Acting out thought: Body in mind, mind in body

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Situating the mind

- "The mind is a machine." But what kind? (Searle, 1994)
  - Ancient Greeks: catapult
  - Freud: hydraulic & electro-magnetic systems
  - Sherrington: telegraph system
  - Searle's childhood: telephone switchboard
  - Searle's adulthood: digital computer
  - Frank Zappa: "The mind is like a parachute. It doesn't work if it isn't open."
  - Clark: "Mind as Mashup"

Reclaiming the body: Six flavors of embodiment

1. **"The brain bleeds through"**
2. The mind is coupled to the body & world
3. The mind shapes the body
4. The mind is grounded in the body
5. The mind is shaped by the body
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"The brain bleeds through" (Kirsh)

- Recall the *Physical Symbol System Hypothesis*: "A physical symbol system has the necessary and sufficient means for general intelligent action."– Newell & Simon
- Functionalism: Mental states (e.g. beliefs) are determined by their functional role (aka causal relations...)
  - ...therefore the implementation doesn't matter. (Putnam)
  - "All that matters is the software!"
- But the meat matters!

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The mind is coupled to the body & world

- Tight real-time coupling between brain, body, world.
- The mind isn't a symbol-crunching computer, but a body-and-world-coupled dynamical system (Thelen & Smith; Varela, Thompson, and Rosch; Spivey)
  - infant walking
  - Braitenberg vehicles
  - cricket phonotaxis

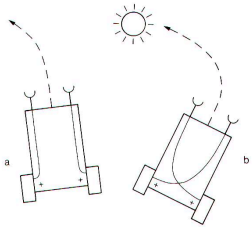

Figure 3
Vehicles 2a and 2b in the vicinity of a source (circle with rays emanating from it). Vehicle 2b orients toward the source, 2a away from it.

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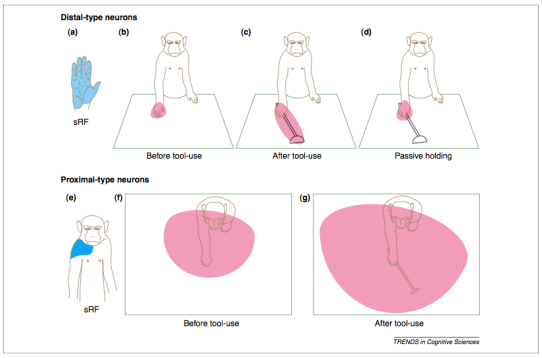
The mind shapes the body

- Body Schemata:
  - Phantom limbs
  - "Alice in Wonderland Syndrome"
- Tool use and peripersonal space:
  - William James and the blind man
  - Monkey rake-use



Maravita and Iriki (2004)

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The mind is *grounded* in the body

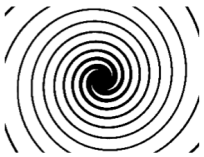

Fig. 1. Spiral stimulus for "towards" and "away" displays.

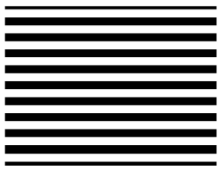

Fig. 2. Horizontal bar stimulus for "up" and "down" displays.

- Abstract thought redeploys the neural substrates that underly perception and action (Barsalou)
- "Language is a new machine built out of old parts." - Elizabeth Bates
- Kaschak et al (2005):
  - "The car approached you." vs. "He rolled the bowling ball down the alley."
  - "The steam rose from the boat." vs. "The sand poured through the hourglass."

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Disciplining the mind 1: The body

- "Mental structures that originally evolved for perception or action appear to be co-opted and run "off-line," decoupled from the physical inputs and outputs that were their original purpose, to assist in thinking and knowing." (Wilson, 2002)
- Conceptual Metaphor (Lakoff & Johnson)

Cold hands, warm heart

- "Send her my warm hellos."
- "He was quite cold to her."
- "I was lukewarm toward the new kid on the block."
- Experiencing physical warmth promotes interpersonal warmth (Williams & Bargh, 2008)
  - Personality judgements
  - Gift-giving behavior

Weighty Issues

- "I really need to weigh the importance of this new policy."
- "My friend's financial difficulties have been heavy on my conscience."
- "I was heavily influenced by..."
- Experience of weight affects perception of steepness (Proffitt 2006)...
- ...and of the importance of an issue, or the value of a currency (Jostmann, Lakens, & Schubert, 2009)

Seat-of-the-pants decisions

(Ackerman et al, 2010)

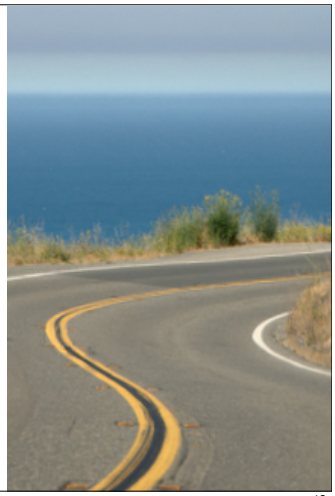
- We conceptualize relationships in terms of haptic sensations:
  - "It's been a rough day."
  - "She's a rock."
  - "Driving a hard bargain"
- Feel a magic trick => judge an interaction?
- Feel a puzzle => play Ultimatum?
- Sit in a chair => bargain for a car?

Sinister thoughts

- Left and right handedness affects good vs. bad judgments (Casasanto 2009)
- ...but this can be changed in a few minutes by changing the way the body interacts with the world. (Casasanto & Chrysikou 2010)

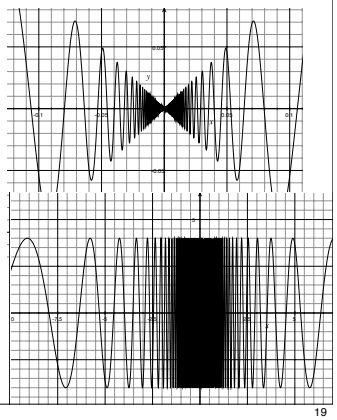
Fictive Motion

- Cognitive process by which we unconsciously conceptualize static entities in dynamic terms. (Talmy 2000)
  - "The road runs along the coast."
  - "The fence stops at the tree."
  - "The equator runs through Brazil."



Fictive Motion in Mathematics 2: Limits and Continuity

- Formally: Let a function f be defined on an open interval containing a, except possibly at f itself, and let L be a real number. Then $\lim (x \to a) f(x) = L$ means that, for all $\varepsilon > 0$, there exists $\delta > 0$, such that whenever $0 < |x - a| < \delta$, then $|f(x) - L| < \varepsilon$.
- Informally: "A function is continuous if you can draw it without lifting your hand."
- A function "**jumps**," "**tends to**," "**moves toward**" or "**reaches**" a limit.



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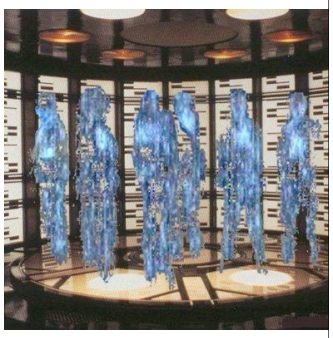
Cognitive Implications of Fictive Motion

- Internal spatial logic: "If you have traversed a route to a current location, you have been at all previous locations on that route." (Lakoff & Núñez, 2000)
- Fictive motion in language may evoke an embodied mental simulation:
  - Reading-time (Matlock 2004)
  - Eye-tracking (Matlock and Richardson, 2004)
  - Reaction-time (Bergen et al, 2007)



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Adjudicating Cognitive Reality

- Are these apparent instances of fictive motion in mathematics merely conventionalized expressions --- so-called dead metaphors?
- Enter gesture as adjudicating evidence...

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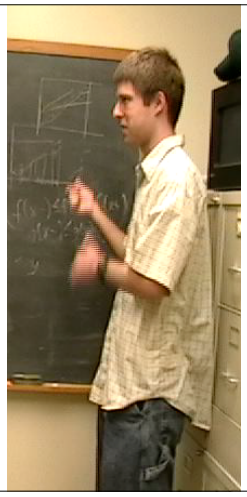
Gesture: Index of cognition

- Metaphoric gesture can parallel or precede metaphoric speech -- and even exist independently of metaphoric speech (Cienki 1998)
- "Gesture can, thus, serve as a useful adjunct to speech when attempting to discover cognitive processes in problem-solving." (Garber & Goldin-Meadow, 2002)



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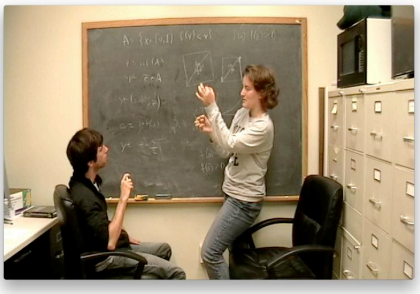

Theorem: Let f be a strictly increasing function from [0, 1] to [0, 1]. Then there exists a number a in the interval [0, 1] such that $f(a) = a$.

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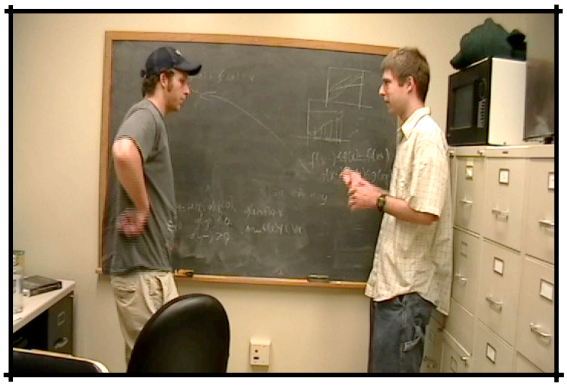

Example 1: Increase & limits

Trajector, path, co-timing

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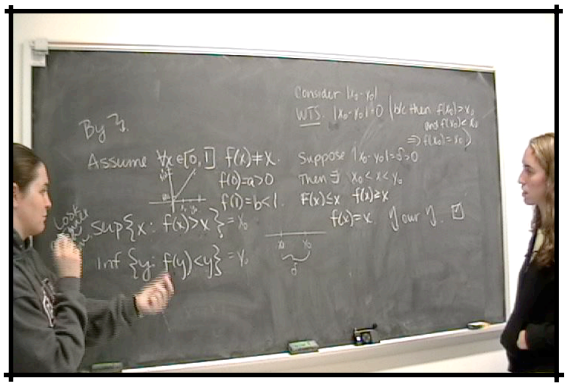
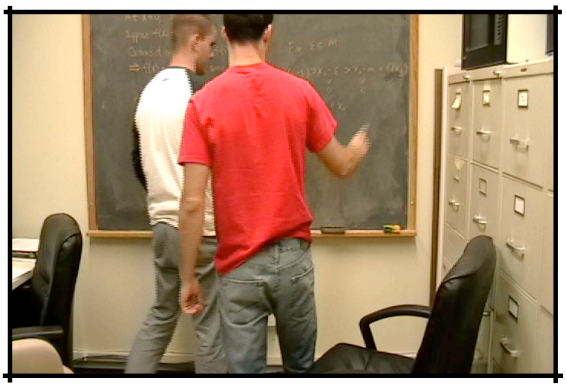


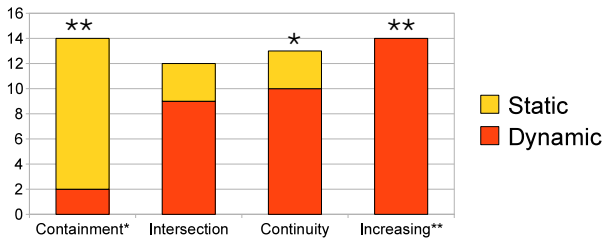
Example 2: Containment

Staccato indexing of endpoints



Example 3: Increasing

Trajector, path, inference



- When talking about increasing functions, gestures were significantly more often dynamic ($F(1,10) = 28.90$, $p = .0003$).

- When talking about containment and closeness, gestures were more often static (respectively $F(1,12) = 6.75$, $p = 0.0232$ and $F(1,10) = 76.73$, $p<0.0001$)

Abstract thought, embodied inference

- Gesture: a tool for the quantitative study of abstract reasoning "in the wild"
- Embodied cognition: Our understanding of highly abstract domains is structured by our sensorimotor engagement with the world
- The body is a privileged resource for reasoning and creating meaning

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Disciplining the mind 2: Language

If the brain is a dynamical system, then how do we engage in structured, stable reasoning -- to "reliably follow a trajectory"?

- "Encounters with words and with structured linguistic encodings act to **anchor and discipline intrinsically fluid and context-sensitive modes of thought and reason**." (Clark 2008, p.53)

Disciplining the mind 2: Language and number

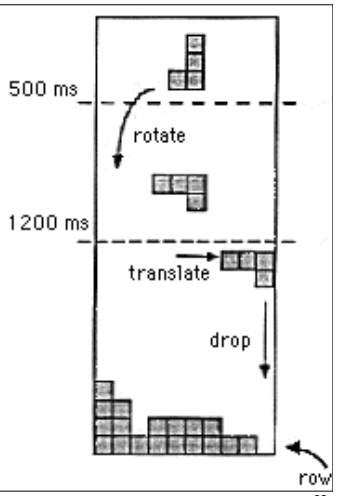
- Two brain-based number-ish systems: large-and-approximate & small-but-exact
- How do we get from these basic capacities to a notion of *unlimited, exact numbers?*
  - Count list & (embodied) count practice
- Cultural lesions:
  - Cultures without numbers (e.g. Pirahã)
  - English-speakers count like the Pirahã when they can't use language (Frank et al 2008)
- Principle of Ecological Assembly in action: "Many of our mathematical thoughts rely, if this is correct, on the coordinated action of various resources."

Disciplining the mind 2: Language and cognition

- According to Clark (2008), words and sentences are...
  - "real-world structures (material symbols)" (p.55)
  - "inputs (whether internally or externally generated) that **drive, sculpt, and discipline the internal representational regime**." (p.54)
- Hutchins (1995):
  - "The language or languages used by task performers to communicate are almost certain to **serve as structuring resources**, and the **structure of language will affect the cognitive properties of the group** even if they do not affect the cognitive properties of individuals in the group." (p232)

Epistemic actions: Acting for thinking

- Epistemic actions (Kirsh & Maglio 1994):
  - "physical actions that make mental computations easier, faster or more reliable"
  - "ways of modifying the external environment to provide crucial bits of information just when they are needed most"



Epistemic actions: Science and math 1

A historian "once remarked casually that [the physicist Richard Feynman's] notes represented 'a record of the day-to-day work,' and Feynman reacted sharply.

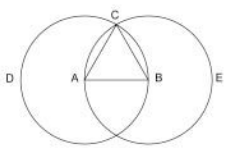
"'**I actually did the work on the paper**,' he said.

"'Well,' [the historian] replied, 'the work was done in your head, but the record of it is still here.'

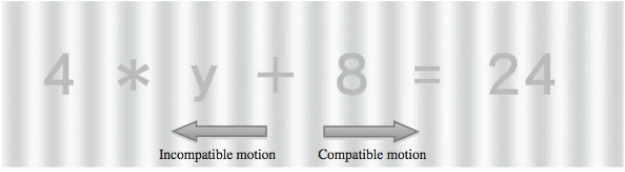
"'**No, it's not a *record,* not really. It's *working***. You have to work on the paper, and this is the paper. Okay?'"

Epistemic actions: Science and math 2

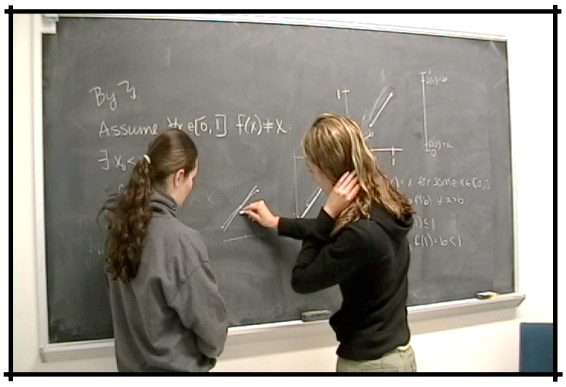
- Kirsh (2009) on C.S. Peirce (1839–1914): "A chemist thinks as much with their test tubes and hands as with pen and pencil."
- Diagrams and notations as vehicles of thought:
  - Euclidean geometric constructions
  - Place-value arithmetic, revisited



R. L. Goldstone, D. H. Landy, J. Y. Son/Topics in Cognitive Science 2 (2010)



What about when we aren't actively inscribing?



Acting out insight

Wittgenstein: “Of course, in one sense, mathematics is a body of knowledge, but still it is also an activity.”

Acting out:
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