Embodied cognition(s), development and language: An outsider’s perspective

Jesse Snedeker
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

Phenomenon: Glenberg & Kaschak, 2002; Zwaan and Taylor, 2006
Activation of Motor Cortices

Motor activation causally implicated

Subthreshold Transcranial Magnetic Stimulation (facilitatory)

Many caveats....

• Effects often depend on semantic context
  – 1\textsuperscript{st} vs. 3\textsuperscript{rd} 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 \textit{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
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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

- phonology
- lexicon
- syntax
- semantics
- pragmatics
Modularity:
Processes sequential & independent

- phonology
- lexicon
- syntax
- semantics
- pragmatics
21\textsuperscript{st} Century Standard Model: Cascaded Processing

- Phonology
- Lexicon
- Syntax
- Semantics
- Pragmatics
21st Century Standard Model: Cascaded Processing

phonology

lexicon

syntax

semantics

pragmatics
21st Century Standard Model: Cascaded Processing

phonology \rightarrow lexicon \rightarrow syntax \rightarrow semantics \rightarrow pragmatics
21\textsuperscript{st} Century Standard Model: Cascaded Processing

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Example: Phonosemantic priming

“Pick up the log...g”

Conceptual priming via phonological associate

Yee & Sedivy (2006)
5 yr old children also show phonsemantic priming

Huang & Snedeker (2011)
21st Century Standard Model: Interactive Processing

- phonology
- lexicon
- syntax
- semantics
- pragmatics
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 = oscillate vertically (motion)
• Activation in V5/MT (motion) is greater for verbs with motion competitors
Informational cascade in object naming
Informational cascade in object naming
Informational cascade in object naming

log

LOG
Informational cascade in object naming

"log"
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)
Phonosemantic activation... without speech

Inspired by Mani & Plunkett (in prep)

1500ms

200ms

2050ms

“cup”

“cat”

“oooh”
Unrelated Trials

- "book"
- 1500ms
- 200ms
- "oooh"
- 2050ms
- "book"
Implicit naming creates phonosemantic inhibition in 24 month olds

Proportion of Looks to Target

Milliseconds from onset of “ooh”
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)
21\textsuperscript{st} century standard model is pervasive

Example: visual areas in macaque

Rees, Kreiman & Koch (2002)
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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 & Baillargeon, 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)
Children learn number words in stages

Two

Three

Four

TWO-KNOWER
Children learn number words in stages

THREE-KNOWER
Children learn number words in stages
• 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*
Initial meaning of number words

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

\[ |U\{X: F(X) \land G(X)\}| = 2 \]

Mapping to objects

1 → triangle
2 → circles
3 → cubes
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

R = .917, p < .001

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

N=68, 2;6 to 3;9
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)

"Is 2 fewer or more than 1?"
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.
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

“Is the sum of 1 and 2 fewer or more than 3?”

“add”
These computations can occur across modalities

"Is the sum of 1 and 2 fewer or more than 3?"
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

Habituation

8

(...)

16

(...)

Test

Xu & Spelke (2000)
Infants discriminate between large numerosities in dot arrays.

8 vs. 16 dots
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 " ... " ra-ra-ra-ra-ra-ra-ra-ra-ra-ra-" ...

or

... " tuuuuu-tuuuuu-tuuuuu-tuuuuu " ... " raaaaaa-raaaaaa-raaaaaa-raaaaaa " ...

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)
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)
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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