Infant Cognition 4: (Abstract) Relational Learning in Infancy

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Readings

- The later sections of Carey's BBS paper cited last week, and these papers both apply to this lecture and next lecture on abstract thinking.

- Gentner, D. (2010). Bootstrapping the mind: Analogical processes and symbol systems. *Cognitive Science*, 34 (5). 752-775.

- Gopnik, A., & Wellman, H. M. (2012). Reconstructing constructivism: Causal models, Bayesian learning mechanisms, and the theory theory. *Psychological Bulletin, 138(6)*, 1085–1108.

The Natural Partitions Hypothesis
Gentner (1982)

- We parse the world into objects, and relations among the objects
  - This sort of distinction is as old as at least Aristotle
- Objects are perceptually cohesive: stable in the world, clear contrast with background, long lasting
- Relations are harder to perceive directly: dynamic/unstable, indefinite number of options
  - Spatial relations, state changes, movement towards/away

The Natural Partitions Hypothesis
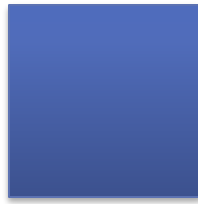# Gentner (1982):
the objects vs. the relations
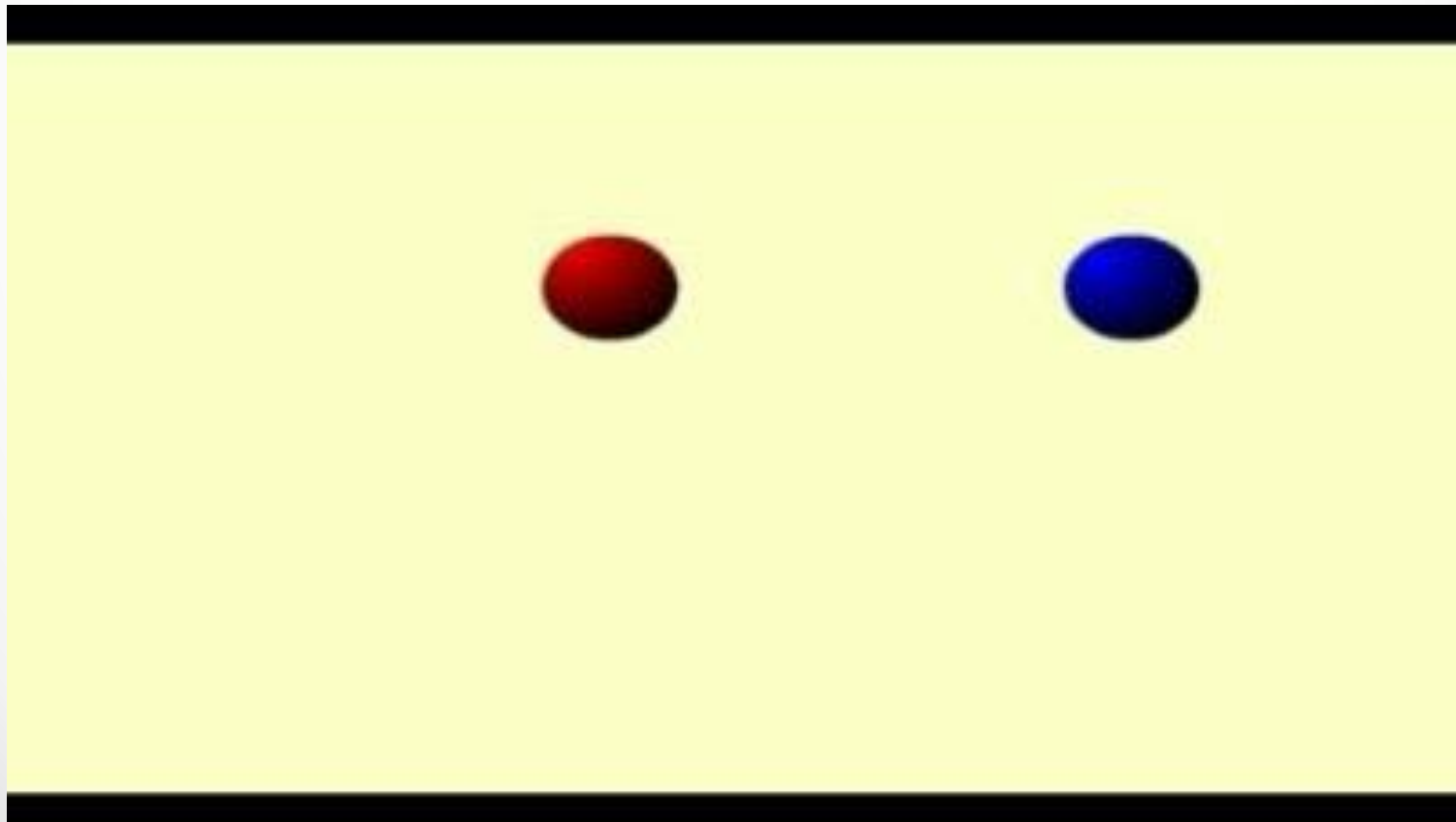
Relational Learning in Infancy

- Can infants learn relations, and generalize these relations across sets of objects?

- Identity relation: same vs. different
- Causal relations
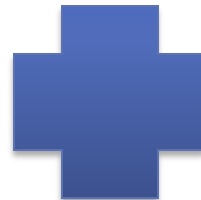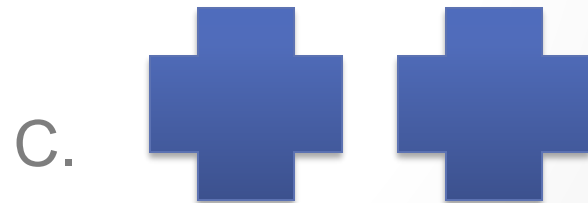
Same & Different
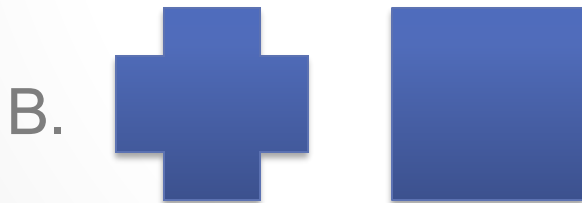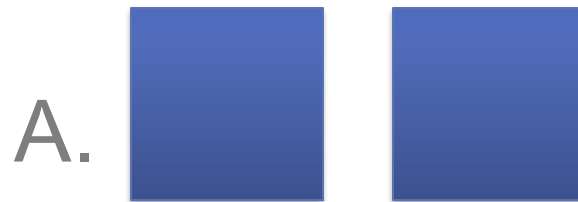
Is B or C more like A?

A.

B.

C.

Same & Different: this is very difficult or impossible for non-human animals

Is B or C more like A?

A.

B.

C.

Principles of Constructivist Infant Cognition

- Innate domain general information processing system that detects low-level featural information, such as color, motion
- Higher-level units formed from relationships among these.
- Higher-level units formed from these units. Learning is hierarchical & constructive
- Infants tend to use highest level units to interpret their environment
- If system gets overloaded, revert to lower-level of processing while incorporating new information
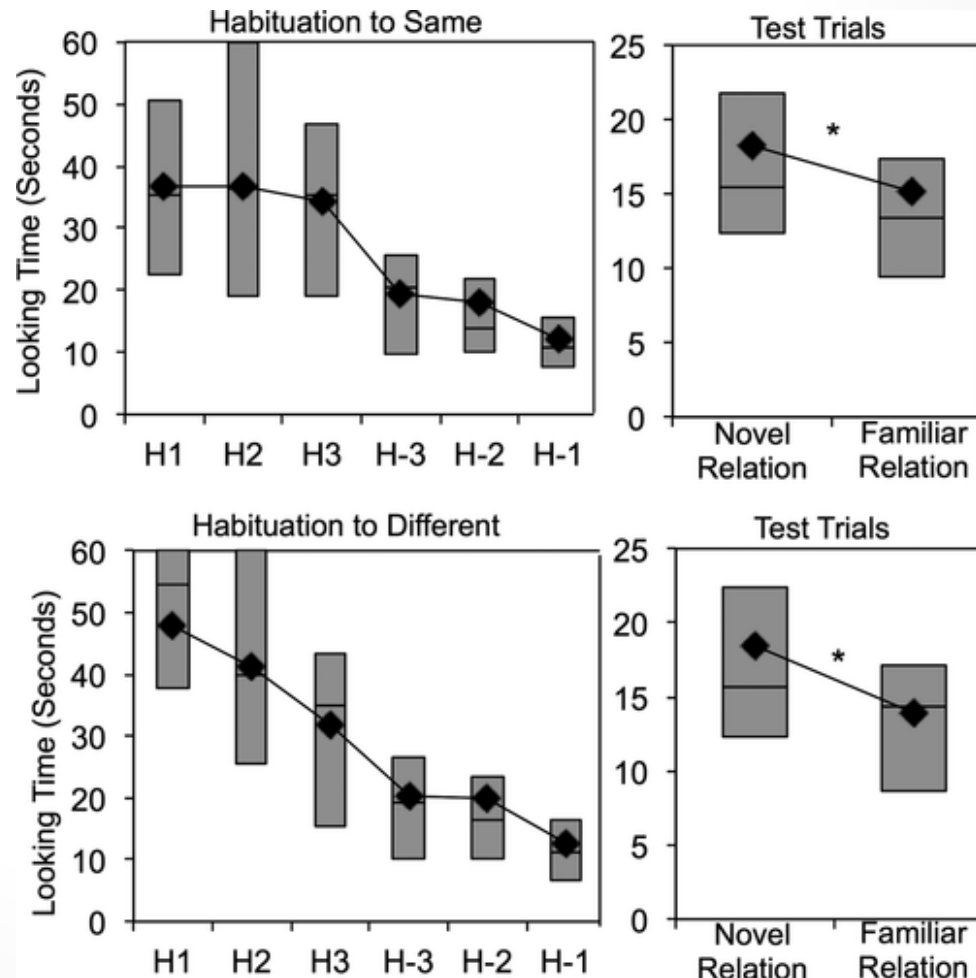
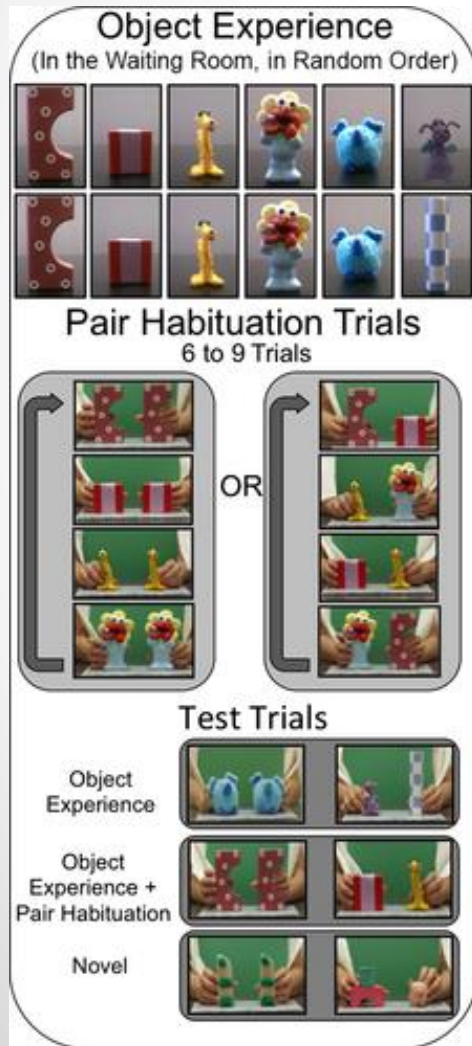# Same/Different in Infancy

- Ferry, Hespos, & Gentner (2015)
- 7-9 month olds
- E1- 1 pair of objects during familiarization, they don't seem to generalize
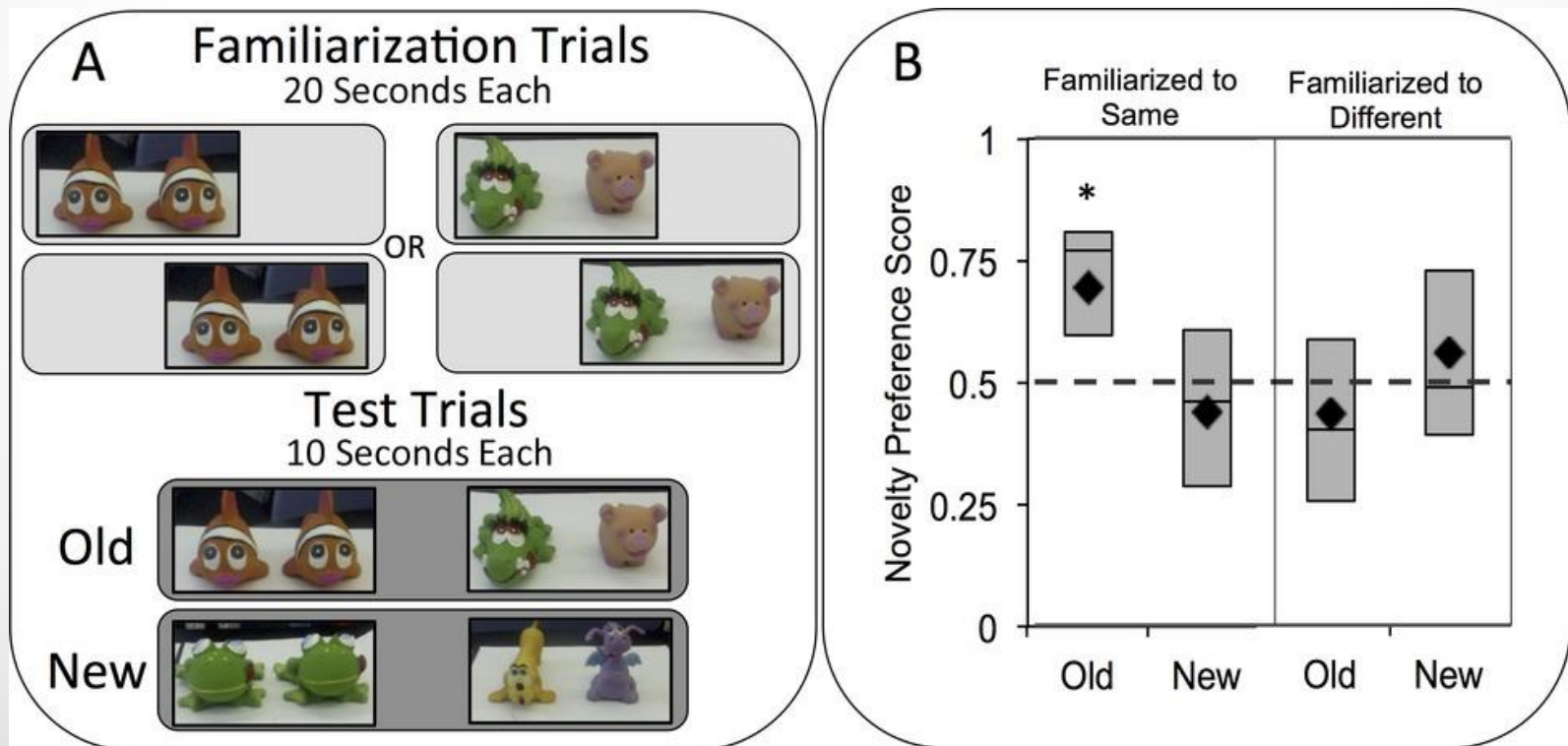
Same/Different in Infancy

- Ferry, Hespos, & Gentner (2015)
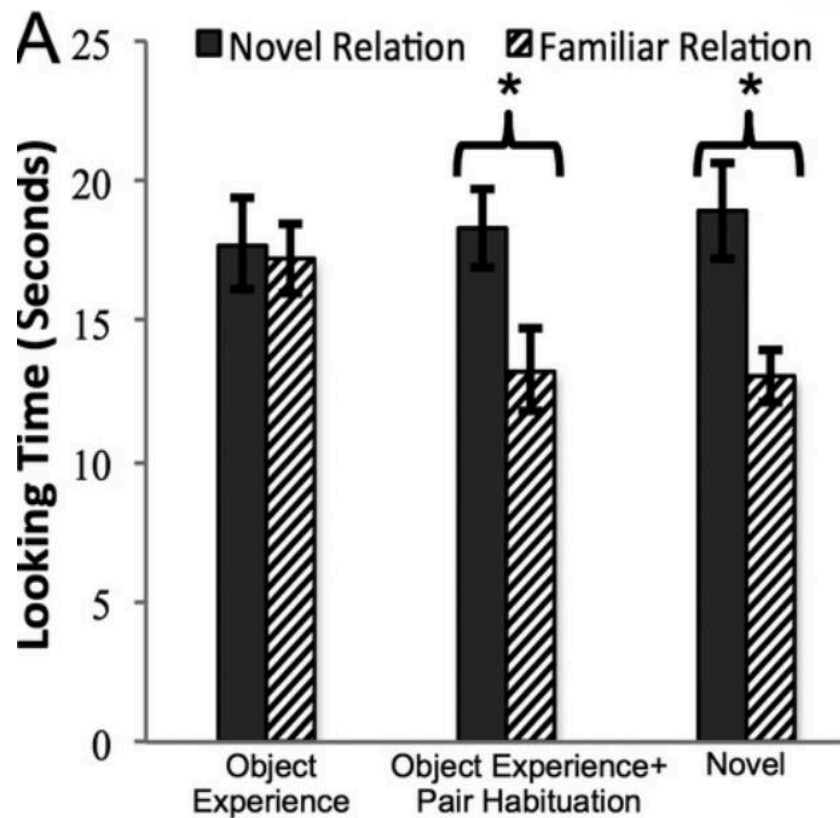- E2- 4 pairs of objects during familiarization, they do!

Same/Different in Infancy

- Ferry, Hespos, & Gentner (2015)
- E2- 4 pairs of objects during familiarization, they do!
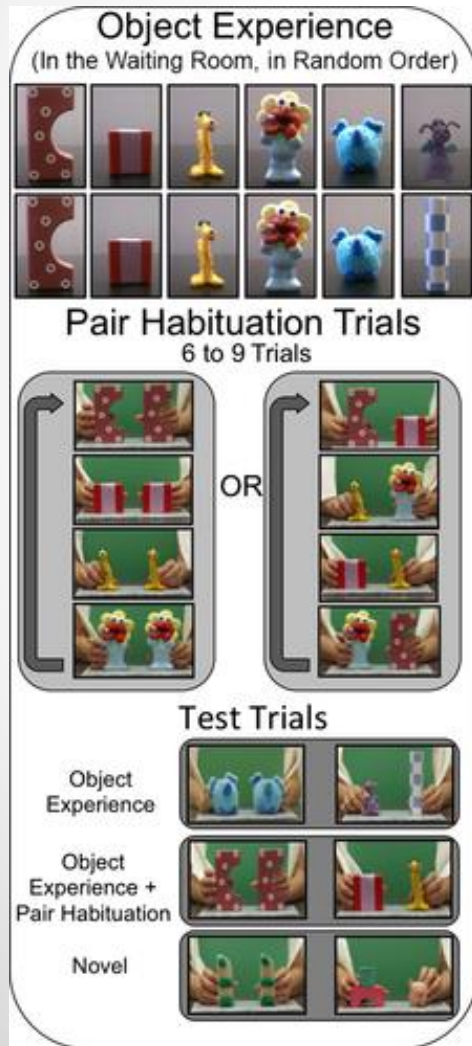
Same/Different in Infancy

- Anderson, Chang, Hespos, & Gentner (2018) 3 months
- E1- 6 pairs of objects during familiarization, they do not!
- E2 – 2 pairs of objects, they do!
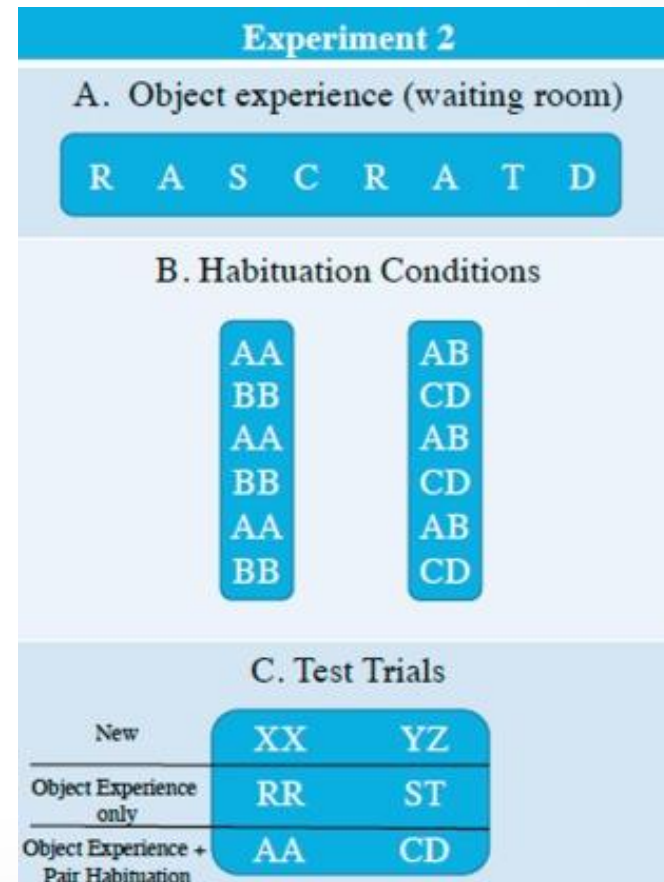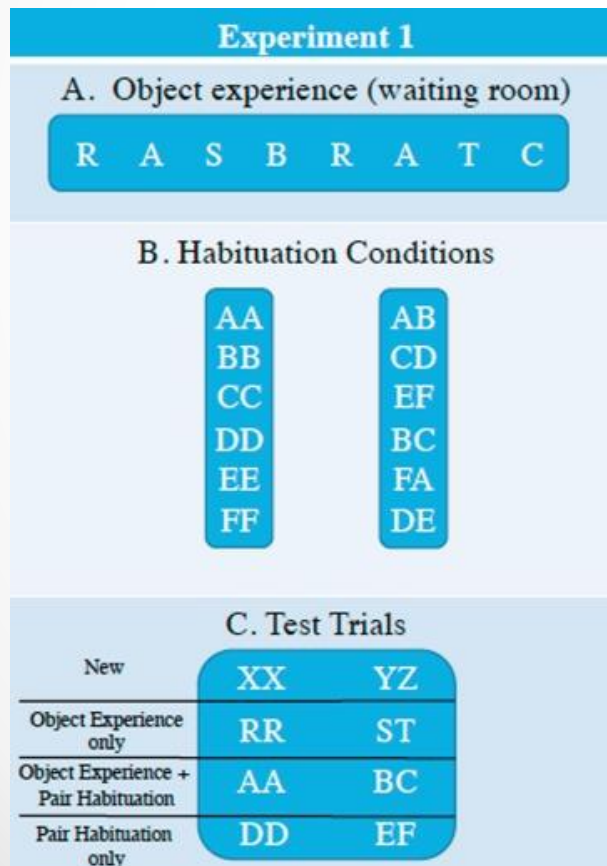
Same/Different in Infancy

- Anderson, Chang, Hespos, & Gentner (2018)
- E1- 6 pairs of objects during familiarization, they do not!
- E2 – 2 pairs of objects, they do!

Experiment 2 Test Trials
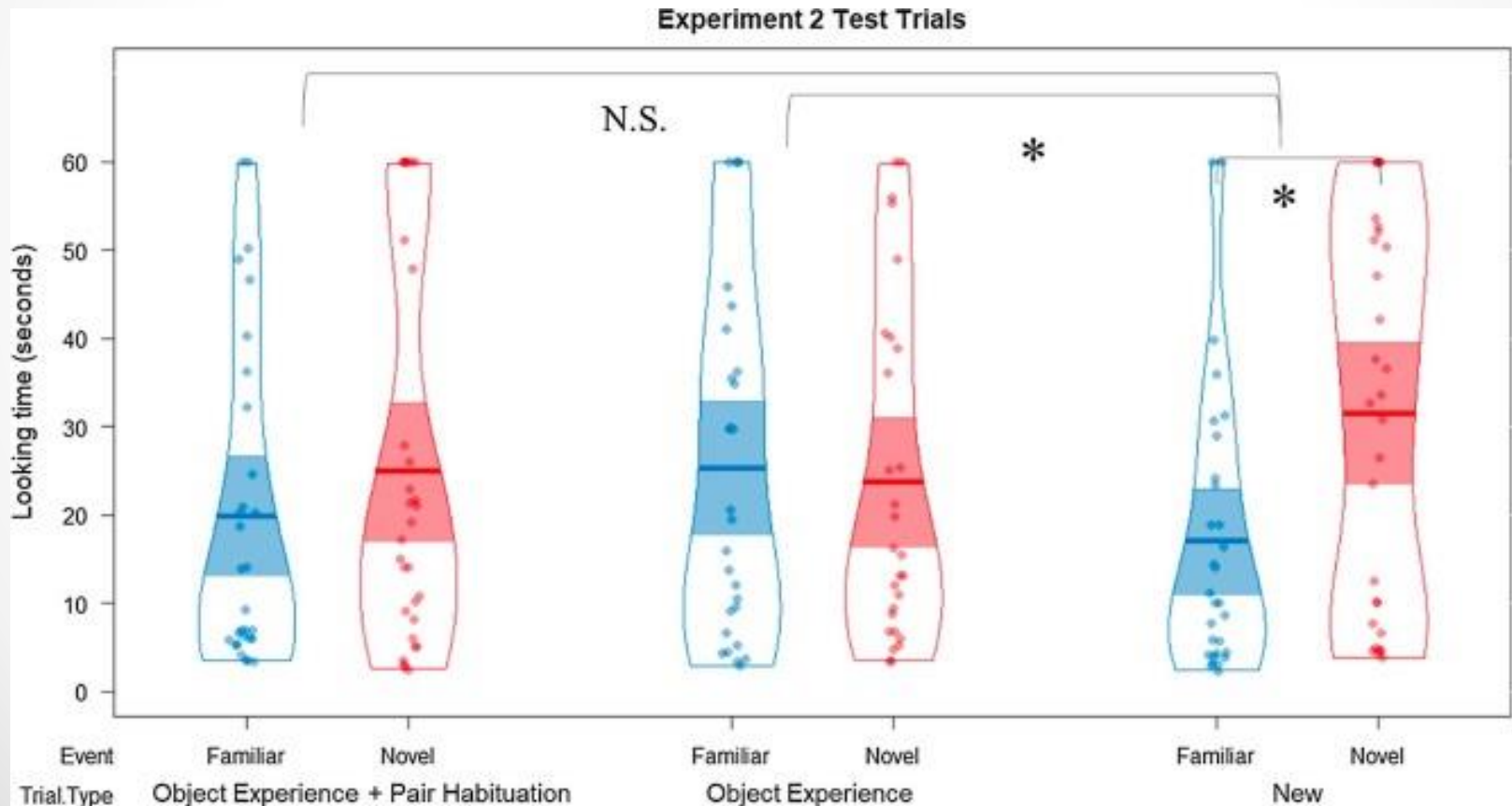
Relational Learning in Infancy

- From 3 months of age, infants, under the right conditions, can abstract same/different relations and generalize across objects

- They can get overloaded!

- For 3-9 months olds, making objects salient, and not part of abstraction learning, interferes with generalization

- Too many pairs for 3-month olds during learning also overwhelms

The perception of causality in events
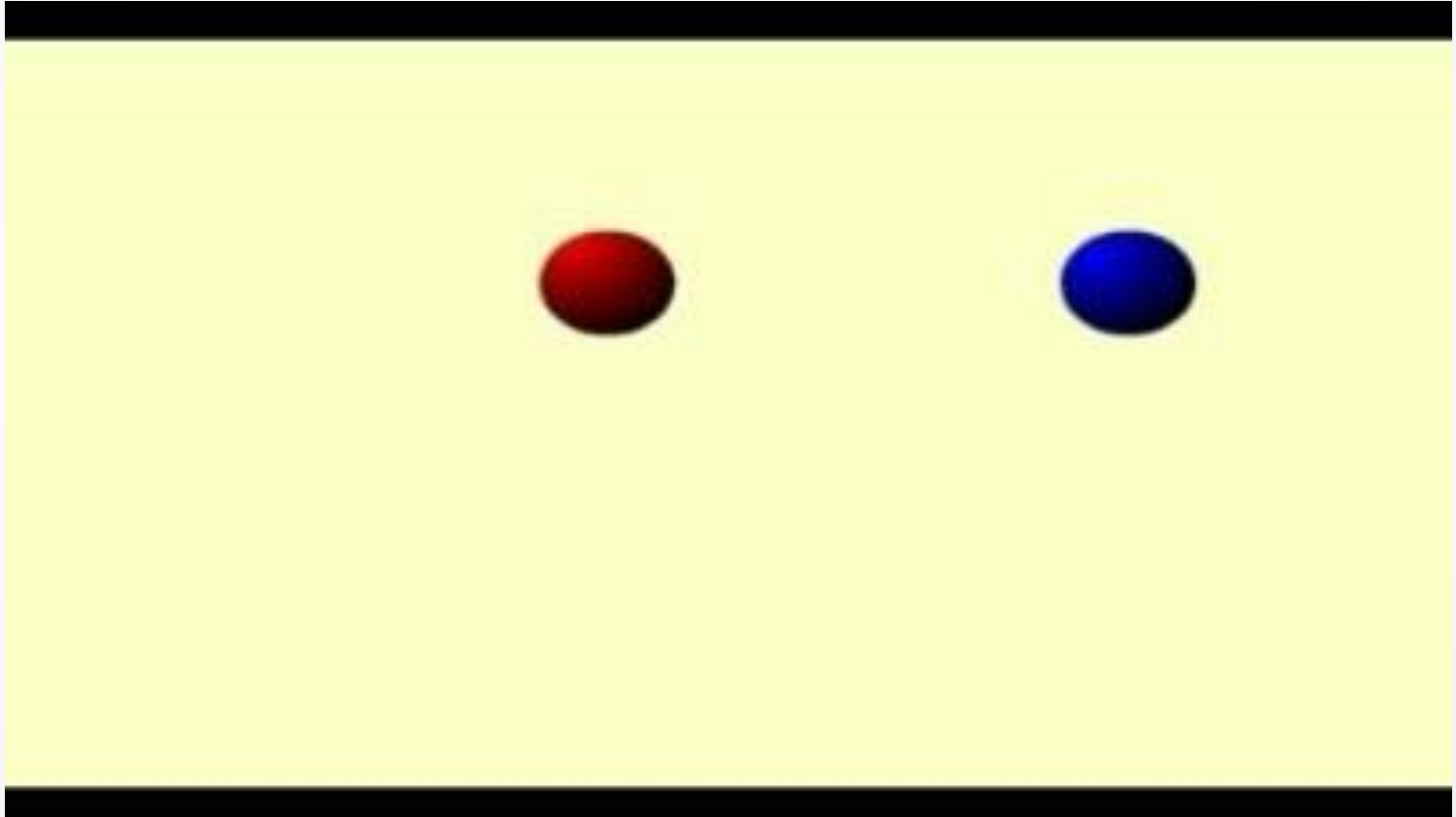
Causal Perception

- We "see" causality given certain spatial and temporal relationships

- Leslie (1984)

- As common moving surfaces are inputs to core object knowledge, certain spatial-temporal motion relationships are input to core causal knowledge

- Will 6 month-old infants see events as collections of spatial & temporal features, or will they use those features to see them as causal or non-causal?
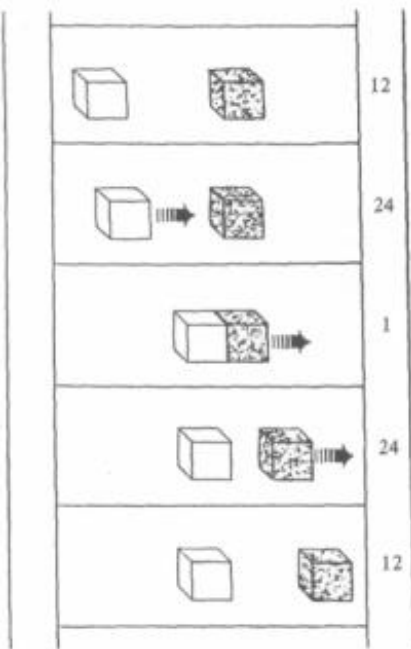
Direct launching
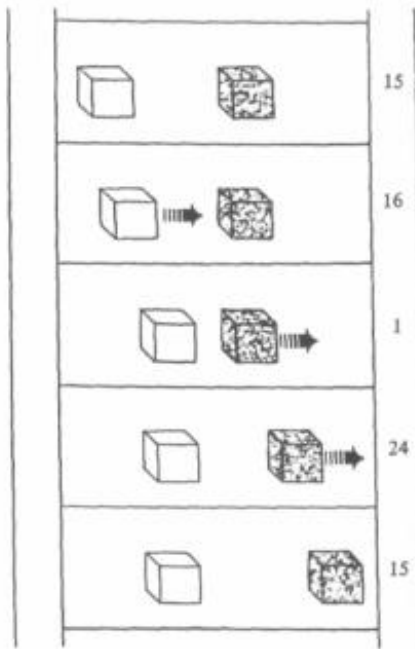
Launching without collision
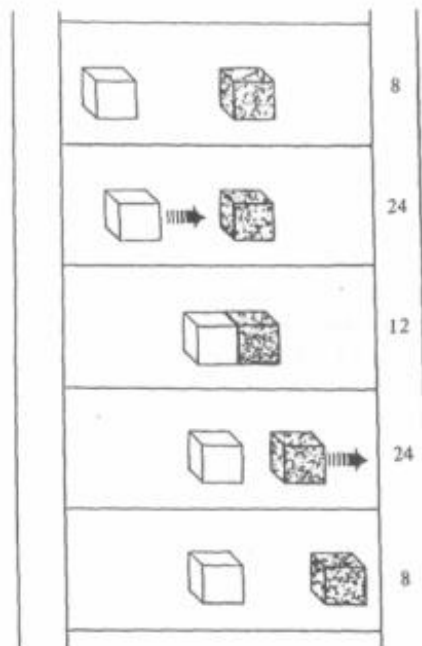
Delayed reaction
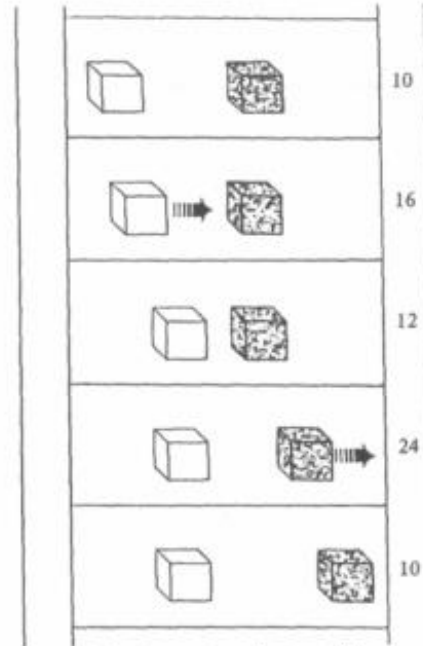
Delayed reaction without collision

Causal Perception

Leslie (1984)

6 month-olds

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] *versus* [−successive −contact] (both features change)	[−successive +contact] *versus* [+ successive −contact] (both features change)
Causal hypothesis	[+ causal] *versus* [-causal] (causal contrast)	[-causal] *versus* [-causal] (no causal contrast)

[a]DL, direct launching; DR, delayed reaction; DRWC, delayed reaction without collision; LWC, launching without collision.

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Causal Perception

Leslie (1984)

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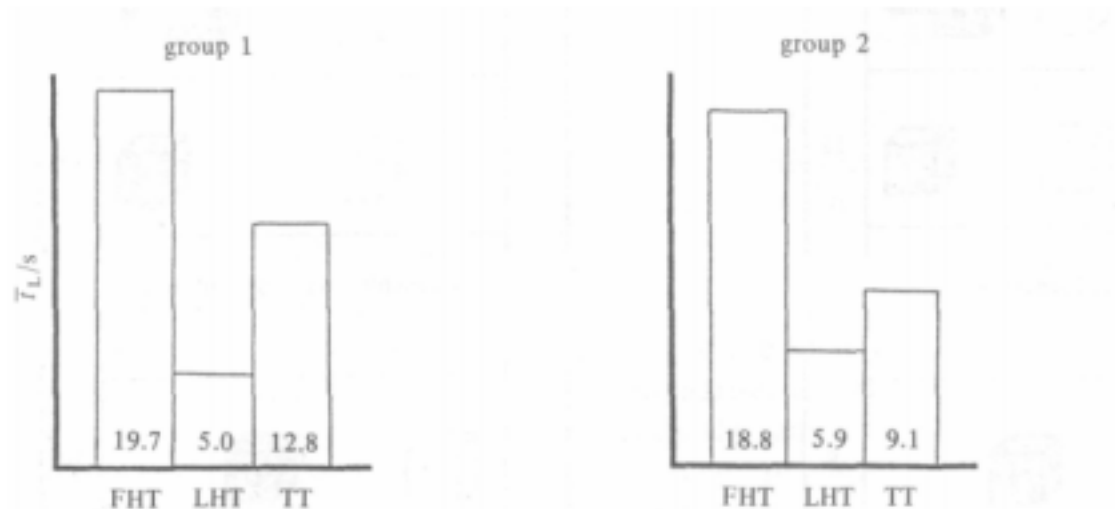

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Group 1: Habituates to causal event, tested with non-causal event with both temporal delay and spatial gaps

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] *versus* [−successive −contact] (both features change)	[−successive +contact] *versus* [+ successive −contact] (both features change)
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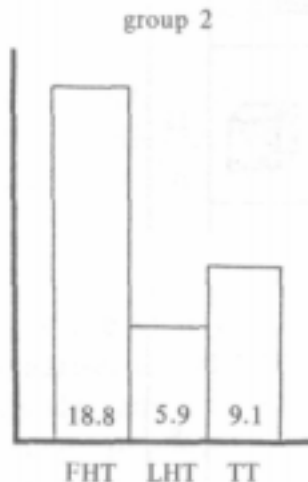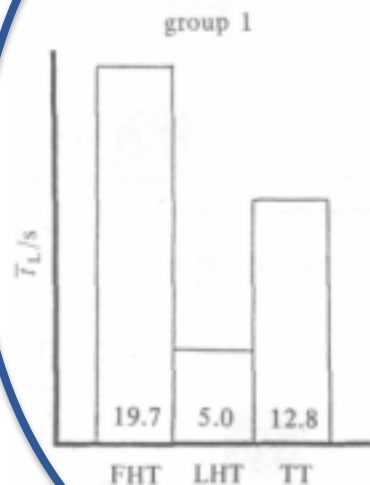

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Group 1: First trial of habituation, long looking times

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] *versus* [−successive −contact] (both features change)	[−successive +contact] *versus* [+ successive −contact] (both features change)
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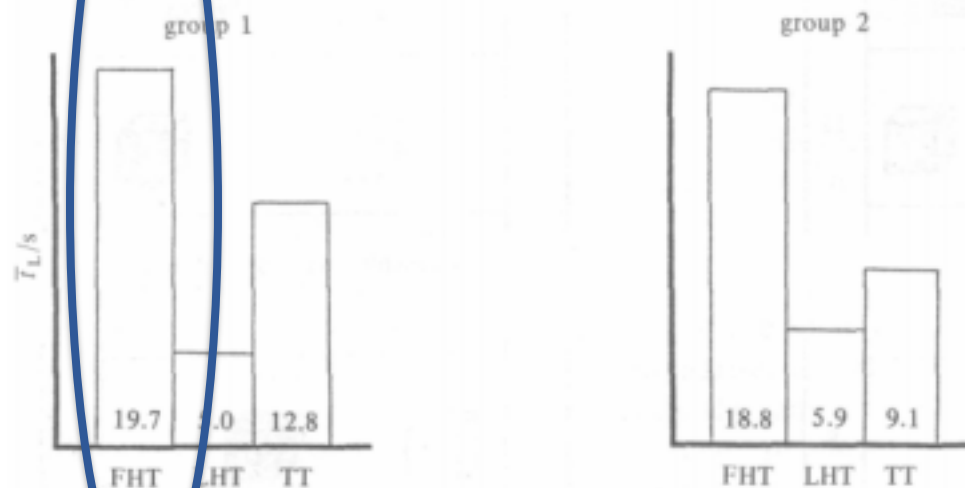

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Group 1: Last habituation trial, short looking times

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] *versus* [−successive −contact] (both features change)	[−successive +contact] *versus* [+ successive −contact] (both features change)
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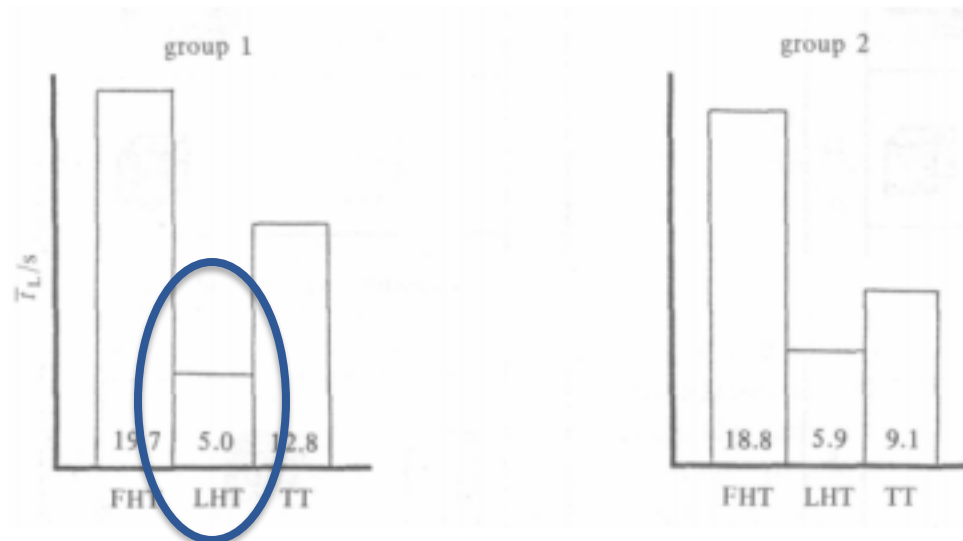

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Group 1: Test trial has long looking times. They discriminate between the causal and non-causal event.

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] versus [−successive −contact] (both features change)	[−successive +contact] versus [+ successive −contact] (both features change)
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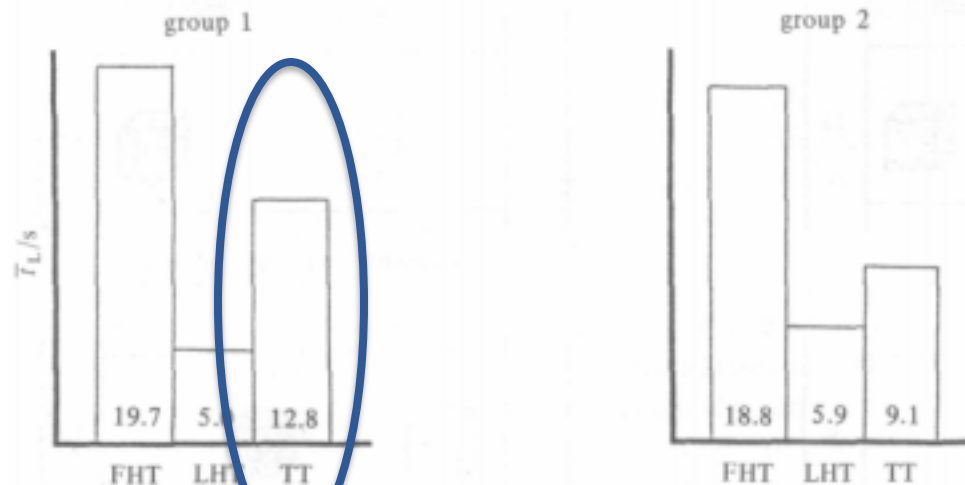

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Group 2: Habituate to a non-causal event (with temporal delay) and then at test see a different non-causal event (spatial gap).

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] *versus* [−successive −contact] (both features change)	[−successive +contact] *versus* [+ successive −contact] (both features change)
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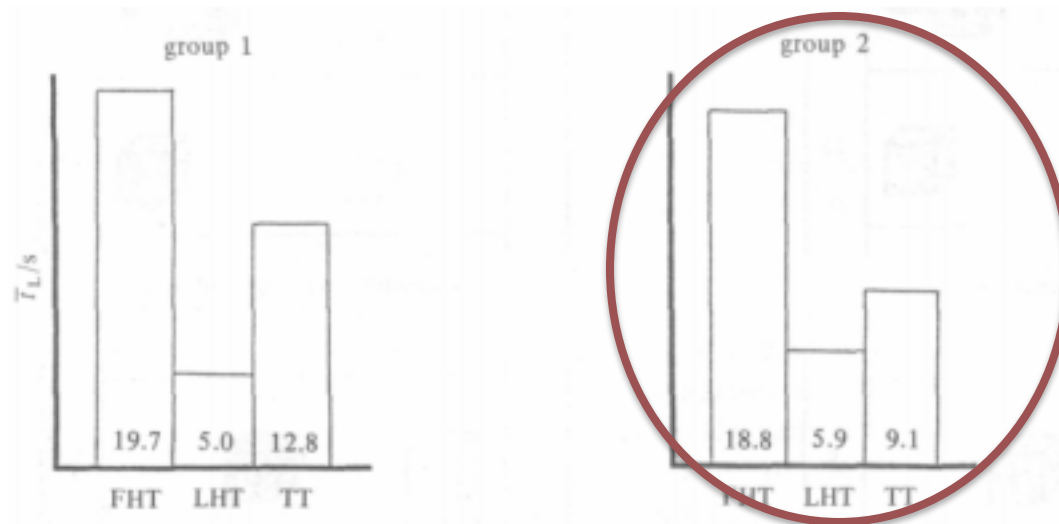

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Group 2: First habituation trial, long looking times

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] *versus* [−successive −contact] (both features change)	[−successive +contact] *versus* [+ successive −contact] (both features change)
Causal hypothesis	[+ causal] *versus* [-causal] (causal contrast)	[-causal] *versus* [-causal] (no causal contrast)

[a]DL, direct launching; DR, delayed reaction; DRWC, delayed reaction without collision; LWC, launching without collision.
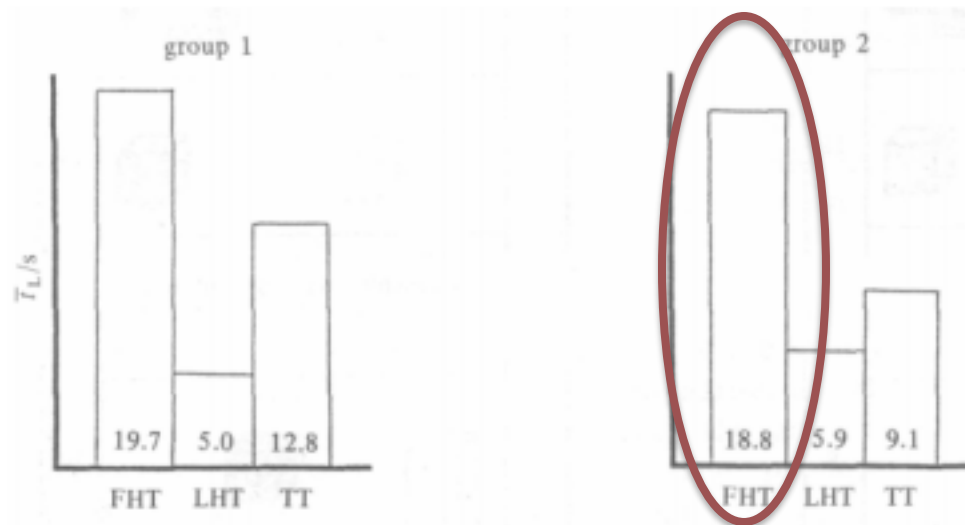

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Group 2: Last habituation trial, short looking times.

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] versus [−successive −contact] (both features change)	[−successive +contact] versus [+ successive −contact] (both features change)
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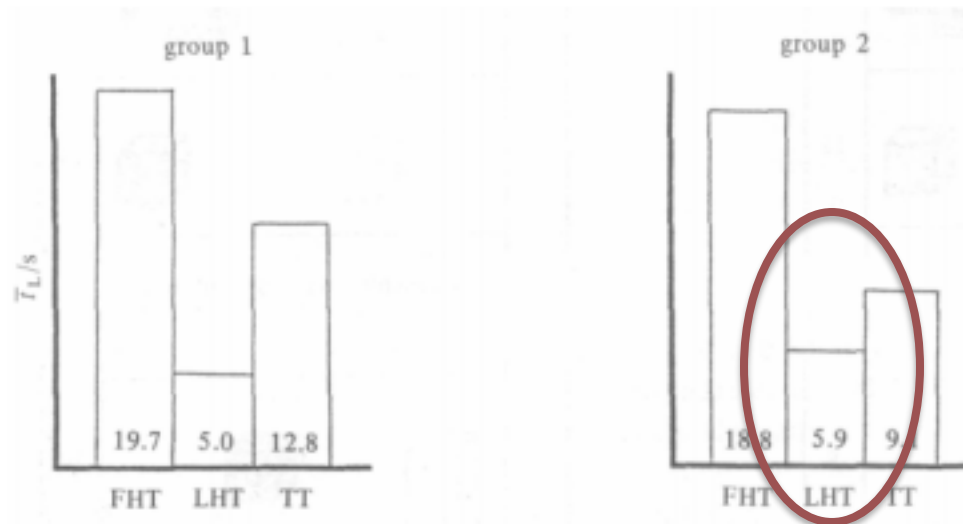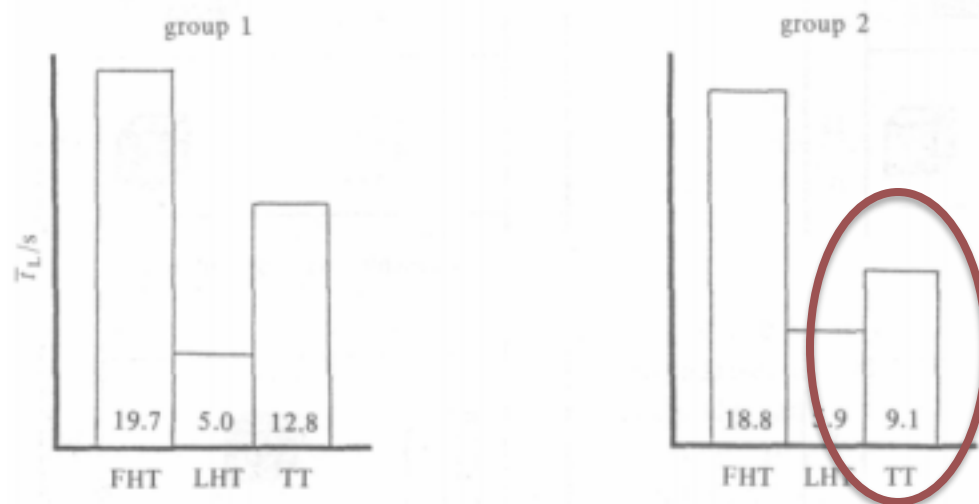

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Group 2: Test trial is not significantly longer than the last habituation trial. They generalized their habituation across non-causal events. They do not appear to discriminate between them, despite their differing spatial and temporal features.

Table 1. Experiment 2: design.

	Group 1	Group 2
Film pairs	DL/DRWC[a]	DR/LWC[a]
Two-feature hypothesis	[+ successive + contact] versus [−successive −contact] (both features change)	[−successive +contact] versus [+ successive −contact] (both features change)
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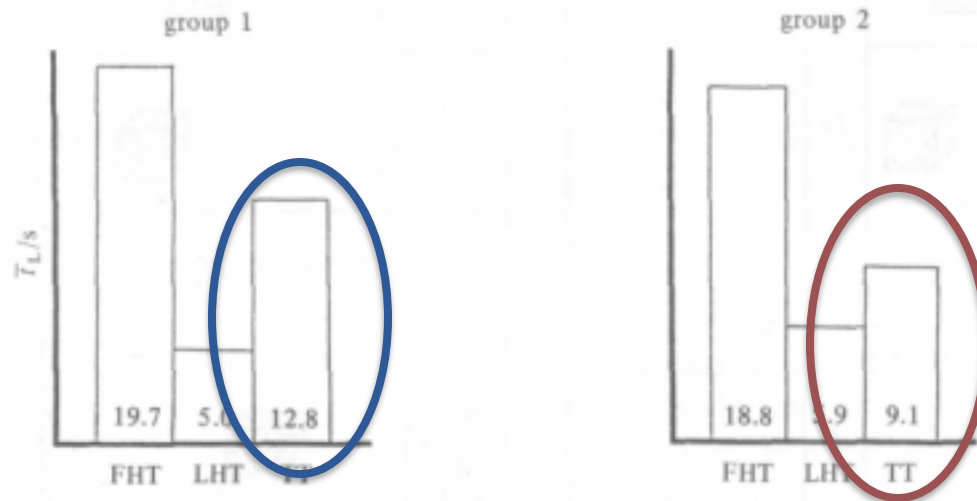

Figure 4. Experiment 2: mean looking time by groups on first habituation trial (FHT), last habituation trial (LHT) and test trial (TT). See table 1 for design.

Across the two conditions, it is clear the infants are responding in terms of causal status.
Group 1 dishabituates to a non-causal event after habituating to a causal one.
Group 2 generalizes their habituation from one non-causal event to another.

Causal Perception

- We "see" causality given certain spatial and temporal relationships

- Leslie (1984)

- As common moving surfaces are inputs to core object knowledge, certain spatial-temporal motion relationships are input to core causal knowledge

- 6 month-olds treat events as causal, not collections of spatial & temporal features

- Leslie interprets results as evidence for innate causal module

Response from Constructivism

- Higher-level units formed lower level units. Learning is hierarchical & constructive
- Infants tend to use highest level units to interpret their environment
- If system gets overloaded, revert to lower-level of processing while incorporating new information

Response from Constructivism

(see Cohen & Cashon, 2006)

- Innate causal module: given certain temporal and spatial cues, infants perceive events as causal
- Constructivism: Causal perception emerges from lower-level features. Infants may be able to perceive causality under some conditions, but may become overloaded in others, and perceive events only in terms of spatial and temporal features.
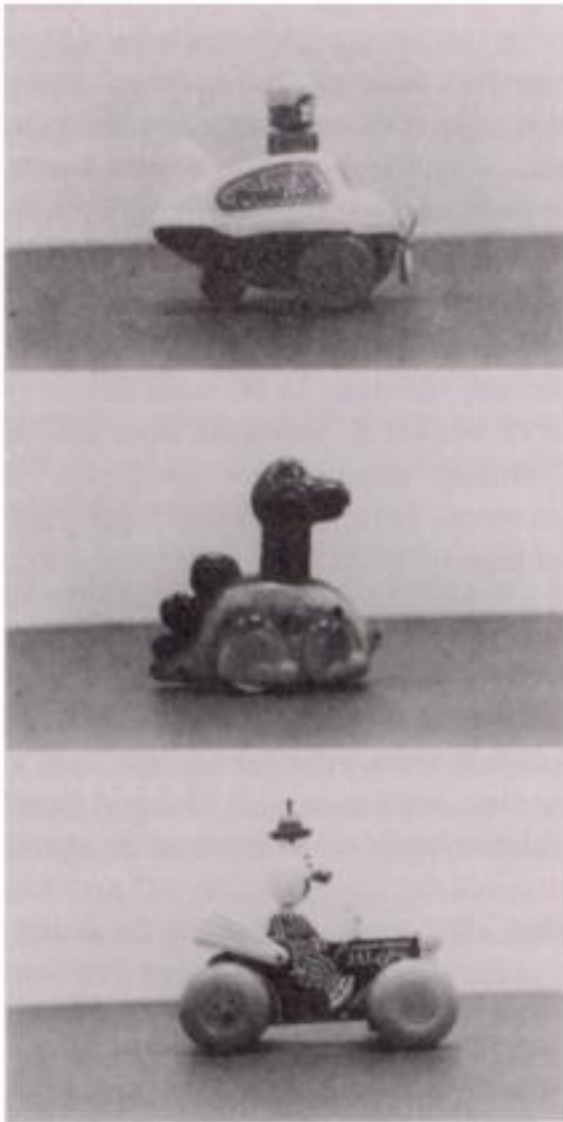
Causal Perception

Oakes & Cohen (1990)

6 & 10 month-olds

Figure 1.   Pictures of the toys used in the events. The airplane and dinosaur were used for the causal and noncausal events. The jalopy was used for the novel event.
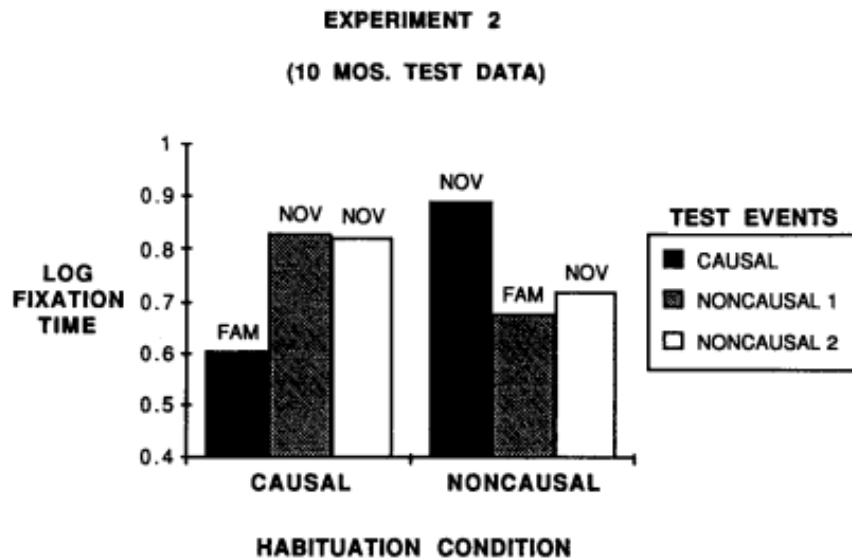
Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.
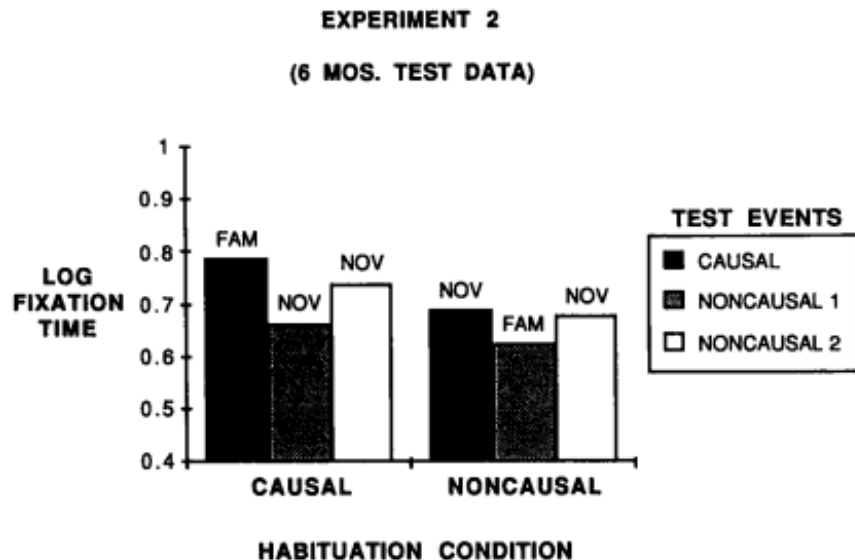
Causal Perception

Oakes & Cohen (1990)

6 & 10 month-olds

EXPERIMENT 2

(10 MOS. TEST DATA)

LOG FIXATION TIME

TEST EVENTS
- CAUSAL
- NONCAUSAL 1
- NONCAUSAL 2

HABITUATION CONDITION

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.

EXPERIMENT 2

(6 MOS. TEST DATA)

LOG FIXATION TIME

TEST EVENTS
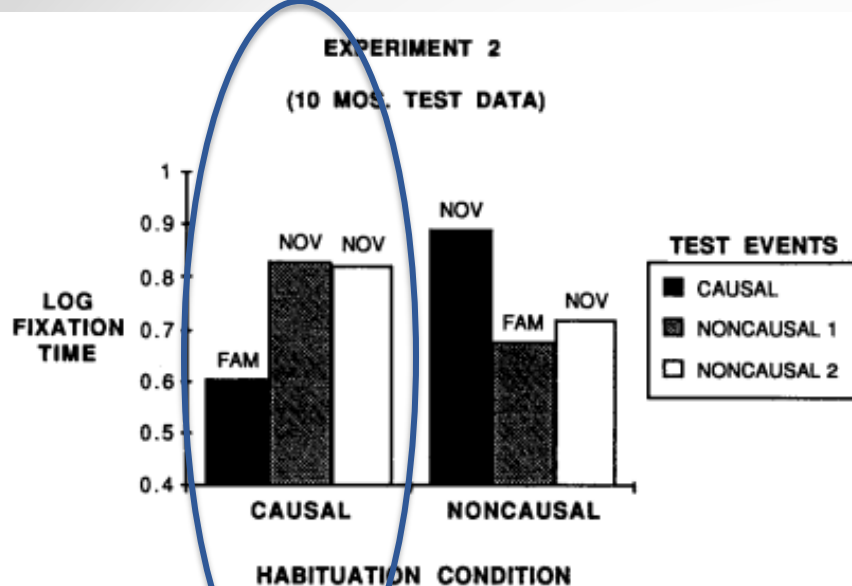- CAUSAL
- NONCAUSAL 1
- NONCAUSAL 2

HABITUATION CONDITION

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.

Test trial data in log (base 10) looking time for 10 month olds habituating to the direct launching causal event.
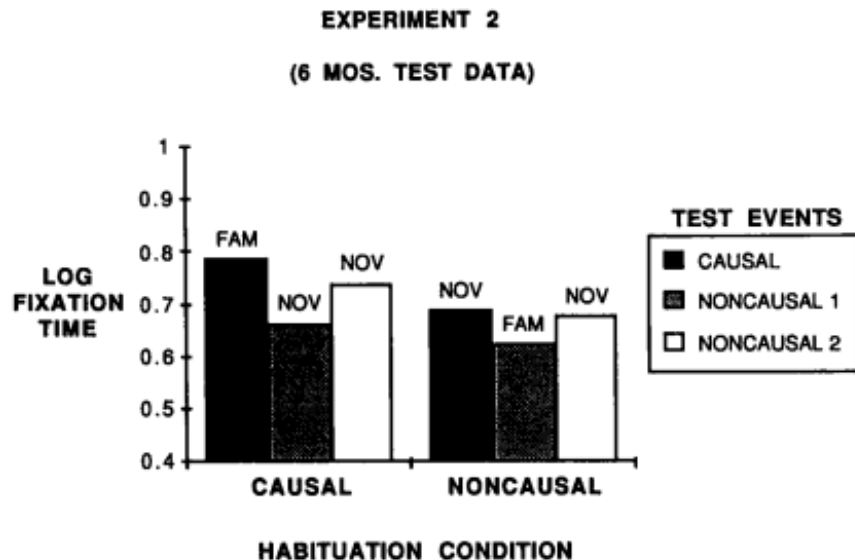
EXPERIMENT 2

(10 MOS. TEST DATA)

TEST EVENTS
- ■ CAUSAL
- ▨ NONCAUSAL 1
- □ NONCAUSAL 2

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.

EXPERIMENT 2

(6 MOS. TEST DATA)

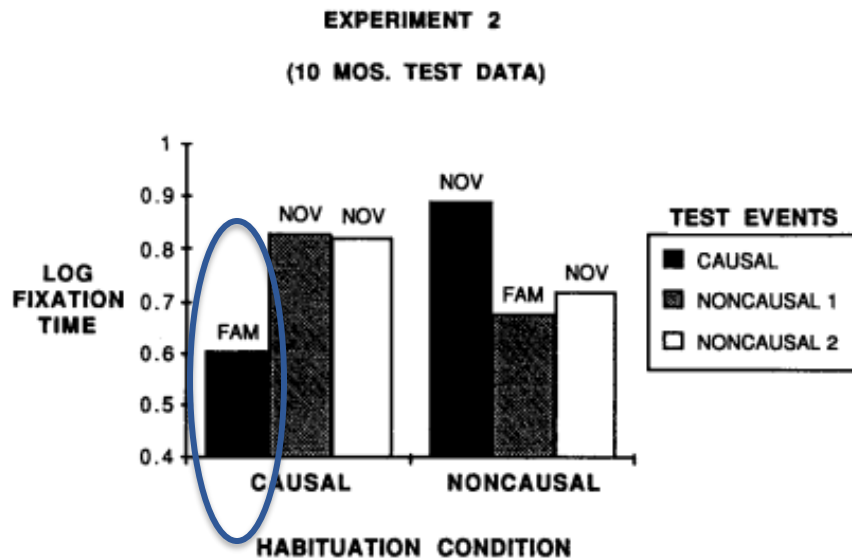**TEST EVENTS**
- ■ CAUSAL
- ▨ NONCAUSAL 1
- □ NONCAUSAL 2

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.
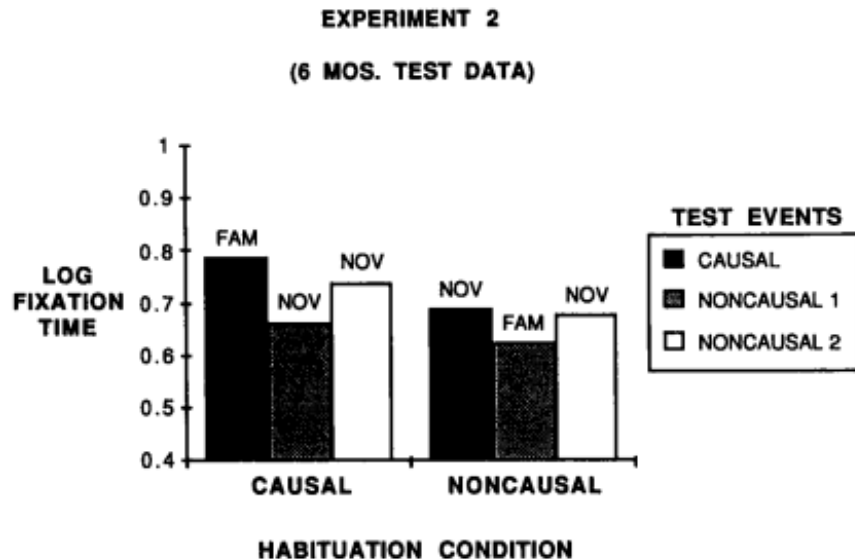
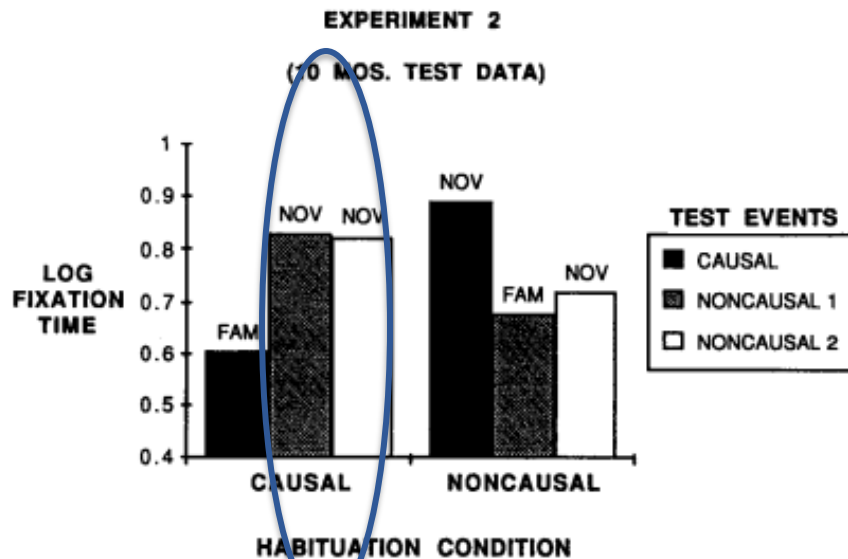The familiar causal event shows a low looking time.

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.
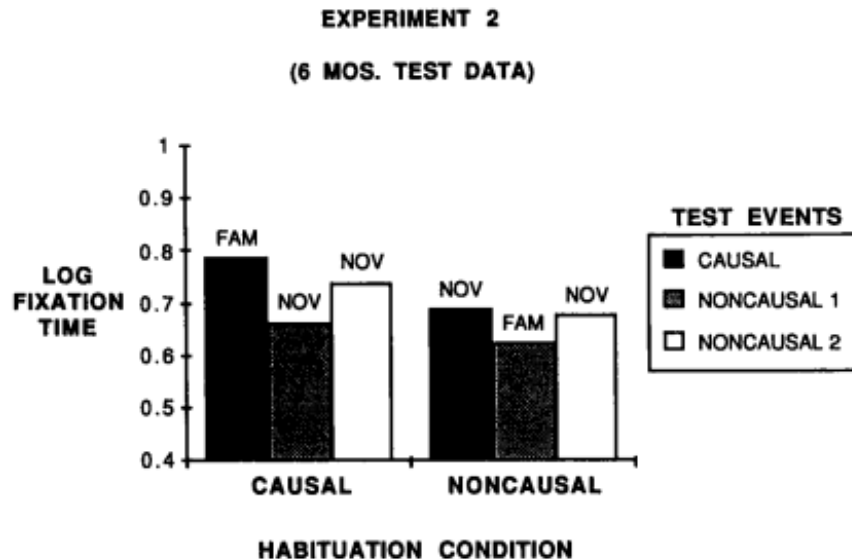

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.

Both novel non-causal events (temporal delay & spatial gap) show long looking times.
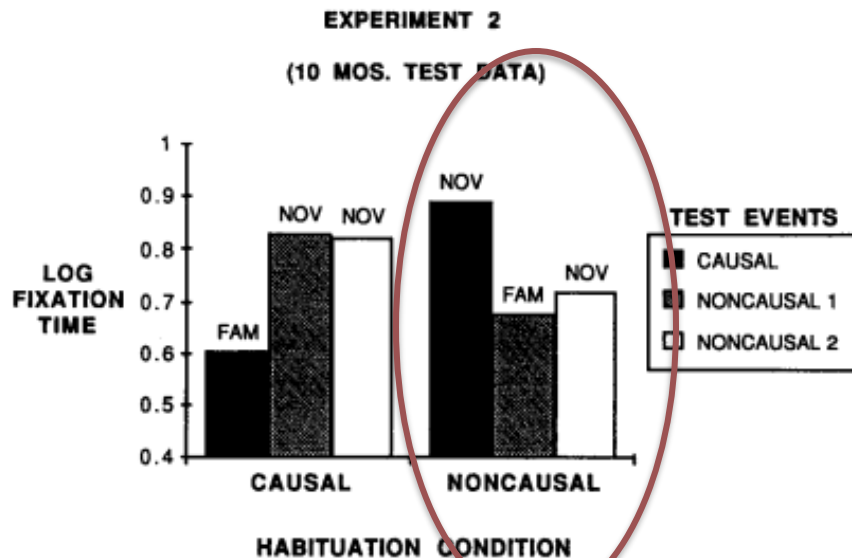They discriminate between causal and non-causal events.

EXPERIMENT 2

(10 MOS. TEST DATA)

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.
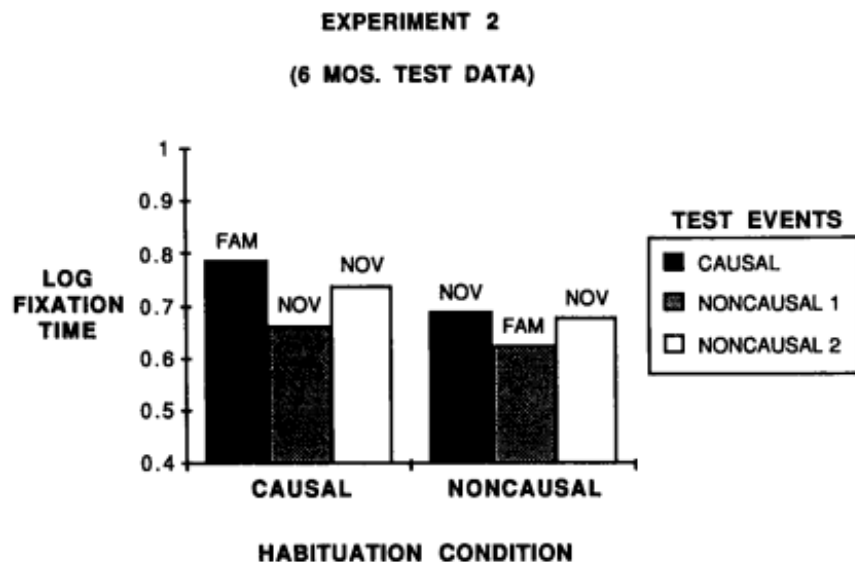

EXPERIMENT 2

(6 MOS. TEST DATA)

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.

Test trial data for 10 month olds habituating to one of the non-causal events
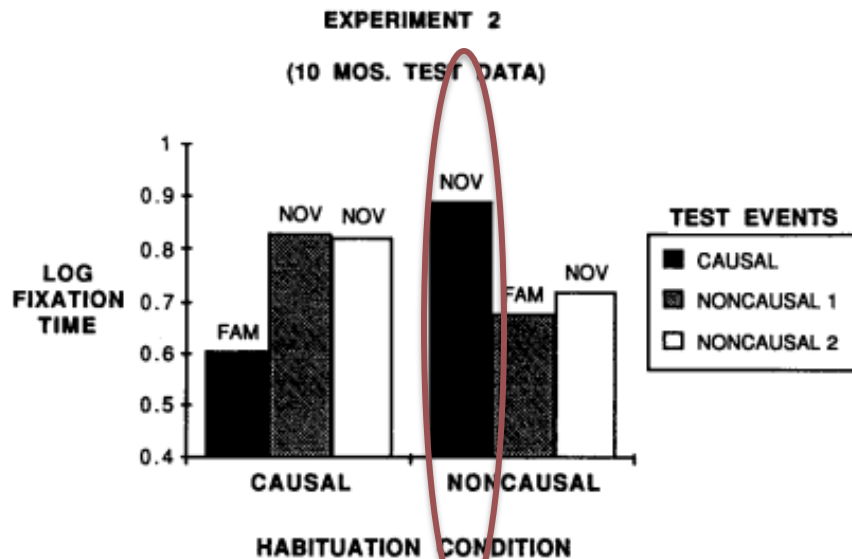
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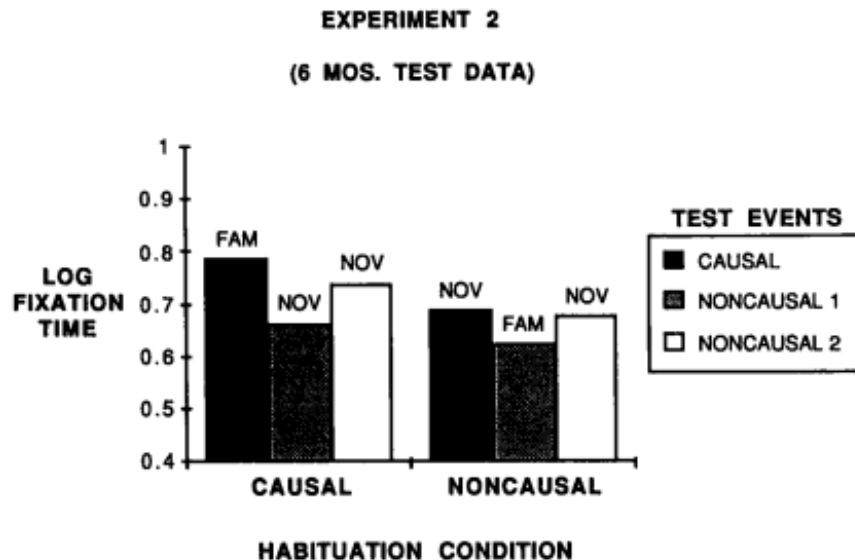

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.
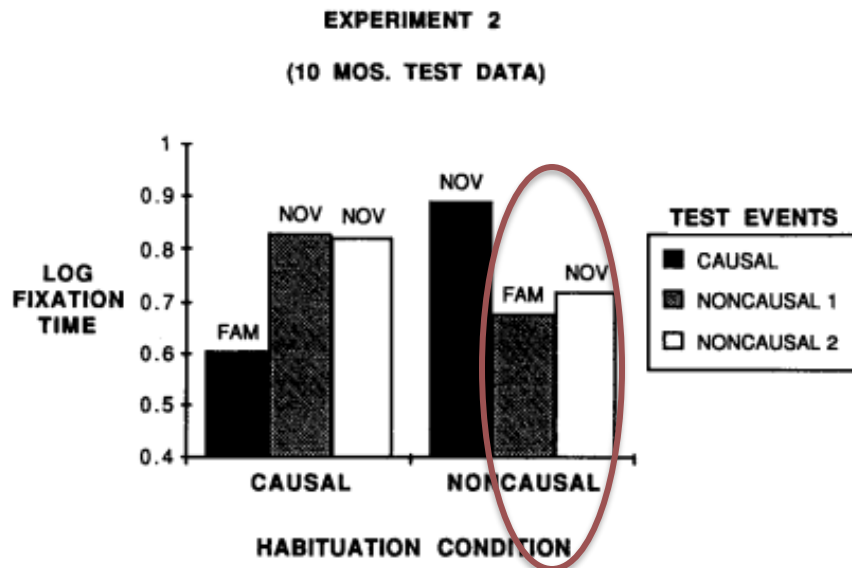
Long looking times for the novel causal event.

EXPERIMENT 2

(10 MOS. TEST DATA)

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.

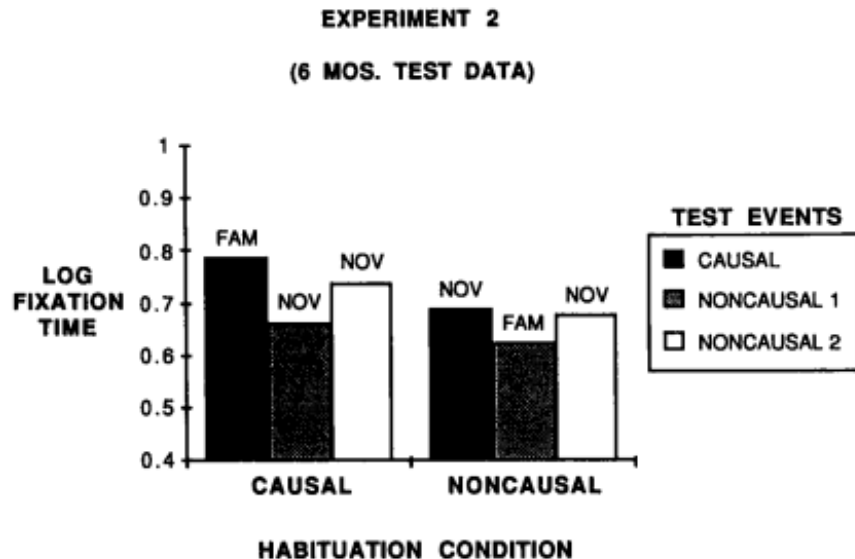**EXPERIMENT 2**

(6 MOS. TEST DATA)

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.

Equally short looking times for the familiar non-causal they habituated to and the novel non-causal. They generalized their habituation across spatial and temporal features because of the shared non-causal classification.
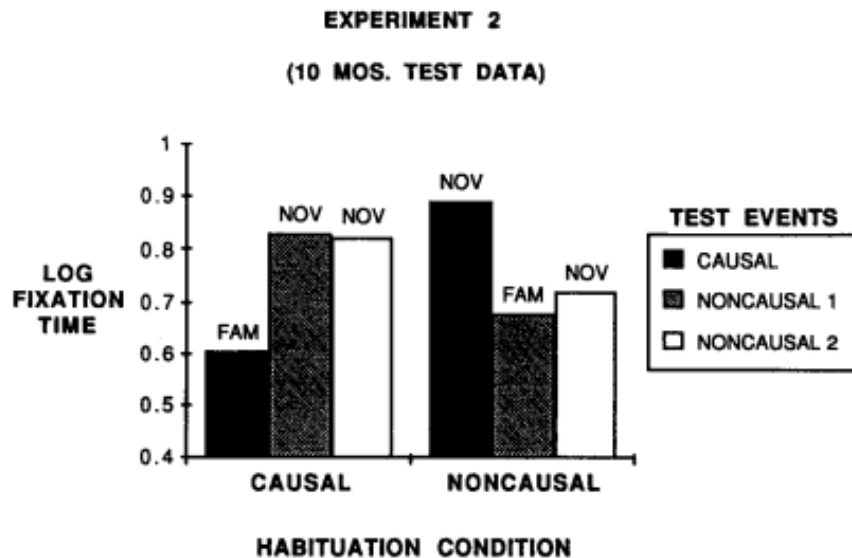
EXPERIMENT 2

(10 MOS. TEST DATA)

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.
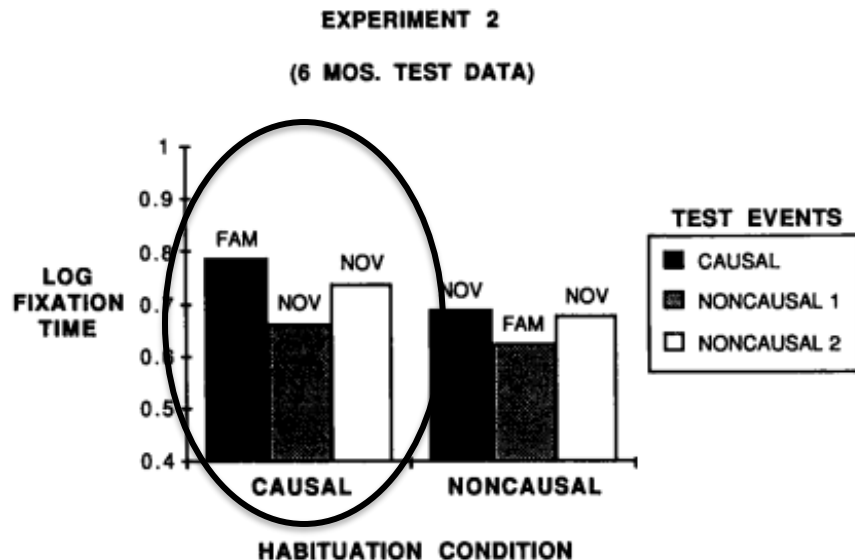
EXPERIMENT 2

(6 MOS. TEST DATA)

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.

6 month olds habituating to the causal events, unlike the 10 month olds do not show a novelty preference to the novel non-causal events at test. Perhaps because the same complex objects are involved, and they can't get passed a focus on them.

EXPERIMENT 2

(10 MOS. TEST DATA)

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.

EXPERIMENT 2

(6 MOS. TEST DATA)

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.

The familiar test trial is actually even longer than the two novel test trials.

EXPERIMENT 2

(10 MOS. TEST DATA)

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.

EXPERIMENT 2

(6 MOS. TEST DATA)

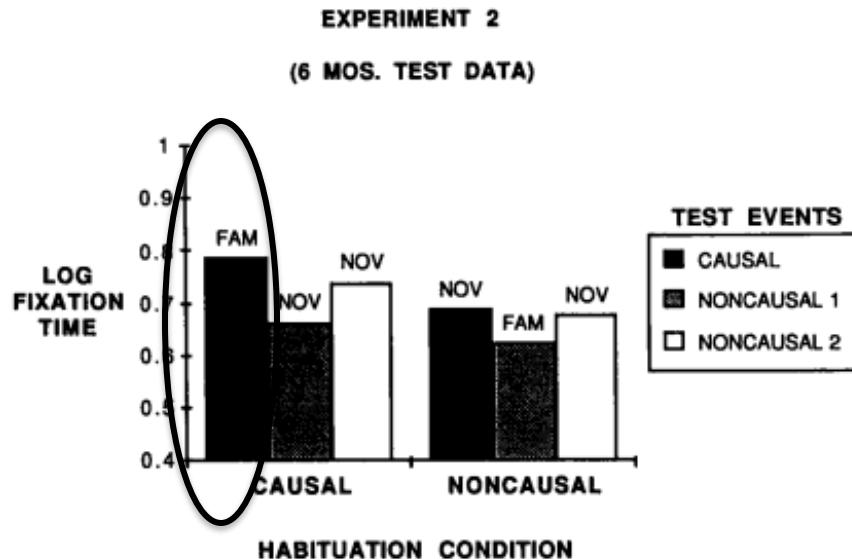**Figure 4.** Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.

The familiar test trial is actually even longer than the two novel test trials.
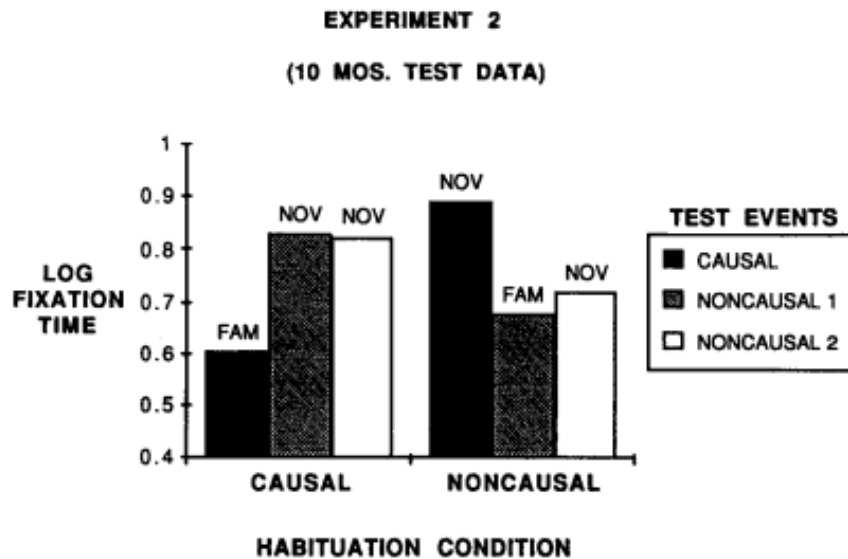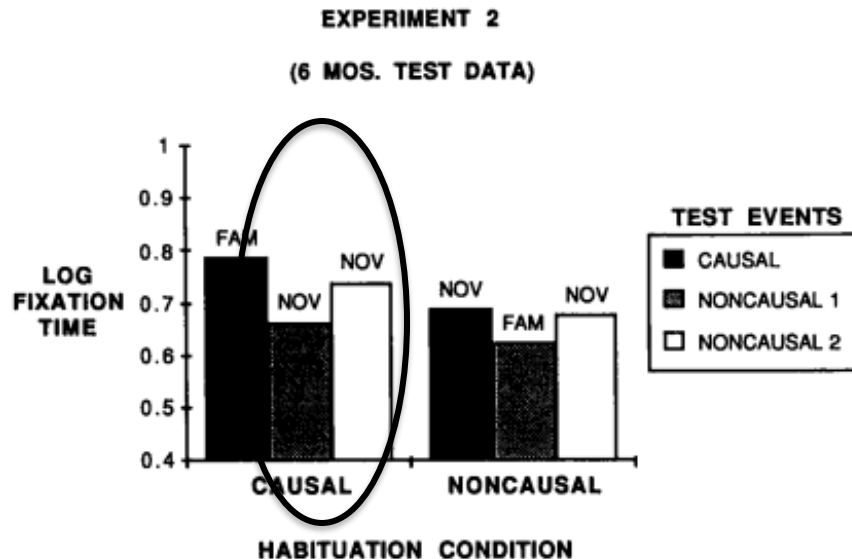
EXPERIMENT 2

(10 MOS. TEST DATA)

TEST EVENTS
■ CAUSAL
▨ NONCAUSAL 1
□ NONCAUSAL 2

Figure 3. Log 10 fixation times of 10-month-old infants to familiar and novel launching events in Experiment 2.

EXPERIMENT 2

(6 MOS. TEST DATA)

TEST EVENTS
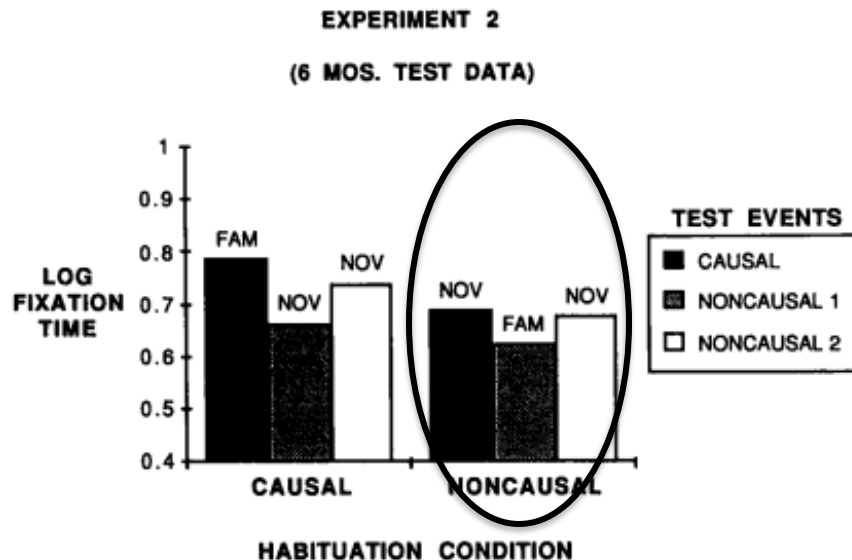■ CAUSAL
▨ NONCAUSAL 1
□ NONCAUSAL 2

Figure 4. Log 10 fixation times of 6-month-old infants to familiar and novel launching events in Experiment 2.

For the 6 month-olds who habituated to a non-causal event, they looked no longer to the novel causal than the novel non causal, suggesting they are not treating the events in terms of their causal classification.

Response from Constructivism

- Leslie (1984) used the same simple objects on every trial

6 months old treated events as causal or non-causal

- Oakes & Cohen (1990) used more complex objects. Same complex objects on every trial

6 month olds responded based on spatial-temporal features

10 month olds treated events as causal or non-causal

- Cohen & Oakes (1993) used complex objects that varied on every trial

Will they be overloaded and revert to spatial-temporal responding?

Cohen & Oakes 1993

- Complex objects that varied on every trial. Same kind of launching events as Oakes & Cohen (1990)

Figure 1. Infant mean fixation times (and standard errors) in Experiment 1 to the causal, delayed, and no-collision test events as a function of type of event received during habituation. (Note that infants habituated to delayed or no-collision events dishabituated as much or more to the novel noncausal event than to the causal event.)

Cohen & Oakes 1993

- Complex objects that varied on every trial. Same kind of launching events as Oakes & Cohen (1990)

- Habituate to causal event

- Do not show much of a novelty preference to either non-causal

Experiment 1

Test Events
- causal
- delayed
- no collision

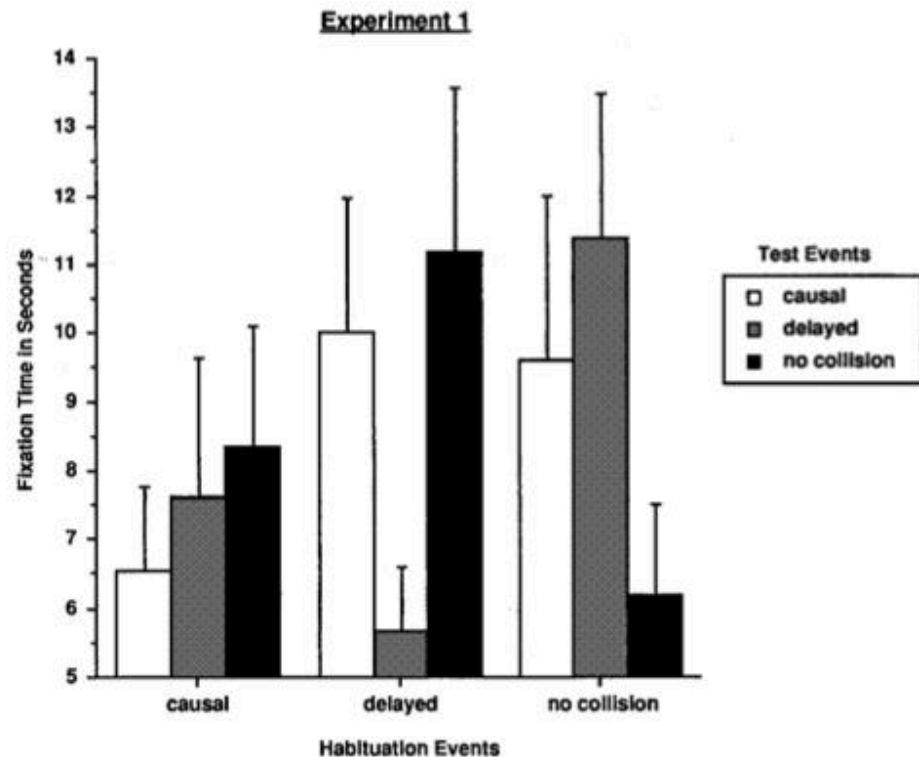Habituation Events: causal, delayed, no collision

Figure 1. Infant mean fixation times (and standard errors) in Experiment 1 to the causal, delayed, and no-collision test events as a function of type of event received during habituation. (Note that infants habituated to delayed or no-collision events dishabituated as much or more to the novel noncausal event than to the causal event.)

Cohen & Oakes 1993

- Complex objects that varied on every trial. Same kind of launching events as Oakes & Cohen (1990)

- Habituate to temporal delay
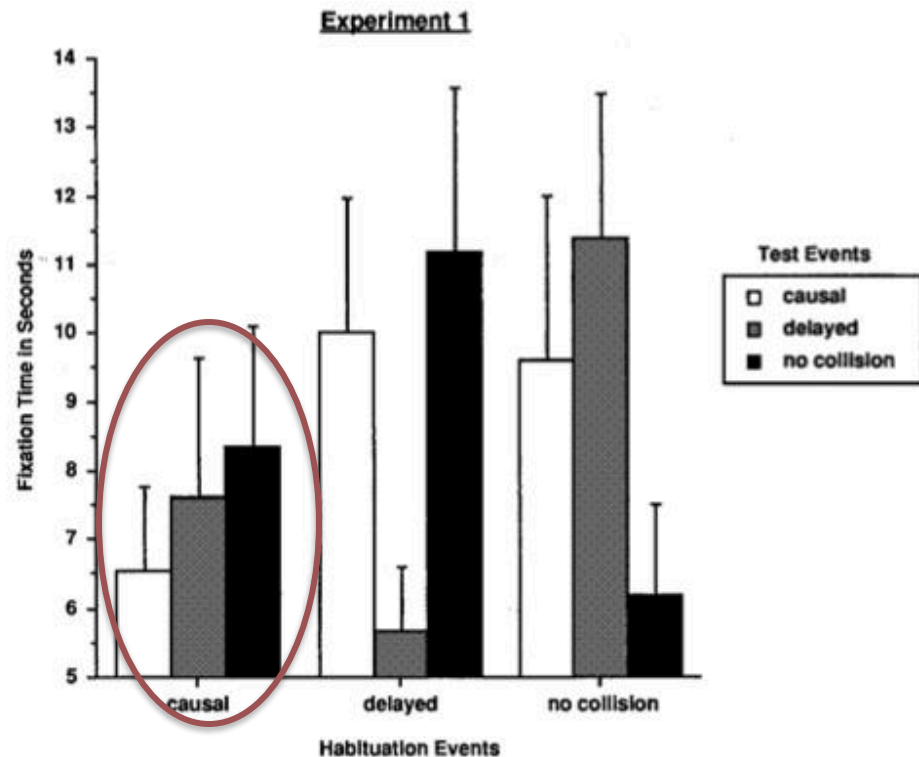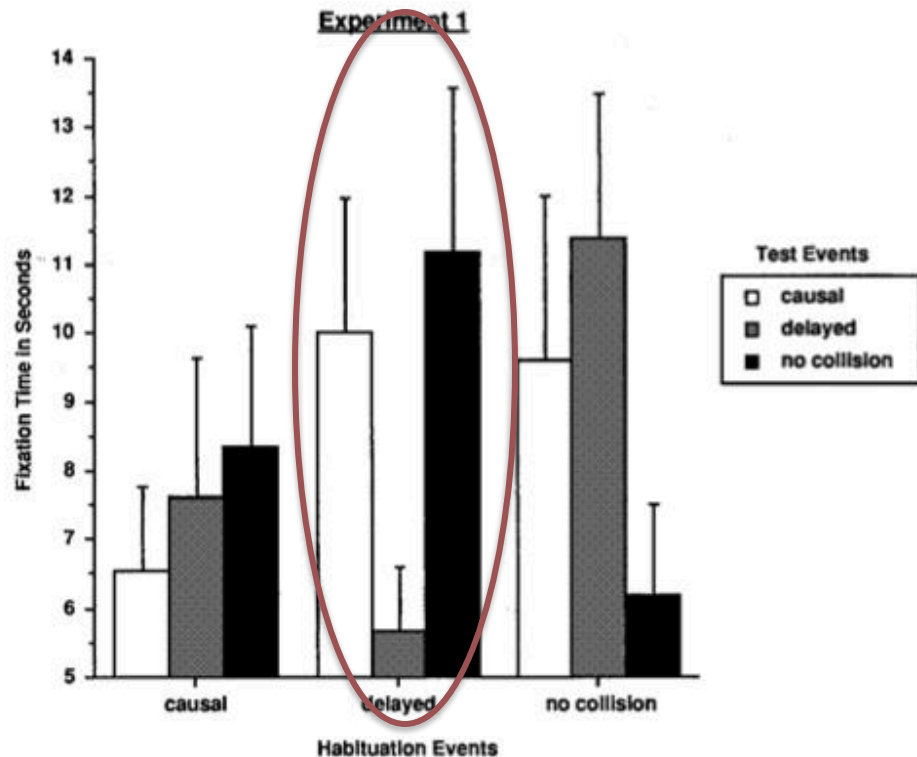- Shows equal novelty preference to causal and spatial gap

Figure 1. Infant mean fixation times (and standard errors) in Experiment 1 to the causal, delayed, and no-collision test events as a function of type of event received during habituation. (Note that infants habituated to delayed or no-collision events dishabituated as much or more to the novel noncausal event than to the causal event.)

Cohen & Oakes 1993

- Complex objects that varied on every trial. Same kind of launching events as Oakes & Cohen (1990)

- Habituate to spatial gap
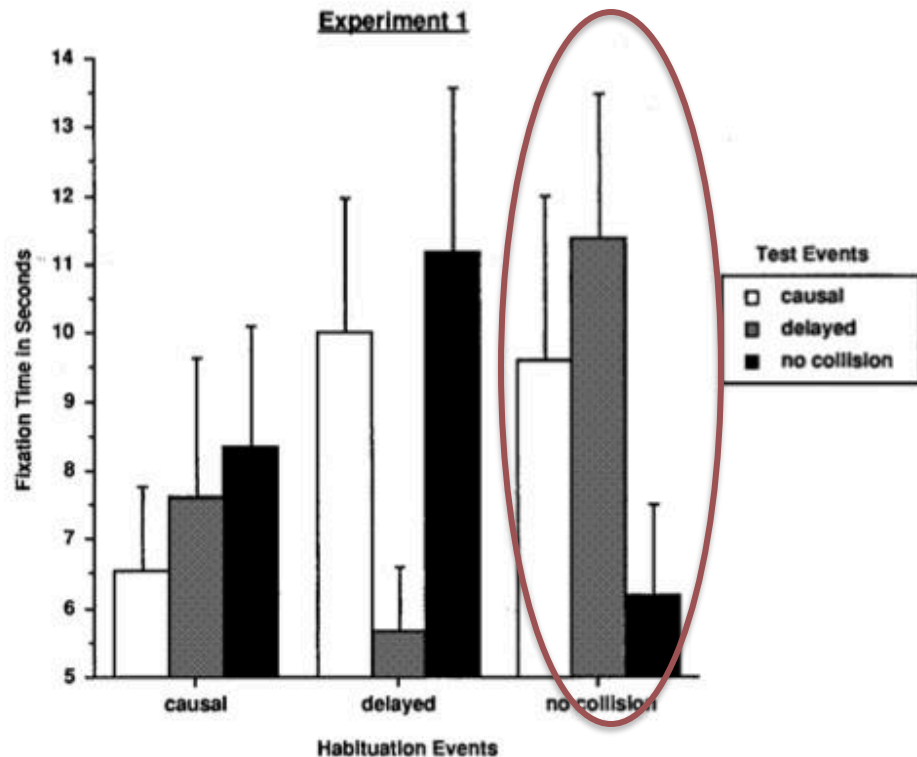- Shows equal novelty preference to causal and temporal delay

Figure 1. Infant mean fixation times (and standard errors) in Experiment I to the causal, delayed, and no-collision test events as a function of type of event received during habituation. (Note that infants habituated to delayed or no-collision events dishabituated as much or more to the novel noncausal event than to the causal event.)

Response from Constructivism

(see Cohen & Cashon, 2006)

- How does an innate modular account explain the progressions? Why would object complexity affect whether the causal module is employed?

- Oakes & Cohen (1990)

6 month-olds perceive events with simple objects causally, but not events with complex objects

10 month olds perceive events with complex objects causally, when all event exemplars had the same few objects

- Cohen & Oakes (1993)

10 Month-olds fall back to the simpler mode of perceiving events as mere collections of spatial and temporal features. when the complex objects vary across examples of events.

Summary of Infant Relational Learning

- Infants can learn relations from three months of age

- Same/Different learning and causal learning follow constructivist patterns where relational representations are built on top of representations of objects

- In both cases, at young ages, relational representations can be formed, but increased cognitive focus on the objects themselves can disrupt relational processing

- This is the same pattern for learning the statistics among the features in Younger and Cohen research from last lecture.