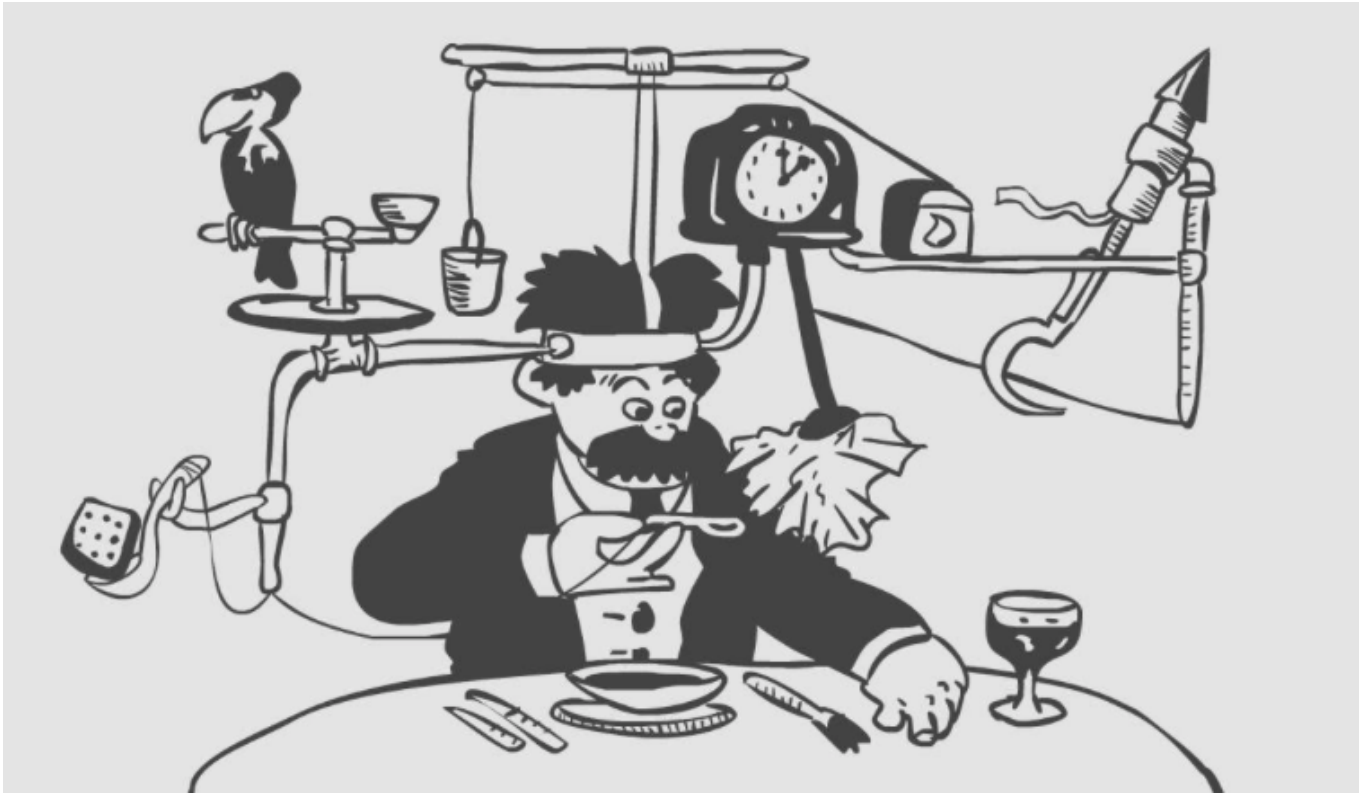


Extended and Distributed Cognition

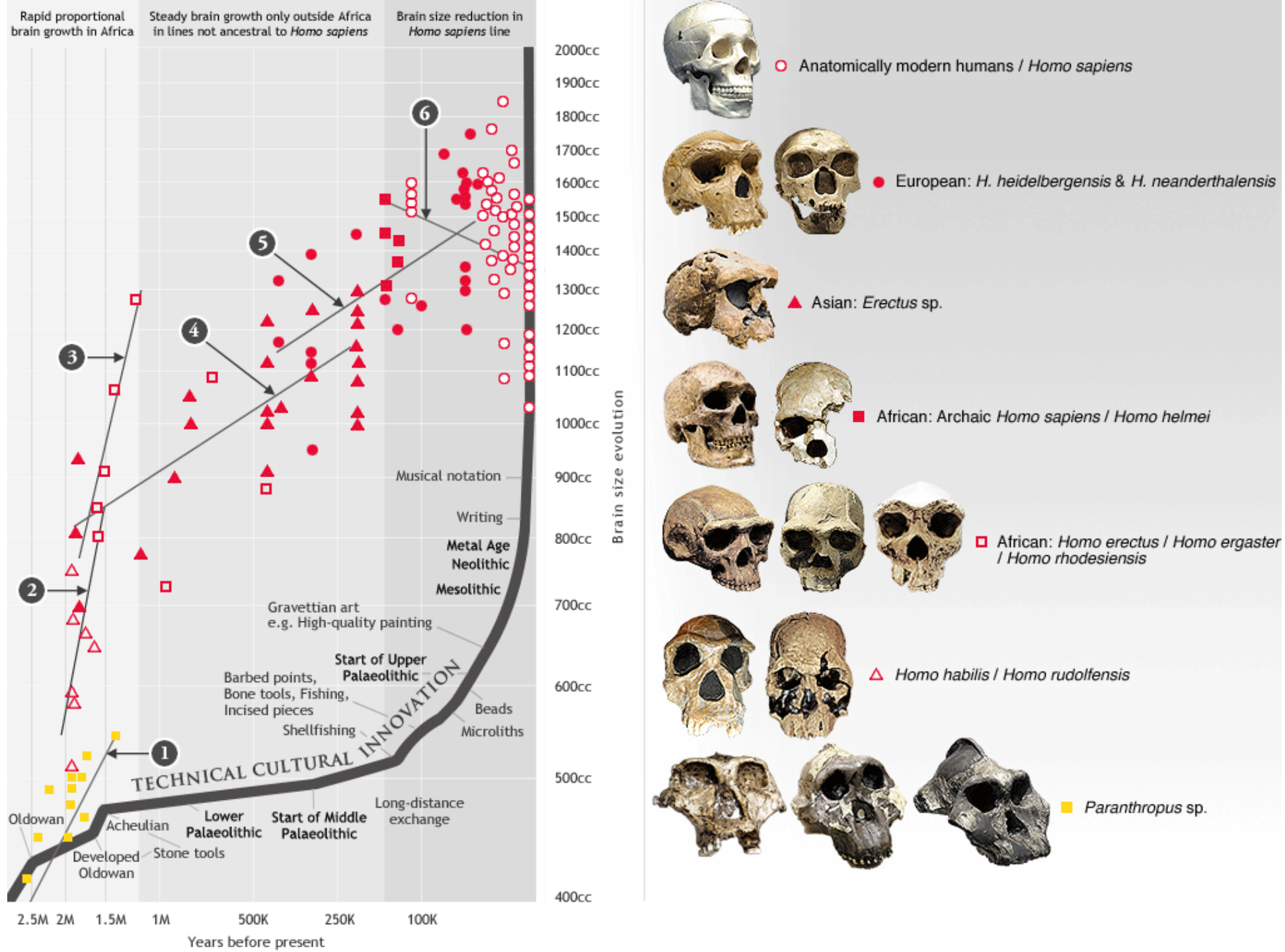
Semiotics and Cognition

Kristian Tylén

Monday Nov 23rd 2020

Agenda

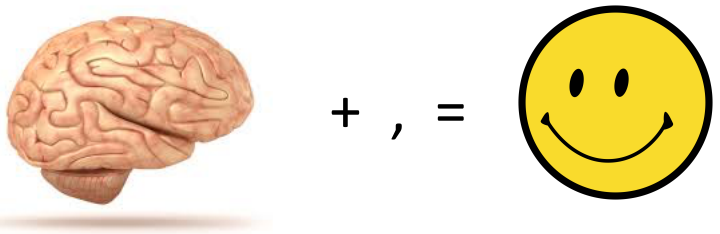
- Cognition beyond the brain?
- On the nature of ‘information processing’
  - Cognition, ontology and functionality
- On the notion of epistemic and pragmatic actions
  - Action for perception and thinking
  - Cognitive technologies
- The extended mind:
  - Extended memory
  - Extended perception
  - Extended executive function/problem solving
- Scrabble exercise
- Distributed Cognition and the *socially* extended mind


Rapid proportional brain growth in Africa
Steady brain growth only outside Africa in lines not ancestral to Homo sapiens
Brain size reduction in Homo sapiens line
2000cc
1900cc
1800cc
1700cc
1600cc
1500cc
1400cc
1300cc
1200cc
1100cc
1000cc
900cc
800cc
700cc
600cc
500cc
400cc
Brain size evolution
Musical notation
Writing
Metal Age
Neolithic
Mesolithic
Gravettian art
e.g. High-quality painting
Start of Upper Palaeolithic
Barbed points,
Bone tools, Fishing,
Incised pieces
Beads
Microliths
Shellfishing
TECHNICAL CULTURAL INNOVATION
Oldowan
Acheulian
Lower Palaeolithic
Start of Middle Palaeolithic
Long-distance exchange
Developed Oldowan
Stone tools
2.5M
2M
1.5M
1M
500K
250K
100K
Years before present
Anatomically modern humans / Homo sapiens
European: H. heidelbergensis & H. neanderthalensis
Asian: Erectus sp.
African: Archaic Homo sapiens / Homo helmei
African: Homo erectus / Homo ergaster / Homo rhodesiensis
Homo habilis / Homo rudolfensis
Paranthropus sp.

Big invensions in the history of math

- … Many cognitive processes rely on external notation (or internalized notation)
- A few of the big ‘inventions’ in math:
  - LXXIII x XXVII = ?
  - 73 x 27 = ?

- Another big invention: ,



The *extended mind* and *distributed cognition*

- Coined in latter half of the 90's

- ”Extended mind” – philosophical tradition
  - Seminal works by Andy Clark (extended mind)
  - Build on traditions from Heidegger, Pierce(?), active externalism

- ”Distributed cognition” – anthropological tradition (cognitive anthropology)
  - Seminal works by Edwin Hutchins
  - Builds on ecological psychology (J. Gibson), activity theory (e.g. Vygotsky), Latour, von Uexküll(?)

Cognition: ontological or functional definitions

cog·ni·tion

/käg'niSHən/

Noun

1. The mental action or process of acquiring knowledge and understanding through thought, experience, and the senses.
2. A result of this; a perception, sensation, or intuition.

Definition:

Cognition is a term referring to the mental processes involved in gaining knowledge and comprehension. These processes include thinking, knowing, remembering, judging, and problem-solving. These are higher-level functions of the brain and encompass language, imagination, perception, and planning.

cog·ni·tion (kŏg-nĭsh'ən)

n.

1. The mental process of knowing, including aspects such as awareness, perception, reasoning, and judgment.
2. That which comes to be known, as through perception, reasoning, or intuition; knowledge.

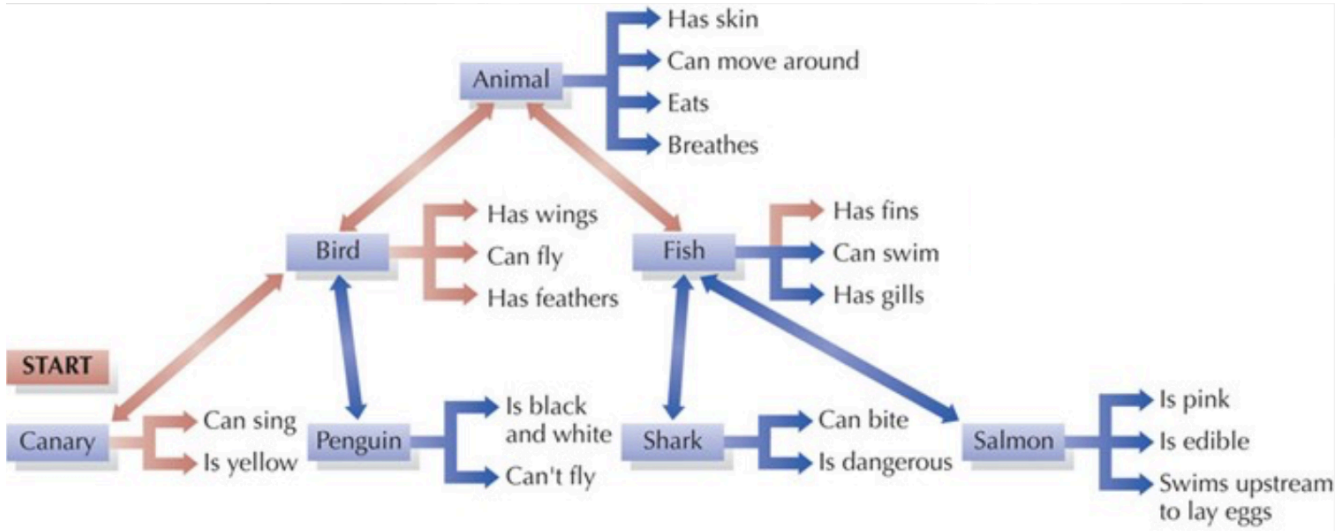
Definition of COGNITION

+1 Like

: cognitive mental processes; *also* : a product of these processes

Classical computationalism

- Classical models of cognition treats perception as “input”: a separate system for ‘representing the world’
- “Cognition proper” is information processing – a bag of algorithms applied to manipulate the symbolic representations of the world
- Quite separate from action which is regarded “output”
- Our cognitive apparatus is just passively waiting for sensory stimulation
- I.e. action is conceived as “response” to an input

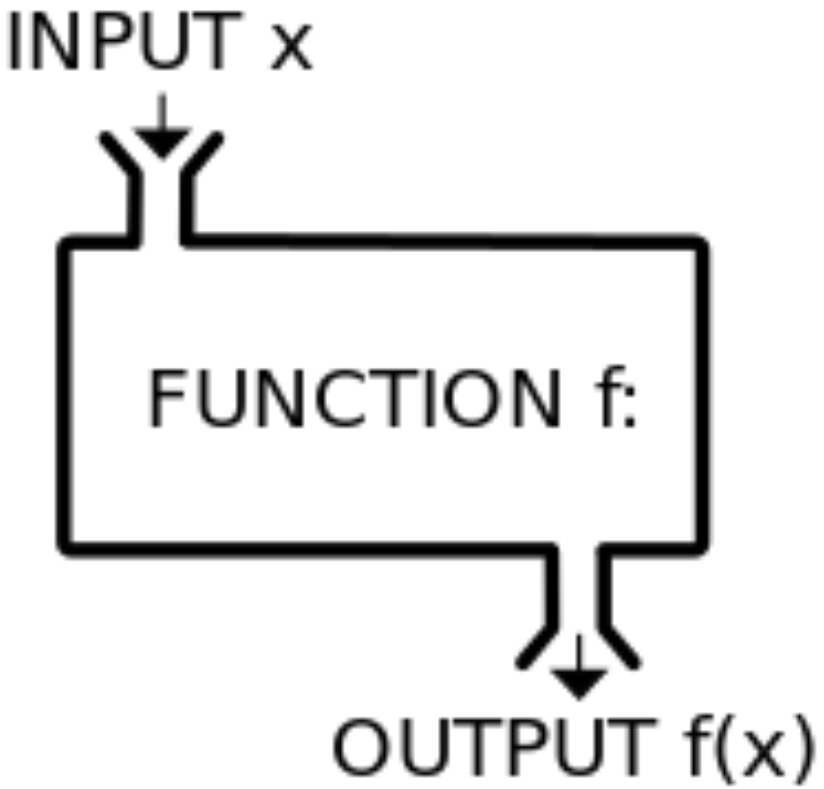


Computation/
Information
processing

Perception

Action

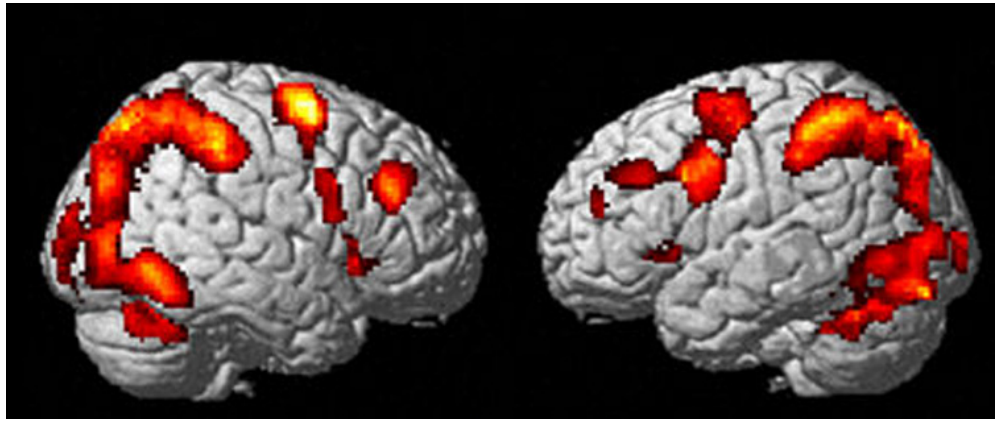
Information processing



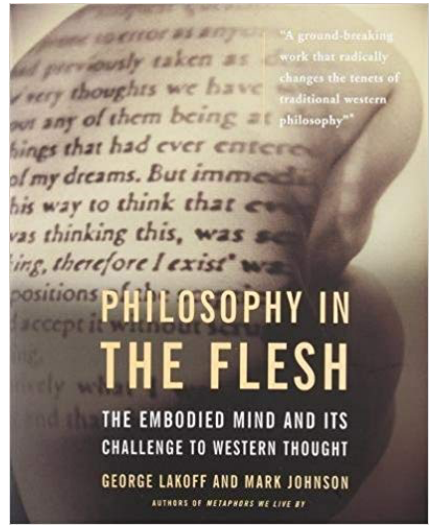
$$\sum_{i=0}^{n} a_i y^{(n-i)} = \sum_{i=0}^{m} b_i x^{(m-i)}$$

$$Y(s)\sum_{i=0}^{n} a_i s^{n-i} = X(s)\sum_{i=0}^{m} b_i s^{m-i}$$

$$H(s) = \frac{Y(s)}{X(s)} = \frac{\sum_{i=0}^{m} b_i s^{m-i}}{\sum_{i=0}^{n} a_i s^{n-i}} = \frac{\mathcal{L}(\text{output})}{\mathcal{L}(\text{input})}$$



Embodiment and representationalism

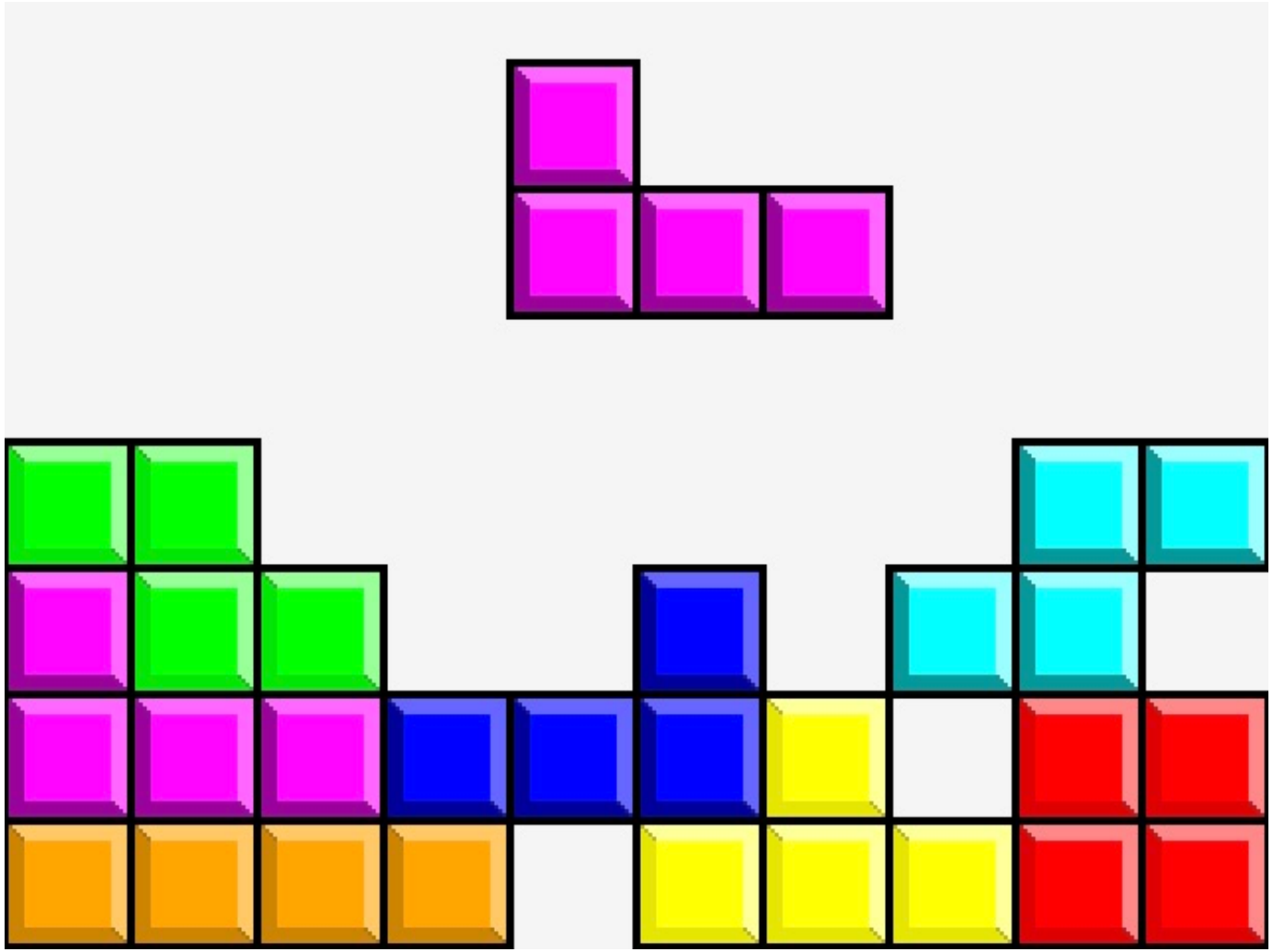


- Embodiment theory, cognitive linguistics, metaphor teory:
  - Also strong emphasis on ”representation”
  - We mentally ”construe” the world, by manipulating mental representations
- Strong load on ”the mental”:
  - Embodiment = our representations are ”motivated” by our bodily experiences, or mentally ”simulated” bodily experiences
  - In contrast to computationalism: representations are modal (but still mental)

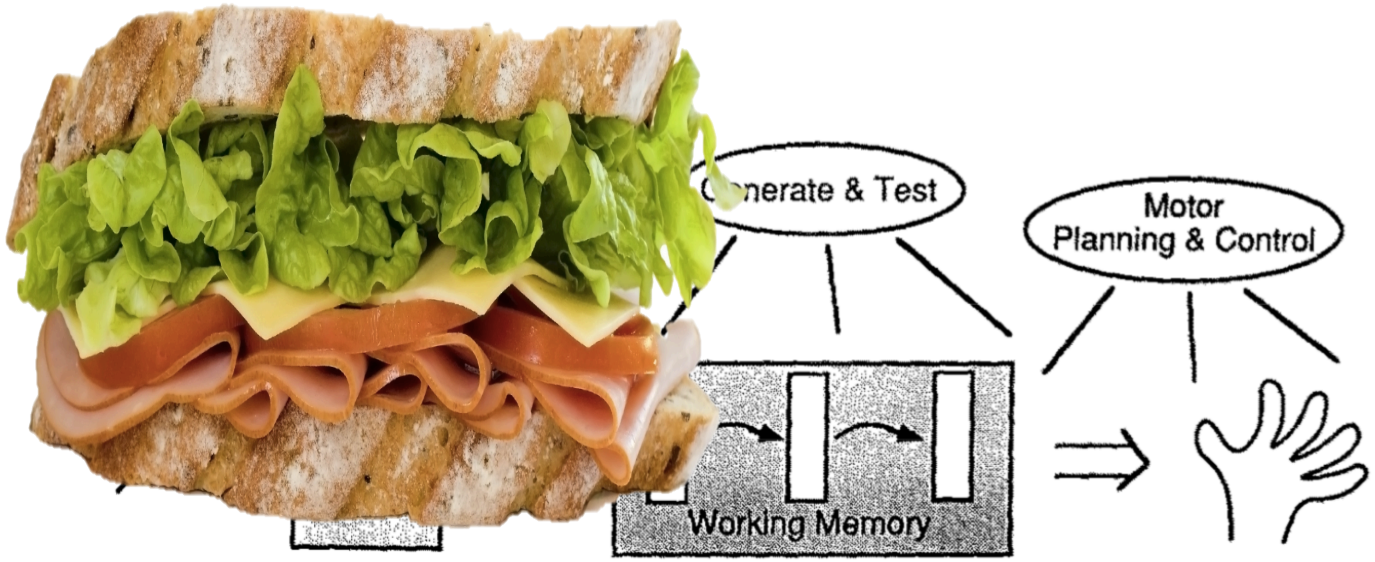
Information processing

- Right or left hand?

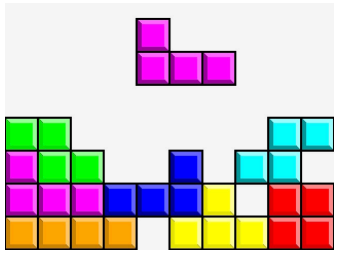
Case: Tetris



Classical information processing model of tetris decisions



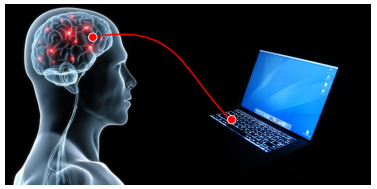
Tetris



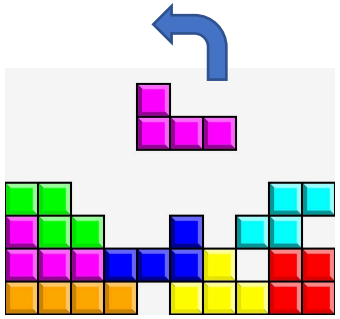
Perception

Mental rotation

Manual rotation



Hybrid robo-style rotation



Decision (Action)

- What do these cases have in common?
- What are the differences?

Clark and Chalmers 1998

Kirsh & Maglio (1994): epistemic actions

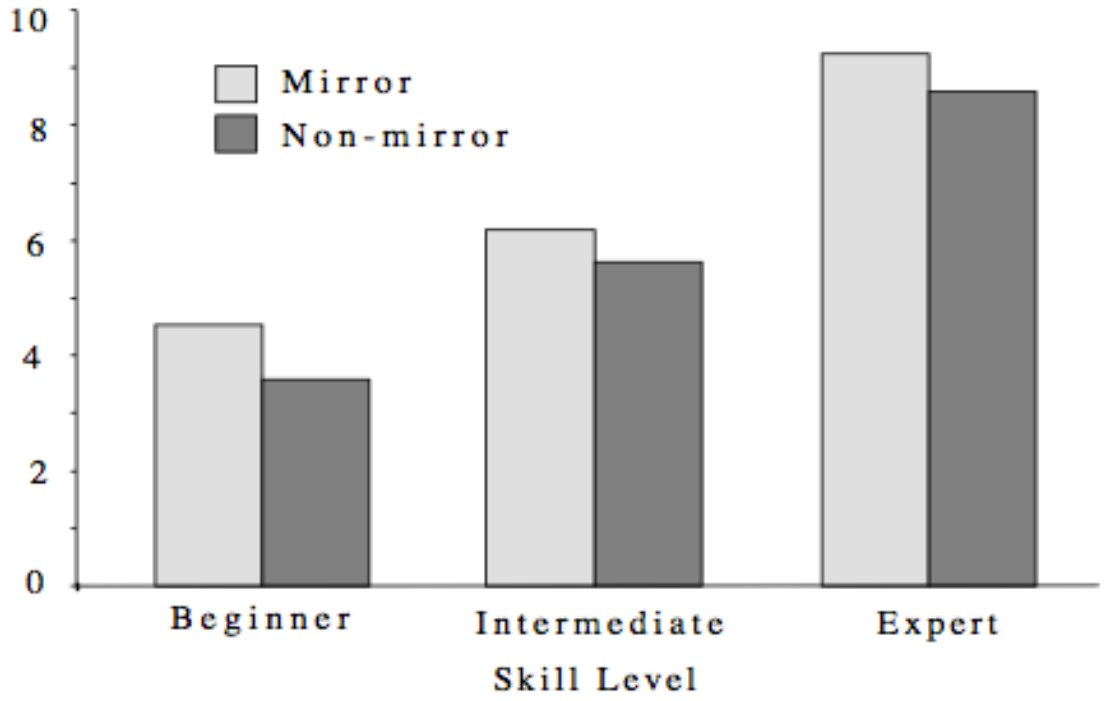
- *Pragmatic actions*: ”[those] actions whose primary function is to bring the agent closer to his or her physical goal (…) [*Pragmatic actions*] are defined as transformations in physical or social space (…) that can serve as a path from initial to goal state.” (Kirsh and Maglio, 1994:519)

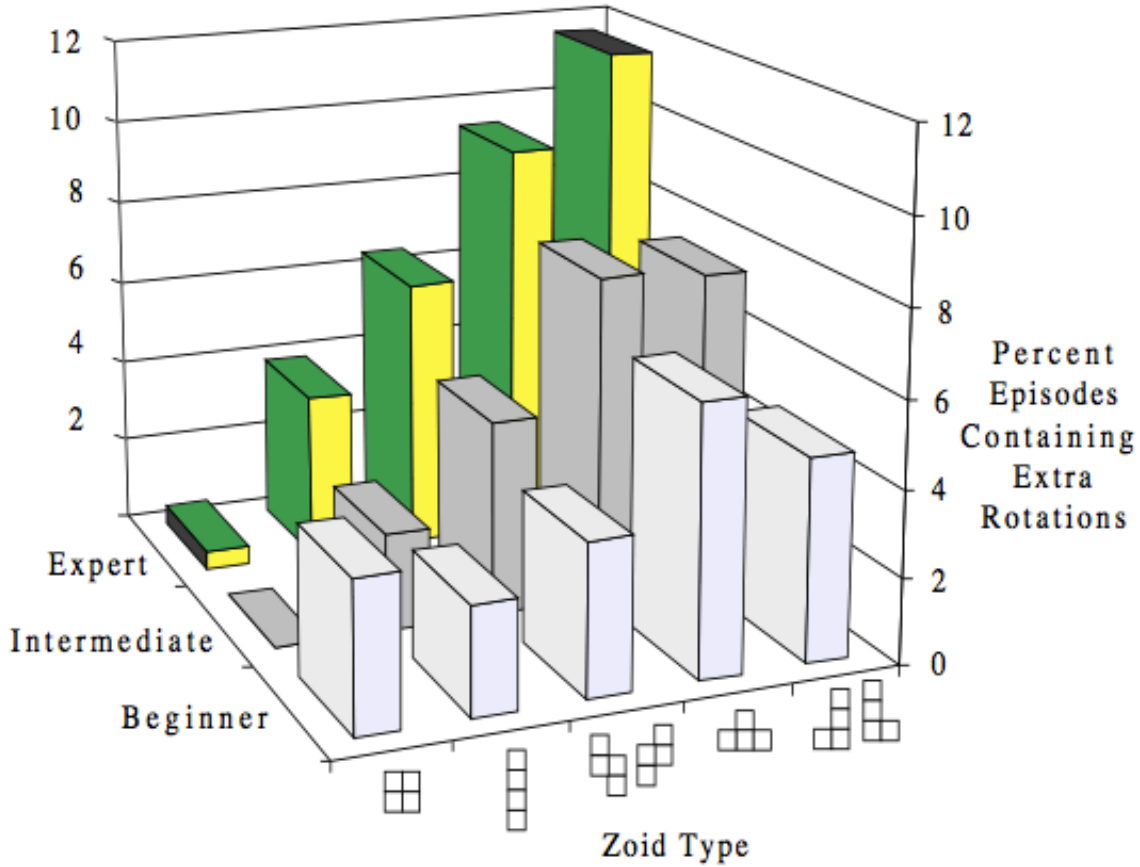
- *Epistemic actions* (Kirsh and Maglio, 1994:514): ”More precisely, we use the term epistemic action to designate a physical action whose primary function is to improve cognition by:
  - reducing the memory involved in mental computation, that is, space complexity;
  - reducing the number of steps involved in mental computation, that is, time complexity;
  - reducing the probability of error of mental computation, that is, unreliability.”

Mental vs manual rotation in Tetris

Who makes more manual rotations in tetris?

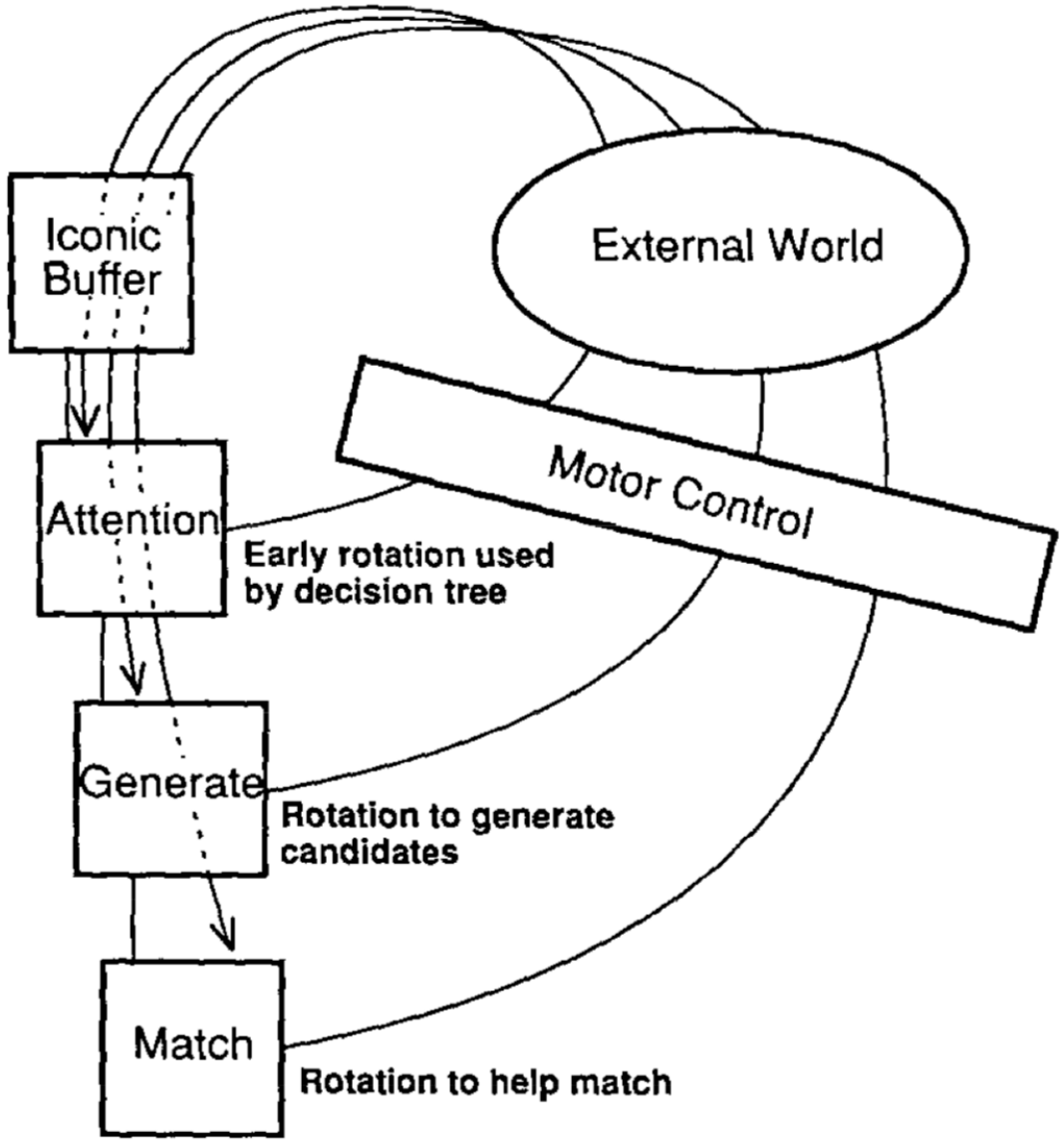
- Beginners
- Intermediate level
- Experts





Kirsh & Maglio 1992; 1995

Perception-action loops in tetris (and beyond?)



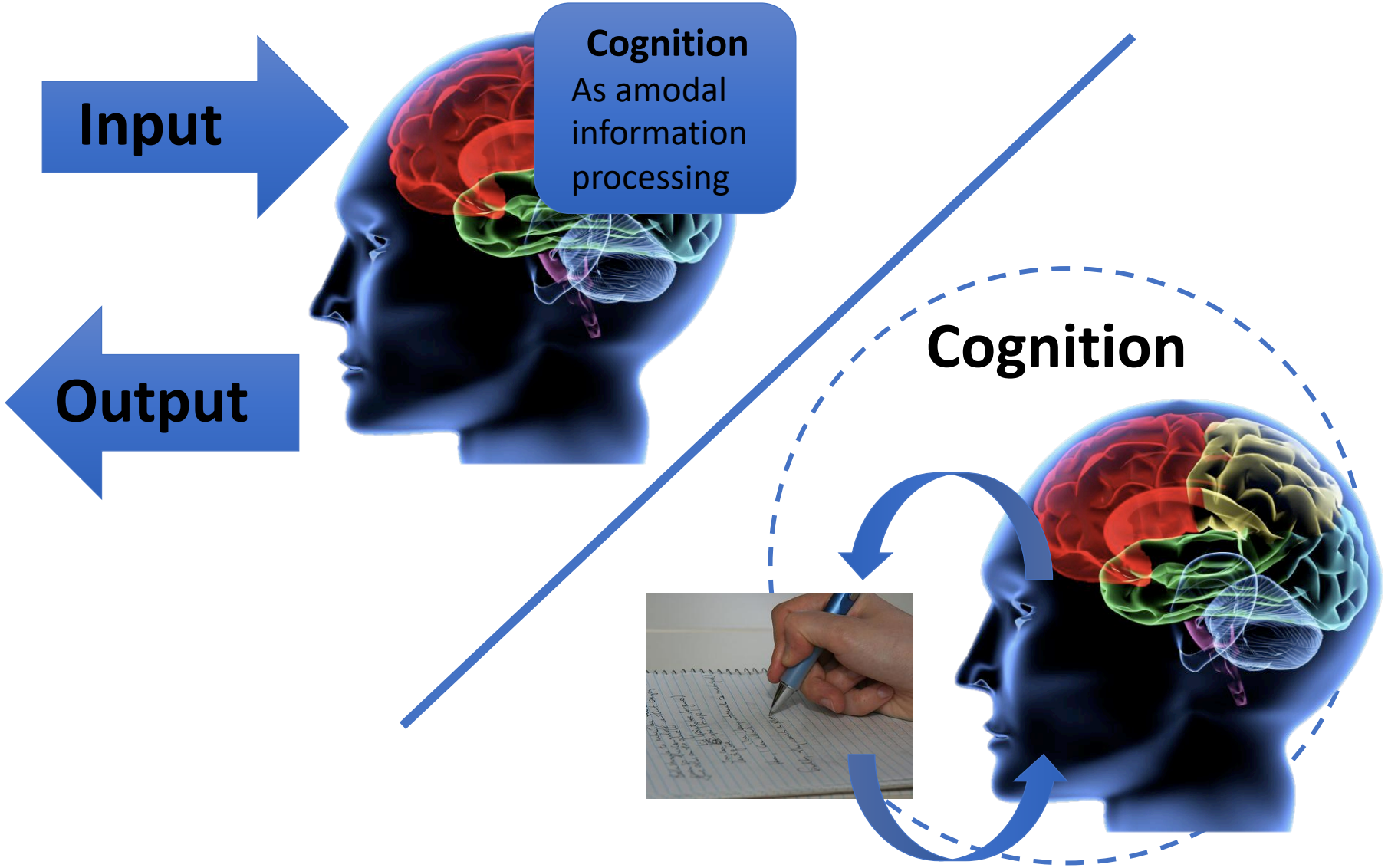
Kirsh and Maglio 1994: 542

Clark & Chalmers (1998)
The Extended Mind

The ‘parity principle’ (Clark & Chalmers 1998:4)

- If, as we confront some task, a part of the world functions as a process which, *were it done in the head*, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world *is* (so we claim) part of the cognitive process.

Cognition as coupling to the environment



Cognition as the result of coupling

- "… In these cases, the human organism is linked with an external entity in a two-way interaction, creating a *coupled system* that can be seen as a cognitive system in its own right.
- All the components in the system play an active causal role, and they jointly govern behavior in the same sort of way that cognition usually does. If we remove the external component the system's behavioral competence will drop, just as it would if we removed part of its brain.
- Our thesis is that this sort of coupled process counts equally well as a cognitive process, whether or not it is wholly in the head." (Clark and Chalmers, 1998)

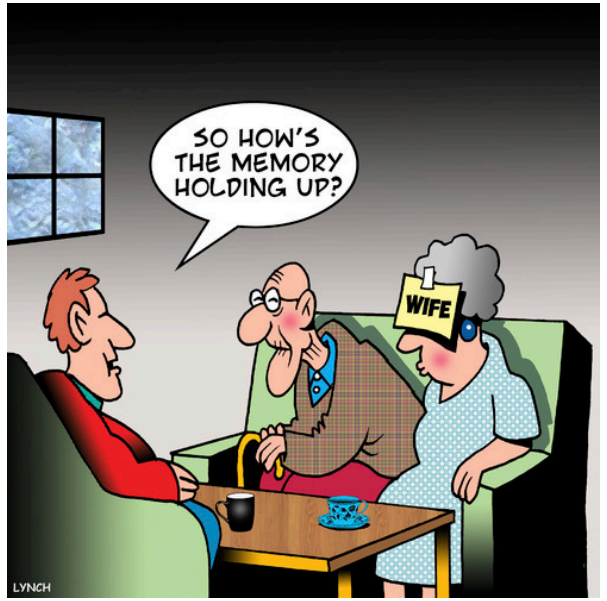
- Coupling?
  - (Partial) interdependence between several autonomous components that together constitute an coherent entity or fulfills a function

The manual tool analogy

- Clark (2006:2): “Compare now the use of a standard tool. When I use a spade to dig the garden, the spade makes an ongoing and complementary contribution to that made by my biological body. There is, in such a case, no obvious sense in which I biologically replicate the essence of the spade’s activity. Instead, the digging power resides in the larger coupled system.”

- In the same way procedural dynamic couplings with manual tools enhance the action potential of our biological bodies, some ‘cognitive artifacts’ (e.g. language, calculators, notebooks) enhance our cognitive powers

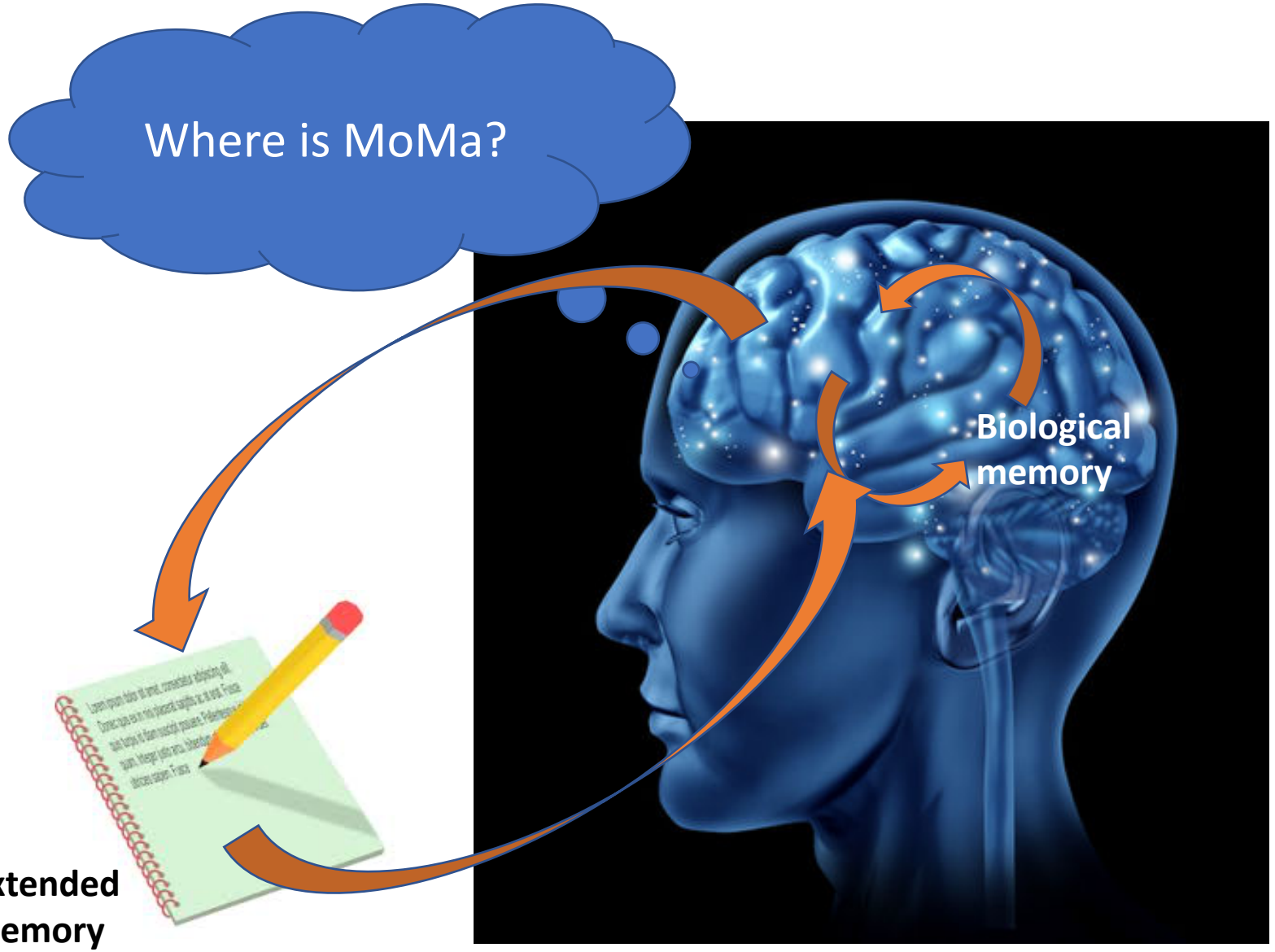
Extended memory: The notebook example



- "Inga hears from a friend that there is an exhibition at the Museum of Modern Art, and decides to go see it. She thinks for a moment and recalls that the museum is on 53rd Street, so she walks to 53rd Street and goes into the museum."

- "Otto suffers from Alzheimer's disease, and like many Alzheimer's patients, he relies on information in the environment to help structure his life. (…) Today, Otto hears about the exhibition at the Museum of Modern Art, and decides to go see it. He consults the notebook, which says that the museum is on 53rd Street, so he walks to 53rd Street and goes into the museum." (Clark & Chalmers 1998:11)

- Is the notebook part of Otto's cognitive system?


Where is MoMa?
Biological memory
Extended memory

Gestures for thinking?

- We spontaneously gesture when our communicative partner can't see us (i.e. our gestures do not serve a communicative function)

- Gesture helps speakers retrieve words from memory (Rauscher, et al. 1996)

- Gesture reduces cognitive burden, e.g. pointing when counting (Alibali & DiRusso 1999)

Gesture and memory

- Jamalian et al (2013) Gestures for thinking:
  - Students, alone in a room, studied descriptions of environments for later tests of knowledge
  - Example:

Example 1: 4S outdoor environment

Etna is a charming town nestled in an attractive valley, entered on River Highway. River Highway runs east-west at the southern edge of the town of Etna. Toward the eastern border, River Highway intersects with Mountain Rd, which runs north of it. At the northwest corner of the intersection is a gas station. North of the gas station, Mountain Road will intersect with Maple Ave, which runs west.

True-false questions

	Verbatim	Inference
Route	Going east on River Highway, at the intersection with Mountain Rd, you will find a gas station on your left.	From Mountain Rd, turn right on River Highway and you will have the Gas Station on your right.
Survey	North of the gas station, Mountain Road will intersect with Maple Ave, which runs east.	South of Maple Ave to the west of Mountain Rd is the Gas Station.

Gestures

- The majority of participants spontaneously gestured while reading the descriptions, and most also gestured while answering true-false questions.

Results

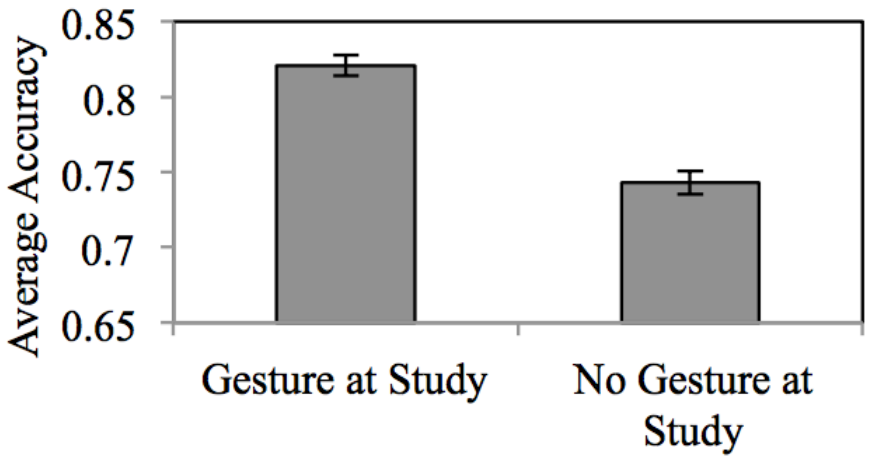


Figure 3. Accuracy by gesturing at study. Error bars represent standard error

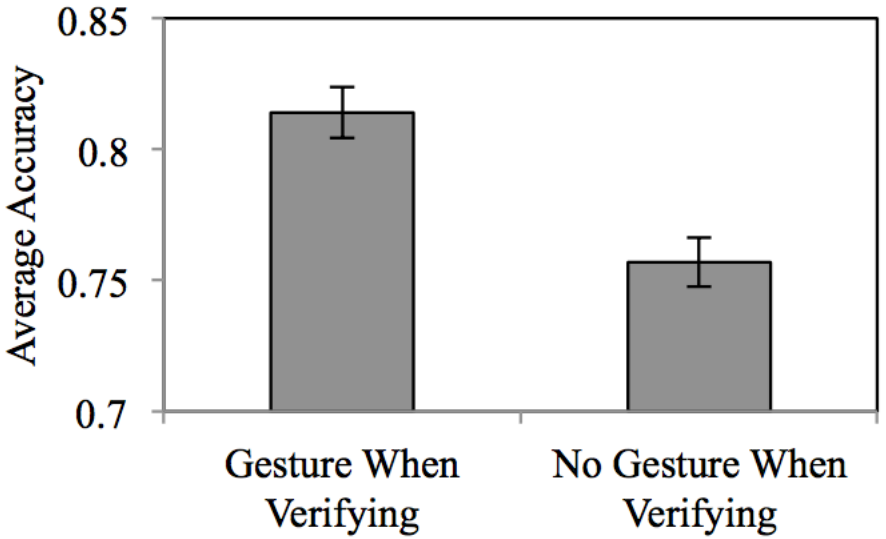


Figure 4: Accuracy by gesturing at verification.

- "the descriptions accompanied by gestures were remembered better than those that were not, and the questions that were accompanied by gestures were answered more accurately than those that were not.(…)

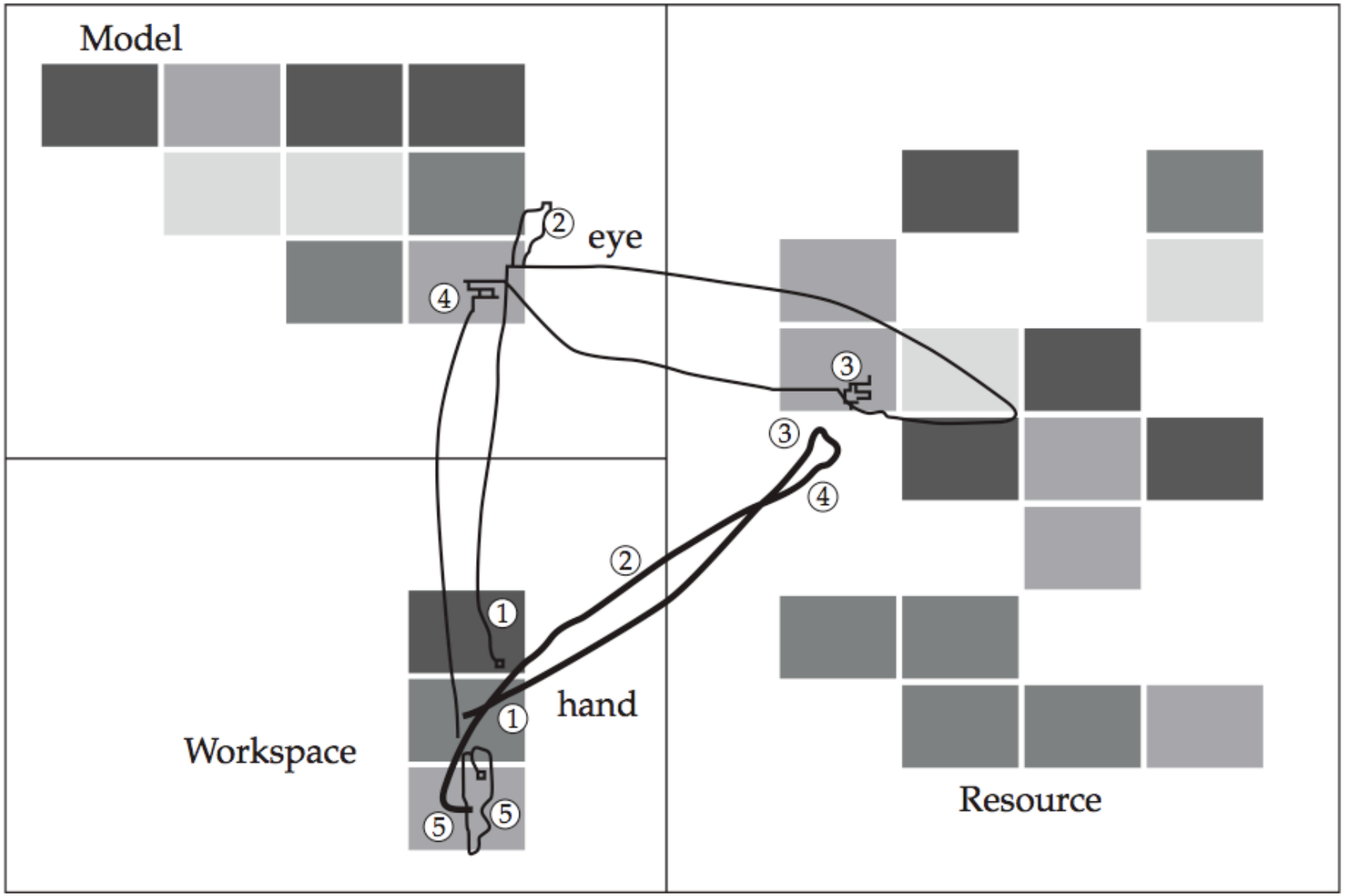
- Gestures appeared to improve learning by establishing embodied representations of the structures of the environments and appear to improve memory by reintegrating the queried parts of the environments. " (Jamalian et al, 2013:649)

Extended perception: Active sensing

- Perception for action – action for perception:
  - We actively and continuously consult environmental resources when solving everyday problems
  - We move our eyes, heads, bodies to alter perceptions
  - We can grasp and manipulate objects to facilitate perceptual exploration

- Perception is *for* action and action is *for* perception:
  - we actively employ our biological bodies in perceptual explorations of the environment creating *time-locked cross-modal* representations

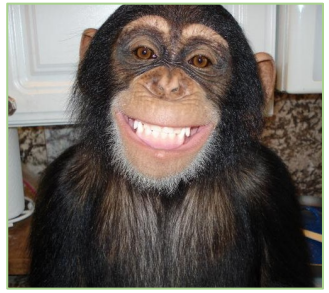
Ballard et al 2001



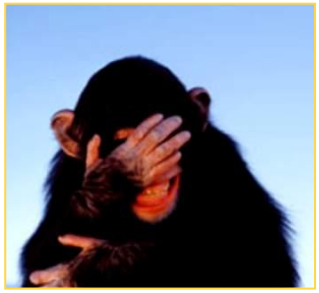
Ballard et al 2001

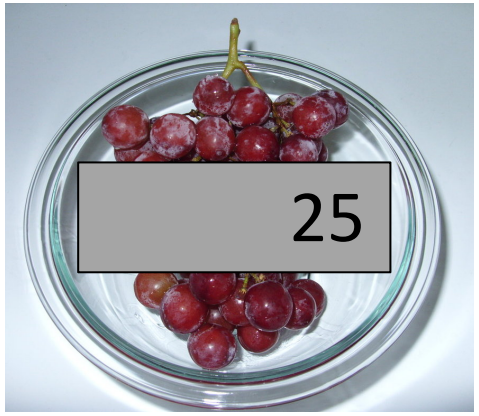
Extended perception: Active sensing

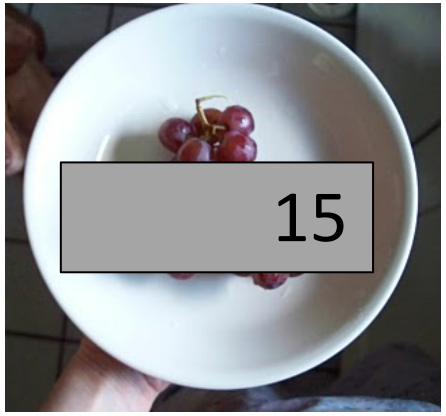
- “In the block-copying scenario, by contrast, the agent does not use sensing to build up a rich inner model sufficient to solve the problem.
- Rather, sensing is used repeatedly, with the external scene functioning as an information store to be called upon just in time for the task fragment at hand.
- During all this, the external, screen-based model acts as “its own best model” (Brooks 1991).
- Sensing here acts as a constantly available channel that productively couples agent and environment rather than as a kind of “veil of transduction” whereby world-originating signals must be converted into a persisting inner model of the external scene.” (Clark 2008:46)



Extended executive function: Sheba and the treats*







- “What seems to be going on here(…) is that the material symbols, by being simple and stripped of most treat-signifying physical cues, allow the chimps to sidestep the capture of their own behavior by ecologically-specific fast-and-frugal subroutines...

- … The symbol loosens the bond between agent and world, (…) qua material symbol, providing a new target for selective attention and a new fulcrum for the control of action.” (Clark 2006:115-16)

(*Boysen et al. 1996)

Types of cognitive extension?

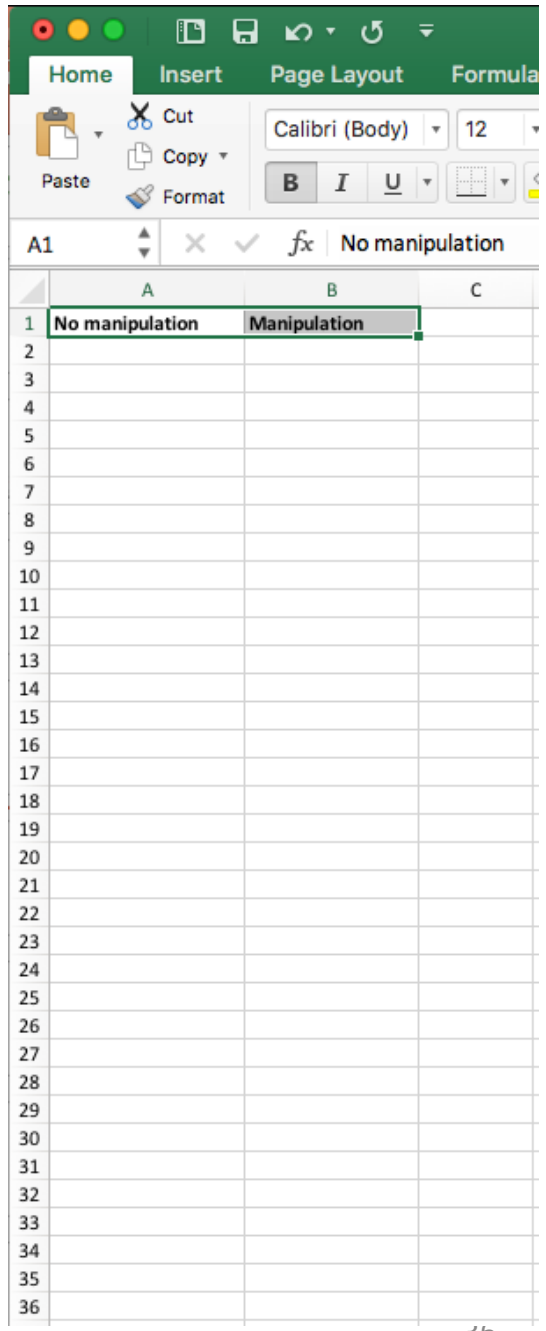
- Replacement of ‘internal processes’:
  - Sometimes an external component can replace an internal one: E.g. Otto’s notebook, mental rotation, active sensing

- Enhancement of cognition:
  - Sometimes engagement with external components can enhance cognitive functioning: E.g. pen and paper for complex calculations, memory

- Radically new cognitive processes:
  - Sometimes engagement with external components can make possible new cognitive activities that were not even possible without this component: E.g. Sheba and the treats?

Scrabble exercise

- Pair up
- One writes (without helping/giving clues), the other names words formed out of 7 designated letters
- You are not allowed to see the words you have already named
- Condition 1: no manipulation (you are not allowed to move letters around)
- Condition 2: manipulation (you are allowed to move the letters tiles in any way you want
- Fixed time: 5 min

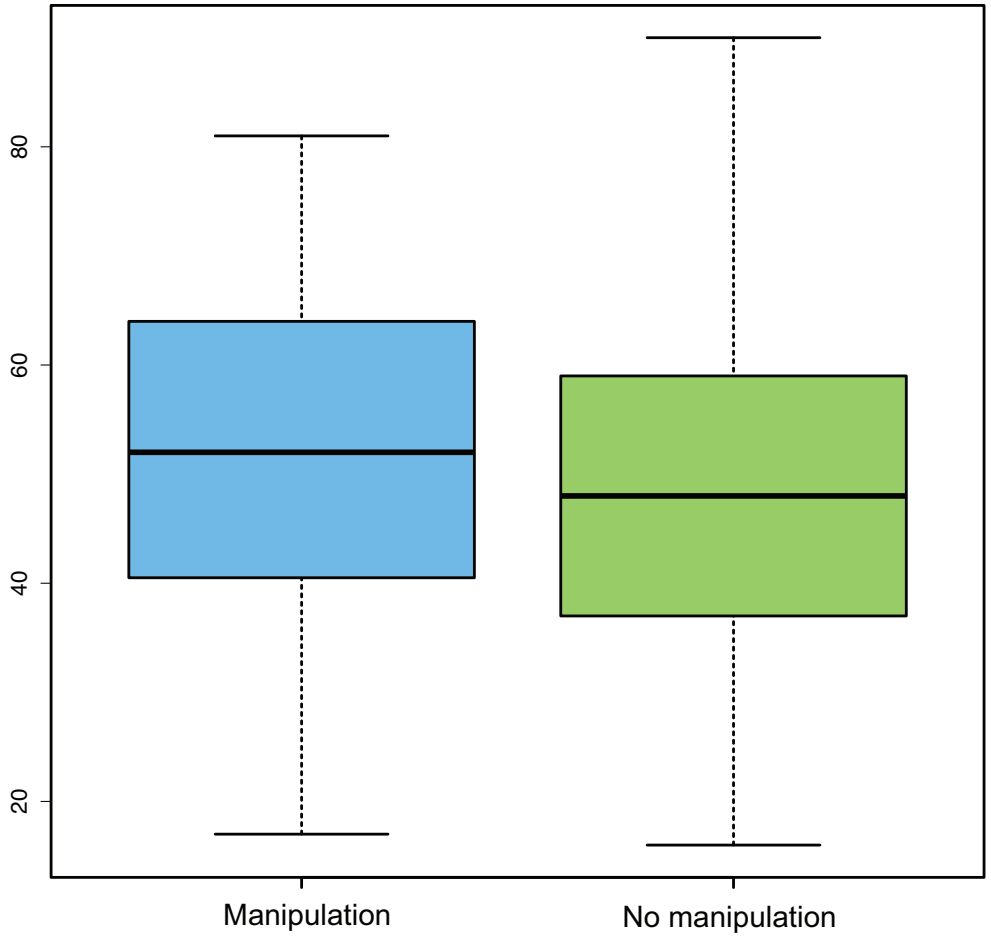


- Maglio, P. P., Matlock, T., Raphaely, D., Chernicky, B., & Kirsh, D. (1999, August). **Interactive skill in Scrabble**. In *Proceedings of the twenty-first annual conference of the cognitive science society* (pp. 326-330). Routledge.

- ”The mean for the Hands condition was 20.70 (SD = 5.00) and for the No Hands condition, 19.30 (SD = 5.58). A two-way repeated measures ANOVA showed a main effect for the within-subjects factor (Hands vs. No Hands), $F(1, 18) = 5.165$, $p < 0.05$, indicating a difference in performance for Hands vs. No Hands.” (Maglio et al 1999:4)

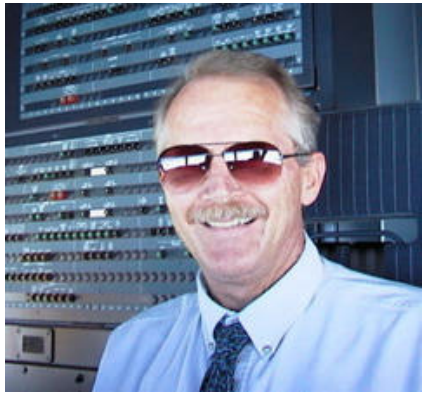
Fusaroli, R., Østergaard, S., Raczaszek-Leonardi, J., Bjørndahl, J. S., Stjernfelt, F., & Tylén, K. (2014). **Doing words together: assessing joint problem solving in a Scrabble task**. In *CogSci 2014*.

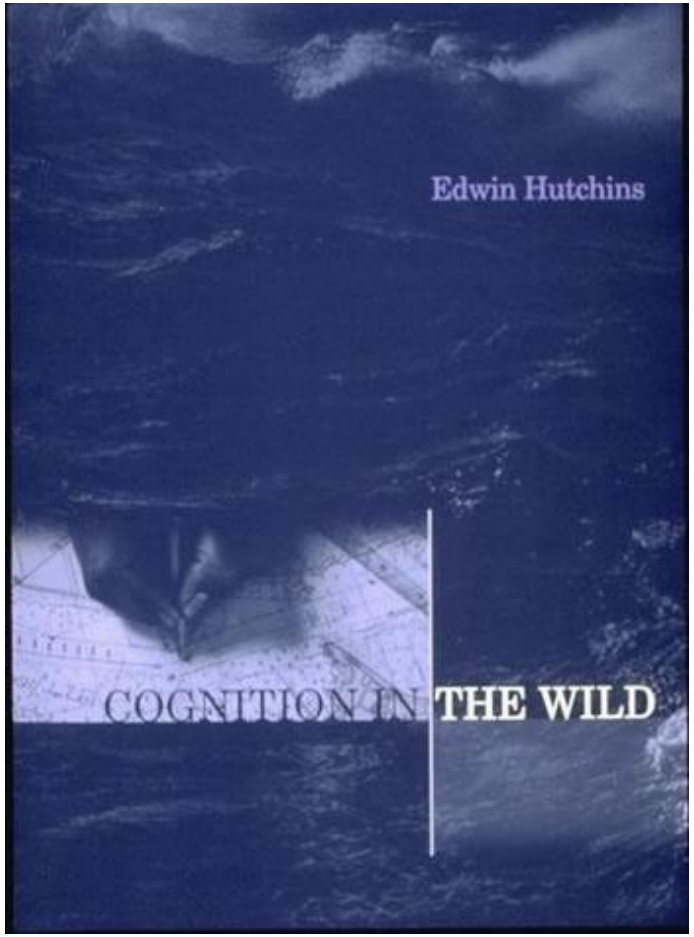
- Main effect of manipulation



No significant effect of manually manipulating letter tiles ($p > .05$)

Hutchins (1995): Cognition In The Wild





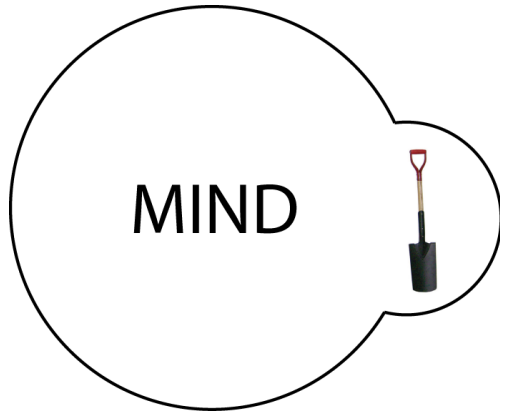
- Cognitive anthropology:
- Studies how ‘cognitive computation’ unfold ”in the wild” (outside the psychologist’s laboratorium) as a largely distributed process involving multiple agents, artefacts, routines and cultural practices
- Case: bringing a large naval vessel into port: the navigation team can be seen as a cognitive and computational system

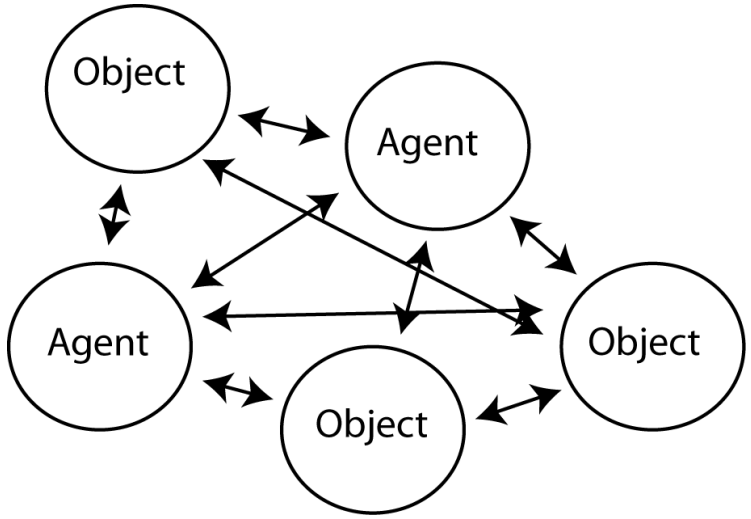
Objections to the Extended Mind:
The extended mind is not radical enough

- Clark 2008 ‘‘...embodied agents exploit the opportunities provided by dynamic loops, active sensing, and iterated bouts of environmental exploitation and intervention.’’

- Hutchins 2010: ”This account is correct, but […] isolated embodied human agents probably do little of this exploitation without the shaping influences of culture.
- […] few of the dynamic loops that link people to their environments are invented by the people who exploit them. Rather, the ability to establish and maintain such loops is acquired via participation in culturally organized activities with other people.”

- E.g. math: 1011/127 = ?





The socially extended mind?

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Cognitive Systems Research xxx (2013) xxx–xxx

Cognitive Systems RESEARCH

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The dialogically extended mind: Language as skilful intersubjective engagement

Action editor: Ron Sun

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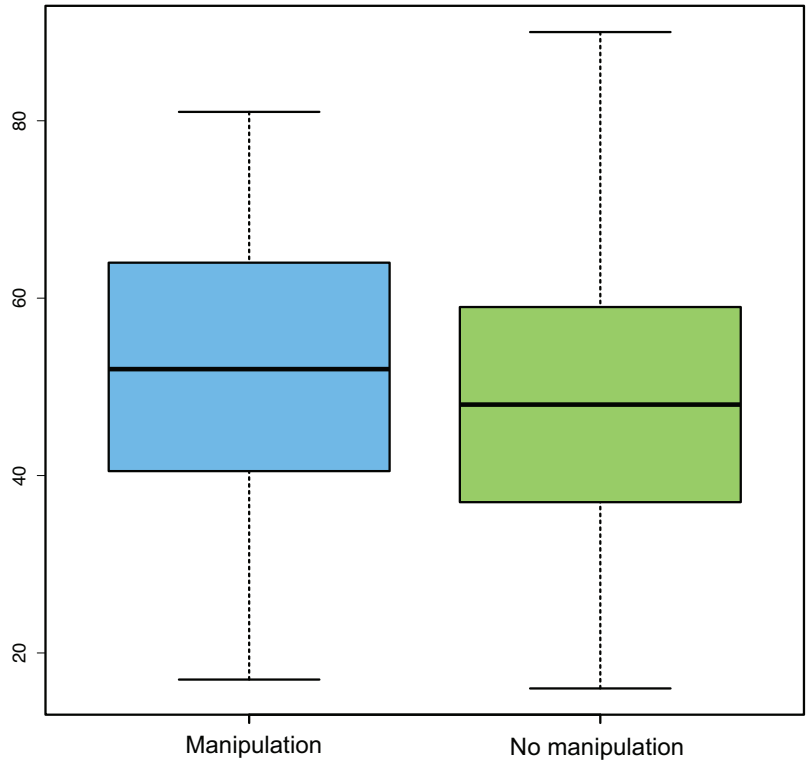
The socially extended mind?

- Most existing research studies the ways that solitary individuals use tools to think

- ‘Public nature’ of material representations …
  - … facilitate powerful modes of joint thinking
  - Interacting individuals bring different perspectives, make different manipulations and might reach different conclusions from these manipulations
  - Hypothesis: By integrating complementary contributions, the group should outperform the better individual group member (1 + 1 = 3)

Scrabble revisited…

- Main effect of manipulation



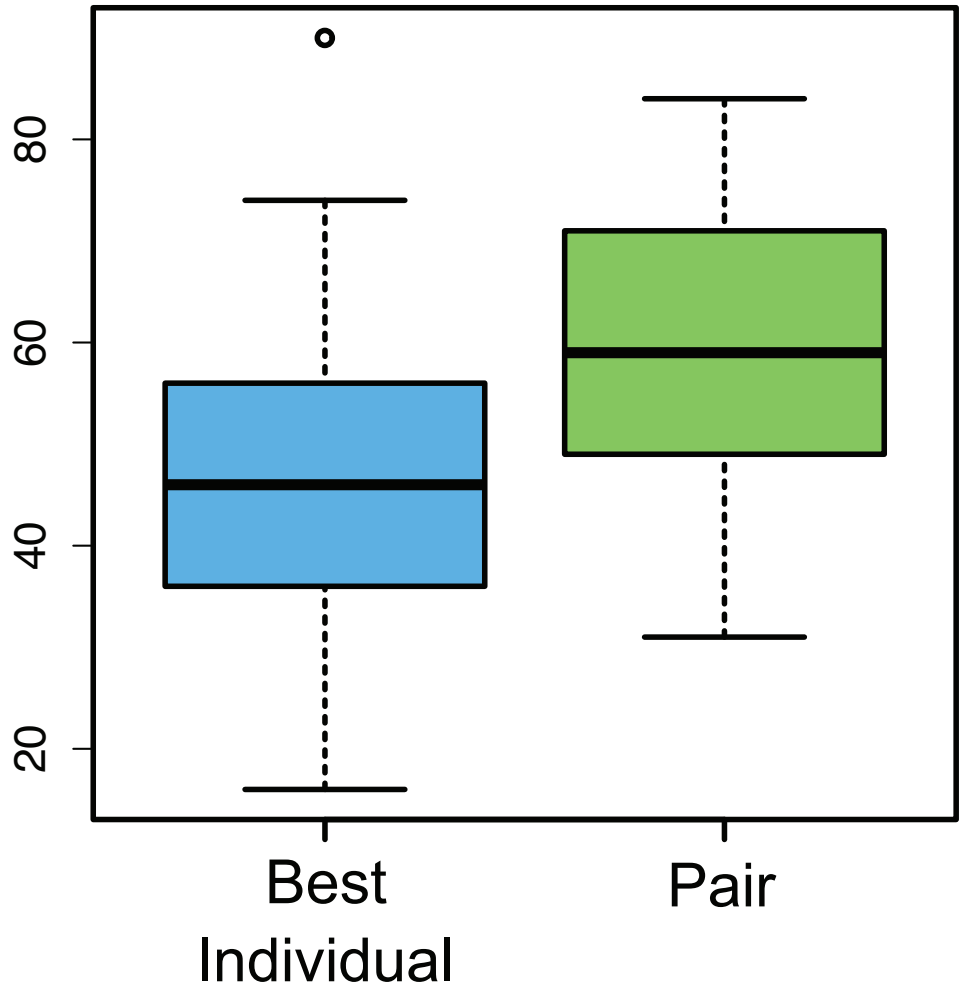
No significant effect of manually manipulating letter tiles ($p > .05$)

Fusaroli, R., Østergaard, S., Raczaszek-Leonardi, J., Bjørndahl, J. S., Stjernfelt, F., & Tylén, K. (2014). **Doing words together: assessing joint problem solving in a Scrabble task**. In *CogSci 2014*.

Doing words together

Results

- Main effect of collaboration



Significant effect of collaboration on performance: β=12.6, SE=1.59, *t*-stat = 7.94, $p < 0.0001$

Discussion:
Huge benefit of working together

Who benefits more from collaboration?

- Cognitive diversity: creating the same or different words from the same letters?

Individual A:

Cat
Fact
Fan
Can
Cast
Tan
Stan

Individual B:

Fan
Can
Fact
Cast
Tan
Cat
Act

Cat
Fact
Fan
Can
Cast
Tan
Stan
Fact
Act

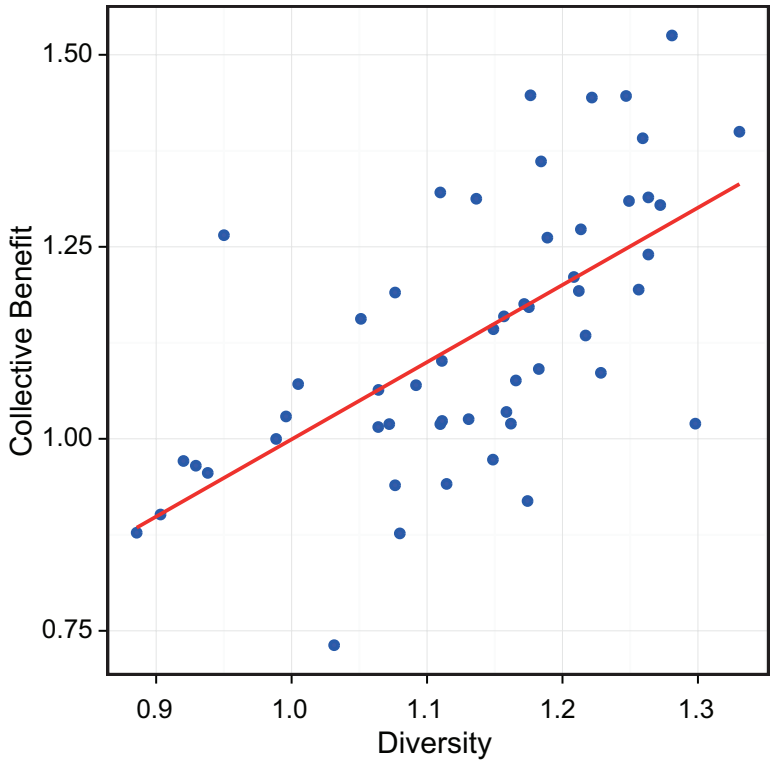
Individual C:

Cat
Cats
Sat
Mat
Mats
Fat

Cat
Cats
Sat
Mat
Mats
Fat
Fact
Fan
Can
Cast
Tan
Stan

Who benefits more from collaboration?

- Other studies have pointed to the way that ‘diversity’ can facilitate collaboration (e.g. Page 2008)
  - If people bring different strategies and perspectives they can combine these to yield better joint performance



Significant effect of cognitive diversity:
$\beta = 1.2$ SE = 0.28 *t*-stat = 4.37 $p < 0.0001$

If individual dyad members apply different strategies, perspectives, and/or procedures (i.e. create different words from the same letters) they gain a higher collective benefit in the joint condition

Take Home

- Some (most?) actions are intended to bring us closer to some physical goal state -> pragmatic actions
- However, another class of actions is intended to assist cognitive processes -> epistemic actions
- If we define cognition in functional terms as information processing, we might consider these actions as ‘part of’ the cognitive process – hence ”extended mind”
- i.e. external actions and objects can be ‘coupled’ to the mind in much the same way as our neurological resources (e.g. our good old biological memory)
- Clark advocates for an extended but *organism centered* mind, that recruits the body and the immediate material surroundings ‘on the spot’ to solve cognitive problems
- Hutchins suggests to consider larger networks of agents, artefacts and procedures scaffolded by *cultural practices*: i.e. socially learned practices of sense making

Objections to the Extended Mind:
The extended mind is too radical

- The Differences Argument:
  - There are significant differences between internal cognitive processes and the external processes. This casts doubts on the claim that both processes should be regarded as belonging to a single psychological kind.

- The Coupling-Constitution Fallacy:
  - EM confuses those structures and processes constitutive of cognition with those in which cognition is (merely) causally embedded. “It does not follow from the fact that one has an “X system” that every component of the system does X” (Adams and Aizawa 2007)

- The Cognitive Bloat Objection.
  - The admission of extended cognitive processes places one on a slippery slope. Once we permit such processes, where do we stop? Our conception of the cognitive will become too permissive, and we will be forced to admit into the category of the cognitive all sort sorts of structures and processes that clearly are not cognitive.

- The Mark of the Cognitive Objection.
  - EM should be rejected on the grounds that it is incompatible with any plausible mark of the cognitive; that is, any criterion that specifies the conditions under which a process qualifies as cognitive.

(slight modification of Rowlands, 2009)

Clark's answer (2008): The revised parity principle

- 1. That the resource be reliably available and typically invoked. (Otto always carries the notebook and won't answer that he "doesn't know" until after he has consulted it.)
- 2. That any information thus retrieved be more or less automatically endorsed. It should not usually be subject to critical scrutiny (e.g., unlike the opinions of other people). It should be deemed about as trustworthy as something retrieved clearly from biological memory.
- 3. That information contained in the resource should be easily accessible as and when required.
- 4. That the information in the notebook has been consciously endorsed at some point in the past and indeed is there as a consequence of this endorsement.

Clark 2008