Learning Non-Physical Properties of Objects from Sequence Statistics

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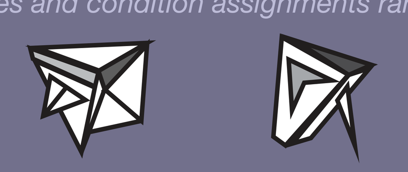
hypotheses

The structure of experience affords many kinds of inferences about the world. **By attending to the structure of events, we can identify non-physical properties of objects in bottom-up fashion from streams of visual experience.** Objects obtain such properties by their modulatory power over events: objects can predict the occurence of certain events, or **contingencies among events, given the object**. These latter allow learners to form structured and causal property representations. These properties can then be used to induce novel object categories (Gopnik & Sobel 2001; Kemp et al 2010).

exp. 1

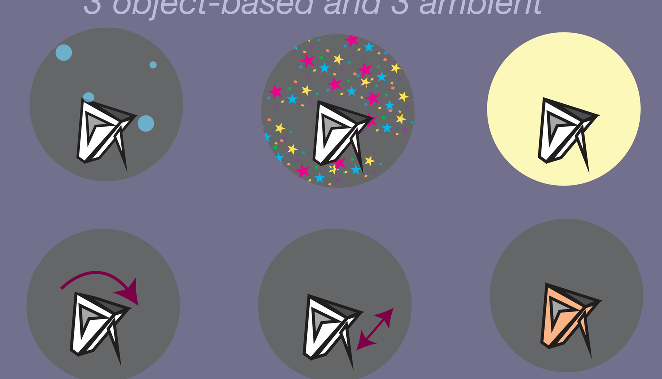
stimuli: objects

names and condition assignments randomized



stimuli: events

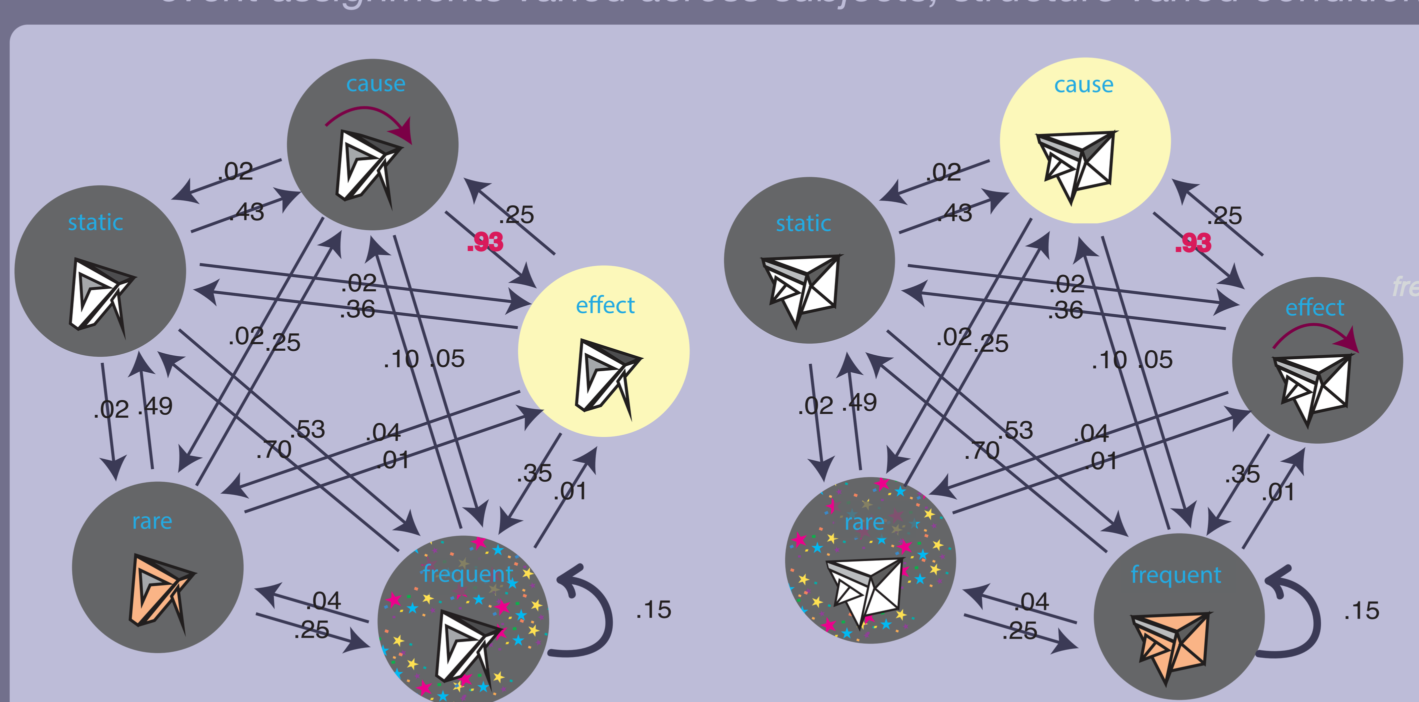
3 object-based and 3 ambient



Object kinds differ in terms of two types of statistics: identity of the rare event, and direction of contingency between two other events.

conditions: transition probabilities

event assignments varied across subjects; structure varied conditional on object identity

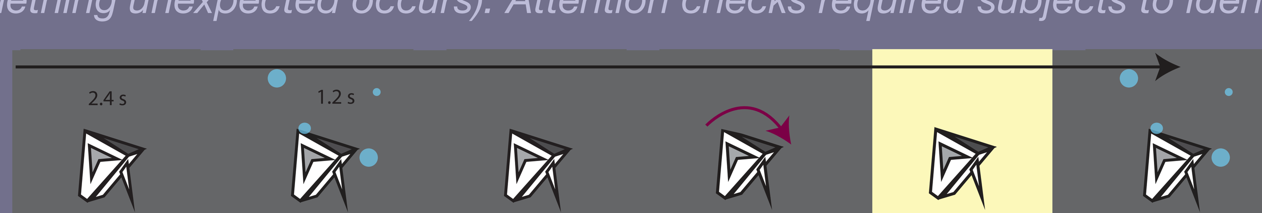


	static	effect	frequent	cause	rare
static	0.00	0.02	0.53	0.43	0.02
effect	0.36	0.00	0.35	0.25	0.04
frequent	0.70	0.01	0.15	0.10	0.04
cause	0.00	0.92	0.07	0.00	0.01
rare	0.49	0.01	0.25	0.25	0.00

Relative frequencies of cause and effect events matched across objects, and equated within object

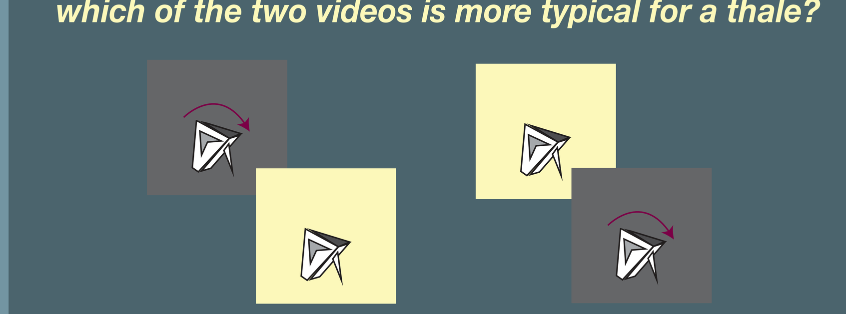
sequence presentation

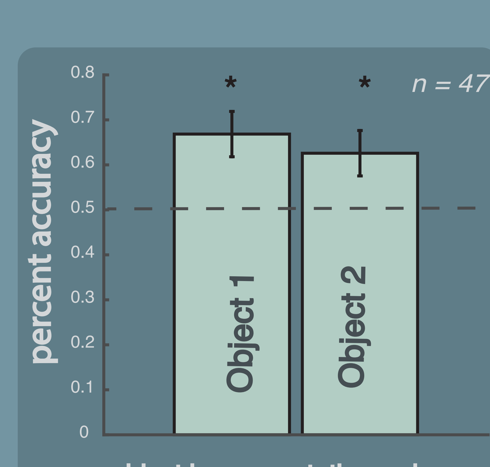
250 trials/object; subjects told to pay close attention and try to predict what will happen next (press a key when something unexpected occurs). Attention checks required subjects to identify the rare event.



familiarity forced choice test

strong transitions compared to weaker transitions to test discrimination of relative contingency strength





Correlation between objects: r(45) = -0.01

Mean percent accuracy = 0.65 with t(46) = 4.19, p < 0.0001

sentence acceptability test

tests explicit access and conceptual interpretation

ordered: effect to cause

After thales tilt, the light tends to flash

1 (definitely false) — 2 — 3 (unsure) — 4 — 5 (definitely true)

ordered: cause to effect

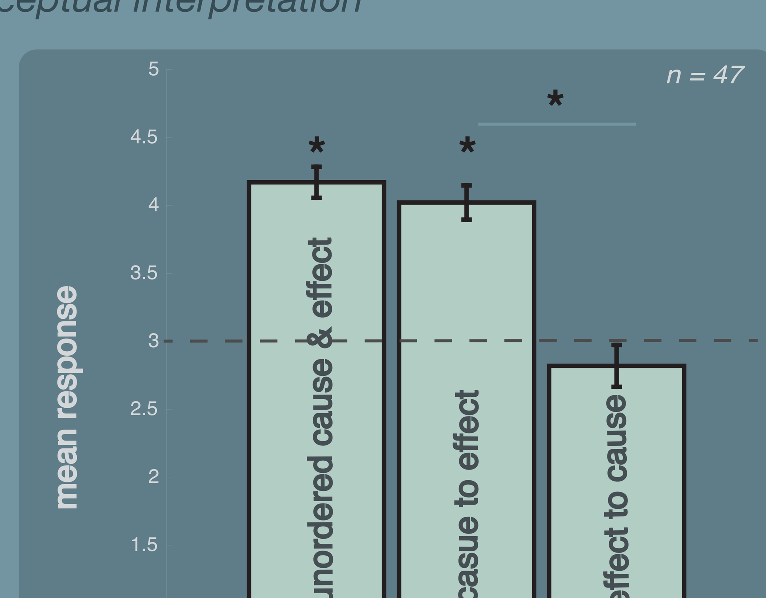
After the light flashes, thales tend to tilt.

1 (definitely false) — 2 — 3 (unsure) — 4 — 5 (definitely true)

unordered: cause & effect

Light flashing around thales and their tilting are strongly related.

1 (definitely false) — 2 — 3 (unsure) — 4 — 5 (definitely true)



1. Subjects can identify which events are contingent on each other from a continuous stream of events with minimal instruction.
2. They can bind different contingency structures to distinct objects.
3. These represenations are explicitly available.
4. And they are naturally directional (i.e., structured).

causal acceptability

effect to cause

only in subjects who were accurate on non-causal questions (n =25)

Thales tilting causes the light to flash.

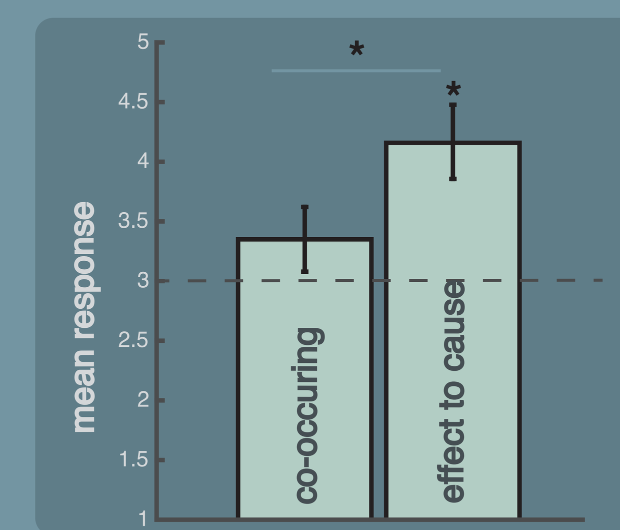
1 (definitely false) — 2 — 3 (unsure) — 4 — 5 (definitely true)

co-occurring (frequent)

only for object where frequent event was ambient, and for subjects who were accurate on non-causal contingency and frequency judgments (n = 20)

Thales cause confetti to appear.

1 (definitely false) — 2 — 3 (unsure) — 4 — 5 (definitely true)



5. Subjects conceptually distinguish event co-occurrence vs. object-dependent contingency structure.

exp. 2

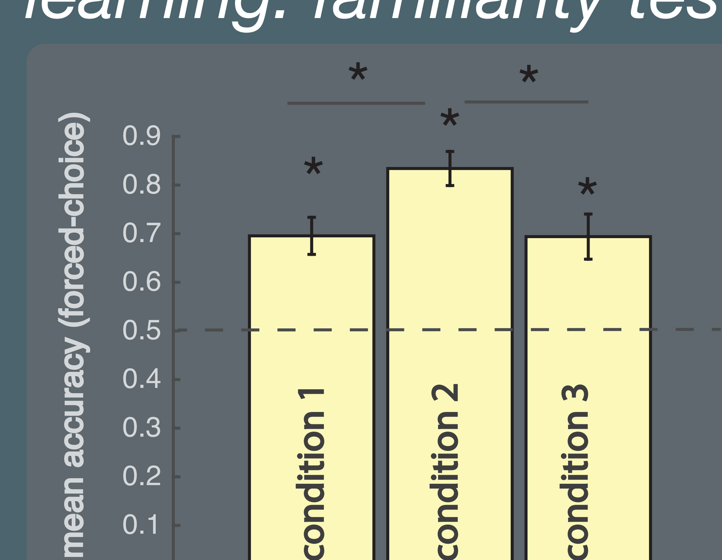
stimuli: objects

names and condition assignments randomized

Object kinds are based on either 1) direction of the contingency (reversal); 2) nature of the effect; 3) which events are related vs. unrelated (rotation), varied between subjects

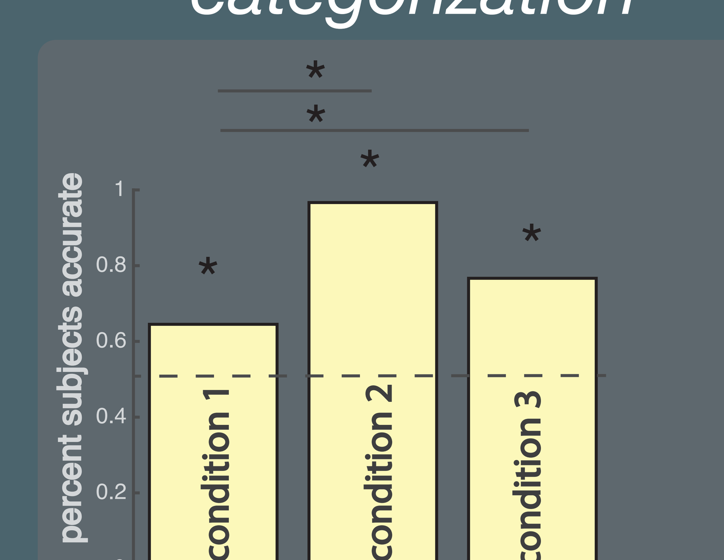
category/condition structure: example

learning: familiarity test



n = 90, 30 / condition, between-subject

categorization



n = 90, 30 / condition, between-subject

assessed with a binomial test for number subjects succeeding where chance = 50%

Similar results when excluding inaccurate subjects

6. Property learning is generalizable: subjects can classify new objects with different physical shapes but similar event structures.
7. Learning is equally difficult when relations reverse vs. rotate among the same set of events.
8. However, reversals of relations are more challenging to generalize.

conclusions

Human adults can learn novel categories of objects on the basis of similar contingencies among the a set of sensory events, in a scenario when the learning is bottom-up and minimally instructed. They can notice these regularities in a stream of events, bind them to distinct object kinds, and extend those properties to novel exemplars for categorization. **We suggest that this hiearchical form of associative learning over event sequences can allow one to build causal and functional object categories more generally.**

Gopnik, A., & Sobel, D. M. (2000). Detecting blickets: how young children use information about novel causal powers in categorization and induction. Child Development, 71(5), 1205–1222.

Kemp, C., Tenenbaum, J. B., Niyogi, S., & Griffiths, T. L. (2010). A probabilistic model of theory formation. Cognition, 114(2), 165–96.

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