Cognition

PSYC 2040

W6: Language

what makes something a language?

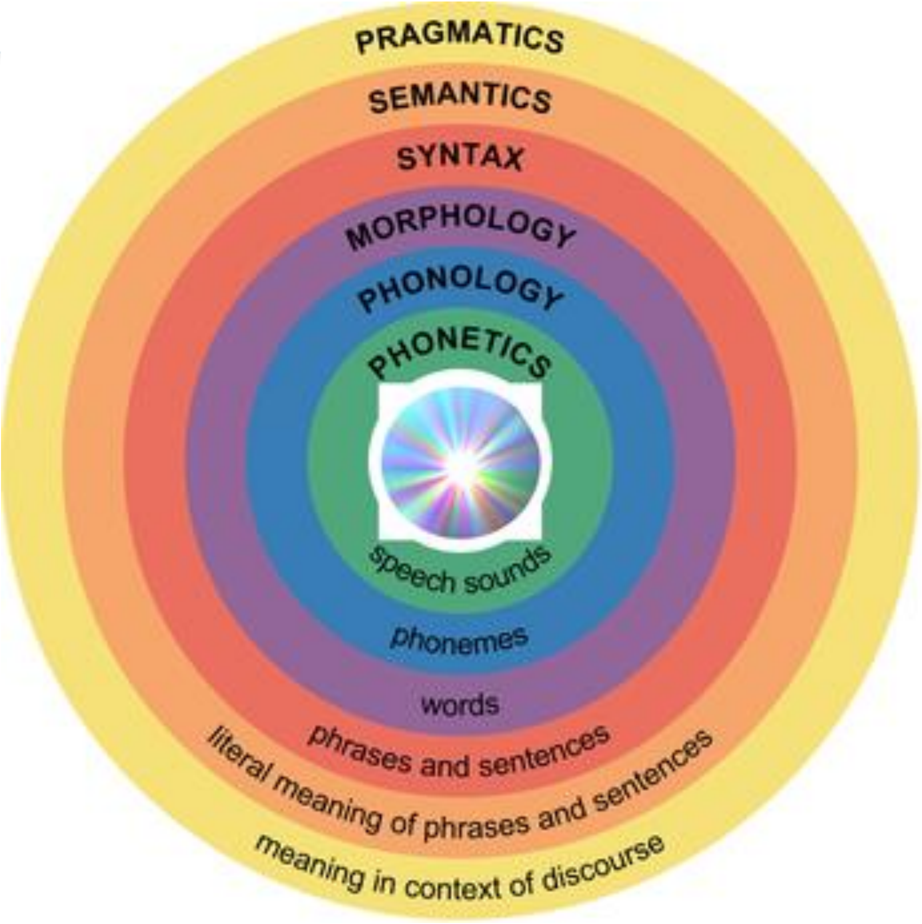
traditional properties of human language

discreteness	• individual units combine to form larger units
grammar	• a set of rules that govern how units are combined
displacement	• being able to use language to talk about events in the past and future
reflexivity	• talk about language itself
arbitrariness	• no strong relationship between form and meaning
productivity	• we invent new words, can create infinite new ideas/concepts
cultural transmission	• we learn the language of the culture we are embedded in

https://www.youtube.com/watch?v=_1FY5kL_zXU

traditional components of human language

- phonetics: speech sounds
- phonology: relationship between letters and sounds (phonemes)
- morphology: smallest meaningful units in speech and writing (words / suffixes / prefixes)
- syntax: set of rules that govern a given language (grammar)
- semantics: the way language conveys meaning
- pragmatics: relationships between context and language use



learning

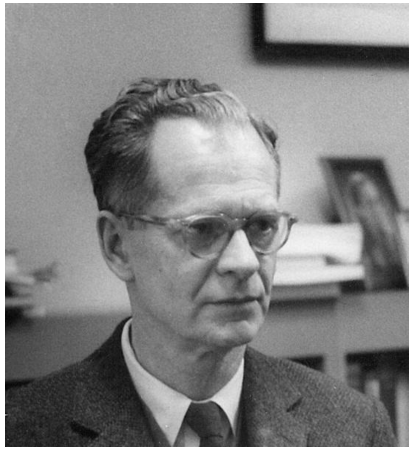
- how do you think you learned language?

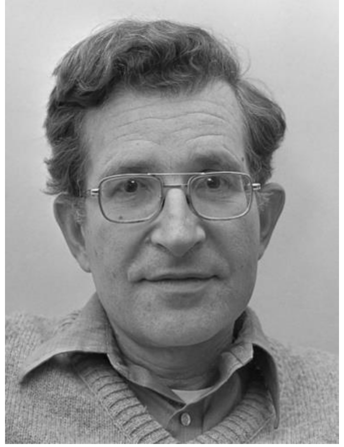
mechanisms of language learning

- statistical regularities / co-occurrences
- prediction
- form to meaning mappings
- social inference

Skinner vs. Chomsky

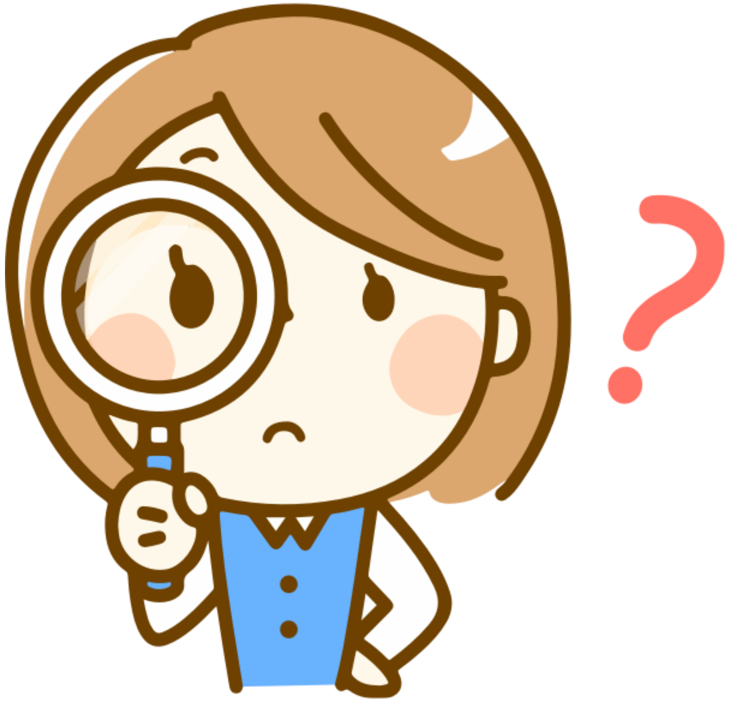
- Skinner: language was a learned behavior (1957)
- Noam Chomsky: language is a result of innate capacities (1959)





testing the claims

- how can we test the merit of these claims?
- some possible methods (not exhaustive):
  - find natural exceptions
  - teach language to an animal
  - find neurological exceptions/examples
  - examine language learning in infants
  - create an artificial language model



some early evidence

- Genie the feral child
- language "universals"
- neurological evidence
    - critical period
    - brain areas (Broca/Wernicke)
    - language & thought
- Nim Chimpsky

Language and thought are not the same thing: evidence from neuroimaging and neurological patients

Evelina Fedorenko[1,2,3] and Rosemary Varley[4]

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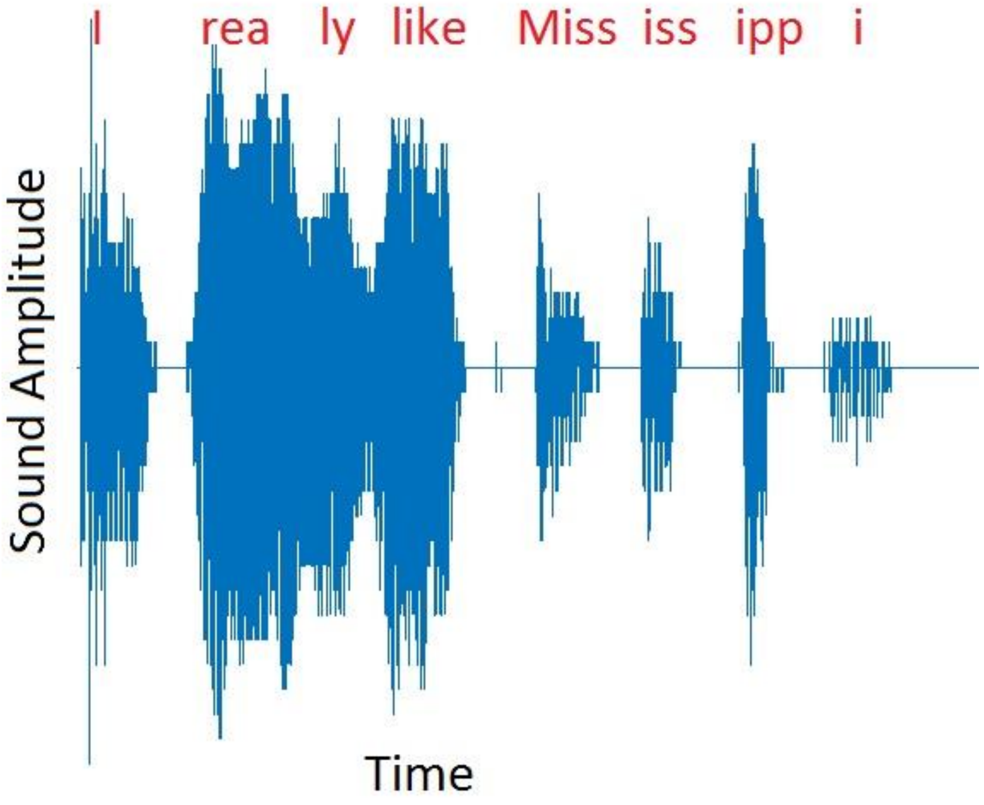
Abstract Go to: ▸

Is thought possible without language? Individuals with global aphasia, who have almost no ability to understand or produce language, provide a powerful opportunity to find out. Astonishingly, despite their near-total loss of language, these individuals are nonetheless able to add and subtract, solve logic problems, think about another person's thoughts, appreciate music, and successfully navigate their environments. Further, neuroimaging studies show that healthy adults strongly engage the brain's language areas when they understand a sentence, but not when they perform other nonlinguistic tasks like arithmetic, storing information in working memory, inhibiting prepotent responses, or listening to music. Taken together, these two complementary lines of evidence provide a clear answer to the classic question: many aspects of thought engage distinct brain regions from, and do not depend on, language.

learning language

- human speech signals are extremely complex
- proposal: humans extract statistical regularities from natural language (and the environment)
- observing which sounds go together or co-occur gives us information about the sounds that make up specific words



activity debrief

- you heard a 2-minute sequence of sounds from an artificial language (close your eyes for this part)
- you were then played “words” or “non words” and had to judge whether you’d heard that word before or not

measuring chance performance

- 16 items were shown to you
- if you were guessing throughout, what would be the mean number of items you would guess correctly?

Saffran, Aslin & Newport (1996)

example speech heard:

prettybabyatepotatoprett
yfloweryummypotatobaby
lovemamapotatoisbrown

tracking co-occurring sounds:

prettybabyatepotatoprett
yfloweryummypotatobaby
lovemamapotatoisbrown

E1: words vs. novel items

words	part-words	novel items
pre-tty	tty-ba	re-ly
ba-by	by-a	ca-so
a-te	te-po	mo-du
po-ta-to	to-ba	si-ma

heard sounds (words and part-words)

never heard sounds (novel items)

E2: words vs. part-words

Saffran, Aslin & Newport (1996)

E1: words vs. novel items

example speech heard:

buladobigokudatibatadup
abigokubuladodatibabula
dobigokudatibatadupabig
okubuladodatiba

words

bu-la-do
bi-go-ku

part-words

do-bi-go
ti-ba-ta

novel items

re-ly
ca-so
mo-du
si-ma

heard
sounds

never heard
sounds

E2: words vs. part-words

Saffran, Aslin & Newport (1996)

- sounds played in the artificial language had different transition probabilities
  - “**words**”: pre – tty
  - “**part words**”: tty – ba
  - “**novel items**”: mo-du
- E1: testing words vs. novel items
- E2: more difficult test, comparing words (higher transition probabilities) and part-words (lower but non-zero transition probabilities)

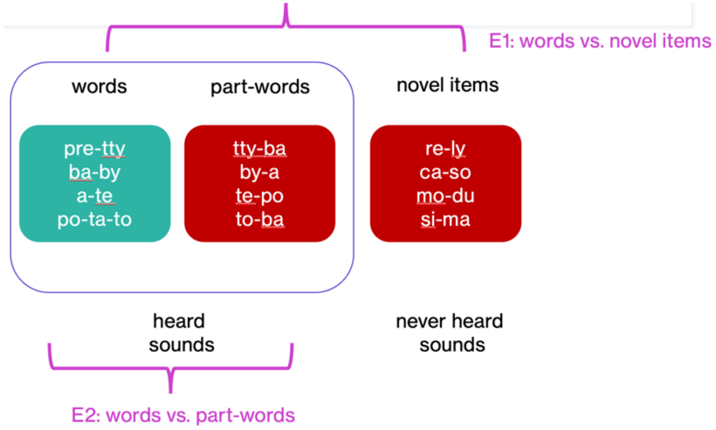


Table 1. Mean time spent listening to the familiar and novel stimuli for experiment 1 (words versus nonwords) and experiment 2 (words versus part-words) and significance tests comparing the listening times.

Experiment	Mean listening times (s)		Matched-pairs *t* test
	Familiar items	Novel items	
1	7.97 (SE = 0.41)	8.85 (SE = 0.45)	$t(23) = 2.3, P < 0.04$
2	6.77 (SE = 0.44)	7.60 (SE = 0.42)	$t(23) = 2.4, P < 0.03$

from artificial to natural language

- Pelucchi, Hay, & Saffran (2009) tested English-learning 8-month-old infants with Italian speech
- familiarization followed by test trials

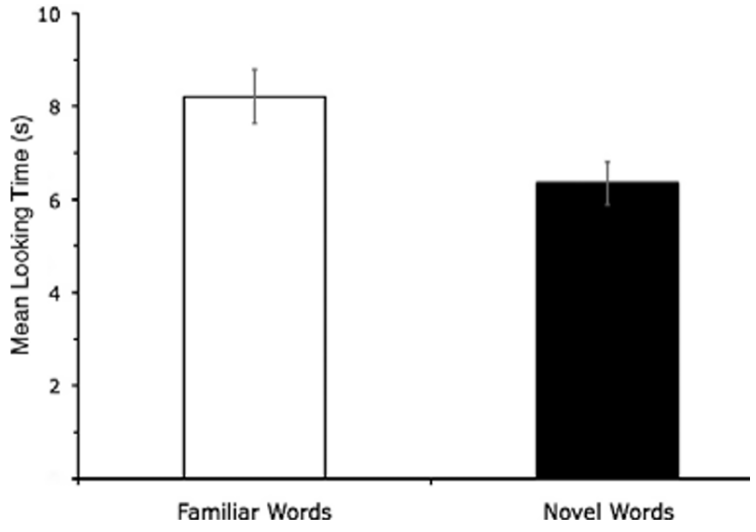


Figure 1. Results of Experiment 1: Mean looking times (±1 *SE*) to familiar words and novel words.

statistical learning in animals

Segmentation of the speech stream in a non-human primate: statistical learning in cotton-top tamarins

Marc D Hauser[a], Elissa L Newport[b], Richard N Aslin[b]

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Abstract

Previous work has shown that human adults, children, and infants can rapidly compute sequential statistics from a stream of speech and then use these statistics to determine which syllable sequences form potential words. In the present paper we ask whether this ability reflects a mechanism unique to humans, or might be used by other species as well, to acquire serially organized patterns. In a series of four experimental conditions, we exposed a New World monkey, the cotton-top tamarin (*Saguinus oedipus*), to the same speech streams used by Saffran, Aslin, and Newport (Science 274 (1996) 1926) with human infants, and then tested their learning using similar methods to those used with infants. Like humans, tamarins showed clear evidence of discriminating between sequences of syllables that differed only in the frequency or probability with which they occurred in the input streams. These results suggest that both humans and non-human primates possess mechanisms capable of computing these particular aspects of serial order. Future work must now show where humans' (adults and infants) and non-human primates' abilities in these tasks diverge.

Learning at a distance II. Statistical learning of non-adjacent dependencies in a non-human primate

Elissa L. Newport[a], Marc D. Hauser[b], Geertrui Spaepen[b], Richard N. Aslin[a]

Trends in Cognitive Sciences

Review

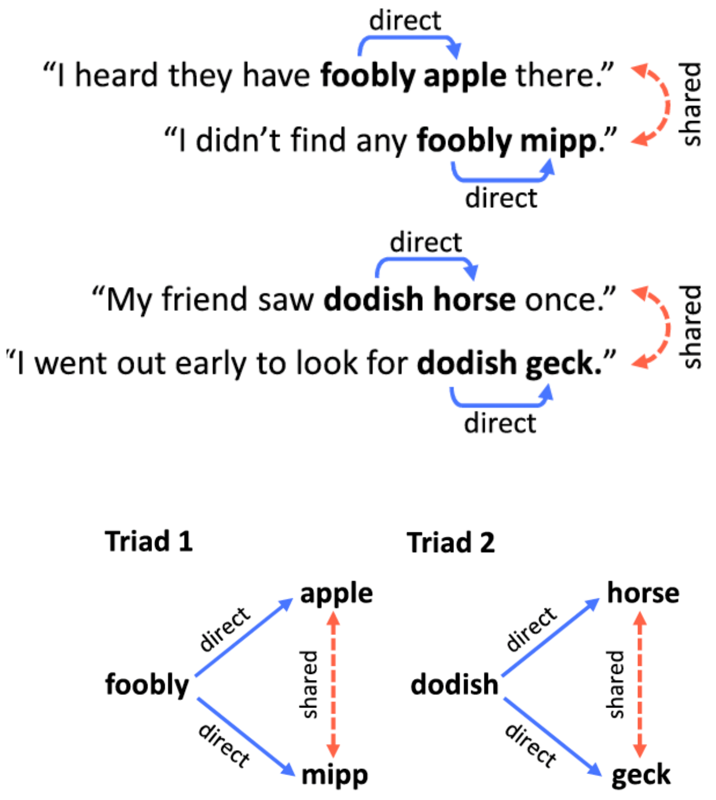
Constraints on Statistical Learning Across Species

Chiara Santolin[1,*] and Jenny R. Saffran[2]

Both human and nonhuman organisms are sensitive to statistical regularities in sensory inputs that support functions including communication, visual processing, and sequence learning. One of the issues faced by comparative research in this field is the lack of a comprehensive theory to explain the relevance of statistical learning across distinct ecological niches. In the current review we interpret cross-species research on statistical learning based on the perceptual and cognitive mechanisms that characterize the human and non-human models under investigation. Considering statistical learning as an essential part of the cognitive architecture of an animal will help to uncover the potential ecological functions of this powerful learning process.

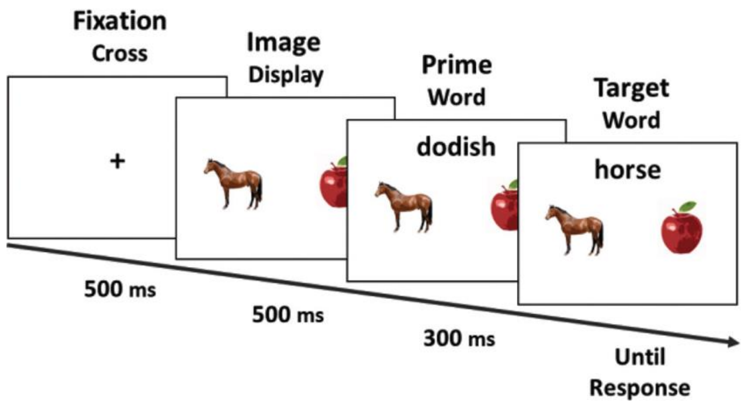
learning from co-occurrence

- meaning of words is learned based on which words it co-occurs with in natural language
  - “you shall know a word by the company it keeps” (Firth, 1957)
- co-occurrence can be defined in two ways:
  - direct: if words occur together in the same context (e.g., eat-food, sit-chair, etc.)
  - indirect/shared: if words occur in similar contexts (e.g., strawberries are red, apples are red)
- co-occurrences = statistical regularities and can extend to any type of input (tones, figures, words, etc.)



learning from co-occurrence

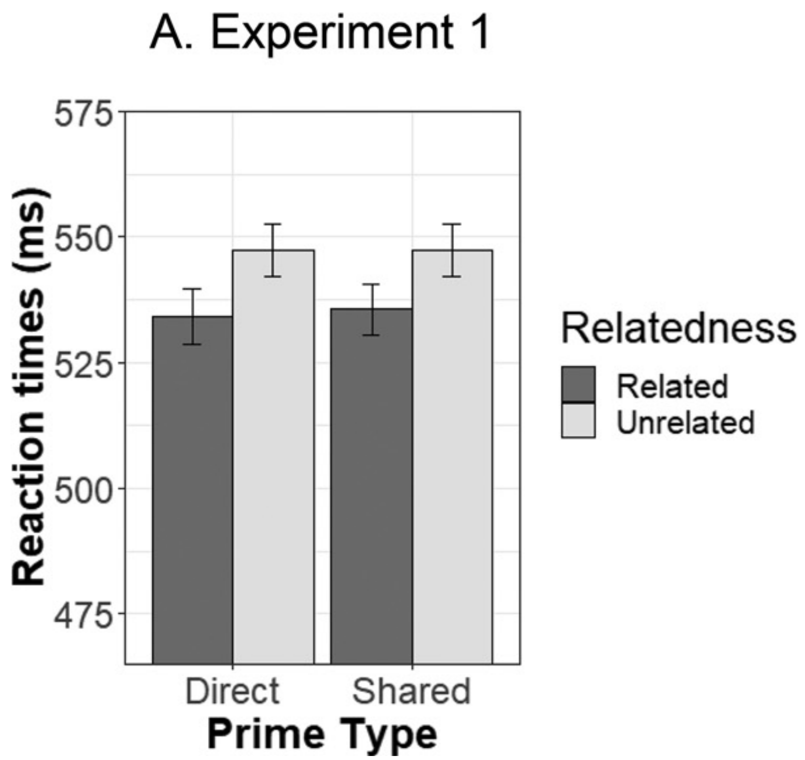
- Savic et al. (2022) had participants read sentences with novel and familiar words
  - novel words co-occurred with familiar words (direct or indirect)
- participants tested in a semantic priming experiment
- novel – familiar words were paired based on whether the pairs were related or unrelated and whether there was direct/indirect co-occurrence



	related	unrelated
direct	dodish-horse	foobly-horse
indirect/shared	geck-horse	mipp-horse

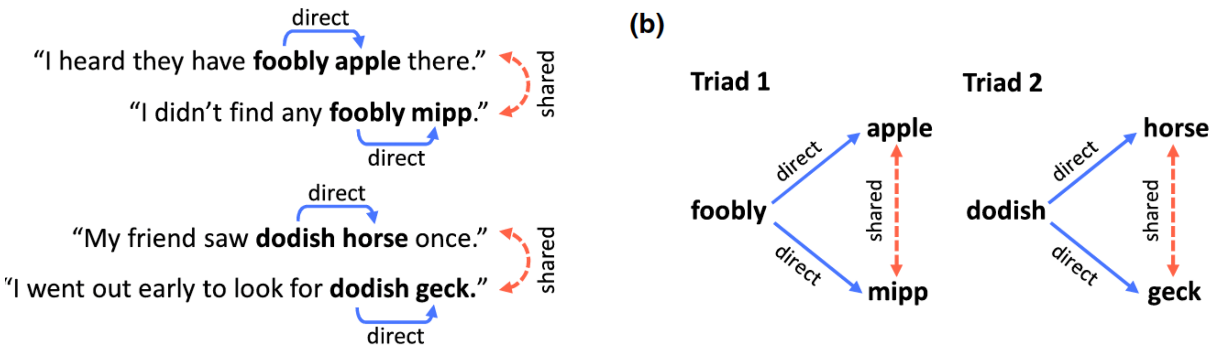
semantic priming and co-occurrences

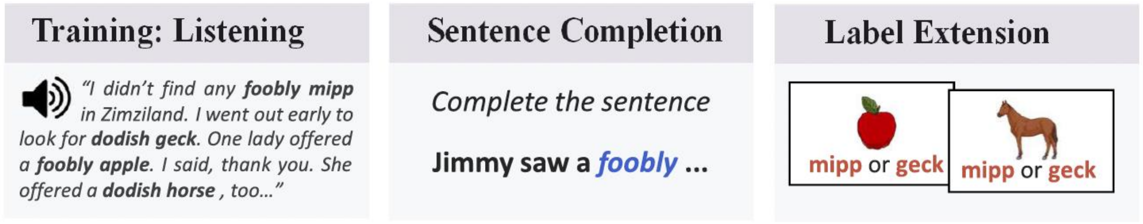
- reaction time to identify targets was faster when they were preceded by novel pseudowords/primes with which they directly co-occurred or shared co-occurrence in training
- pattern did not differ for direct and indirect co-occurrences
- inference: co-occurrences in natural language can drive semantic integration of new words



developmental evidence

- “silly stories” told by a character, “Jimmy,” who sometimes uses “silly words.”
- sentence completion and label extension task

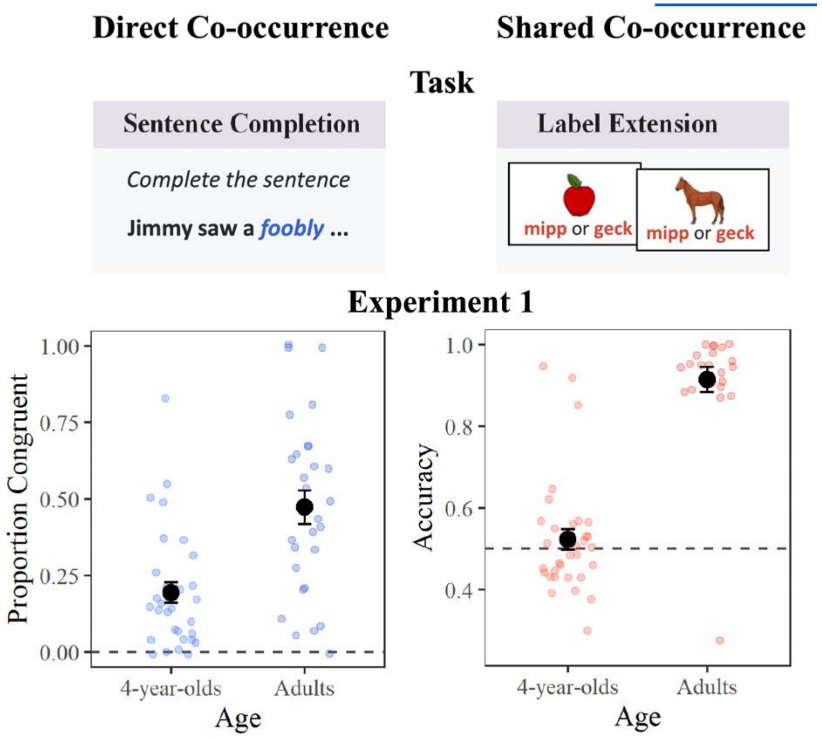




Savic et al. 2023

developmental evidence

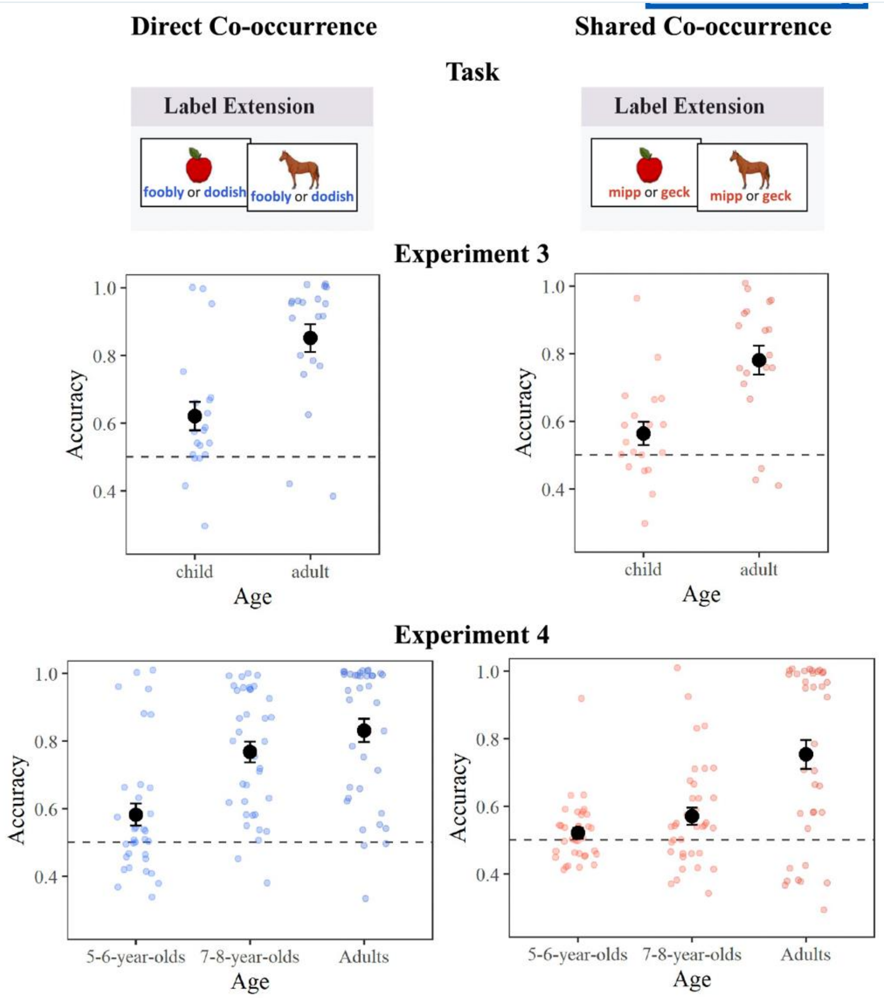
- children and adults form semantic links based on exposure to co-occurrence regularities
- differences in the formation of links based on shared co-occurrence



Savic et al. 2023

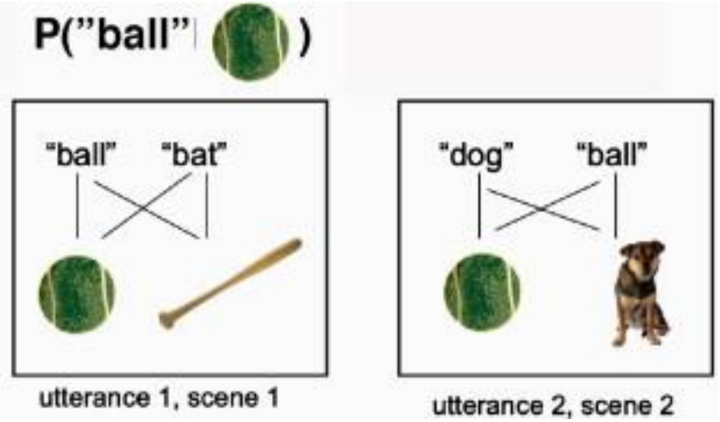
developmental evidence

- formation of shared co-occurrence links linked to maturation



labels to referents: cross-situational statistics

- mapping labels ("ball") to the object is difficult as multiple objects may be in view when the label is used
- Smith and Yu (2008) showed that 12- and 14-month-old infants resolve this uncertainly by combining statistics across situations



labels to referents: cross-situational statistics

- infants first "studied" referents and novel word labels
- infants were tested by playing a sound and then displaying the target referent and a distractor 4 times and recording looking times
- key finding: infants looked reliably longer to the target than to the distractor
- inference: infants were able to identify label to referent mappings by tracking cross situational statistics

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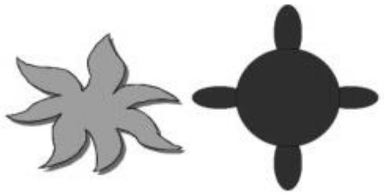

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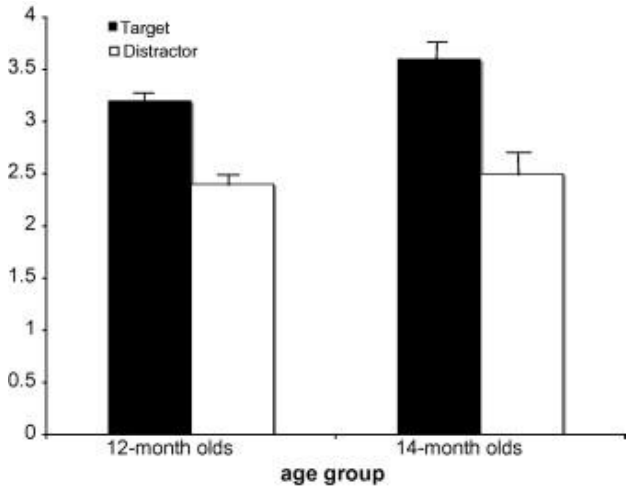
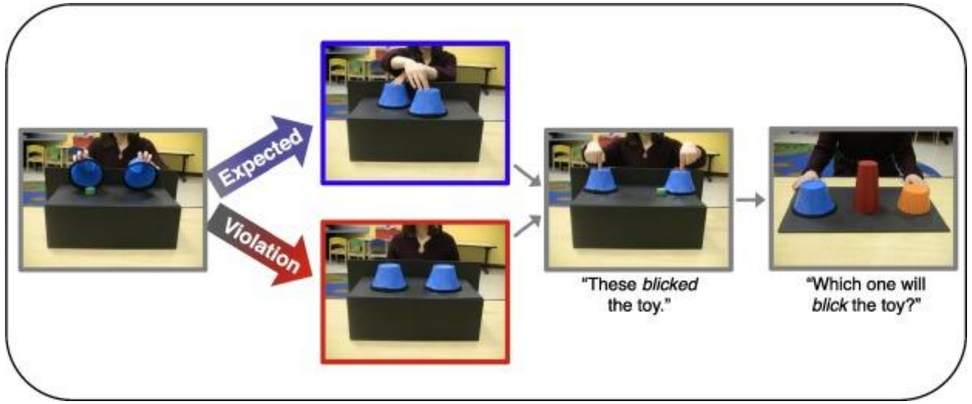


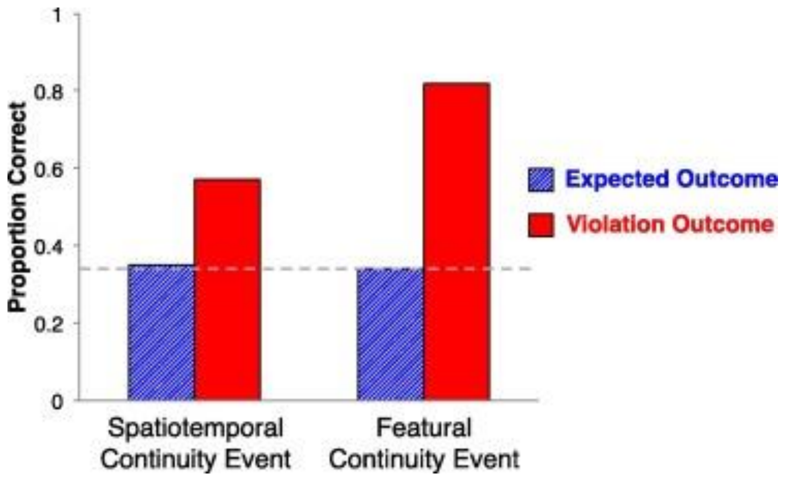
why track statistics?

- infants are not required to or motivated by reward to track statistics, so why do they do it?
- possible hypotheses:
  - infants want to communicate with their caregivers
  - infants want to generate predictions about the environment

statistical learning and prediction

- Stahl & Feigenson (2017) tested 3- to 6-year-old children in an experiment where novel labels (blick) were mapped to actions in expected or violation conditions
    - expected : toy in the expected location
    - violated: toy in the unexpected location
- learning was maximized when children were surprised by the outcomes



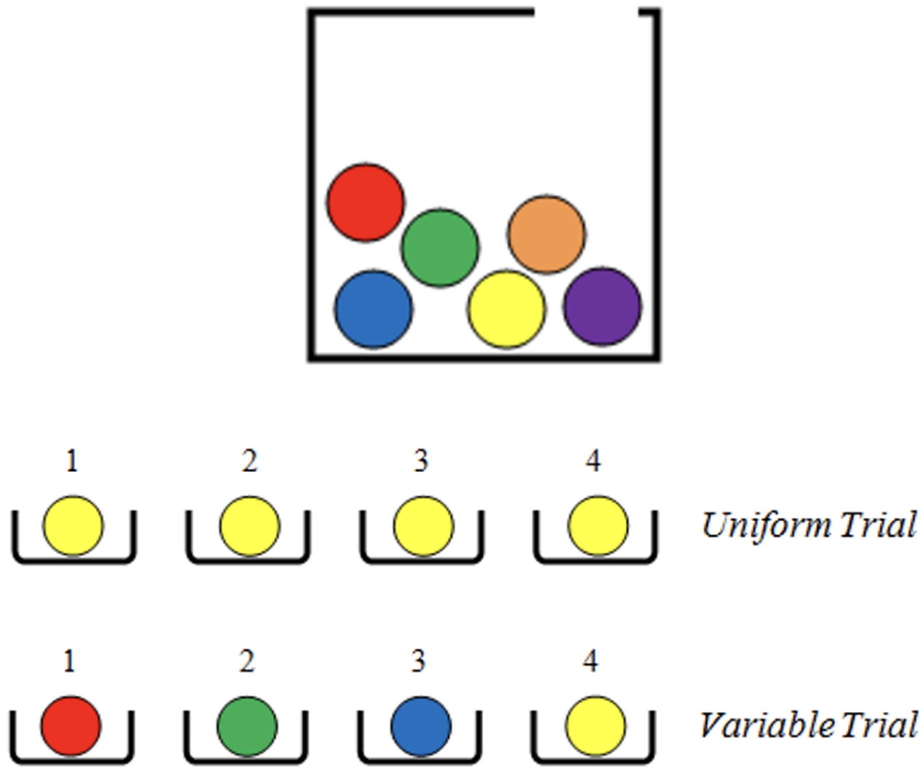


statistical learning and curiosity

- statistical learning may also inform what to learn about in the first place
- curiosity may be particularly important in creating learning opportunities and minimizing uncertainty in the environment

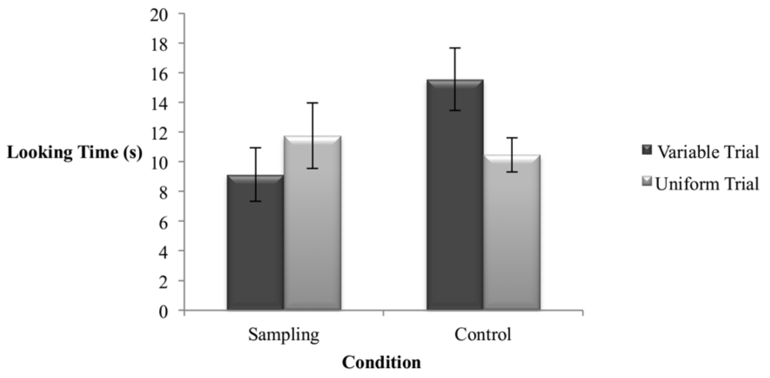
statistical learning and curiosity

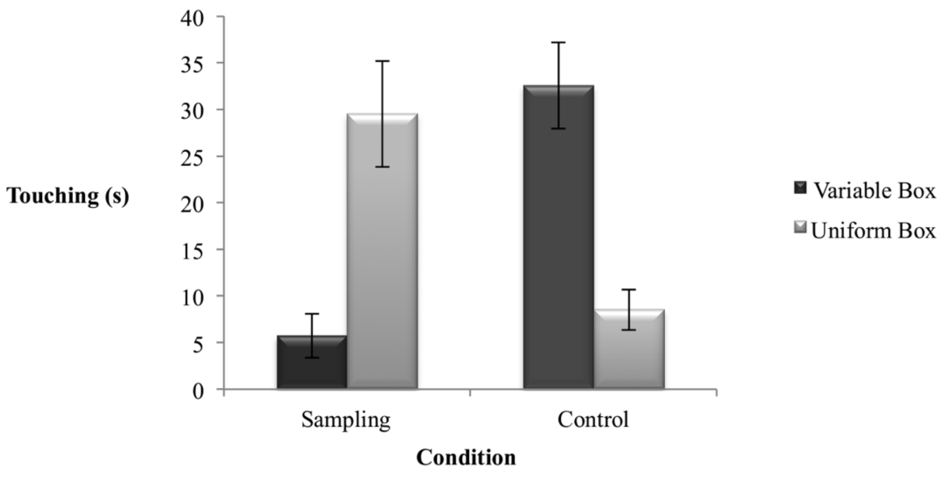
- Sim & Xu (2017) tested 13-month-old infants in a violation of expectation (VOE) and crawling paradigm
- conditions:
    - control condition (experimenter looked into the box before drawing out the balls) or sampling (no looking)
    - draw: could be "uniform" or "variable"
- two experiments: looking time (VOE) vs. touching/reaching time (crawling)

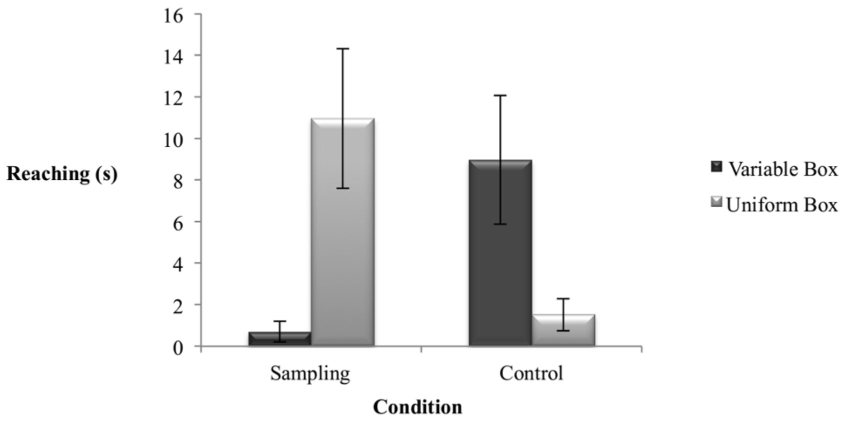


statistical learning and curiosity

- Sim & Xu (2017) showed that 13-month-old infants preferentially explore sources of unexpected events







review of findings/inferences

- we track statistical regularities
- we learn from prediction error
- we are inherently curious and want to reduce uncertainty

next class

- more on language learning (and models)