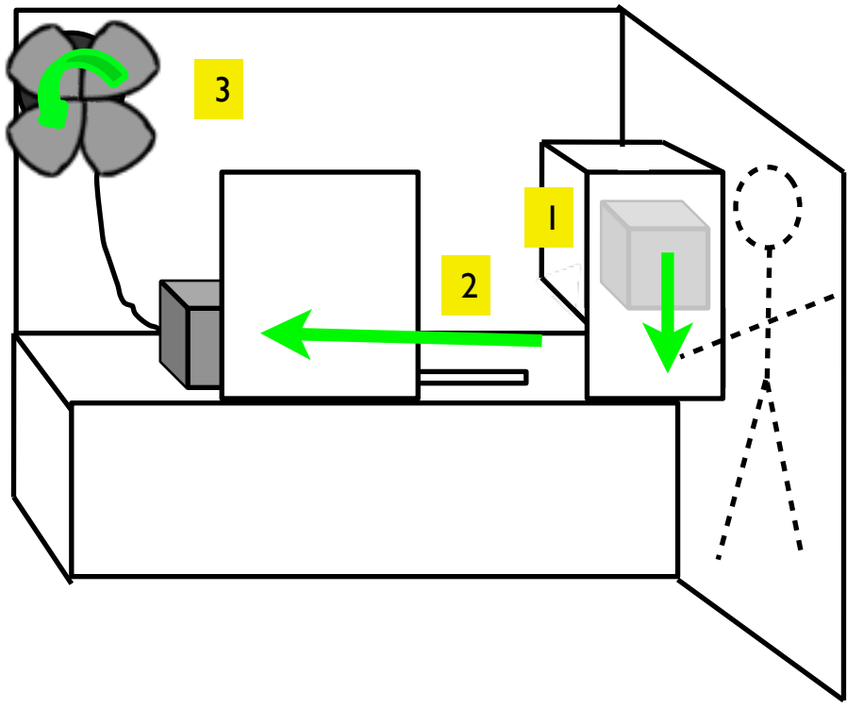
Bonawitz et al (2010) *Cognition*

Spontaneous motion



Inferred agent



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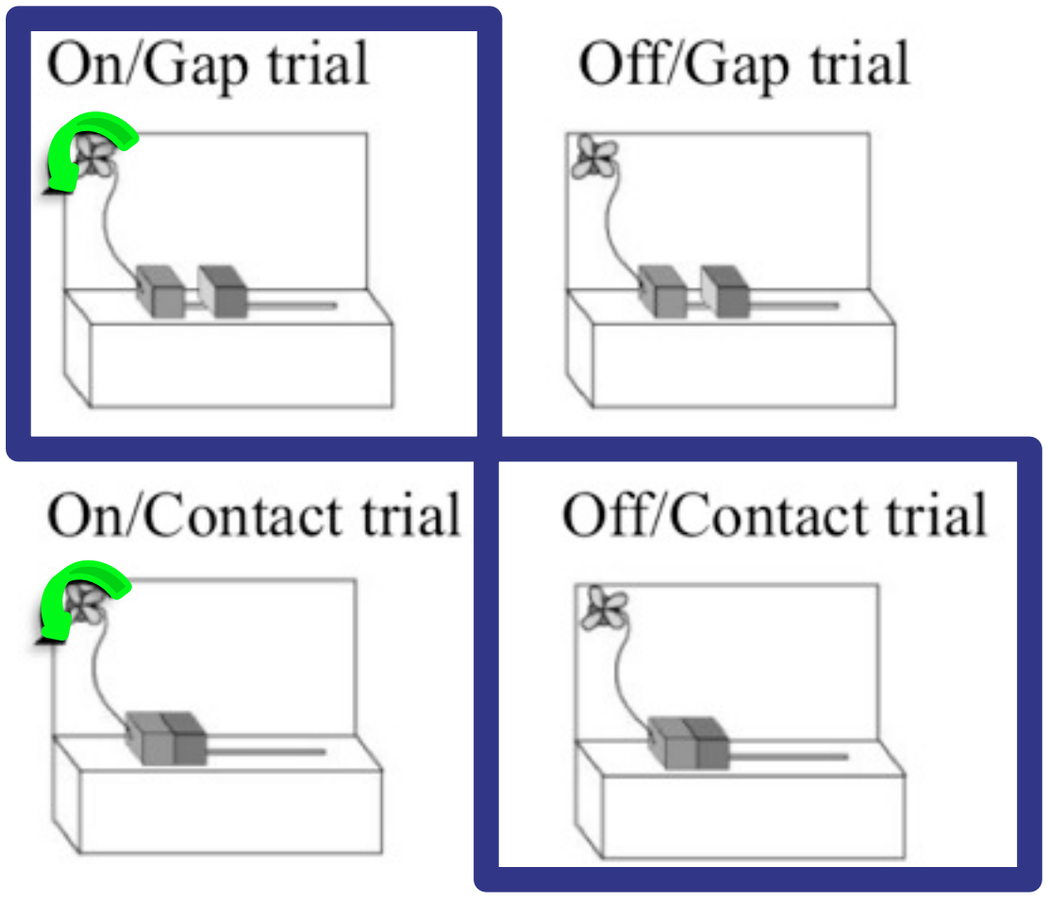
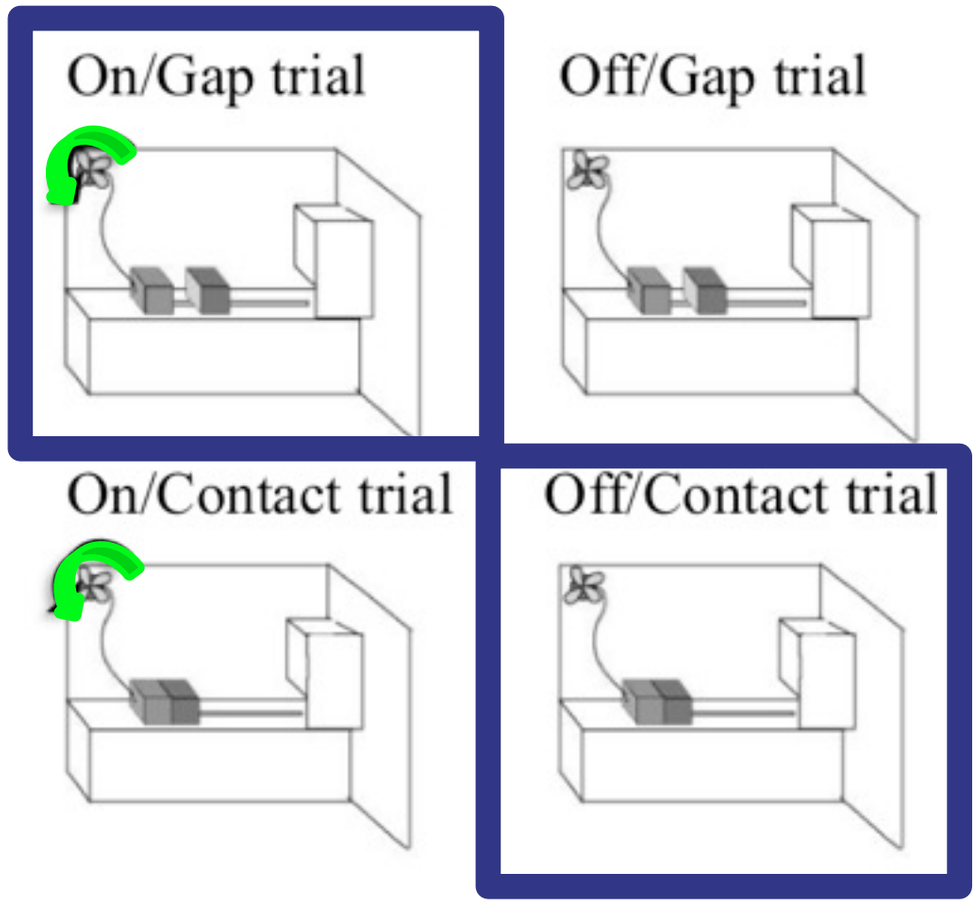
Muentener et al (2012) *PLOS*

Spontaneous motion



Inferred agent



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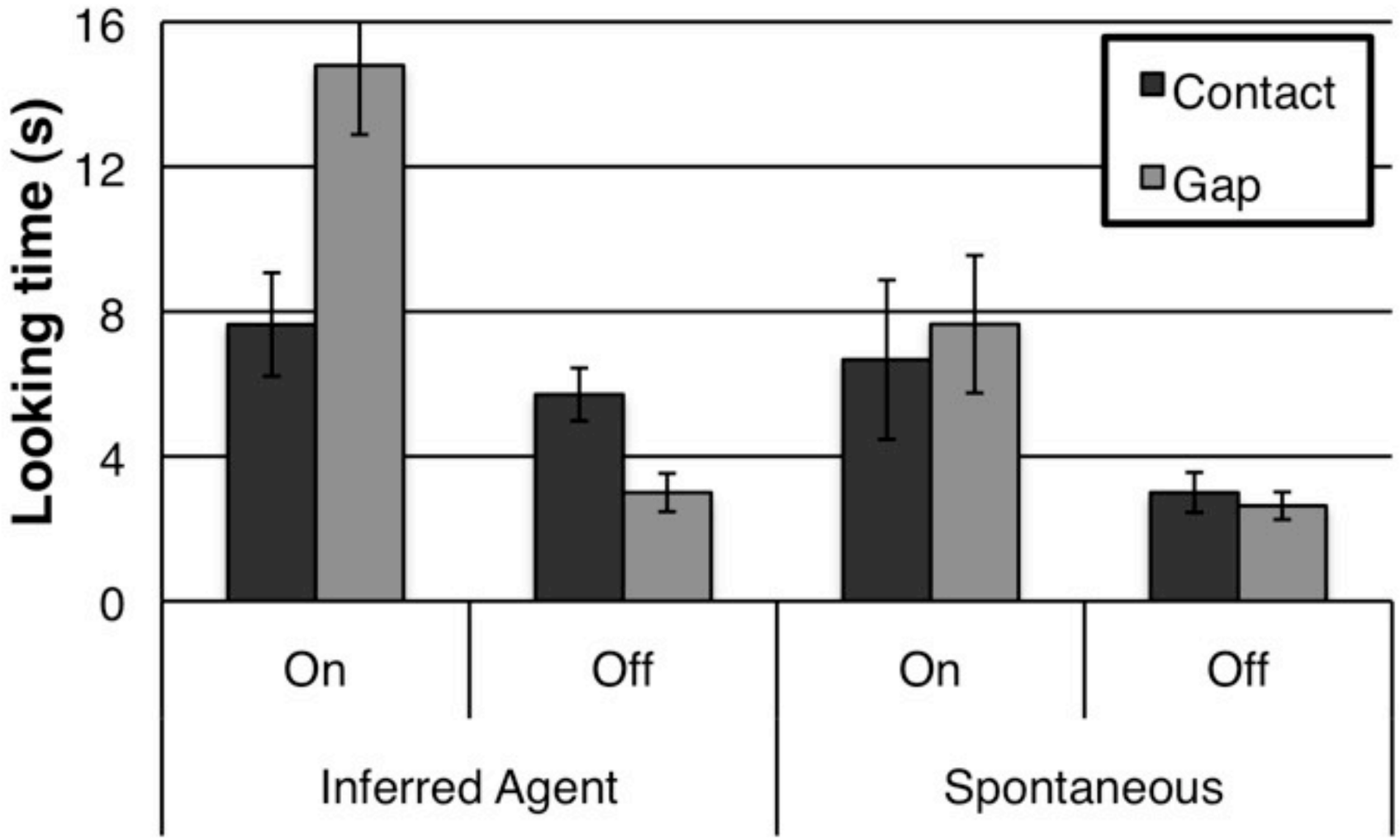

Source: Muentener, Paul, Elizabeth Bonawitz, Alexandra Horowitz, and Laura Schulz. "Mind the gap: Investigating toddlers' sensitivity to contact relations in predictive events." *PLoS One* 7, no. 4 (2012). License CC BY.

* all *ps* < .05

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Part II: Toddler causal reasoning

- Like infants, toddlers seem to represent state change events as causal when the events are initiated by dispositional agents, but not when they are initiated by objects.

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Discussion

- What is infants' initial concept of causation?
  - Evidence suggests a close relation between agency and causality early in development
    - Multiple domains: motion, non-motion physical outcomes, psychological outcomes
    - Multiple ages: infancy through toddlerhood
    - Multiple measures: behavioral and looking-time measures

Two possibilities

- Infants may have an adult-like, integrated concept of causation but find it easiest to recognize goal-directed actions as instances of causation early in development
- Infants' initial concept of causation may be conflated with goal-directed action

- However, the vast majority of studies of children's causal reasoning have occurred **in the context of goal-directed action**.
- In these contexts, infants and children have quite sophisticated inferential abilities.

Sparse data and causal inference

Peanuts comic removed due to copyright restrictions.

Snoopy and Statistics

- Snoopy and Woodstock observe a correlation between kicking snowmen and snow falling.
- But Snoopy knows that kicking snowmen and snow falling are also correlated with snow clouds.
  - If you don't kick snowmen, the probabilistic dependence between snow clouds and snow falling still holds.
  - But if there are no snow clouds, kicking snowmen and snow falling become independent.

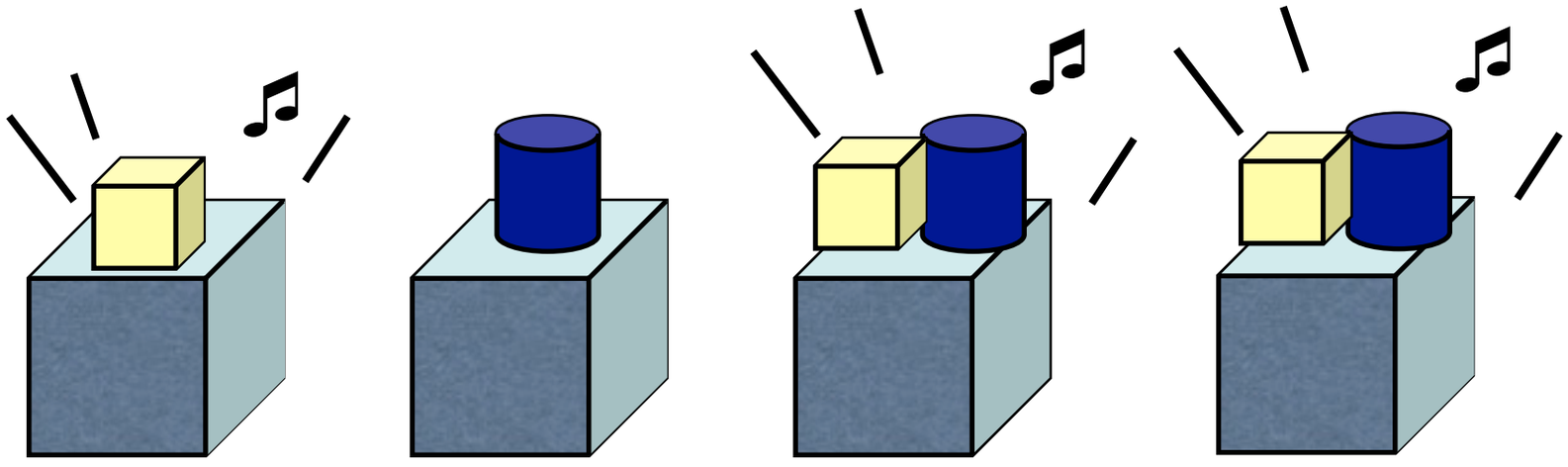
- Therefore clouds ***screen-off*** kicking as a cause of snow.

Formally:

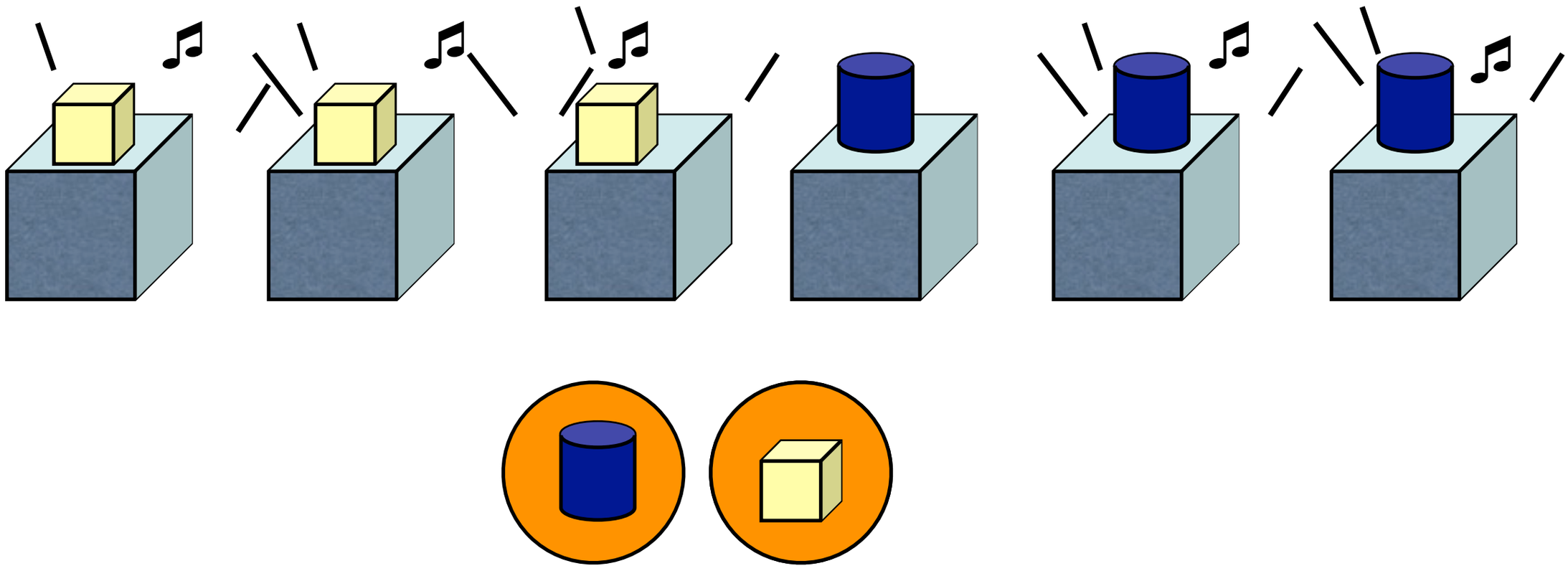
- If A, B, and E are all correlated
- And A and E are correlated in the absence of B (are unconditionally dependent).
- But B and E are independent in the absence of A (are independent conditional on A).
- Then A screens-off B from the effect.

Gopnik, Sobel, Schulz & Glymour, 2001, *Developmental Psychology*

Test condition

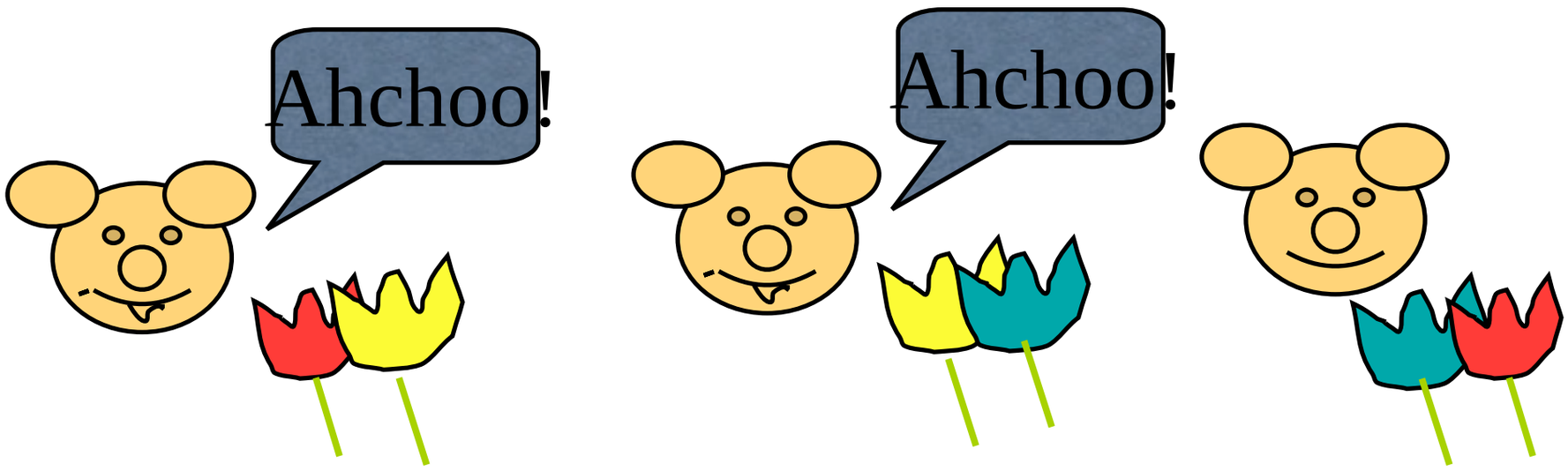


Frequency Control condition

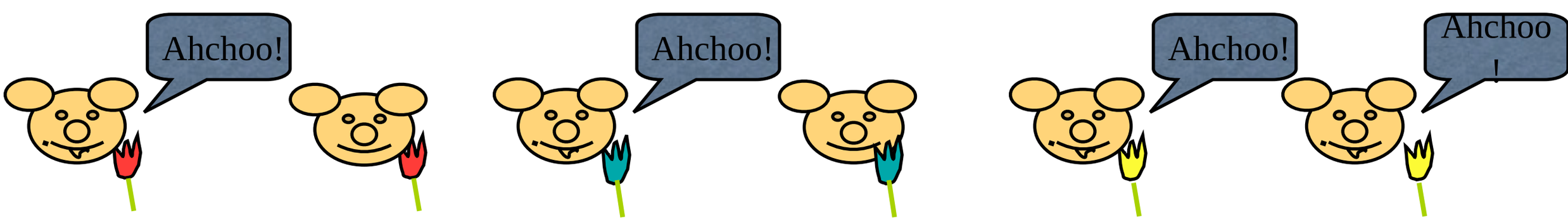


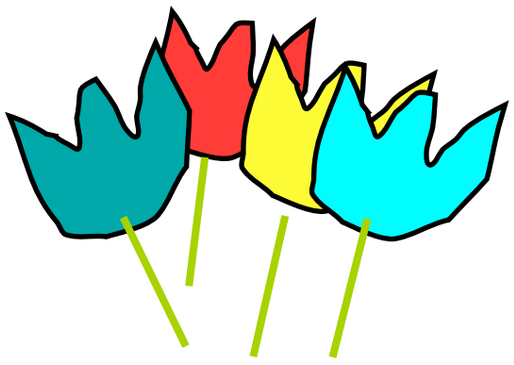
But maybe they are just ignoring the two blocks on together?

Test condition



Frequency Control condition





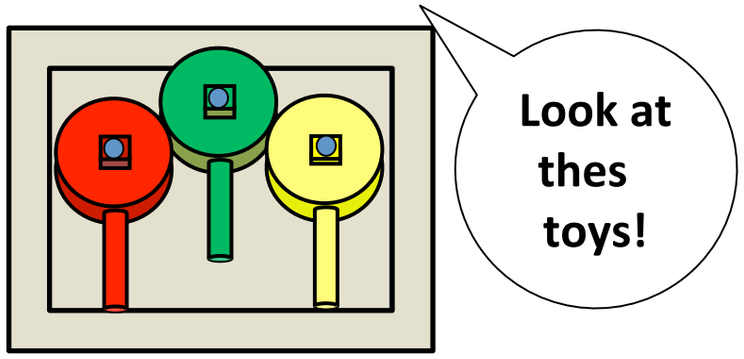
Remove yellow flower at test but all except distractor in control

Schulz & Gopnik, 2004, *Developmental Psychology*

Discussion

- Simple forms of tracking covariation data by age four and using it for causal inference

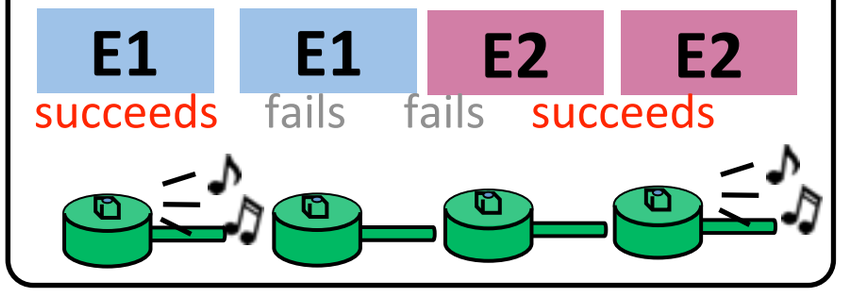
- And indeed, now we know infants can do it by 16-months ...

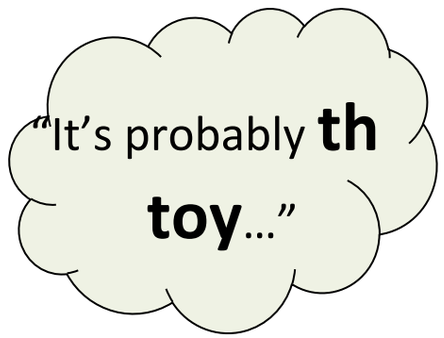


Distribution of successes and failures within & between different agents

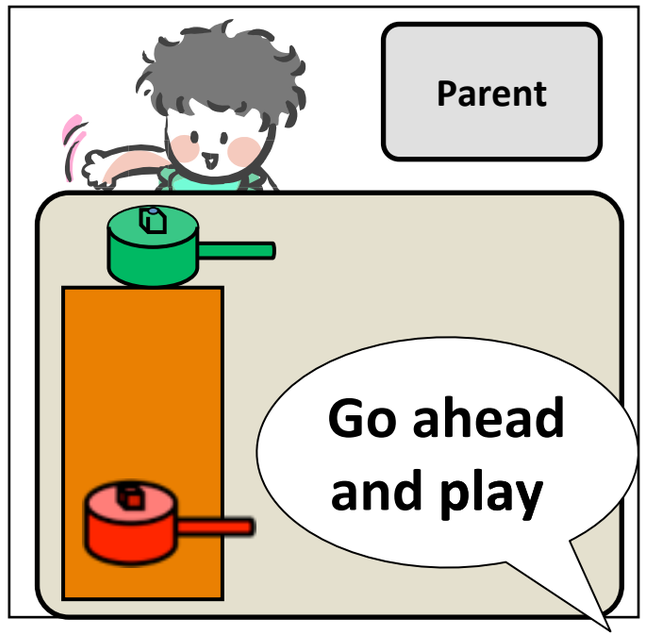
DEMONSTRATION | ATTRIBUTION | ACTION

Within Agents

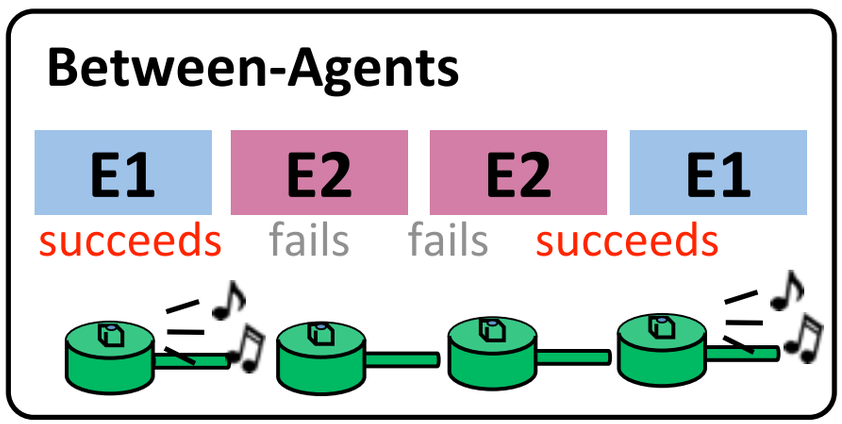


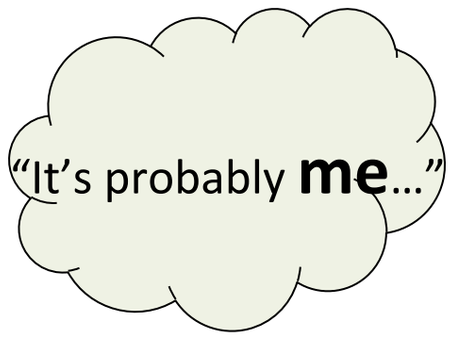


Change the Object



Between-Agents





Change the Agent

Gweon & Schulz, 2011, *Science*

Results

Histogram showing number of infants performing each action first in each condition
N = 36 infants, mean: 16 months; range: 13-20 months

Change Agent
Change Object

Within-Agent

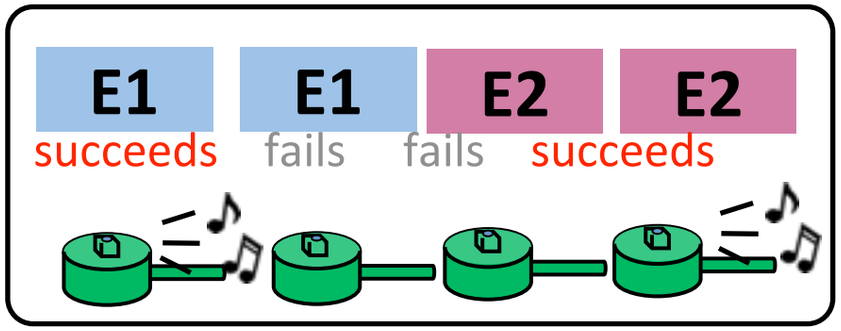
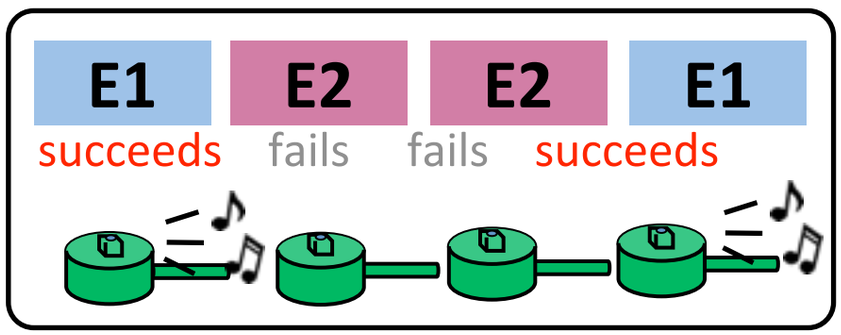


Figure removed due to copyright restrictions. Figure 1D-E. Gweon, Hyowon, and Laura E. Schulz . "16-month-olds rationally infer causes of failed actions." *Science* 332, no. 6037 (2011): 1524.

Between-Agent



* difference between conditions,
$p < .05$ Fisher's exact test

Gweon & Schulz, 2011, *Science*

Rational causal inference in infants

- 16-month-olds…
  - –track the statistical dependence between agents, objects and outcomes
  - –can use minimal data to make rational causal attributions about the cause of failed goal-directed actions
- These distinct causal attributions (self vs. world) help them choose between two different strategies for learning
  - seeking instruction from others
  - self-guided exploration

How about other animals?

- I think the jury is out ...
- Animals make very sophisticated inferences about the relationship between interventions and outcomes.
  - If rats see that a light predicts both a tone and food (T<-L->F) and they hear the tone, they'll go to the food; but if they intervene to cause the tone themselves, the will not.
- But they do not spontaneously go from learning a predictive relationship (T-->F) to intervening to cause the tone. (NB: neithe do our infants and toddlers)
- And they take hundreds of trials to pass blicket detector tasks (i.e., they can do "blocking" by associative learning but unlike children, they do not seem to draw the inference from sparse data or use it for novel interventions)
- Nonetheless, other animals clearly successfully navigate (and innovate) on the physical world ....

Causal reasoning in non-human animals

Chimpanzee termite fishing image removed due to copyright restrictions. http://www.arkive.org/chimpanzee/pan-troglodytes/image-G4230.html

Best acknowledgement in a paper:
"Thanks to Richard Leaky whose termite-collecting skills so outstripped mine"

Causal reasoning in non-human animals

Courtesy of Alex Kacelnik. Used with permission. http://users.ox.ac.uk/~kgroup/tools/photos.shtml

Causal reasoning in non-human animals

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Flexible ability to observe the physical environment and design effective interventions

- Select appropriate tools
- Shape appropriate tools
- From novel materials

Courtesy of Alex Kacelnik. Used with permission. http://users.ox.ac.uk/~kgroup/tools/photos.shtml

Figure removed due to copyright restrictions. Weir, Alex A. S., Jackie Chappell, et al. "Shaping of Hooks in New Caledonian Crows." *Science* 297, no. 5583 (2002): 981.

"Genius" Chimp Outsmarts Tube

- http://www.youtube.com/watch?v=yrPb41hzYdw

Uniquely human exploration?

- All sorts of animals explore novel spaces, novel conspecifics, novel objects.
- Possibly only human beings explore in order to understand causal relationships. Exploration -- not just to make something happen (peanuts appear) but to know why it happens.
- Critical to science ...
- Emerges in childhood.

9.85 Infant and Early Childhood Cognition

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