Embodied cognition(s), development and language:

An outsider's perspective

Jesse Snedeker

Google books Ngram Viewer

Graph these comma-separated phrases: embodied cognition case-insensitive

between 1980 and 2008 from the corpus English with smoothing of 0 .

Search lots of books

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Embed Chart

Google books Ngram Viewer

Graph these comma-separated phrases: embodied cognition,amodal symbols,mirror neurons,situated cogniti case-insensitive

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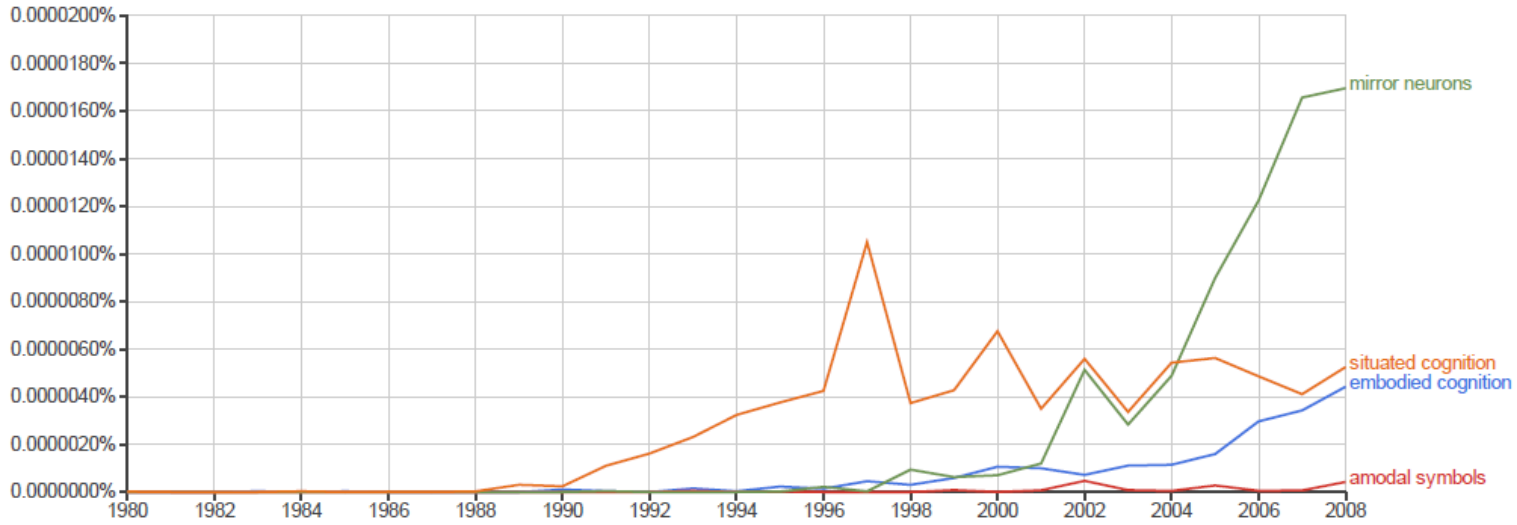
Embed Chart

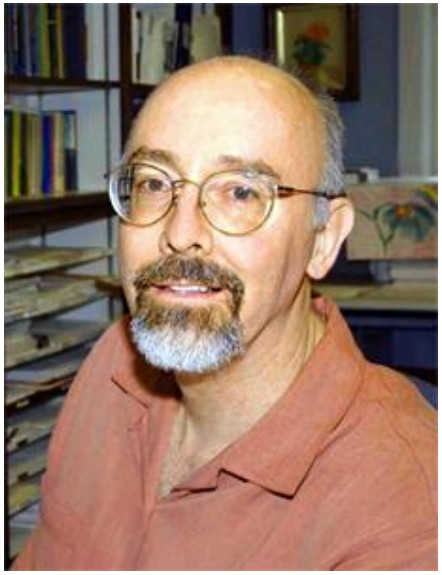


Embodiment takes many forms

- Our bodily actions, in an environment, driven by goals, shape cognition 3 time scales
  - Evolutionary (Phylogenetic)
  - Development (Ontogenetic)
  - As we plan them (Chronometric)

This is a claim about outcomes, not cognitive architecture or representations

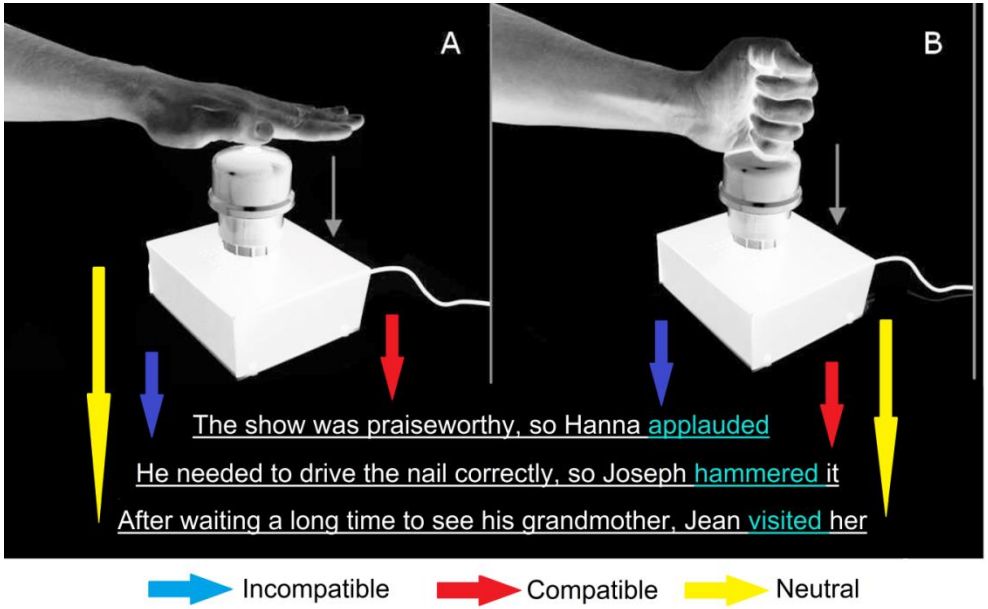
Embodiment takes many forms

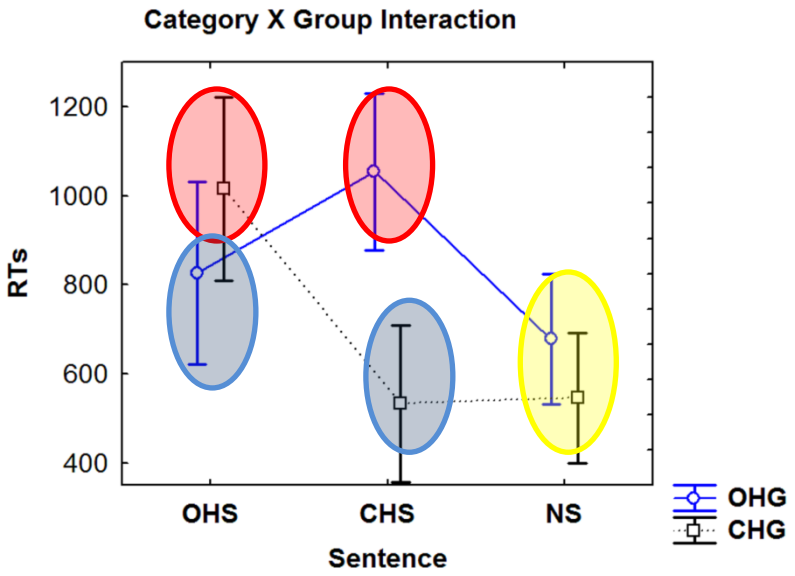


Barsalou: Perceptual Symbol Systems

- Traditional view: cognition is computation on modal symbol systems that are “independent of perception, action & introspection”
- Claim: cognition grounded in modal simulations, bodily states, and situated action

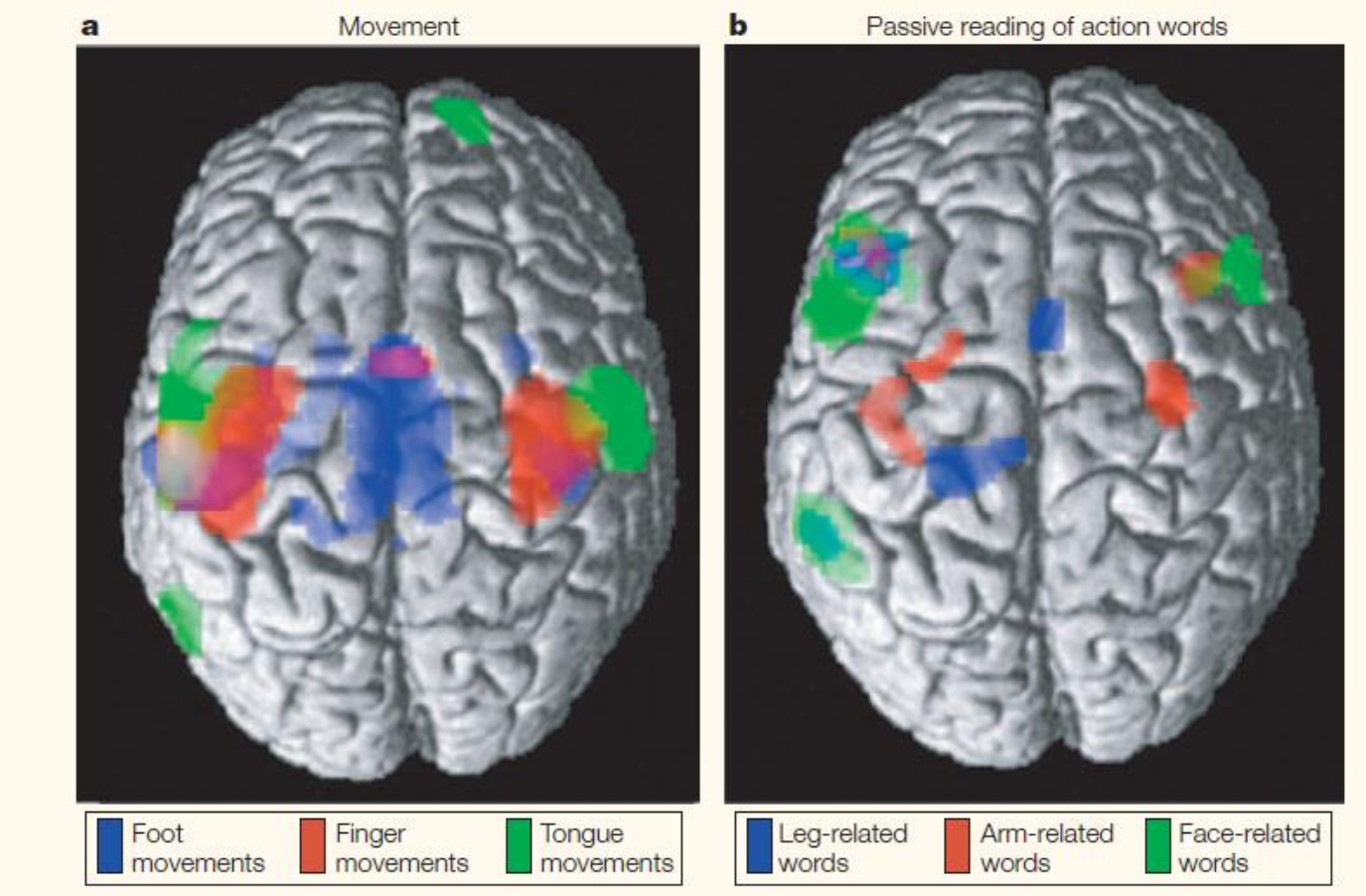
Action Compatibility Effect





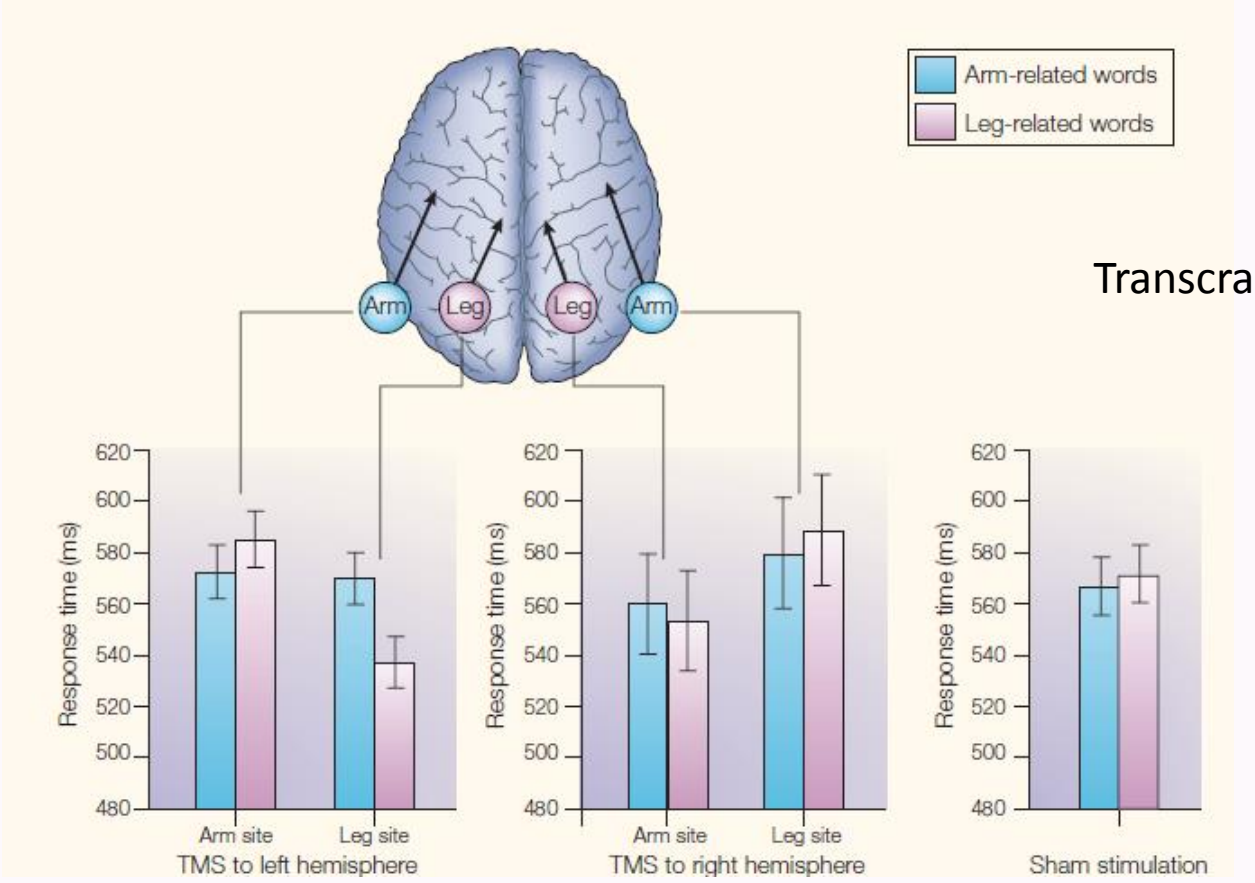
Example: Aravena P, Hurtado E, Riveros R, Cardona JF, Manes F, et al. (2010)
Phenomenon: Glenberg & Kaschak, 2002; Zwaan and Taylor , 2006

Activation of Motor Cortices



Tettamanti, M. *et al.* Listening to action-related sentences activates fronto-parietal motor circuits. *J. Cogn. Neurosci.* **17**, 273–281 (2005).

Motor activation causally implicated



Subthreshold
Transcranial Magnetic Stimulation
(faciliatory)

Interaction

No Differences

No Differences

Pulvermüller, F., Hauk, O., Nikulin, V. V. & Ilmoniemi, R. J. Functional links between motor and language systems. *Eur. J. Neurosci.* **21**, 793–797 (2005).

Many caveats….

- Effects often depend on semantic context
  - 1st vs. 3rd person, negation & tense
- Effects for abstract metaphoric language unstable across studies
- Disputes about which regions are truly motoric
- Disputes about time course of the effects

But there is no denying:

- That perceptual and motor cortices are activated during language processing
- This activation *can* effect language processing

But what do these effects tell us about *conceptual representation*?

Embodied cognition(s)

- Embodiment: the claim that concepts are grounded in sensory-motor systems
- Grounded =
  - Linked to, connected with
  - Processing causally influenced by these links
  - Partially composed of
  - Initially completely composed of
  - Completely composed of

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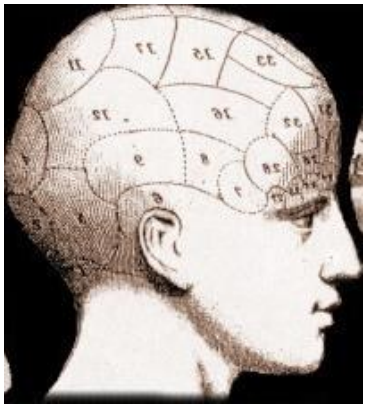
All theories are embodied in this sense

Embodiment in Fodor

- Concepts are constituents of beliefs
  - Roughly word-sized
  - Mental representations
- Manipulated in central workspace (LoT)
- Concepts have no internal structure
- Conceptual content is due to causal link between referent and mental tokens of that concept
  - *Experiential grounding!*

Modularity



Fodor (1983)

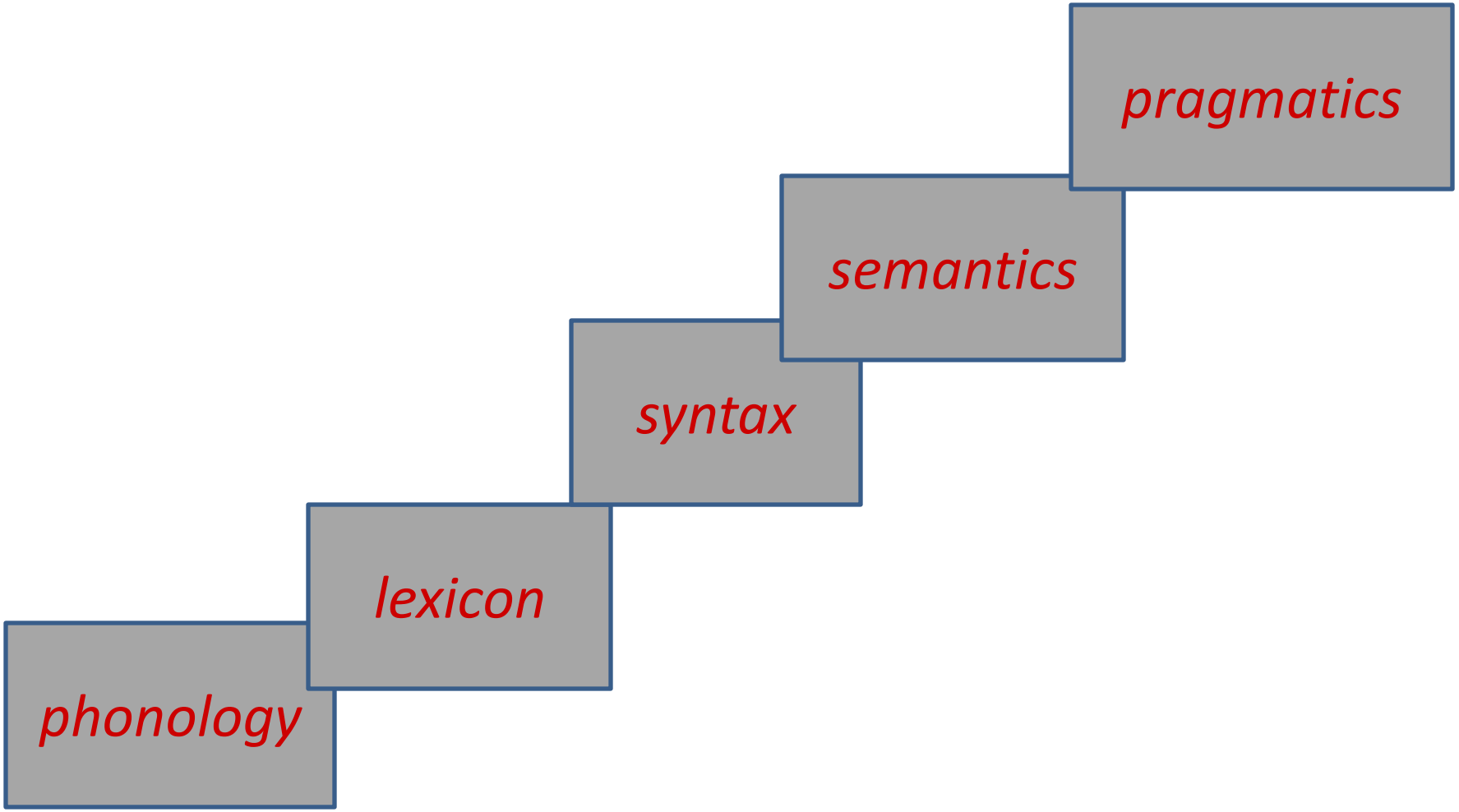
- Modular perceptual systems
  - vision, audition
- Modular input systems
  - object recognition, language
- Central workspace
  - Higher Cognitive Functions: science, analogy

Places limitations on the role of perception and action in cognition

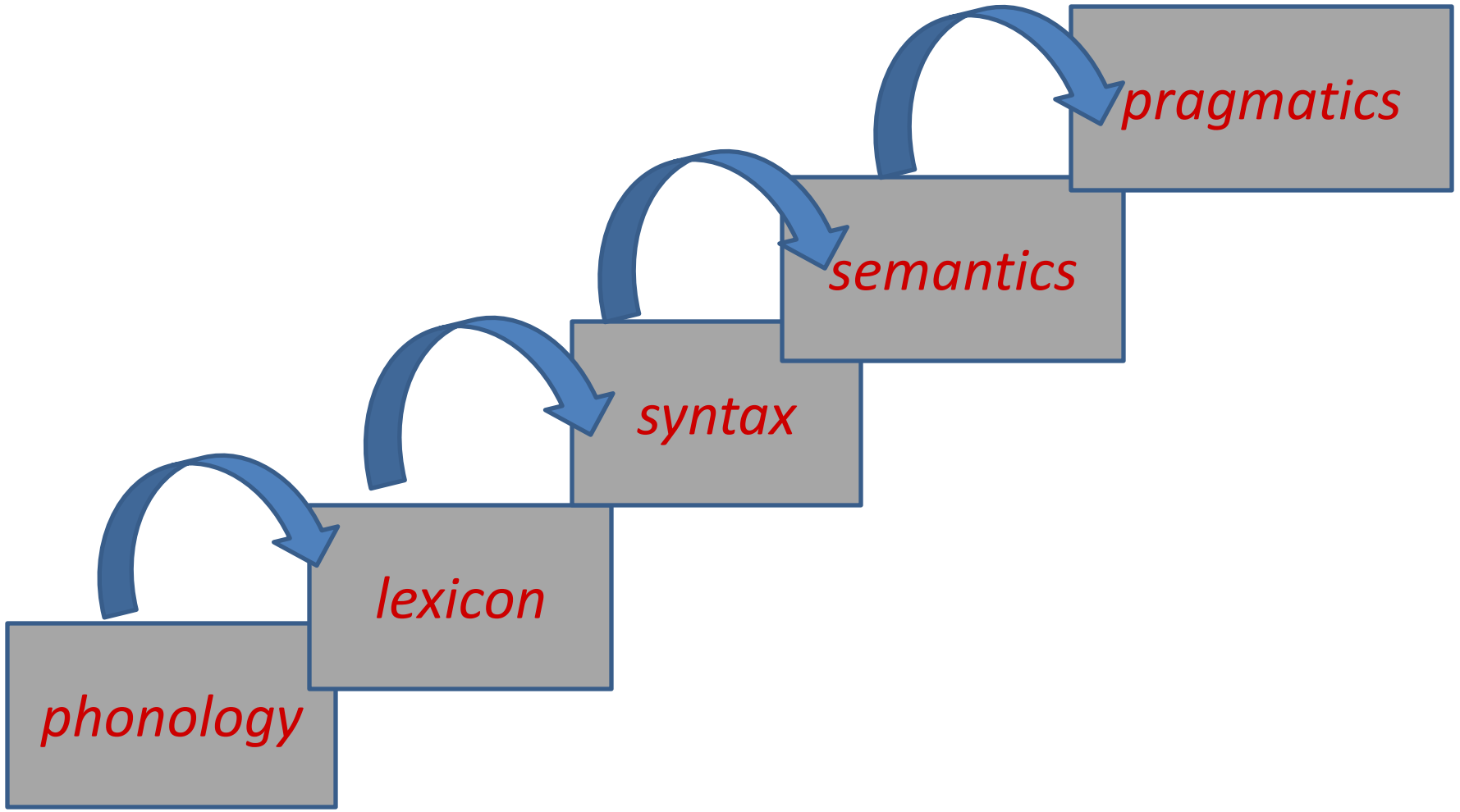
Fodor's criteria for modules

1. Domain specific
2. Innately specified
3. Shallow well-defined outputs
4. Information encapsulation
5. Mandatory

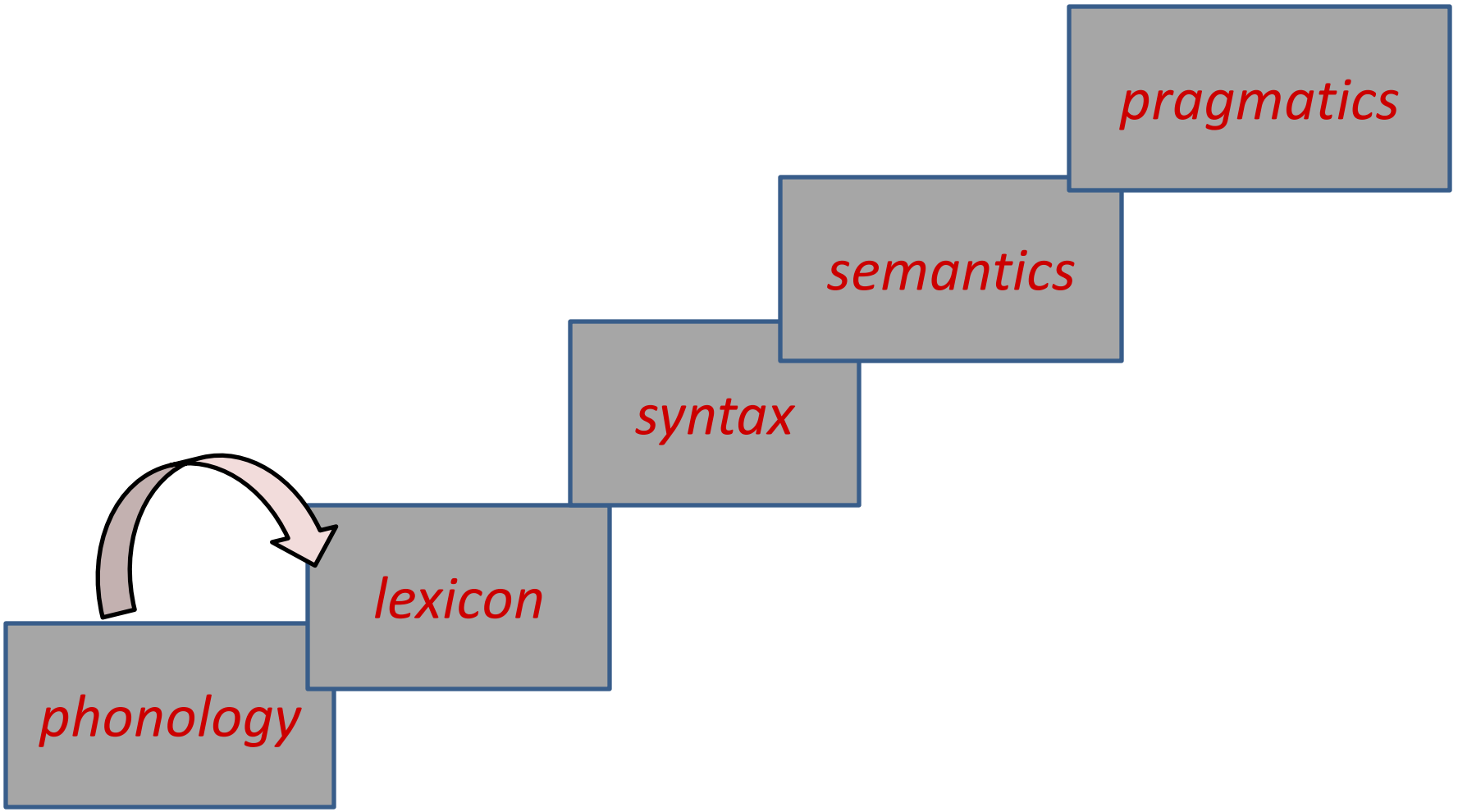
Comprehension is a series of processes



Modularity:
Processes sequential & independent



21st Century Standard Model:
Cascaded Processing



21st Century Standard Model:
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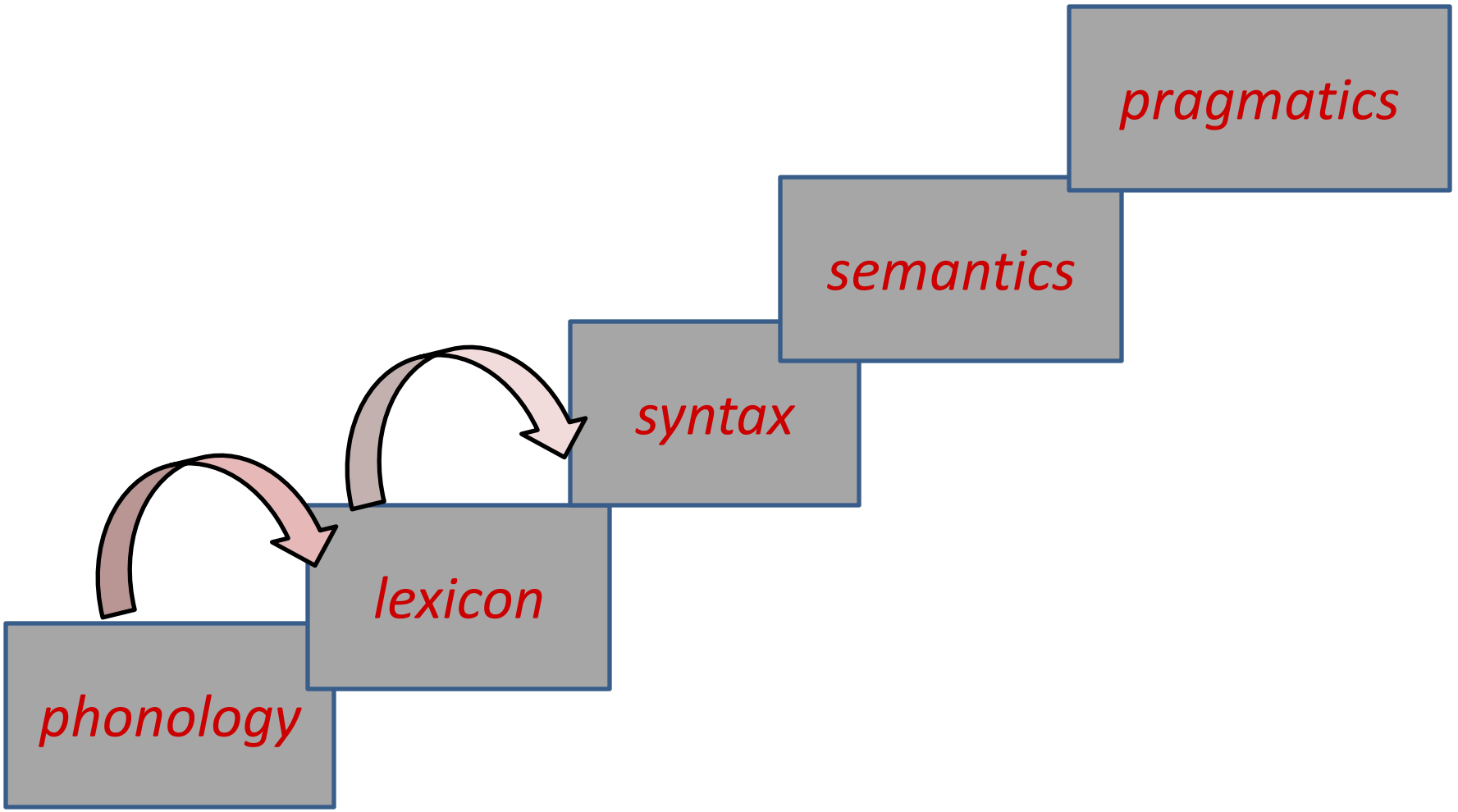

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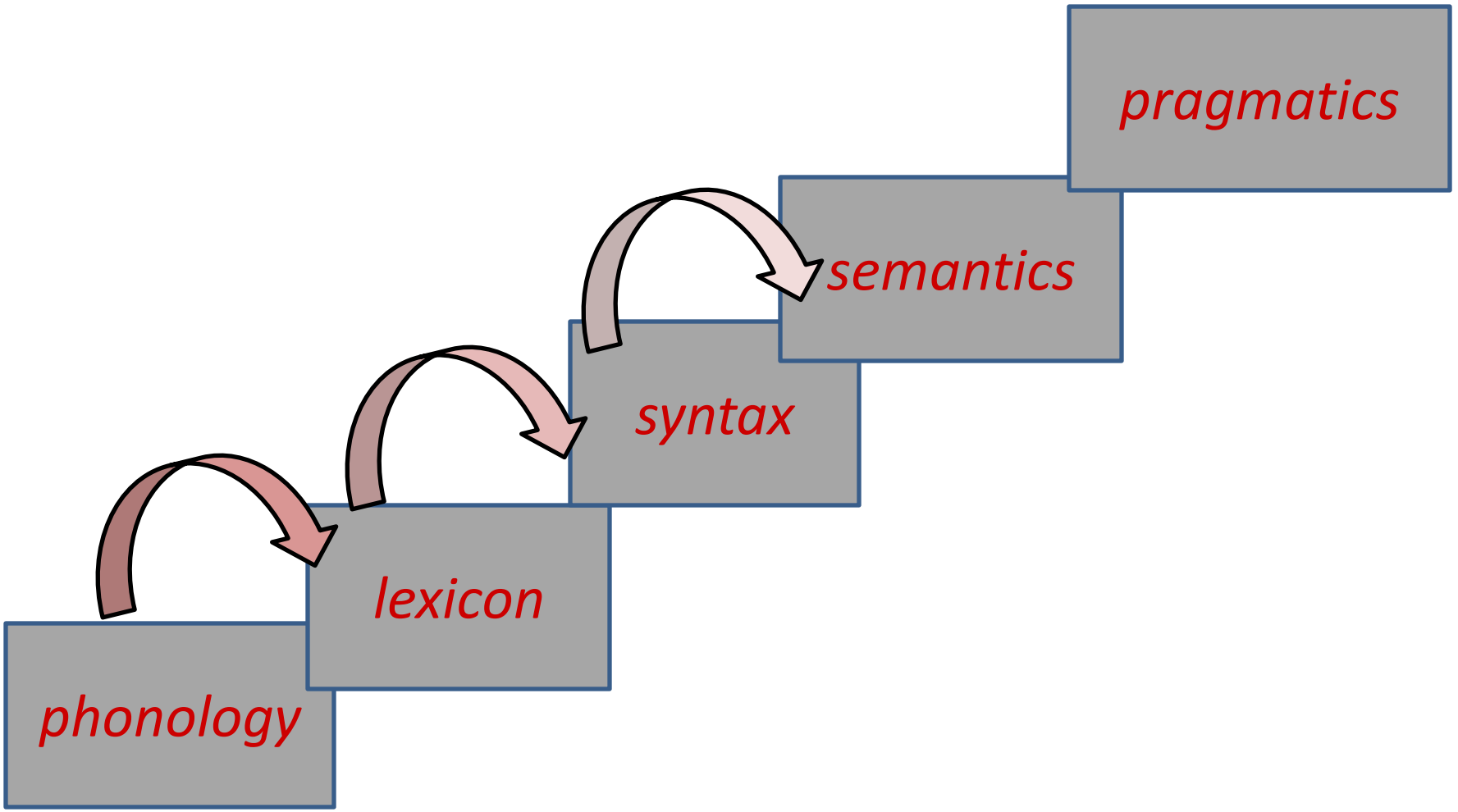

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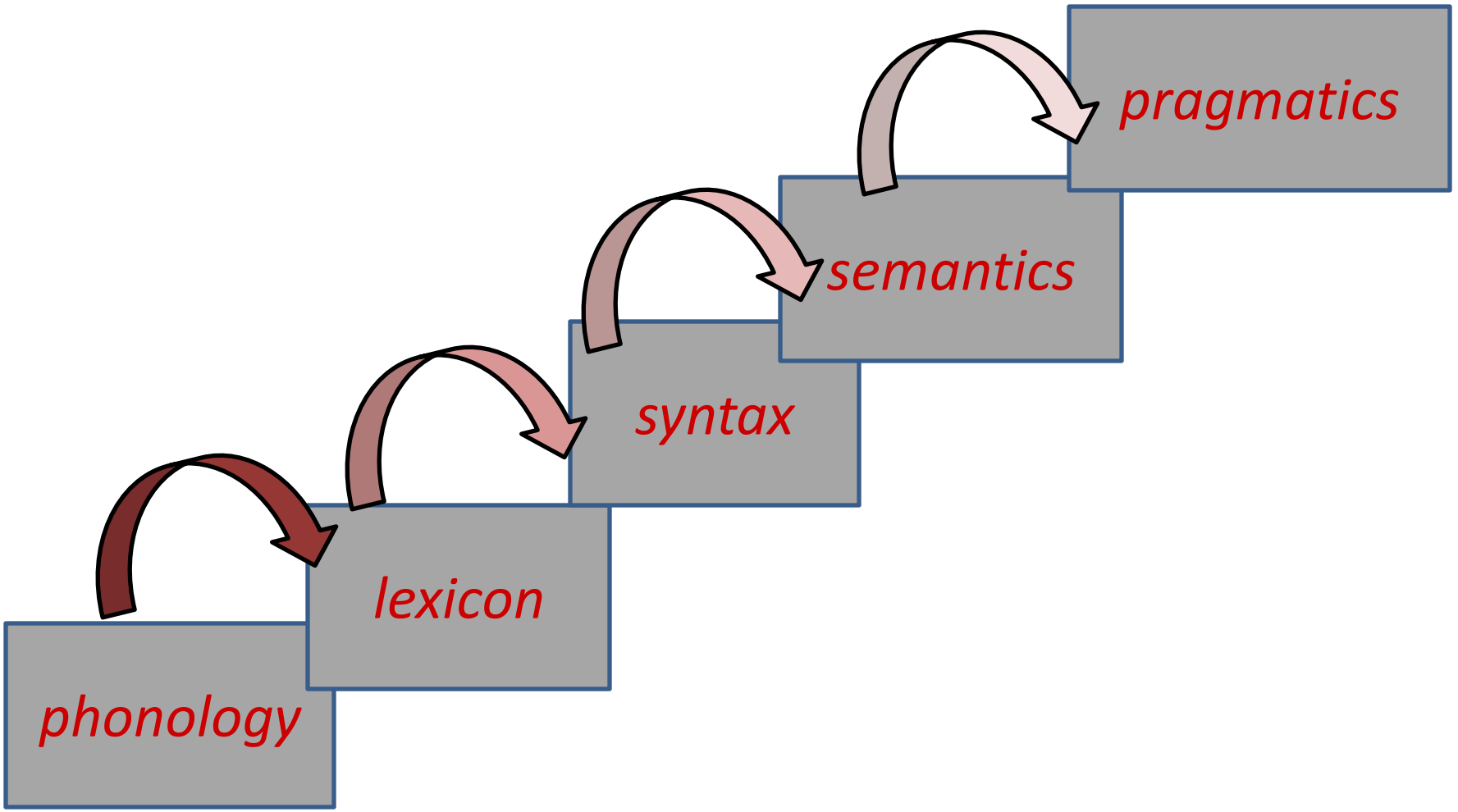
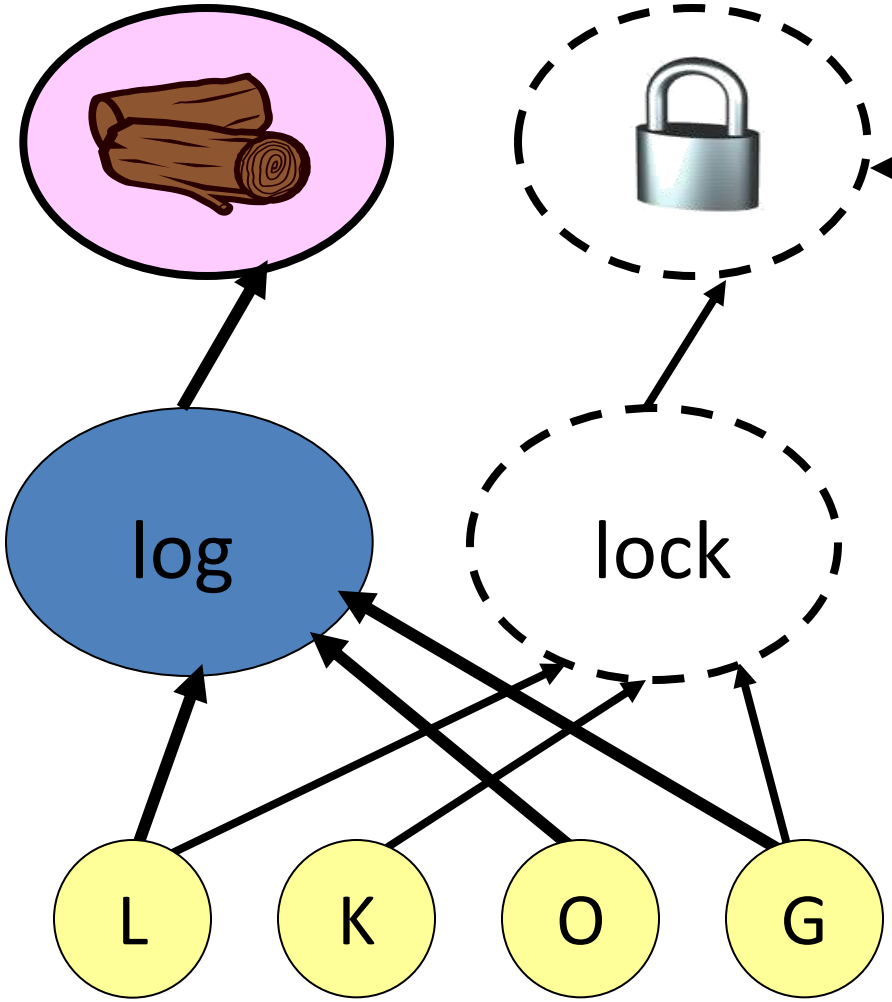


Example: Phonosemantic priming

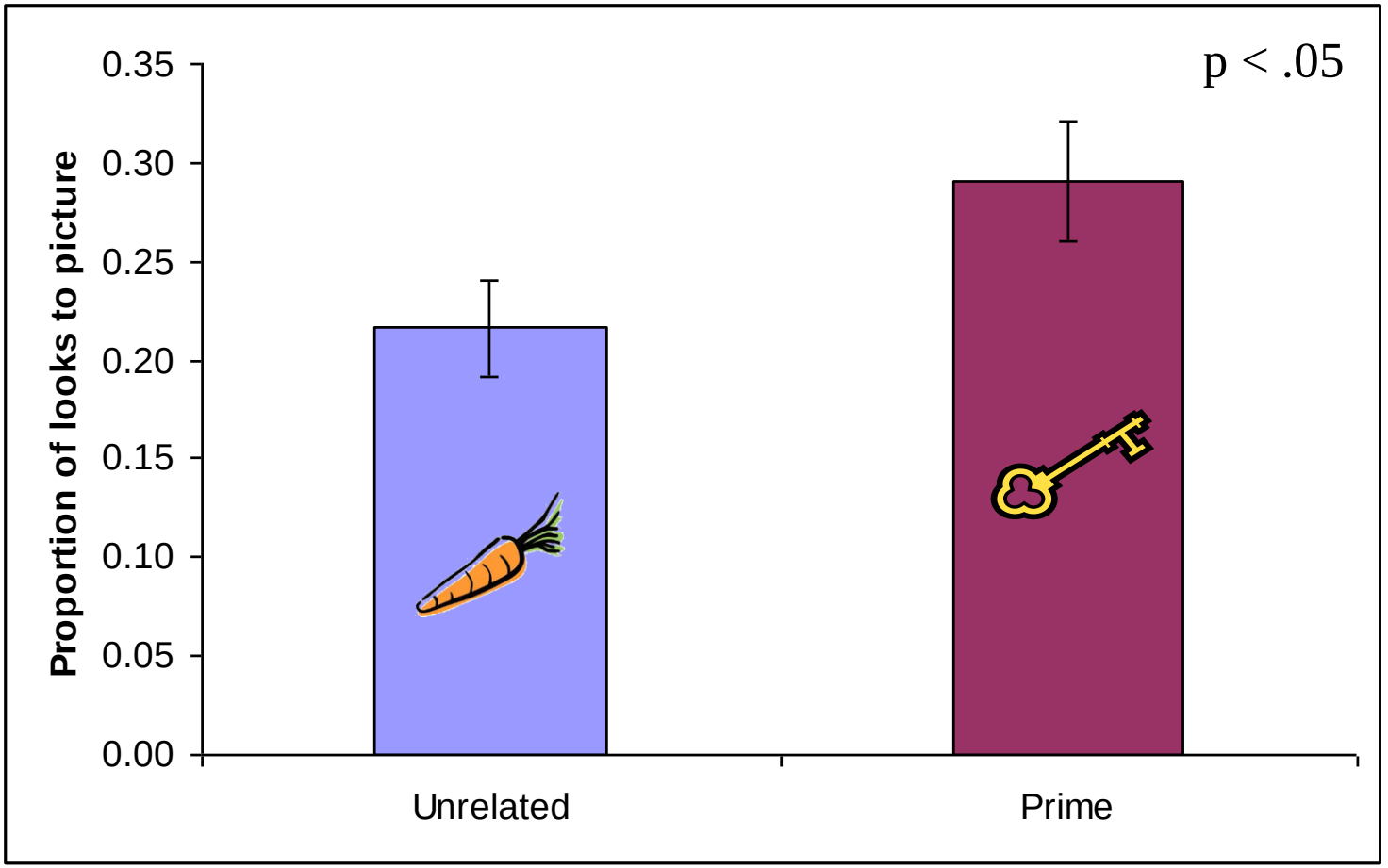


"Pick up the **log**…g"

Conceptual priming via phonological associate

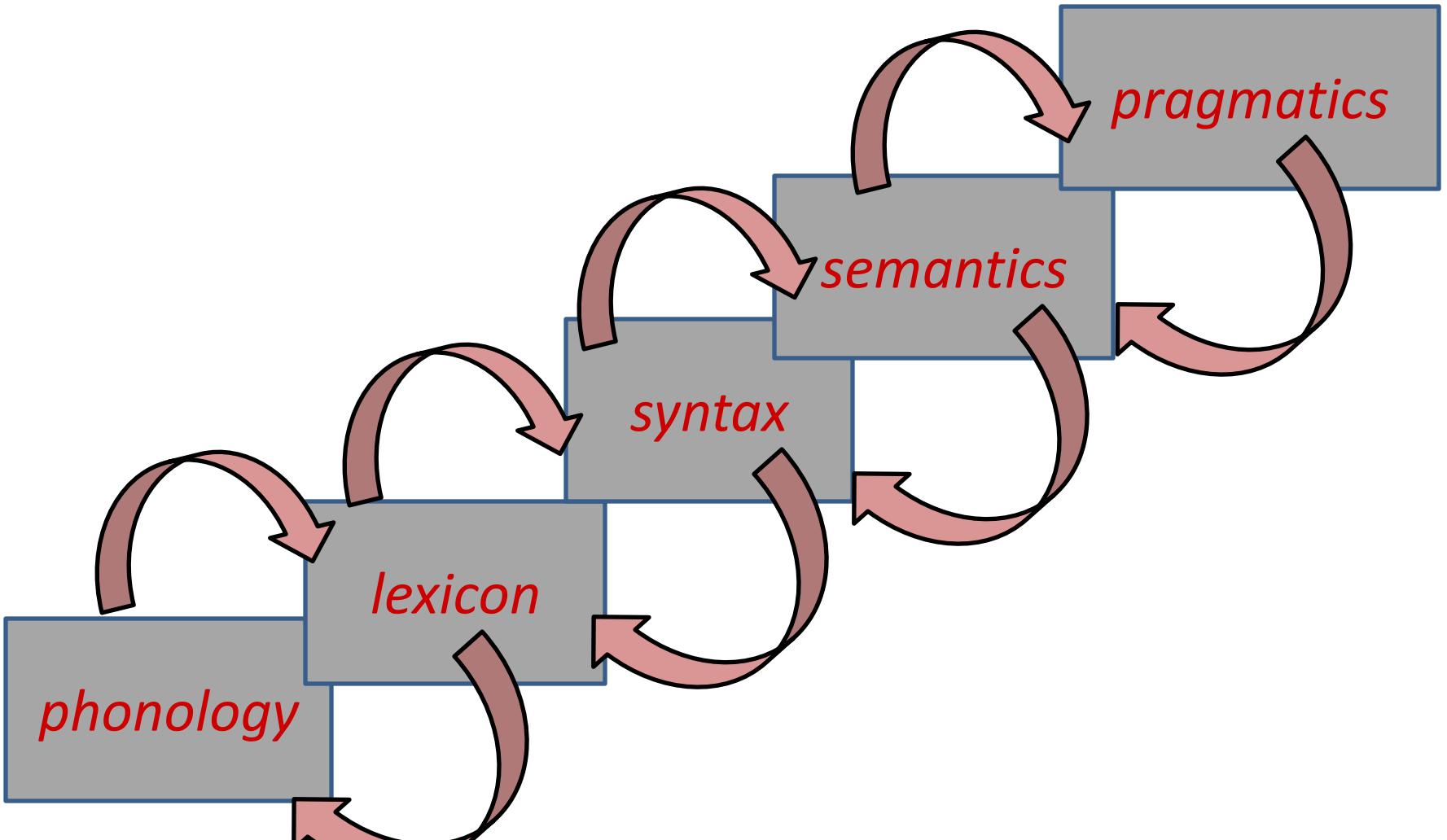
Marslen-Wilson & Zwitserlood (1989)
Yee & Sedivy (2006)

5 yr old children also show phonsemantic priming

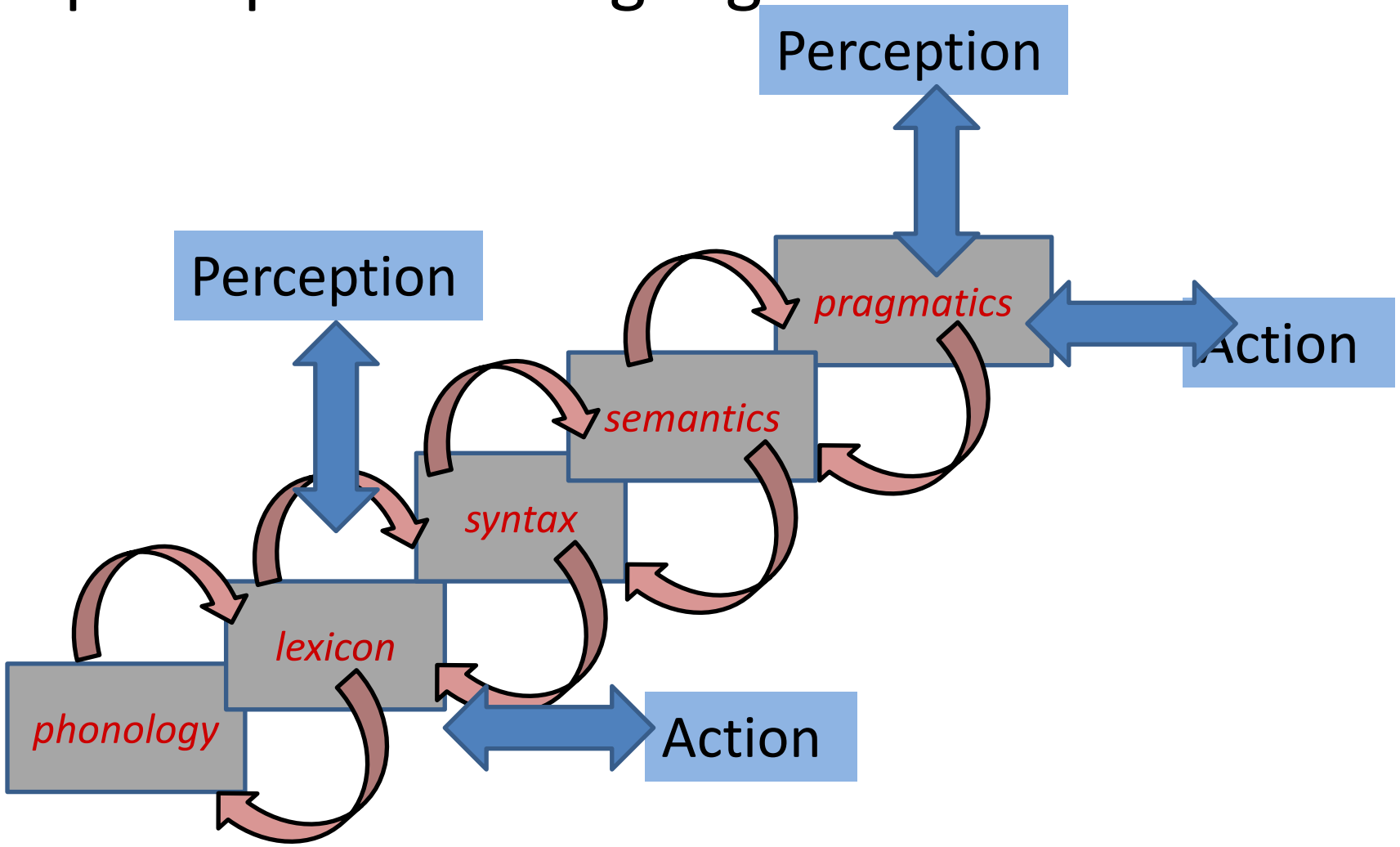


Huang & Snedeker (2011)

21st Century Standard Model:
Interactive Processing



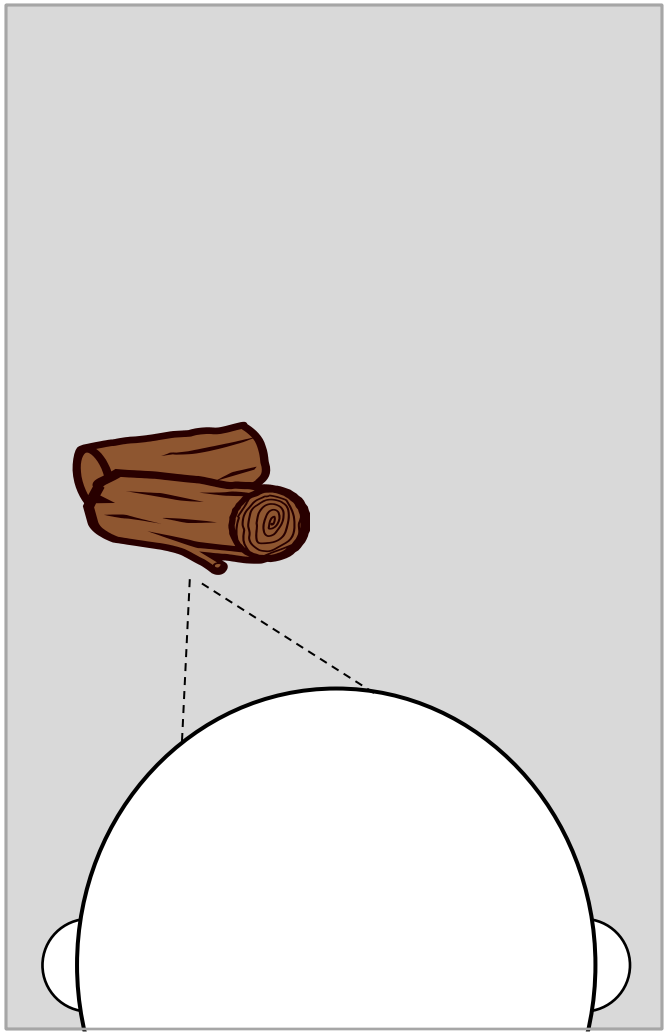
Incremental, interactive processing crosses from perception to language



Incremental visual activation from words
(Pirog Reville, Aslin, Tanenhaus & Bavalier, 2008)

- Learn novel motion and state change verbs
- Words have phonological cohort members from the same class or from a different class
  - gapito = turn white (state change)
  - gapitu = oscilate vertically (motion)
- Activation in V5/MT (motion) is greater for verbs with motion competitors

Informational cascade in object naming



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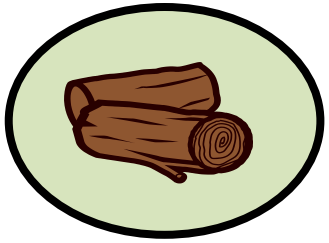

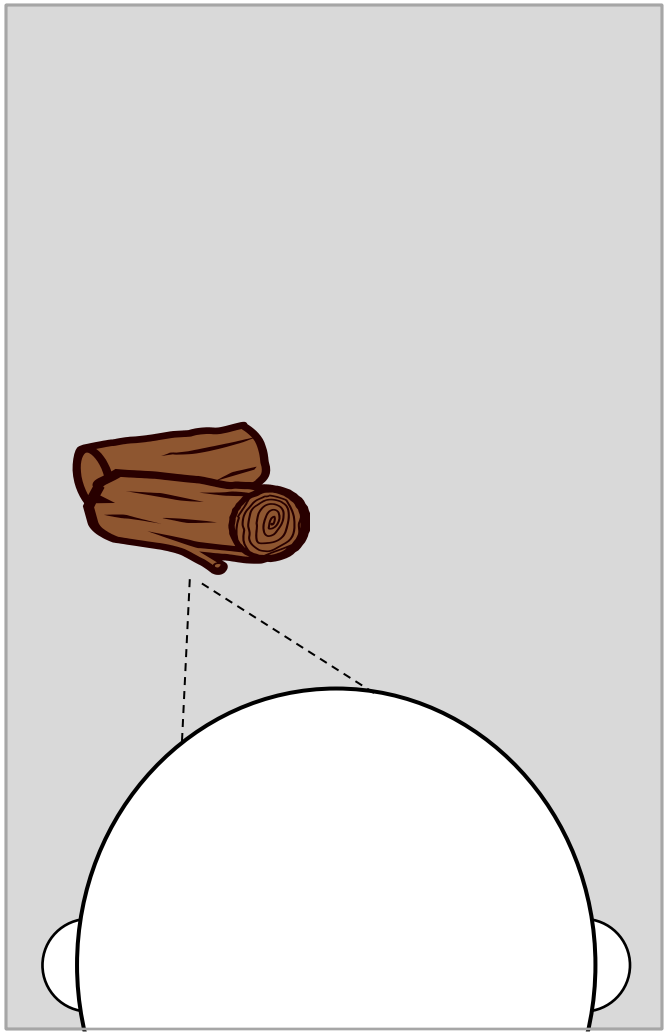

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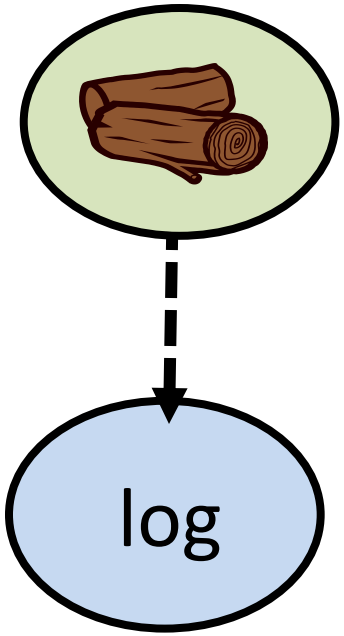

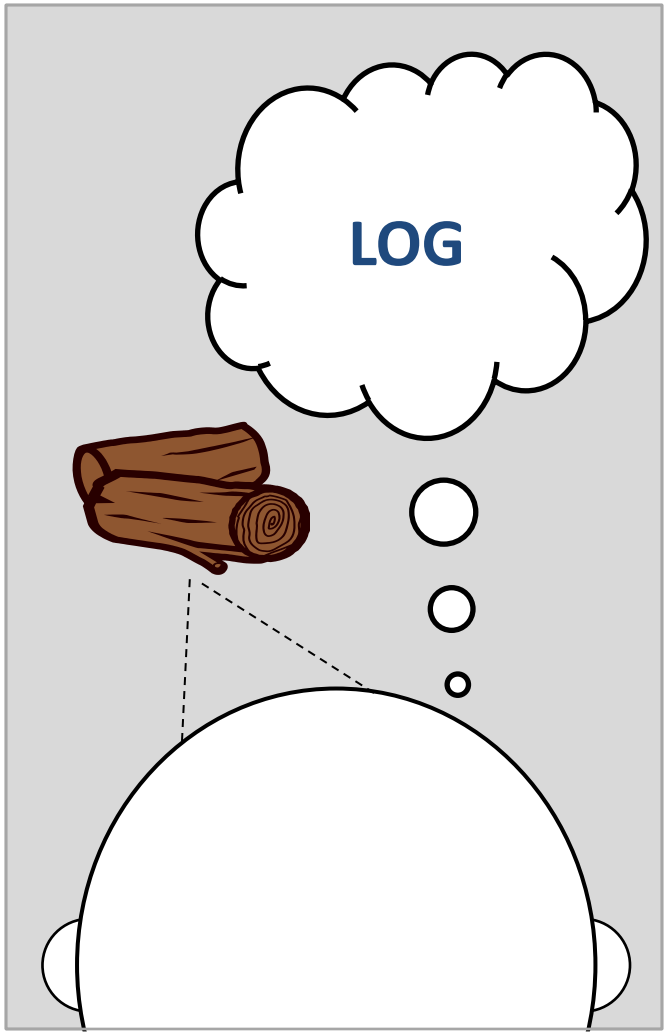

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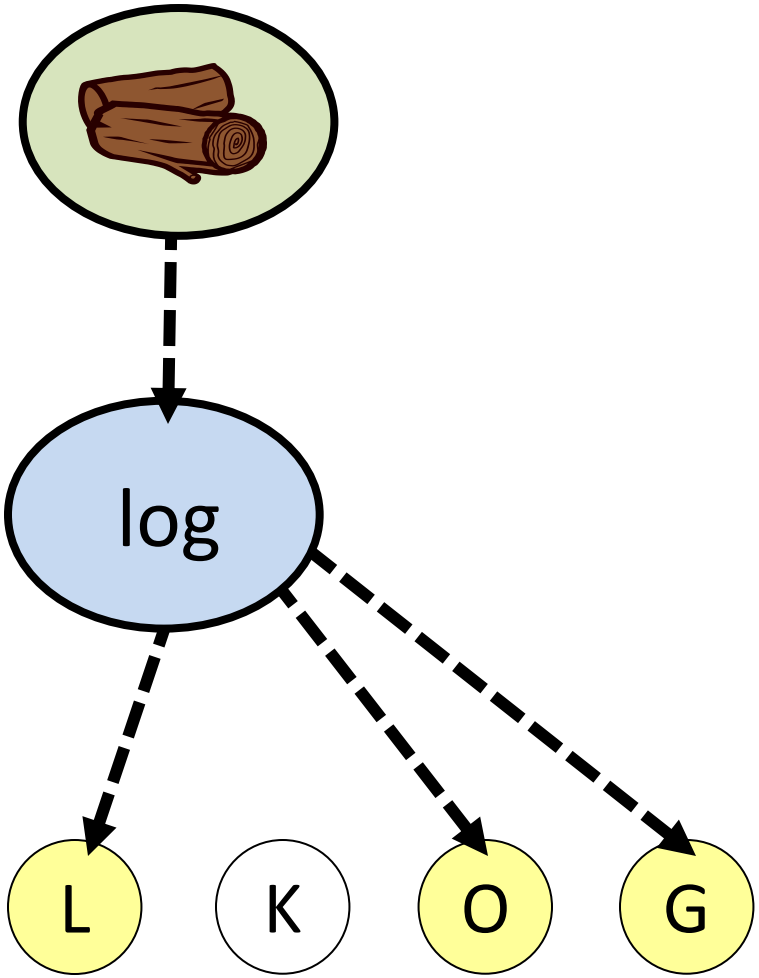
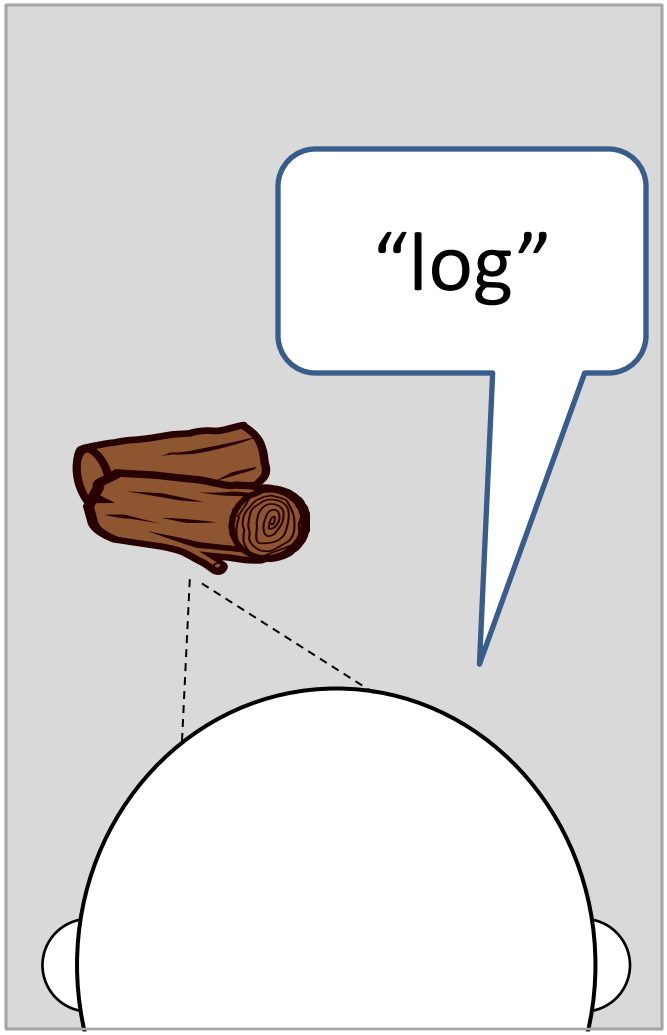




This conversion must occur during speaking, but is it present otherwise?

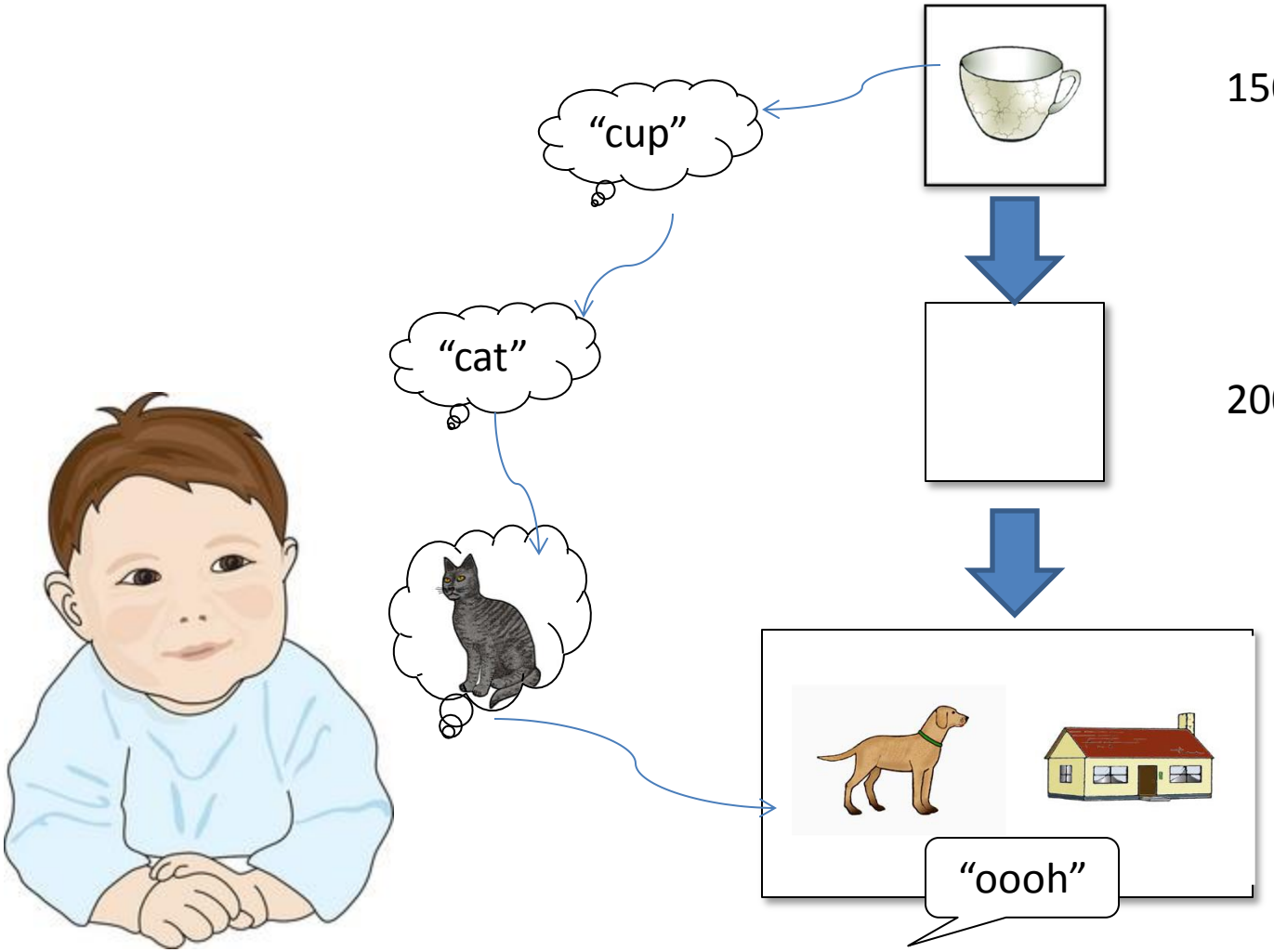
Implicit Naming: the activation of linguistic representations in a non-communicative task

Evidence:

- Phonosemantic activation in infants (Manizeh Khan)

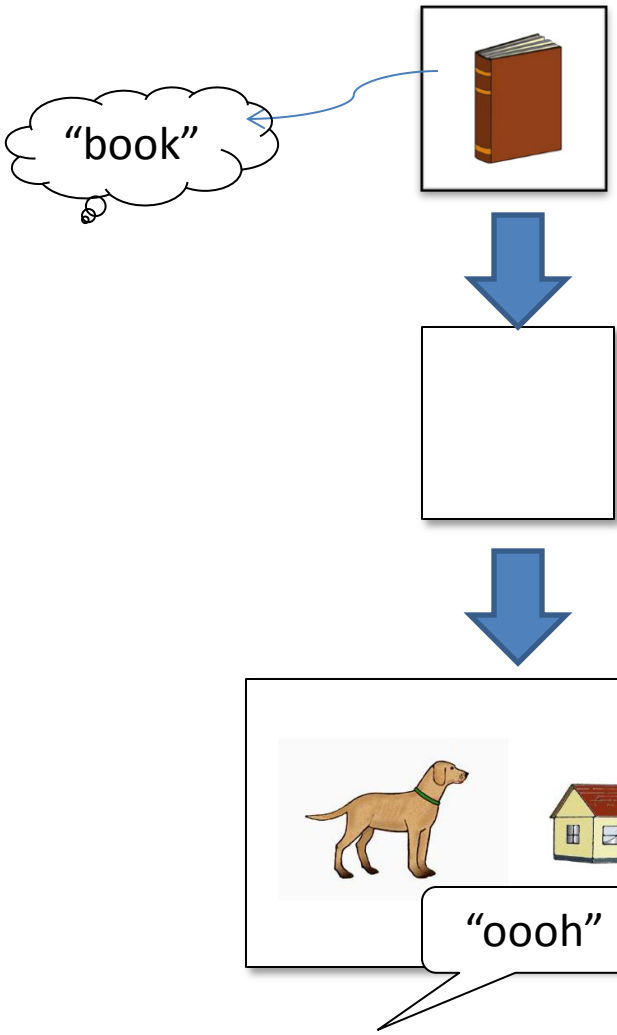
Manizeh Khan

Phonosemantic activation…. without speech

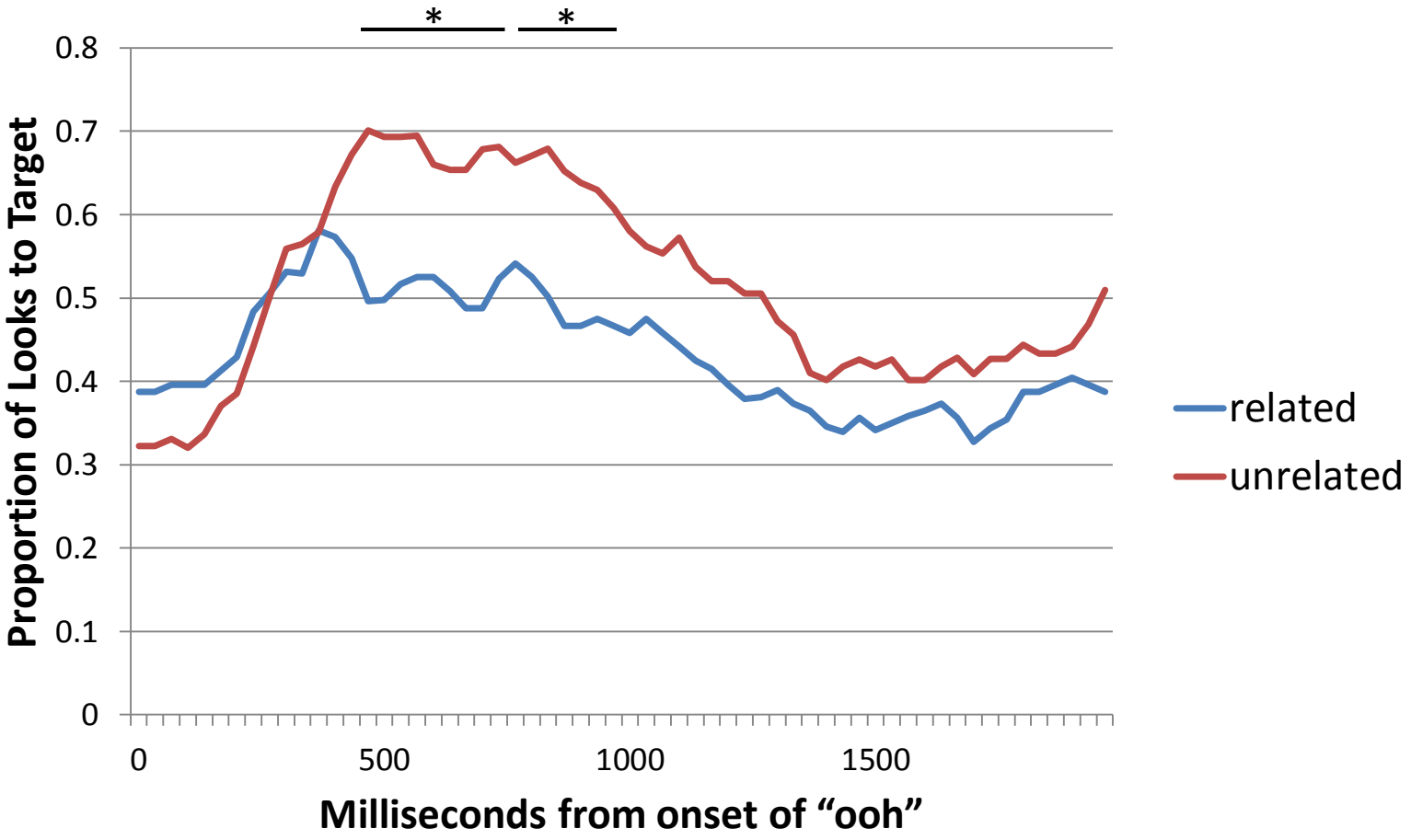


Inspired by
Mani & Plunkett (in prep)

Unrelated Trials



Implicit naming creates phonosemantic inhibition in 24 month olds

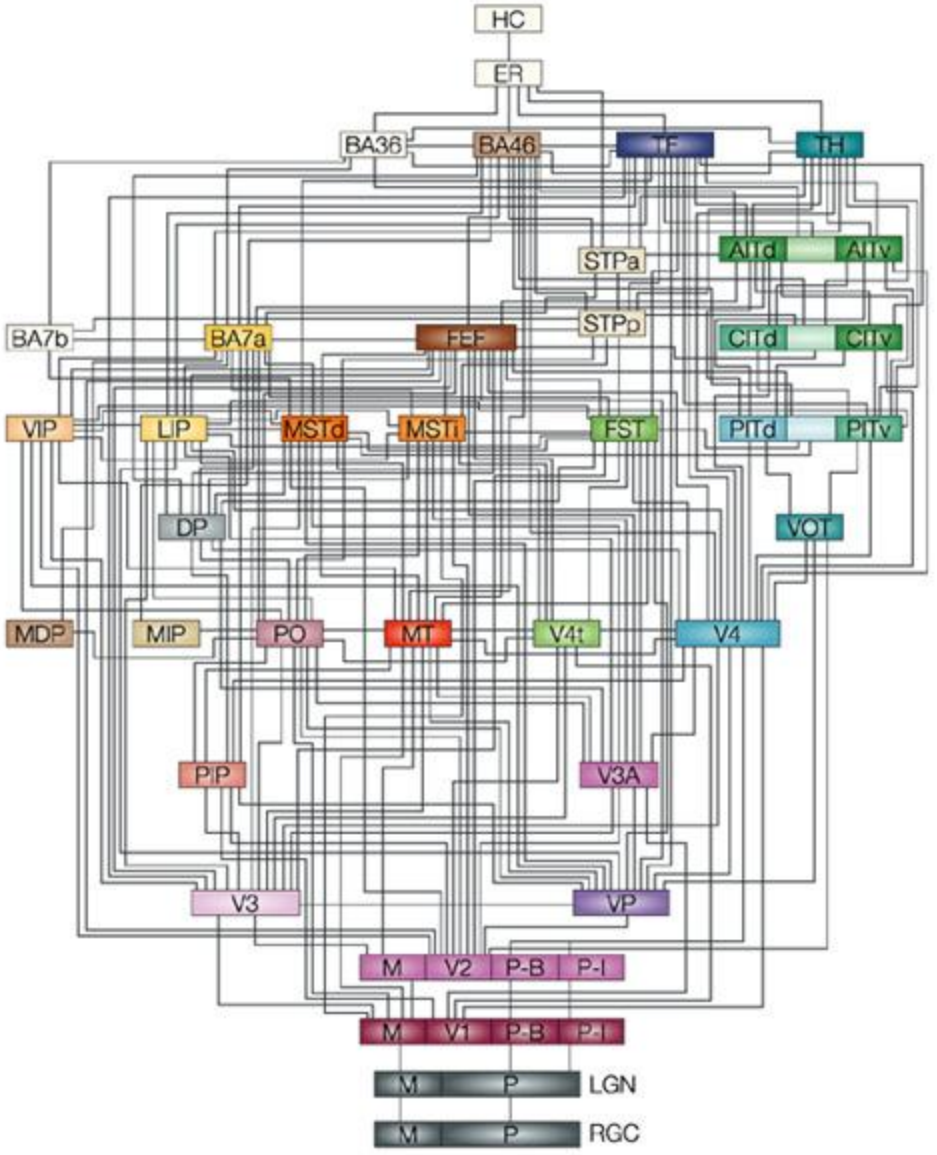


What about adults?

- Little evidence for *phonological* activation
  - Yes: working memory (Zelinsky & Murphy, 2000)
  - No: visual search (Telling, 2009; Zelinskey & Murphy, 2000) and free viewing (Khan, Fitts & Snedeker, in prep)
- But *lexical* activation is common
  - Homophonous competitors are fixated in visual search (Meyer et al., 2007) and free viewing (Khan et al., in prep)

21st century standard model is pervasive

Example:
visual areas
in macaque



Rees, Kreiman & Koch (2002)

Embodied cognition(s)

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If we accept the 21st century standard model, this follows on any theory of concepts

Embodied effects in 21st century standard model

Assume non-embodied conceptual content

- Activation in sensory and motor cortices*
  - Spontaneous activation of representations linked to concept (or form)
- Action Compatibility Effect
  - Interference/facilitation from linked representation
- Transcranial Magnetic Stimulation
  - Interference/facilitation from linked representations

* Interpretation depends on our belief that brain chunk X builds sensory representation (vs. conceptual ones). This is often unclear (e.g., Bedny et al., 2008; Kemmerer et al., 2012)

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Sensory-motor concepts

- Is conceptual content *perceptual*?
  - Question is ill-defined
  - Perception can be as abstract as you want
  - Agent detector and causal perception (Carey, 2010)
- Is conceptual content solely sensory-motor?
  - Concept well-described in sensory or motor primitives
  - Concept well-justified on basis of sensory-motor experience
- What is conceptual content?
  - Individuates concepts
  - Involved in semantic composition
  - *May* underlie perceptual categorization or analytic truth

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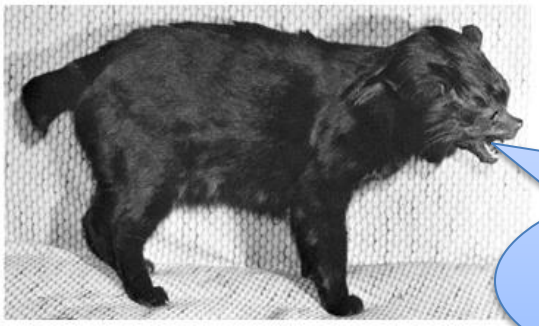
Could all concepts be entirely sensory-motor?

- Philosophical concepts? (truth, knowledge)
- Mathematical concepts? (infinity, variable, real numbers)
- Moral concepts?
- Kinship relations?
- Quantifiers?

Could work-a-day concepts be entirely sensory-motor?

- Adults' deliberate categorization based on non-sensory information
  - Animals identity based on birth/parentage
  - Artifact identity based on creator's intentions
  - Naïve essentialism



What am I now, a cat or a dog?

Bloom, Gelman, Wellman, Markman, Atran, Waxman, Medin, Carey

Abstract semantic representations allow for better descriptions of language

- Theories of syntax-semantic interface invoke abstract meanings (act, cause, become, state)
- Predict verb alternations and typological differences

(7) manner → [x $ACT_{<MANNER>}$]
(e.g., jog, run, creak, whistle, . . .)
(8) instrument → [x $ACT_{<INSTRUMENT>}$]
(e.g., brush, hammer, saw, shovel, . . .)
(9) container → [x CAUSE [y BECOME AT <CONTAINER>]]
(e.g., bag, box, cage, crate, garage, pocket, . . .)
(10) internally caused state → [x <STATE>]
(e.g., bloom, blossom, decay, flower, rot, rust, sprout, . . .)
(11) externally caused state →[[x ACT] CAUSE [y BECOME <STATE>]]
(e.g., break, dry, harden, melt, open, . . .)

Rappaport Hovav & Levin 2010

Abstract semantic representations allow for better descriptions of language

- Semantic structure constrains production and comprehension of negative polarity items
  (Chierchia,2004; Steinhauer et al., 2010; Drenhaus et al. 2004)

1a. John didn't eat any of the cookies
1b. John ate any of the cookies.*

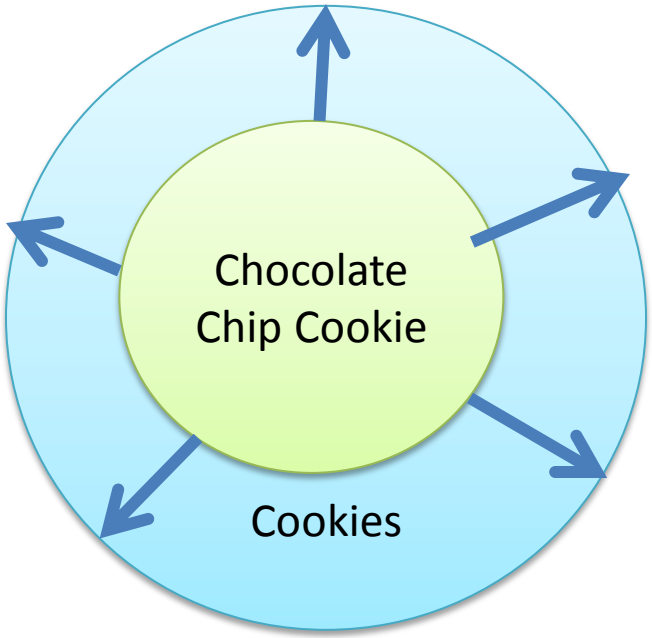
2a. If John ate any of the cookies, then he will be sick.
2b. If Mary is gone, then John ate any of the cookies.*

3a. Every boy who ate any of the cookies will get punished.
3b. Some boy who ate any of the cookies will get punished.*

Entailment context

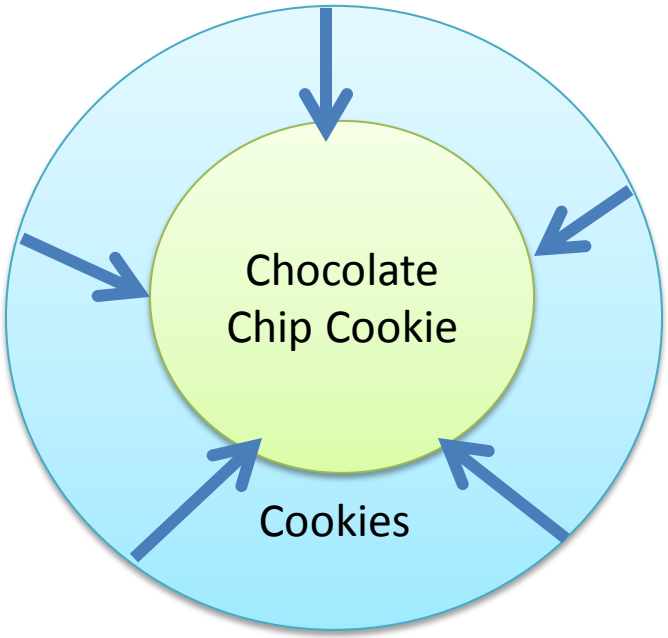
Upward Entailing

- John ate chocolate chip cookies → John ate cookies



Downward Entailing

- John didn't eat cookies → John didn't eat chocolate chip cookies



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Are children's concepts sensory-motor?

- Categorization of animals and artifacts
  - Children (sometimes) rely more on perceptual features than adults
  - But reliance on internal properties emerges early
  - As does sensitivity to *history* and *intention* for artifacts

Bloom, Gelman, Wellman, Markman, Kemler-Nelson, Waxman, Carey, Baldwin

Infants have a rich conceptual repertoire

- Pre-linguistic infants infer:
  - Goals of agents (including unfamiliar agents)
  - Causal structure of events
  - Beliefs of other people
- By 18-27 months abstract linguistic operators appear
  - *More*, *want*
  - Tense and plural markers
  - Negation

Onishi & Baillergeon, Saxe, Woodward, Leslie, Schultz, Carey, Gergeley, Csibra

Could children acquire these concepts *through language*?

Assume infant has only sensory-motor concepts

- Hearing the phonological form won't cause new concepts to grow
- How could linking a sound to the sensory-motor primitives *change* their content?
- Maybe we come to define words via other words:
  - But they would either be ungrounded or reducible to sensory primitives…..

So why does this idea persist?

Folks can't imagine the alternative.

The core knowledge hypothesis (Carey & Spelke, 1996)

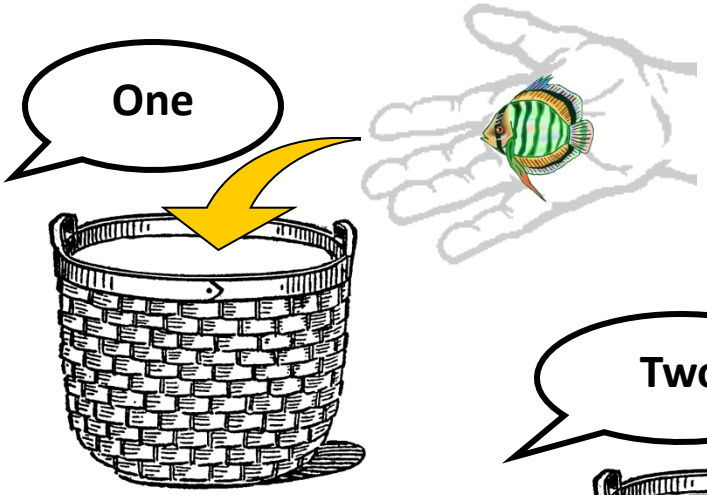
- Evolution provides cognitive procedures to extract high-level *conceptual* regularities from our experience
- These procedures are, or produce, innate concepts
- They are informed by perception but not built anew from sensation by brute force

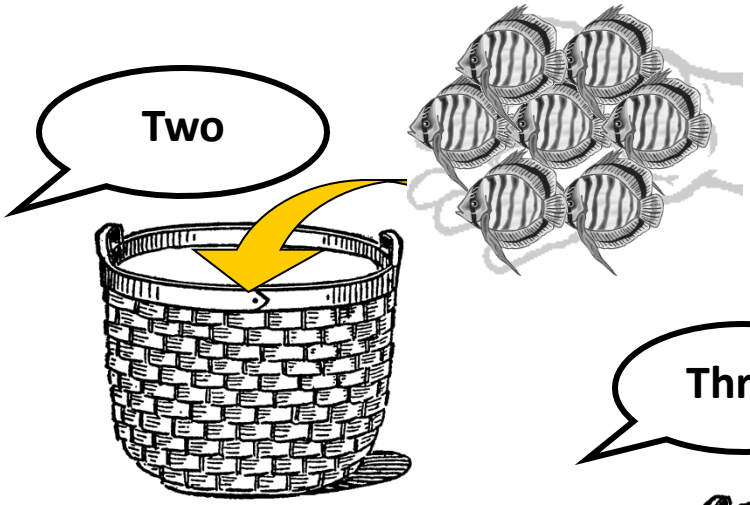
Number

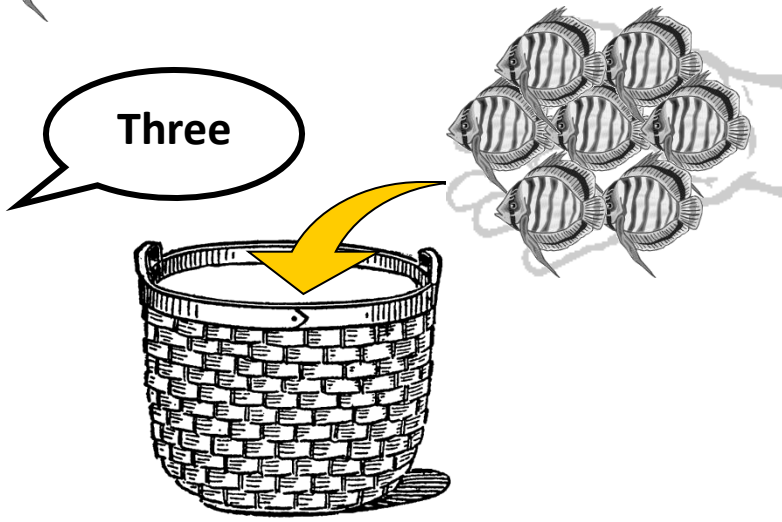
As a case study in innate abstraction

Children learn number words in stages

(Wynn, 1990)

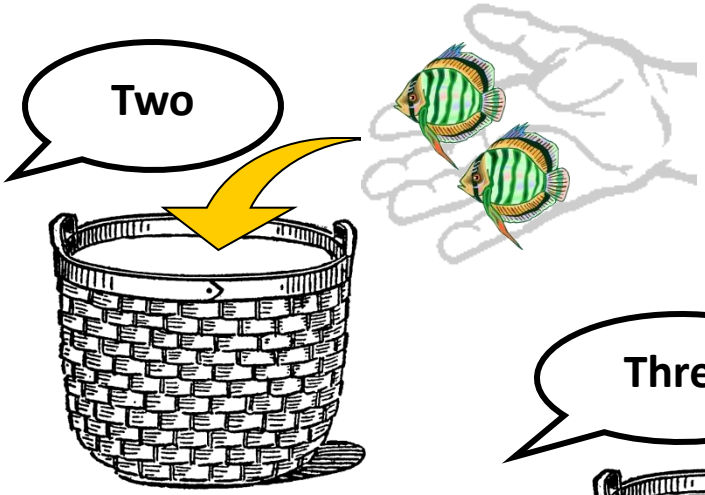


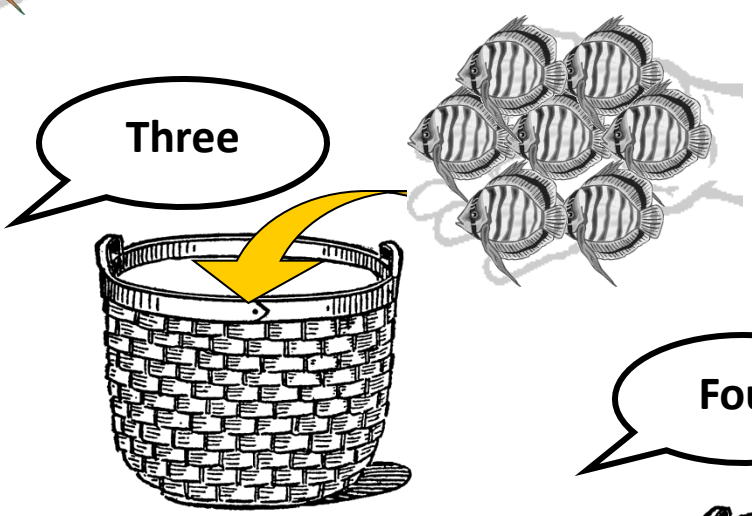


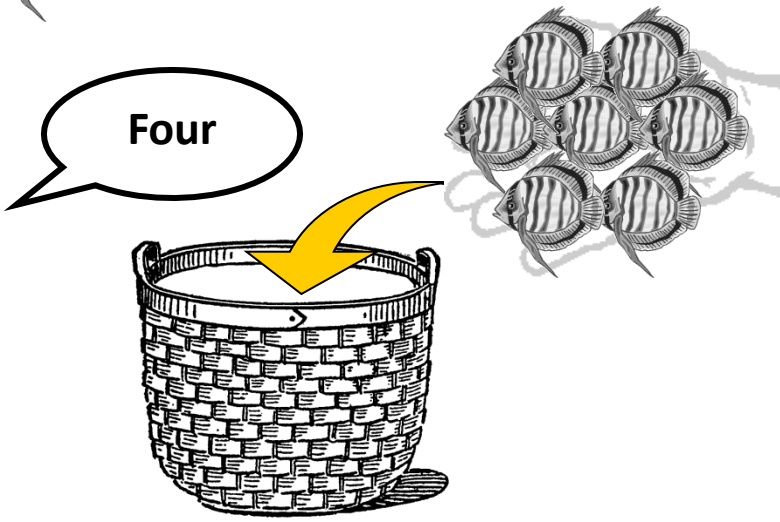


ONE-KNOWER

Children learn number words in stages

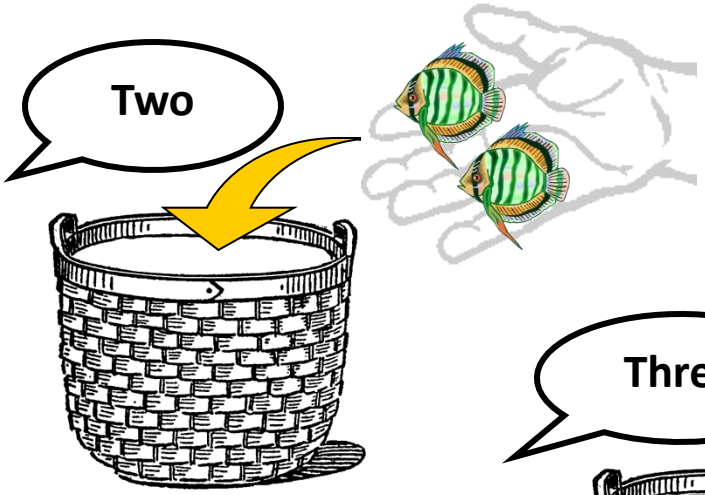


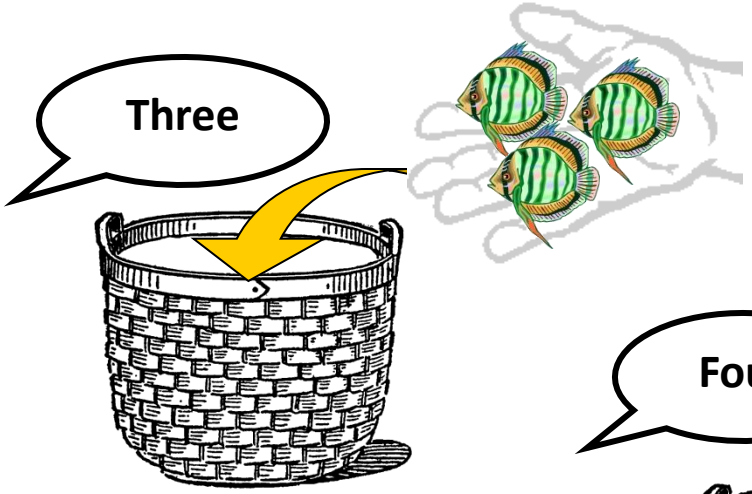


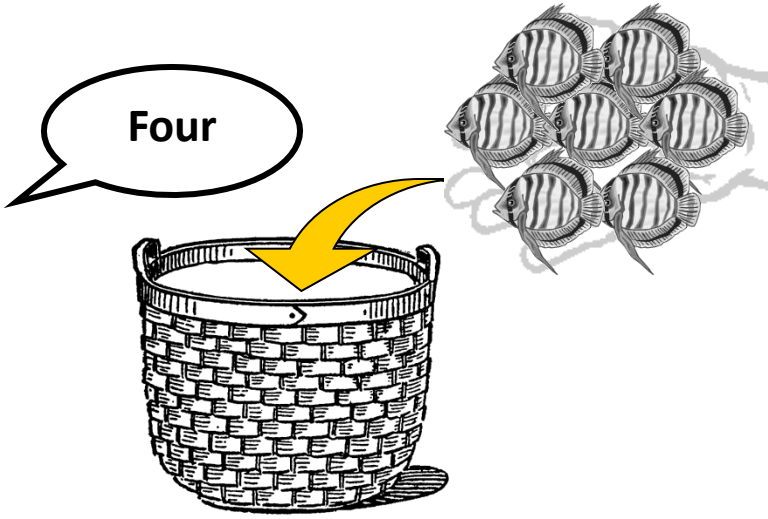


TWO-KNOWER

Children learn number words in stages







THREE-KNOWER

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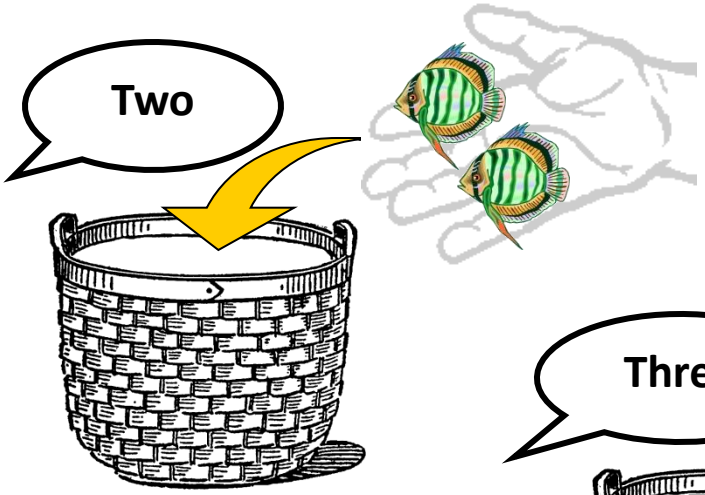
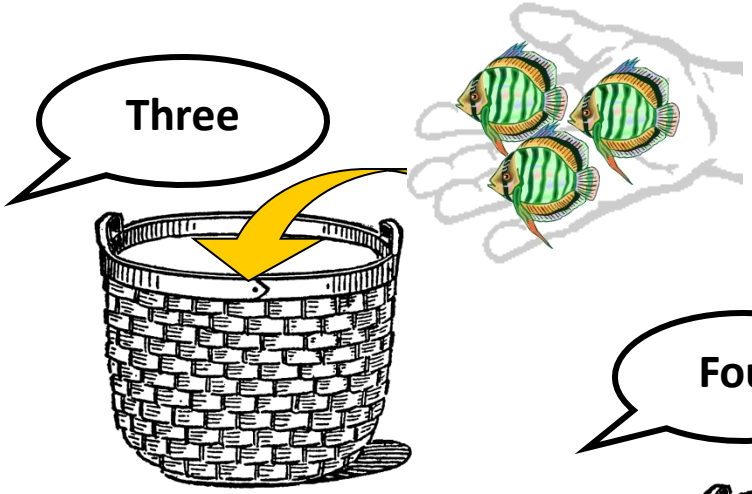
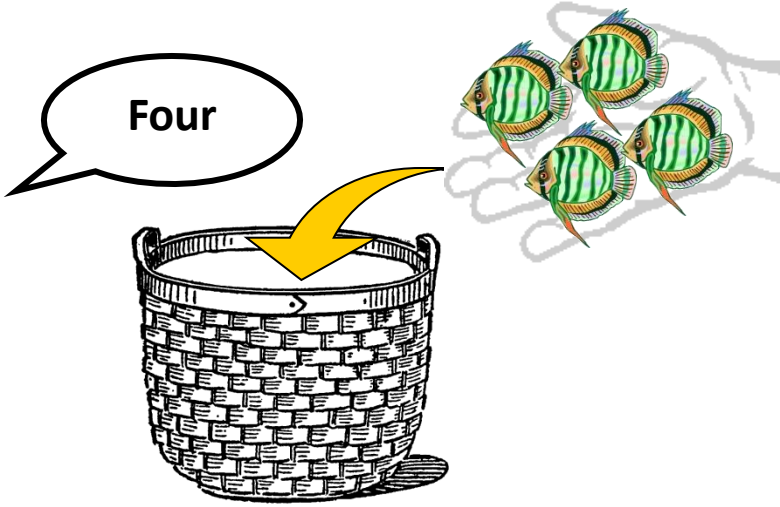




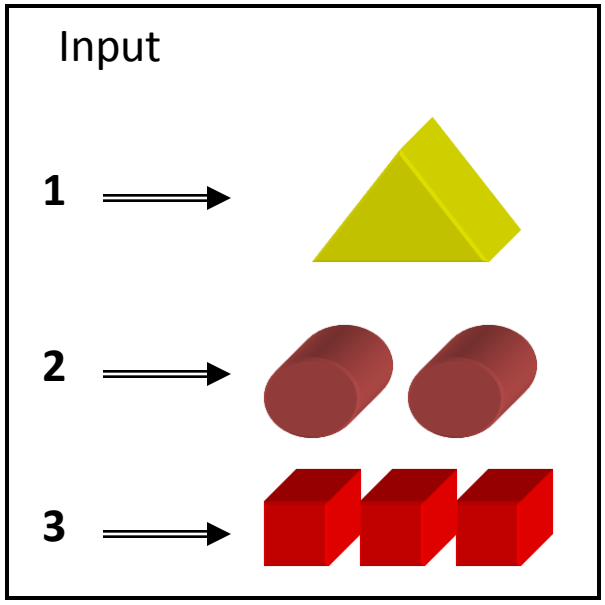


FOUR-KNOWER

- For adults number words are abstract
  - Don’t refer to things or properties
  - Predicates over sets of individuals from different ontological categories (e.g., objects, events)
- Children primarily learn to count objects….

Initial meaning of number words

- numbers acquired via experience with objects
- if initial concepts are abstract they should be quickly extend to other *individuals*



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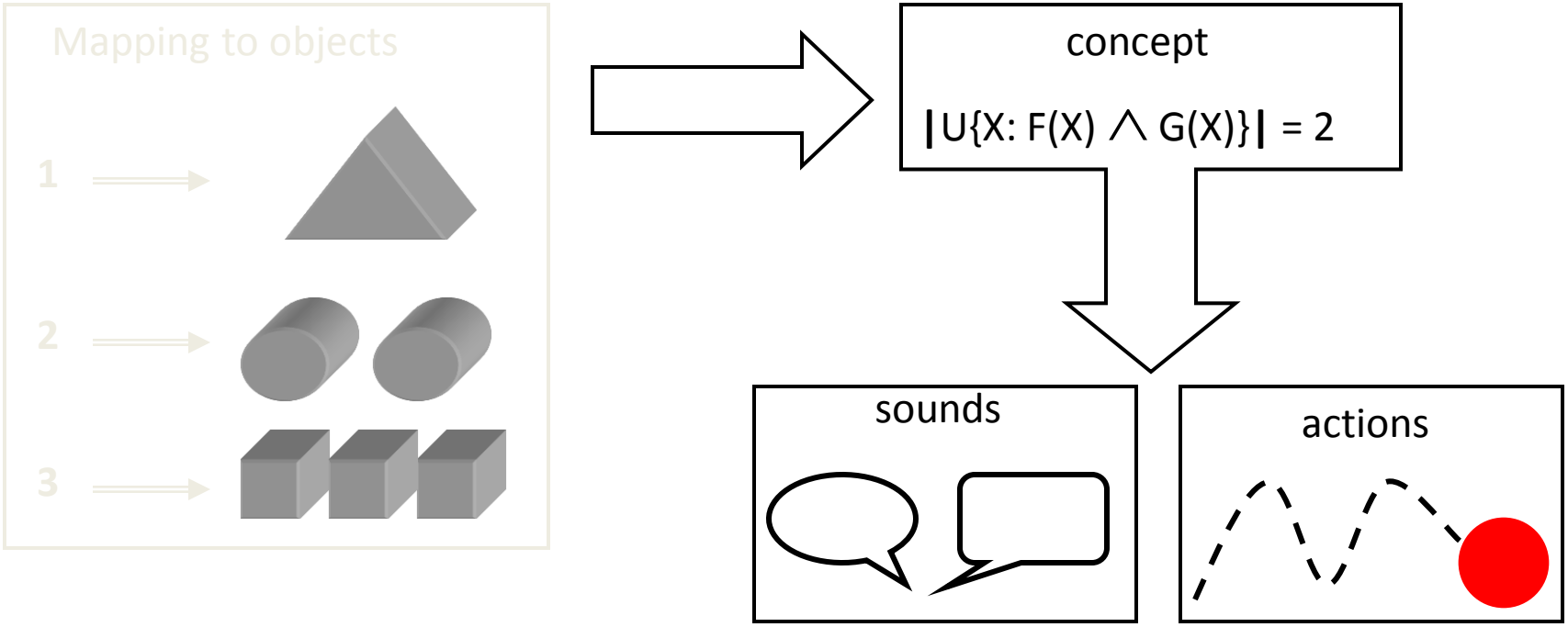
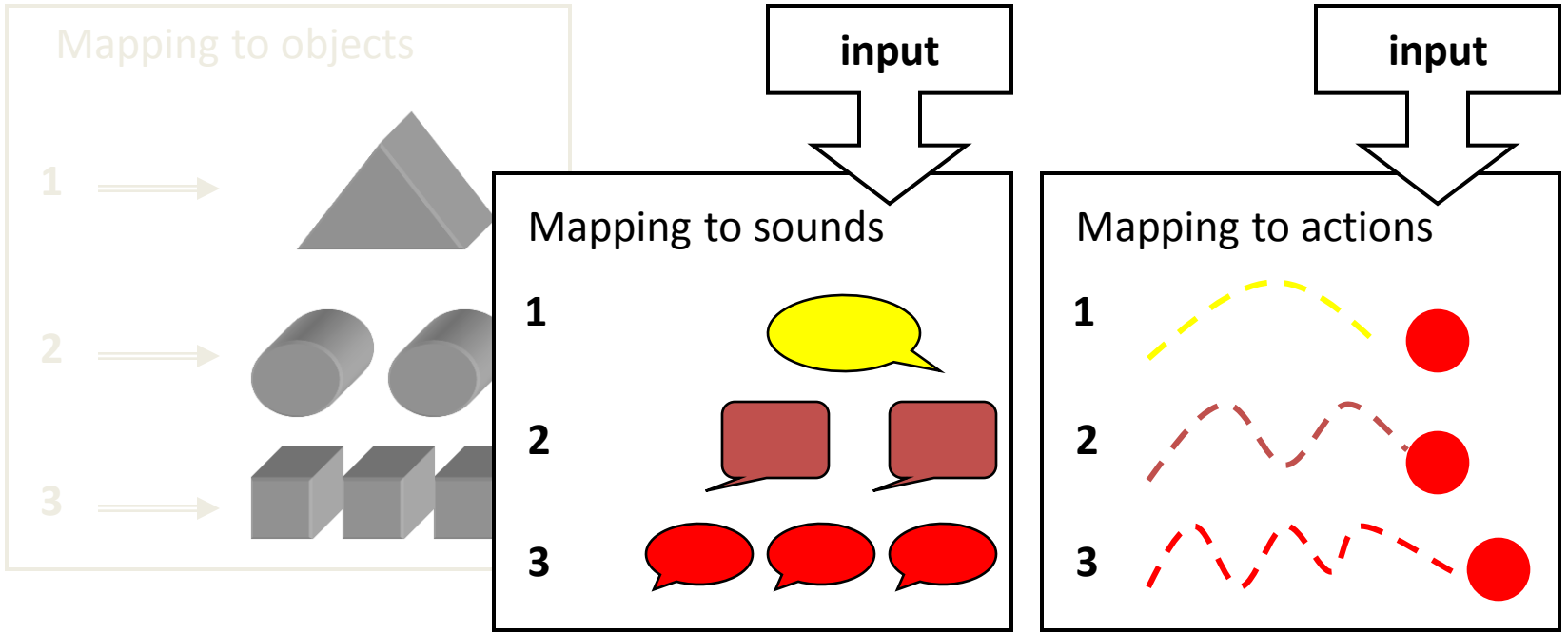


Initial meaning of number words

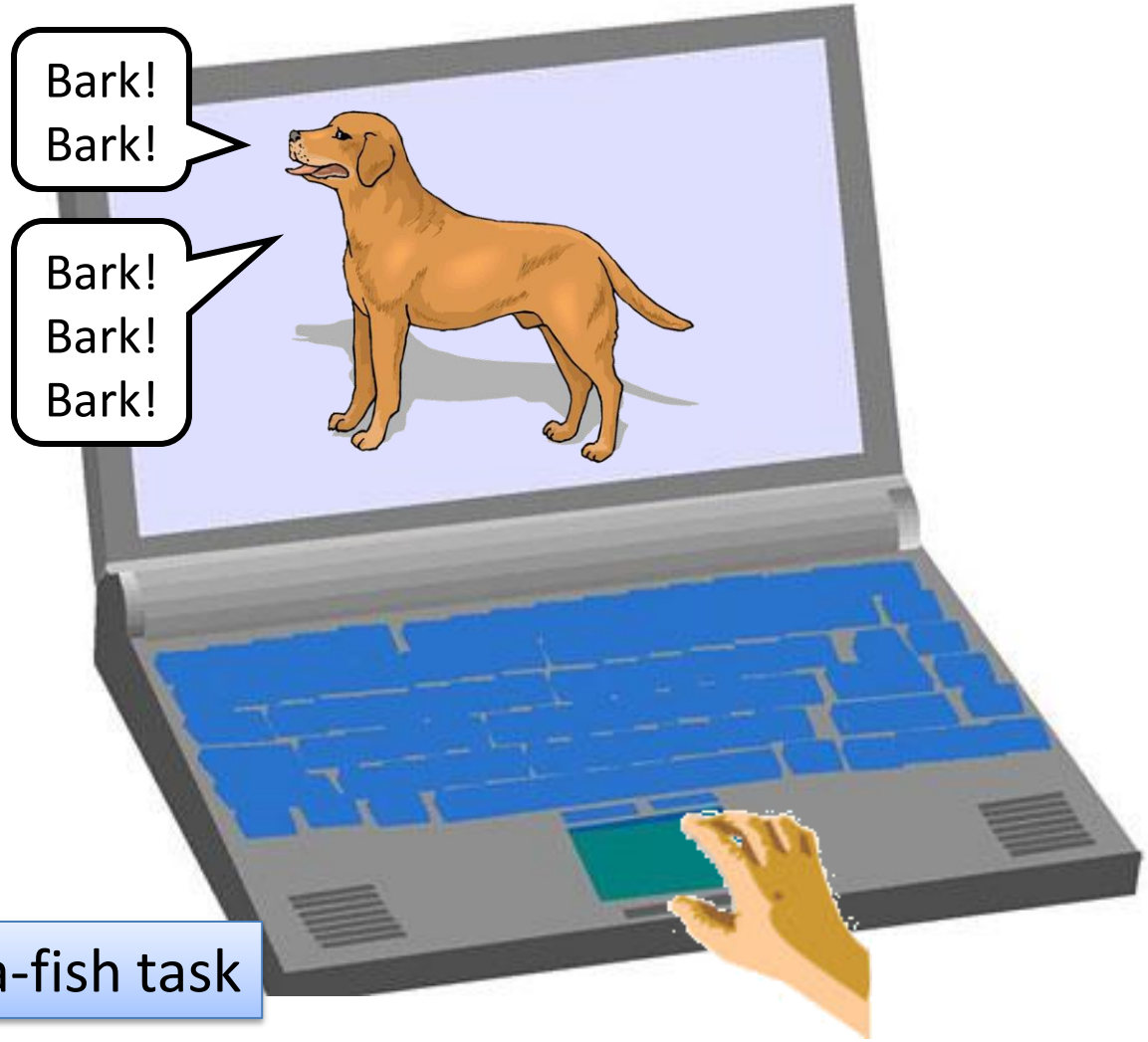
- If the initial meaning is concrete and applies only to objects, other uses acquired gradually via input



Produce-a-number sound task

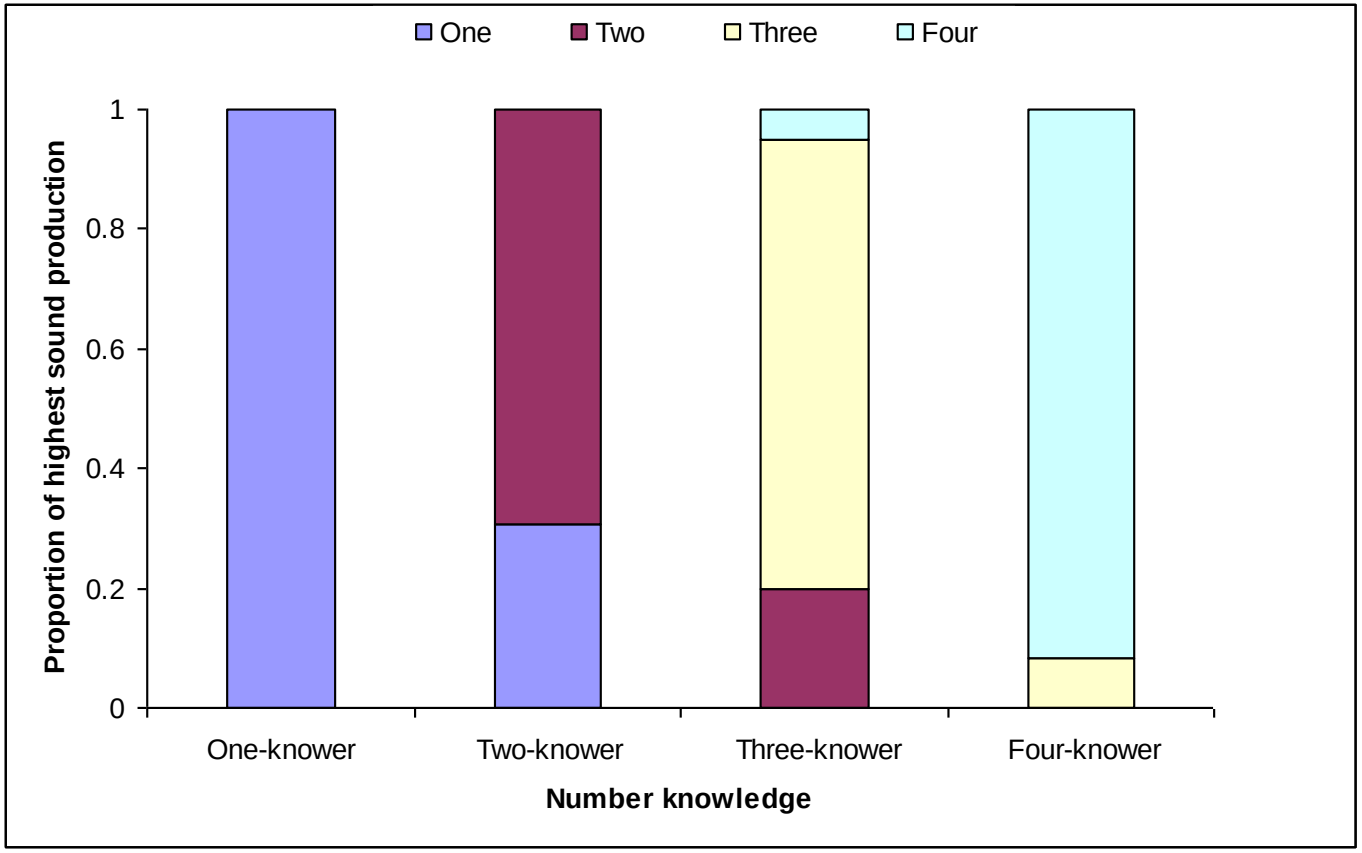
Make the dog bark **two** times

...**three** times



Compared to the give-a-fish task

Early number words apply to events as well as objects



N=68
2;6 to 3;9

R= .917, p < .001

Huang, Snedeker & Spelke (cut by over zealous reviewers)

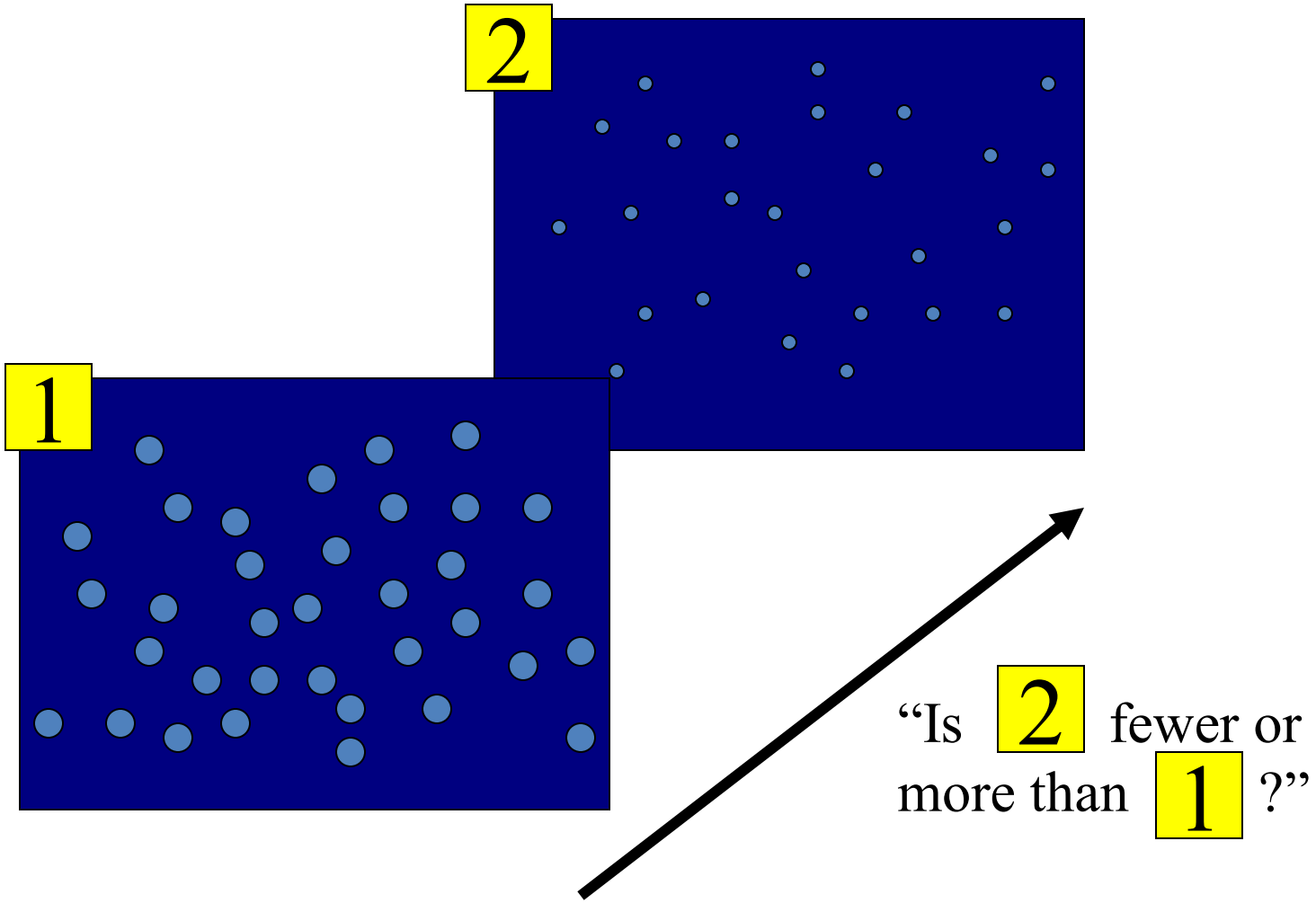
Where do these exact number concepts come from?

Pre-linguistic children have 2 systems for representing number….

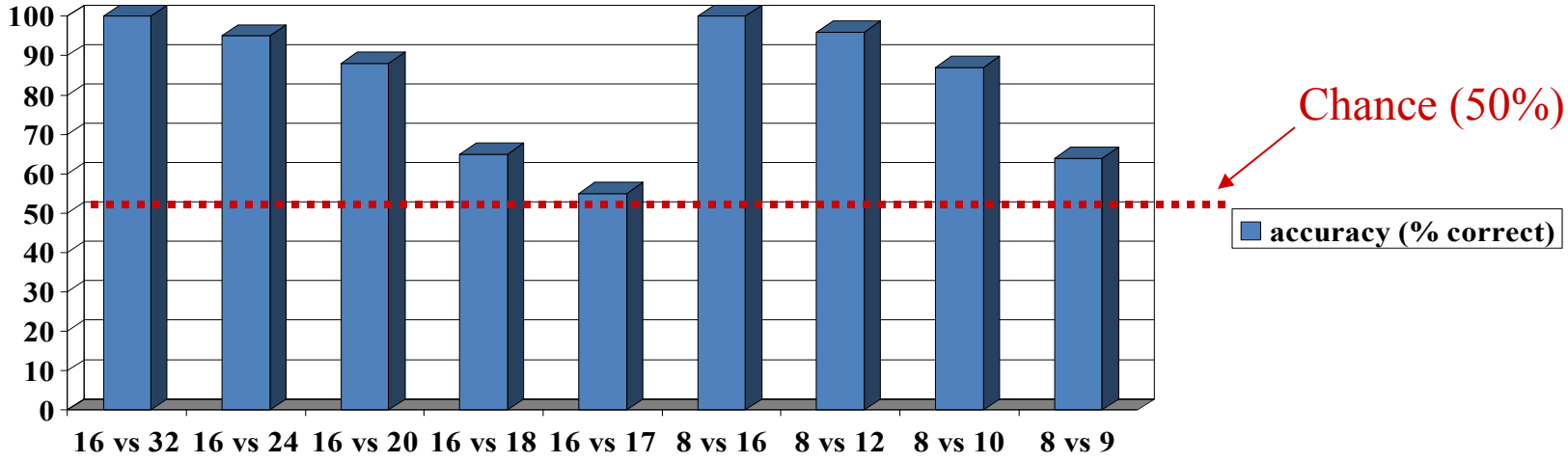
- Small Exact Number
  - Represents sets 1, 2 & 3
- Large Approximate Number System
  - Analog Magnitude System

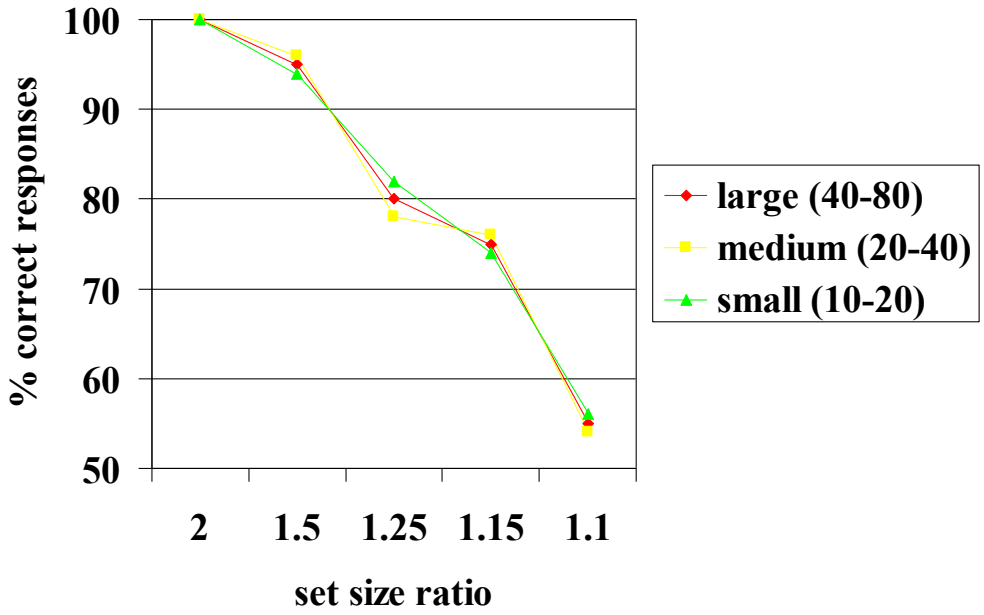
Approximate Number System in Adults

(Barth, Kanwisher & Spelke, 2003)



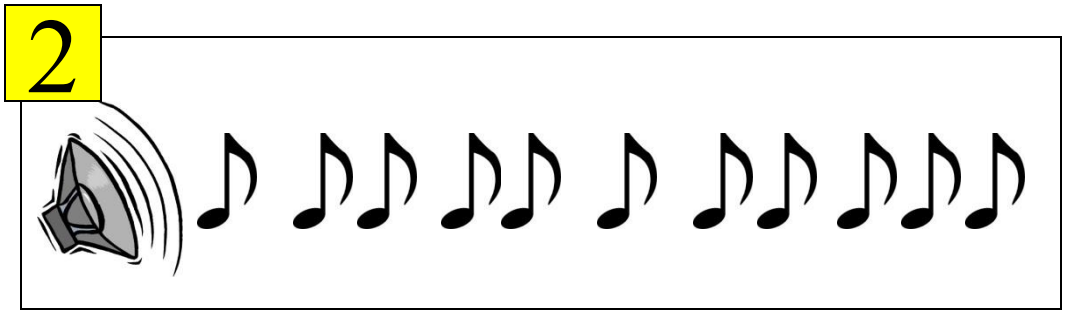
Numerosity discrimination by adults (Barth)

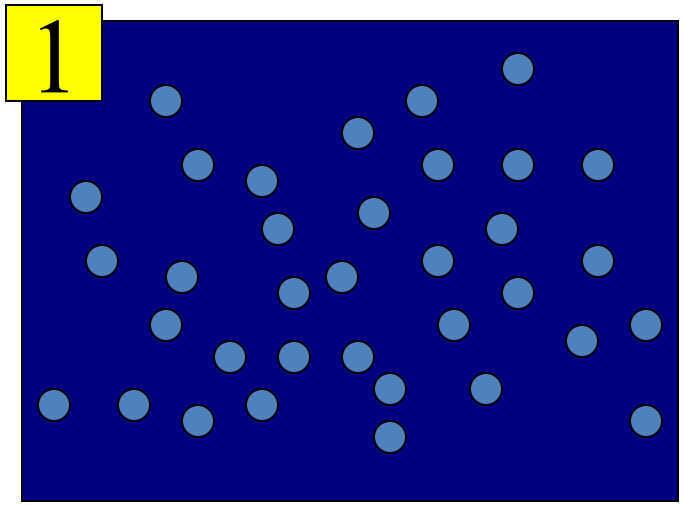




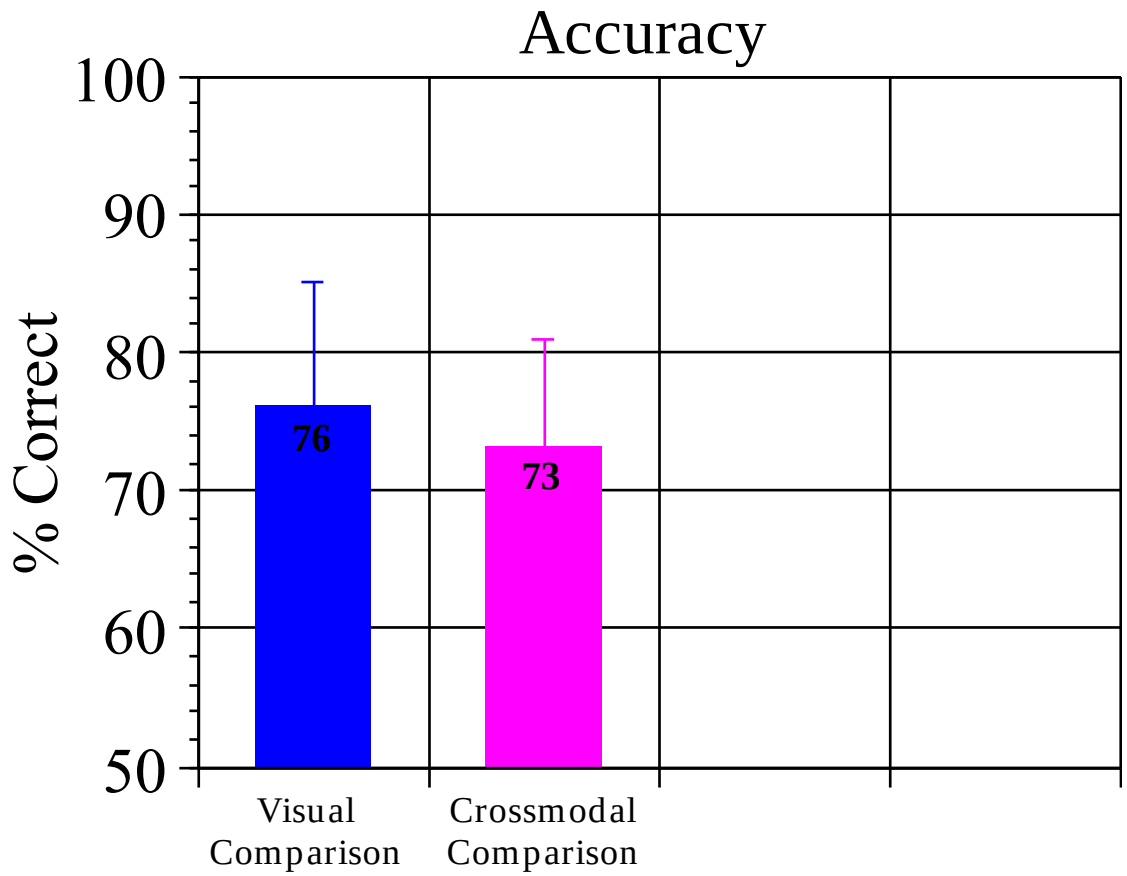
Weber's Law:
The discriminability of two numerosities depends on their ratio.

These representations are abstract: apply to individuals across domains and modalities



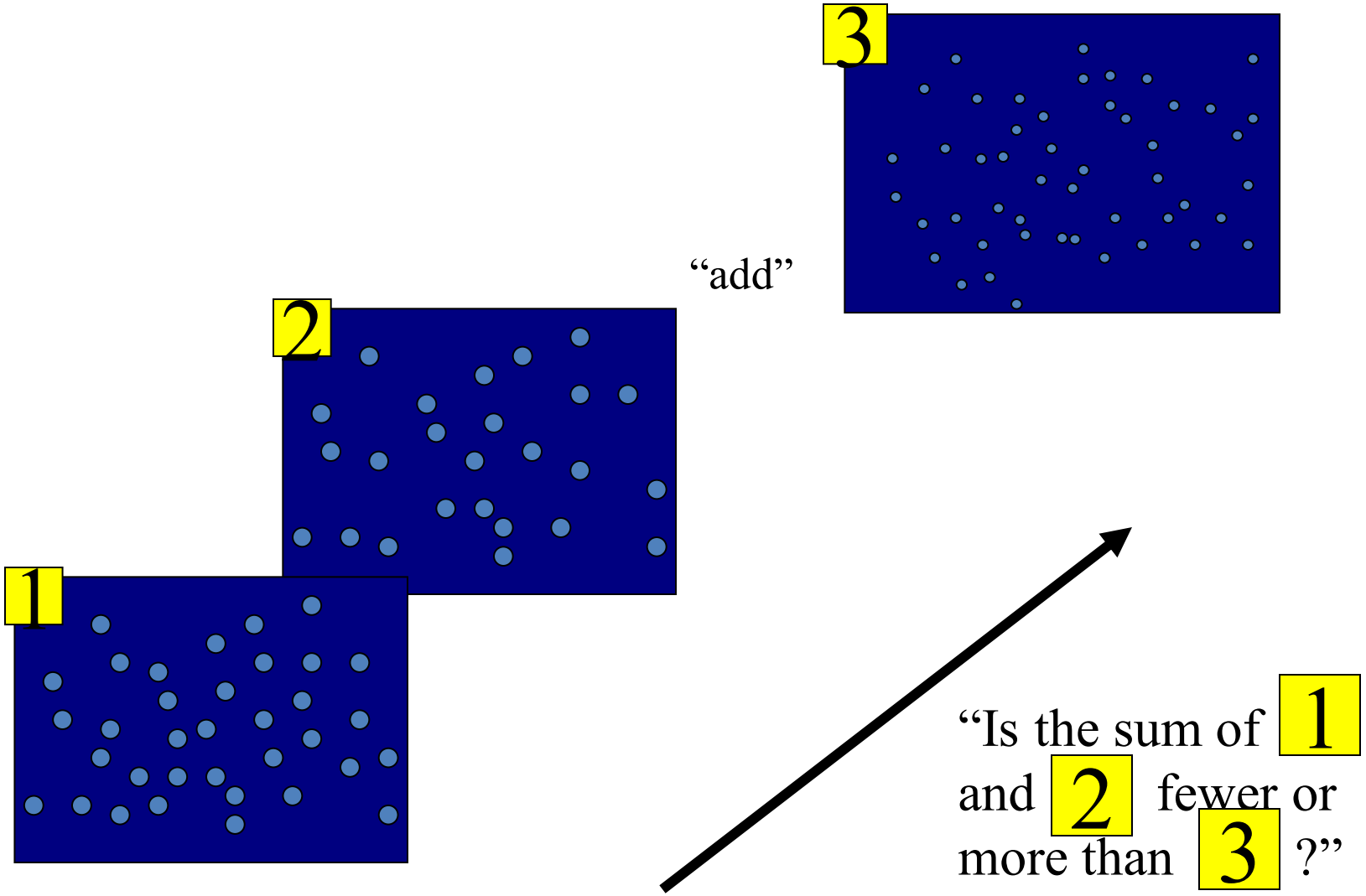


"Is 2 fewer or more than 1 ?"

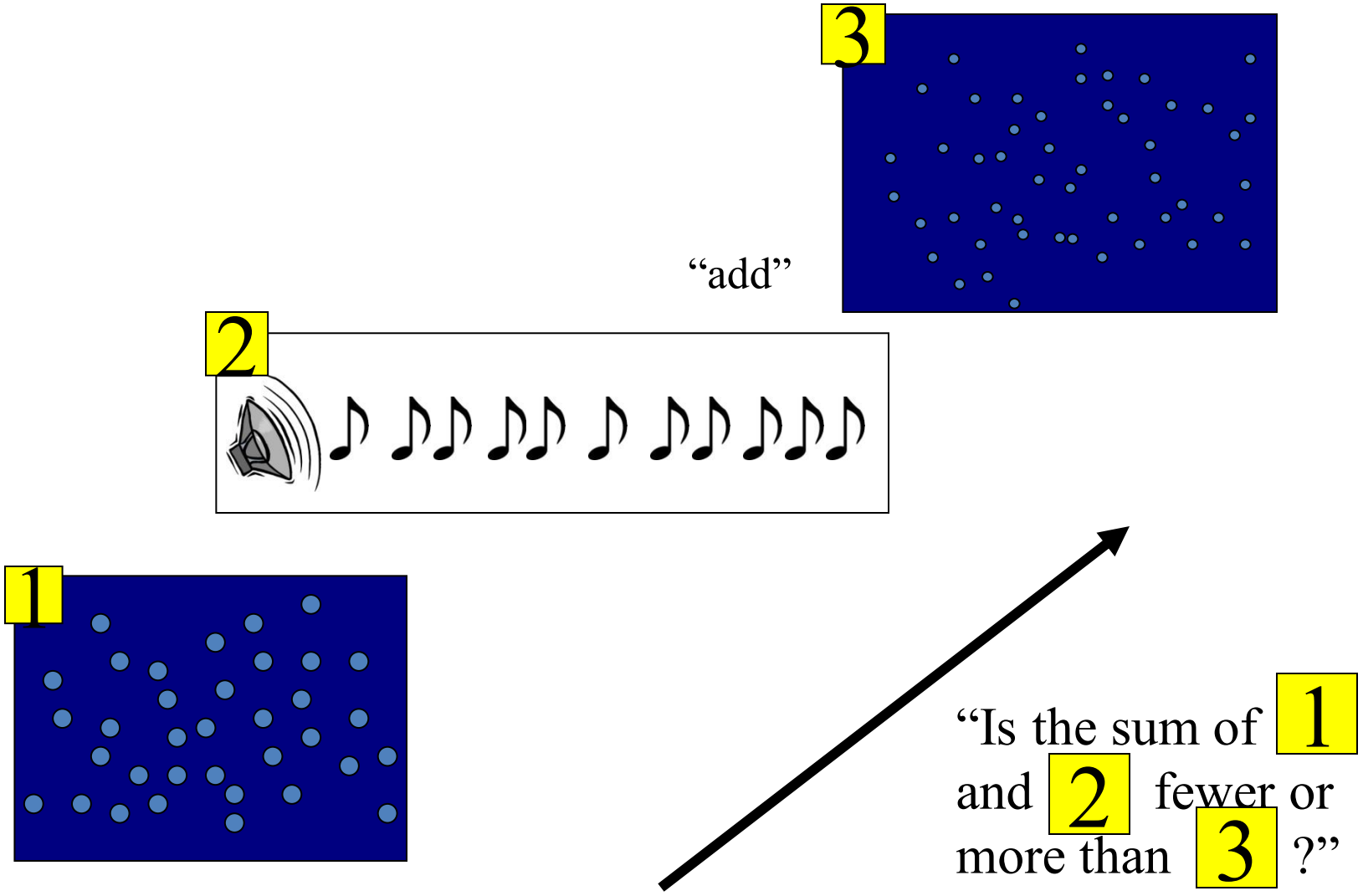


Cross-modal comparisons are almost as accurate as comparisons within the visual modality alone.

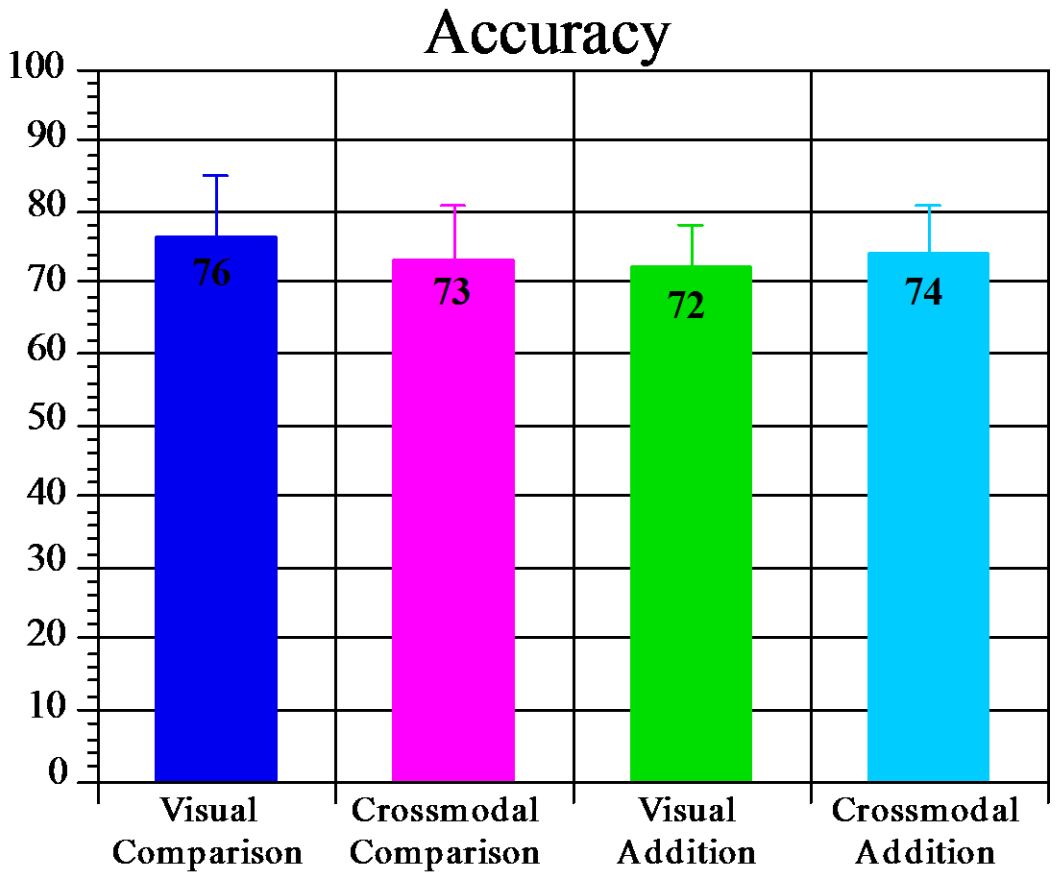
Adults can perform computations over these concepts: Addition of visual arrays



These computations can occur across modalities

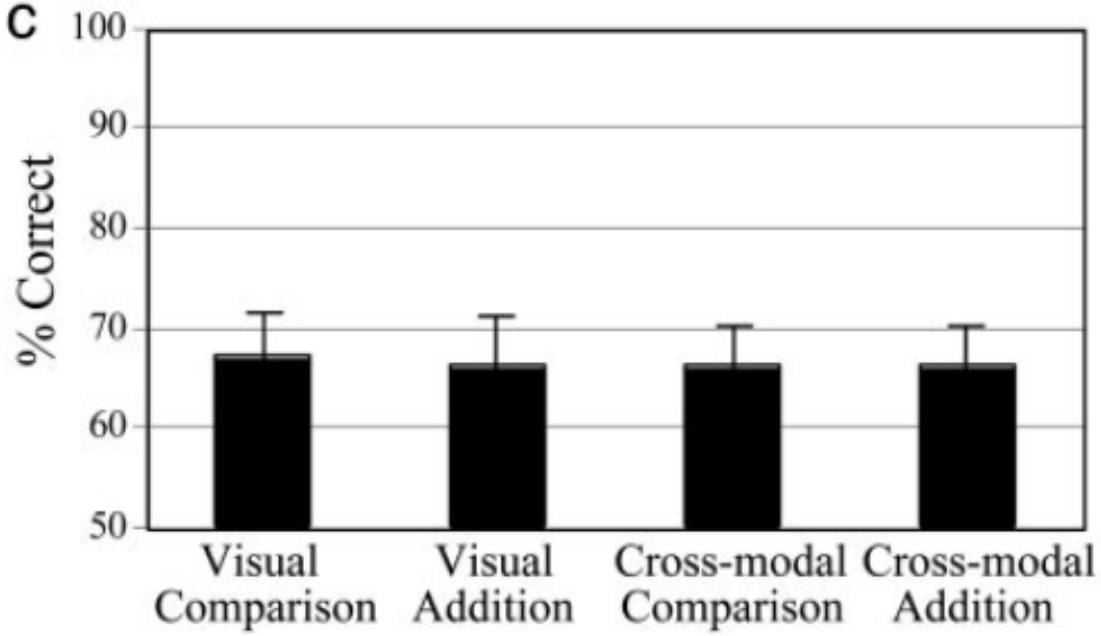


Nonsymbolic Comparison and Addition



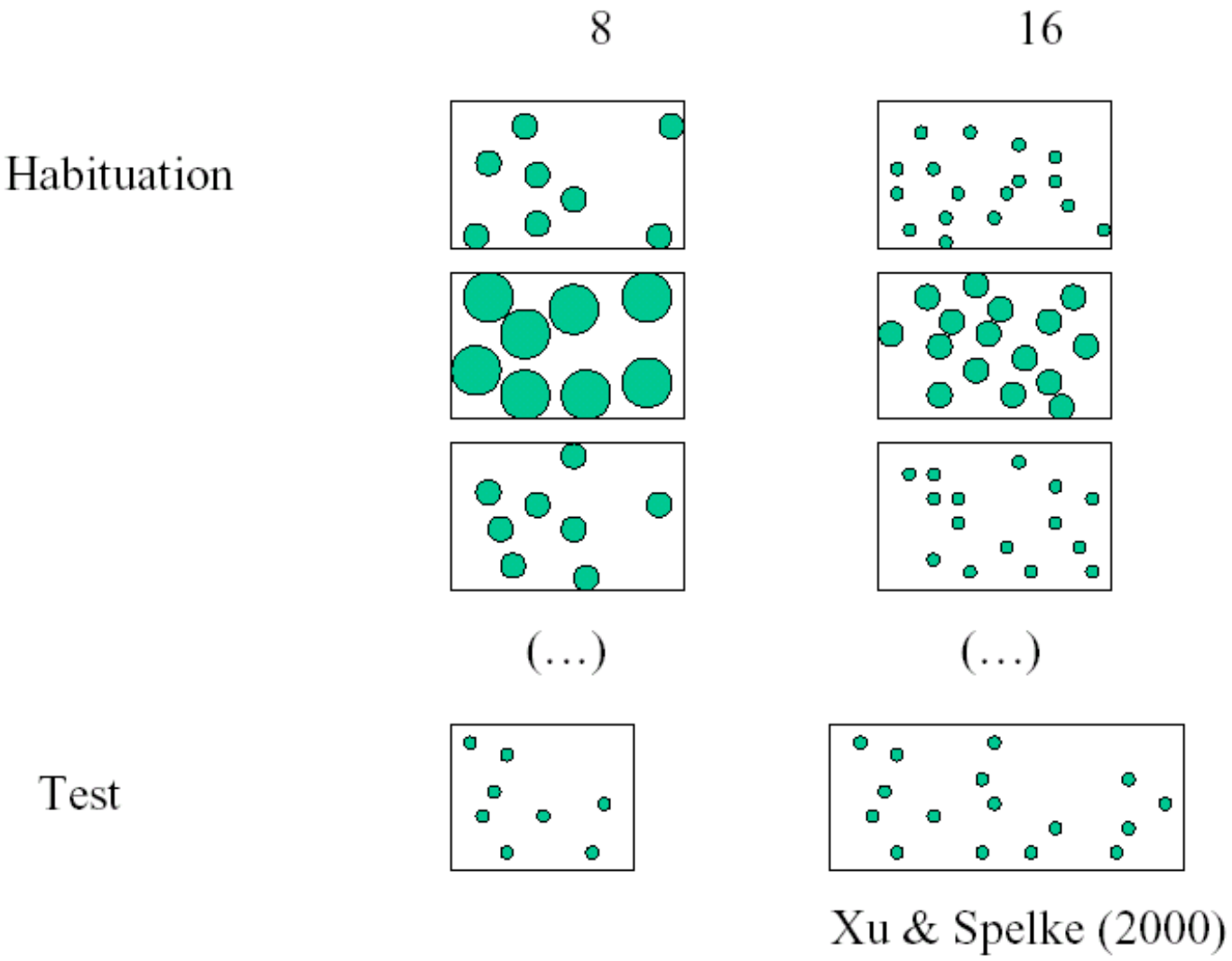
Barth, Kanwisher & Spelke (2003)

5-year-old children also have abstract large number representations



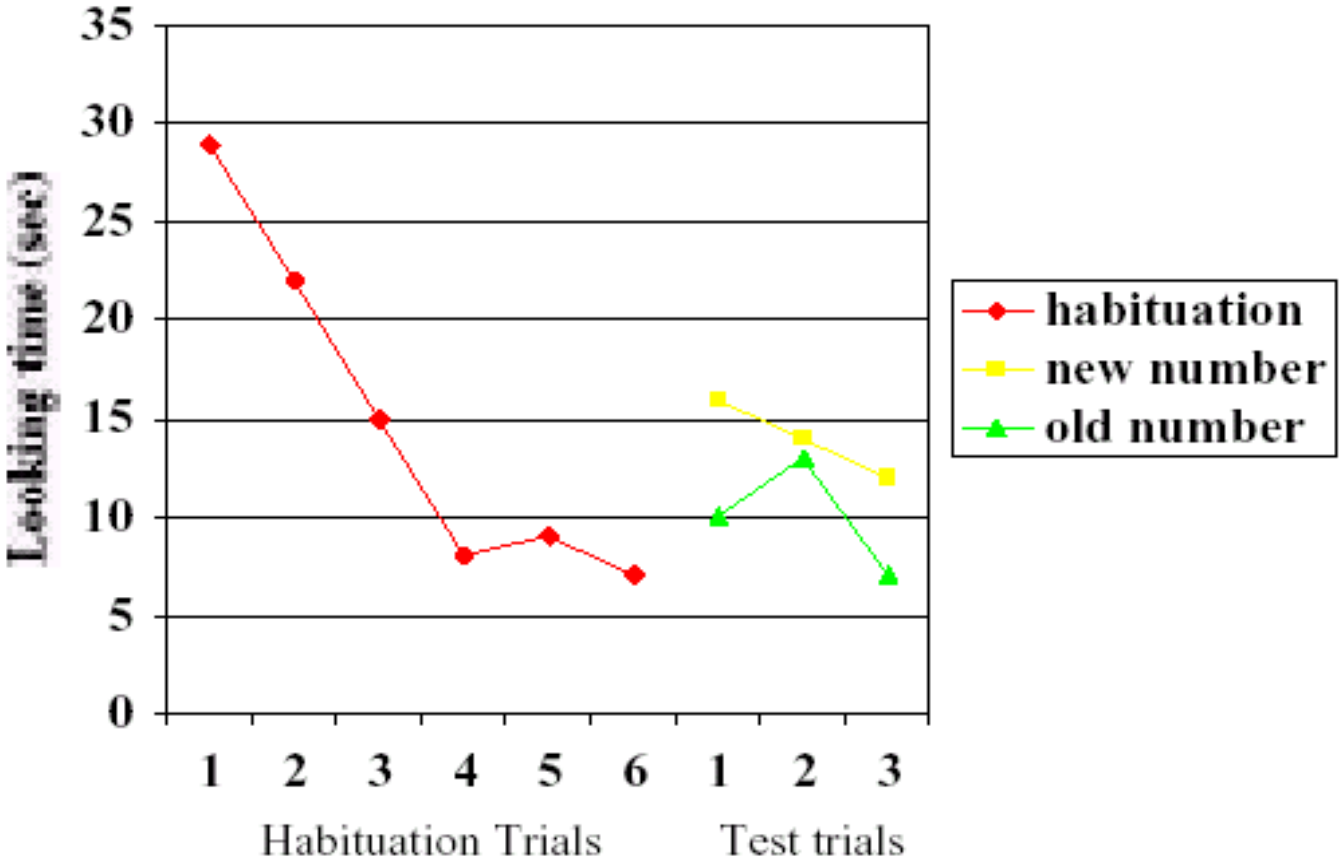
Barth, Lamont, Lipton & Spelke (2005)

Infants also have a large approximate number system



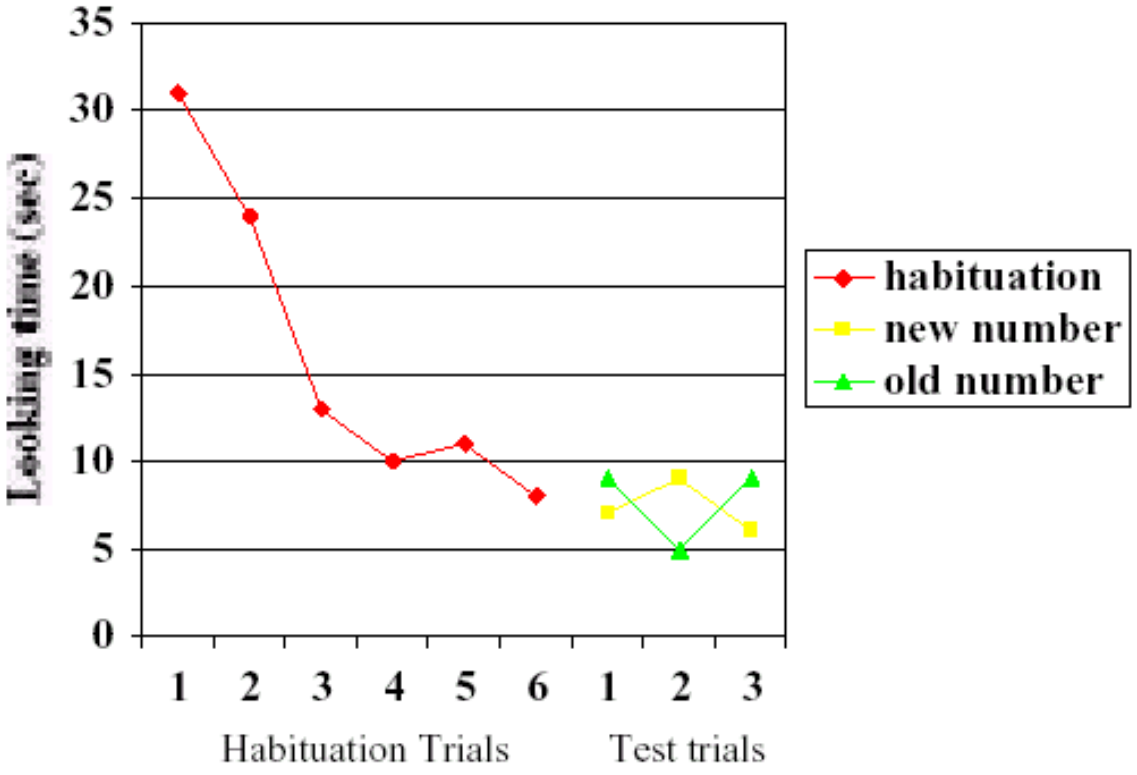
Xu & Spelke (2000)

8 vs. 16 dots



Infants discriminate between large numerosities in dot arrays.

Discriminating 8 vs. 12 dots at 6 months



Infants' number representations are imprecise.

Newborn infants match number across modalities

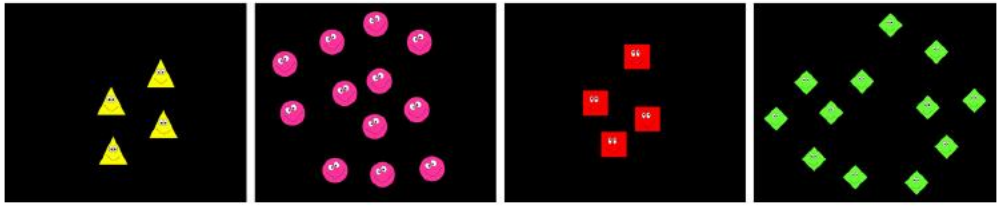
Familiarization (2 min)

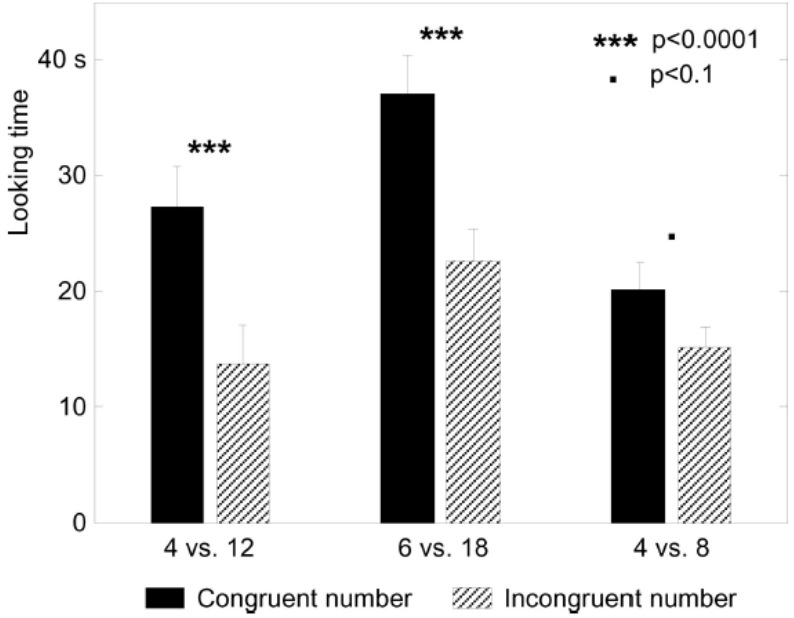
... " tu-tu-tu-tu-tu-tu-tu-tu-tu-tu-tu-tu " ... " ra-ra-ra-ra-ra-ra-ra-ra-ra-ra-ra-ra- " ...

or

... " tuuuuu-tuuuuu-tuuuuu-tuuuuu " ... " raaaaa-raaaaa-raaaaa-raaaaa " ...

Test (4 trials)

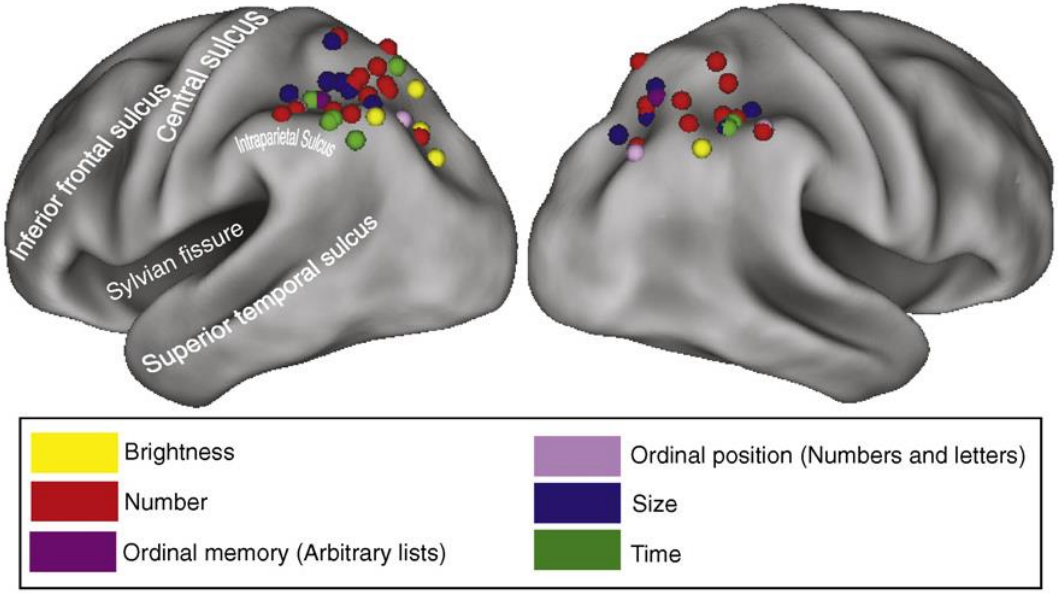




Izard, Saan, Spelke & Sterhi (2009)

How are these abstract number representations created

- Evolutionarily old system (rats, ants…)
- Associated with interparietal sulcus
- Spatial (and functional) overlap with other magnitude estimates



Cantlon et al. (2010)

How are these abstract number representations created

- Mechanism allows for *accumulation* on the basis of *individuation*

abstraction is in the creation of an individual
(filling the cup)

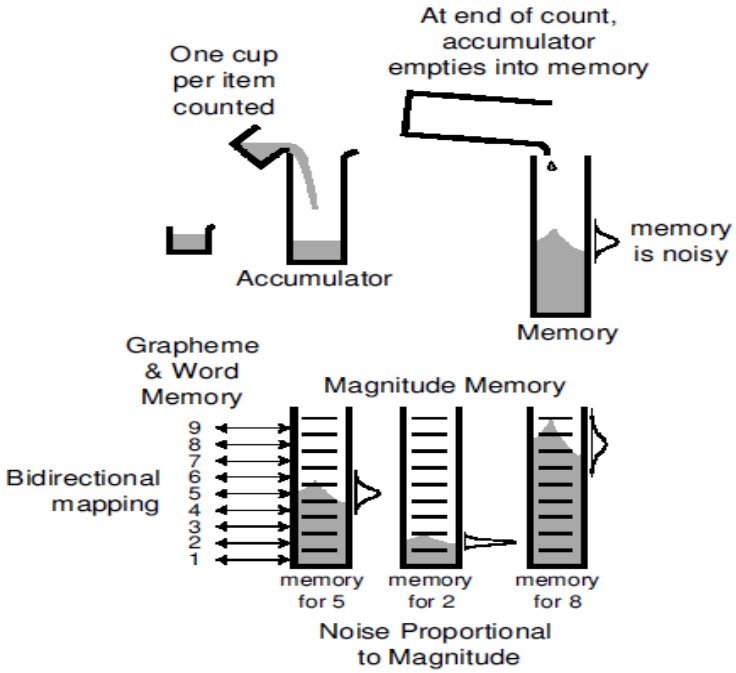


Figure 1. The accumulator model. A magnitude representing a numerosity is formed through accumulation of "cup fulls" of activation, one cup for each item or event enumerated. Accumulated magnitudes from an ongoing count may be compared to a magnitude stored in memory or may be mapped to symbols for quantities. However, magnitudes read from memory have inherent scalar variability that may result in errors. The greater the magnitude, the more likely an error.

Where do integers come from….

- They are more powerful than either pre-linguistic representation
  - Infinite set size and precise numerosity
  - Can distinguish 17 from 18 or 200 from 201
- Possible ingredients:
  - Counting routine
  - Integrated with approximate number system?
  - Integrated with small exact numerosities?
  - Integrated with natural language quantifiers?

See Carey (2009)

Embodied cognition(s)

- Embodiment: the claim that concepts are grounded in sensory-motor systems
- Grounded =
  - ~~– Linked to, connected with~~ √
  - ~~– Processing causally influenced by these links~~ √
  - – Partially composed of
  - – Initially, completely composed of
  - ~~– Completely composed of~~ X

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  - ~~– Completely composed of~~ X

Partially embodied concepts?

- Mechanism for integration will depend on theory of conceptual content
  - Feature theories (arguably exhausted: exemplar, prototype etc.)
  - Conceptual Role Semantics (Keil, Carey)
  - Atomic theories (Laurence & Margolis, 2002)
  - Neo-Classical theories (Kemmerer & Gonzalez-Castillo, 2010)
- Some traveling tips
  - Decide what you want your theory of conceptual content to do (we may need more than one)
  - Consider theories of content with complementary strengths