Affordances, Actionability, and Simulation

The notion of affordances depends crucially on the actions available to an agent in context. When we add the expected utility of these actions in context, the result has been called **actionability**. There is increasing evidence that AI and Cognitive Science would benefit from shifting from a focus on abstract "truth" to treating actionability as the core issue for agents. Actionability also somewhat changes the traditional concerns of affordances to suggest a greater emphasis on active perception

An agent should also **simulate** (compute) the likely consequences of actions by itself or other agents. In a social situation, communication and language are important affordances.

Cognitive Science and Neuroscience

- Cognitive Science ~ Behavior
- Neuroscience ~ Structure and Function

Unification

Requires good behavioral theories/models.
Research on the physical basis of the ether or the life force did not work out well.

Language as Logic

Yet every sentence is not a proposition; only such are propositions that have in them truth or falsity. Thus a prayer is a sentence, but it is neither true nor false. Let us therefore *dismiss* all other types of sentences but the proposition, for this last concerns our present inquiry, whereas the investigation of others belongs rather to the study of rhetoric or poetry.

Aristotle (De Interpretatione 17a1-8).

Functionalism

In fact, the belief that neurophysiology is even relevant to the functioning of the mind is just a hypothesis. Who knows if we're looking at the right aspects of the brain at all. Maybe there are other aspects of the brain that nobody has even dreamt of looking at yet. That's often happened in the history of science. When people say that the mental is just the neurophysiological at a higher level, they're being radically unscientific. We know a lot about the mental from a scientific point of view. We have explanatory theories that account for a lot of things. The belief that neurophysiology is implicated in these things could be true, but we have very little evidence for it. So, it's just a kind of hope; look around and you see neurons: maybe they're implicated.

Noam Chomsky 1993, p.85

Embodiment

Of all of these fields, the learning of languages would be the most impressive, since it is the most human of these activities. This field, however, seems to depend rather too much on the sense organs and locomotion to be feasible.

Alan Turing (*Intelligent Machines*,1948)

< Continuity Principle of Darwin, American Pragmatists >

Substitution

- “When faced with a difficult question, we often answer an easier one instead, usually without noticing the substitution,” writes psychologist and Nobel Prize winner Daniel Kahneman, in his new book: “Thinking Fast and Slow“
- If the question is “Should I invest in Ford Motor Company stock?” the easier question to answer is “Do I like Ford cars?”

Actionability

Observational learning without a model is influenced by the observer's possibility to act: evidence from the Simon task

Cristina Iani, Sandro Rubichi, Luca Ferraro, Roberto Nicoletti, Vittorio Gallese
Cognition 01/2013; 128(1):26-34.

" the Simon effect is reduced, eliminated, or even reversed when participants perform a spatial compatibility task in which they are required to respond to a stimulus location by emitting a spatially incompatible response in advance"

" Indeed no evidence of transfer of learning was found when, during passive observation, the participants' hands were tied, or a transparent barrier prevented them from potentially interacting with the response device, or no response device was present. "

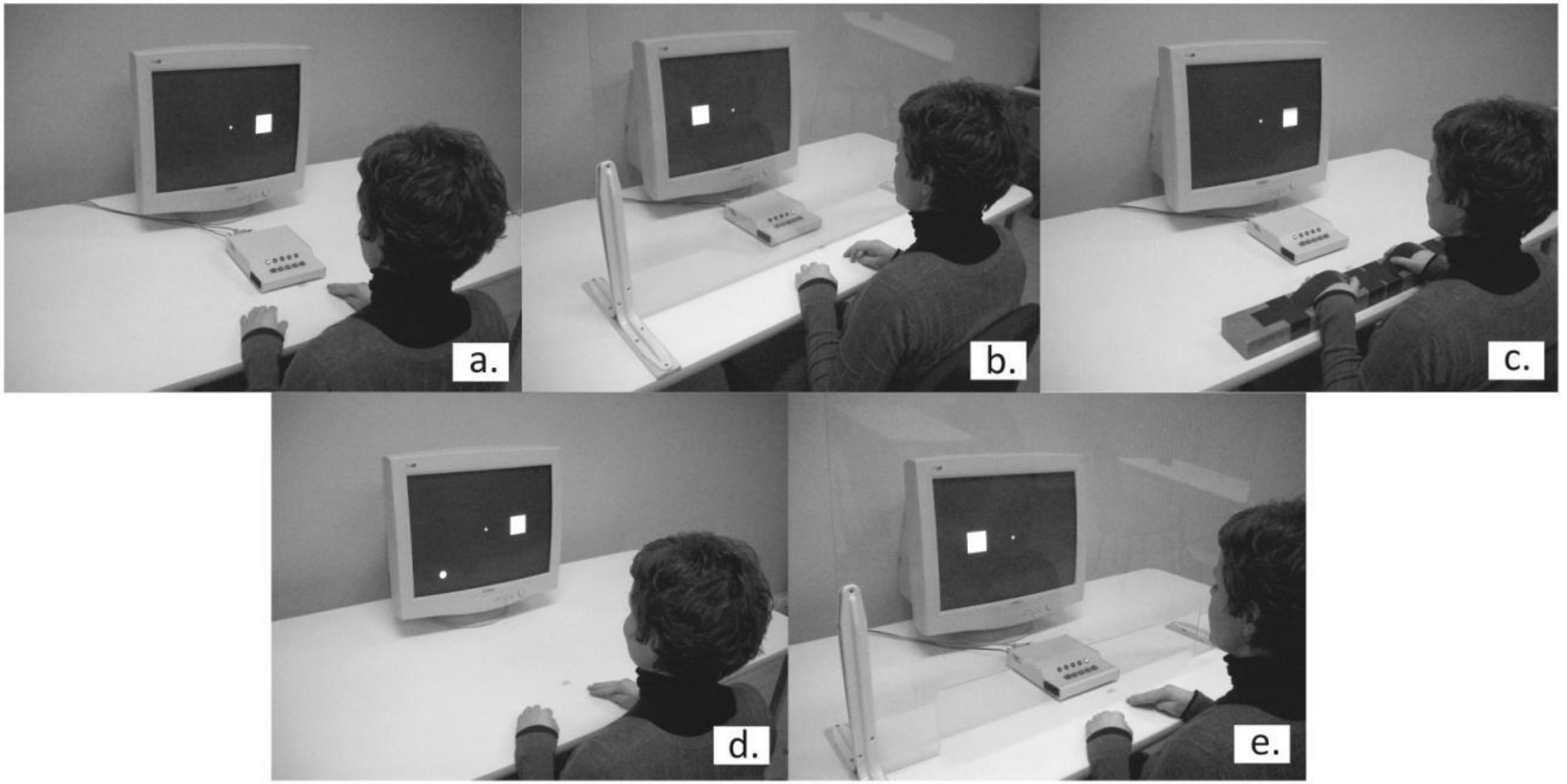


Figure 1. Illustration of the experimental setting used in the passive observational practice sessions of the three Experiments. In Experiment 1, the response box was positioned in front of the
participant (a.). In Experiment 2, in the “unreachable response device” condition, the response box was positioned behing a plexiglass barrier (b.), in the “constrained hands” condition, participant’s hands were tied to the table (c.), and in the “response device absent” condition, the response box was absent (d.). In Experiment 3, the plexiglass barrier presented an horizontal opening (e.).

Actionability, Simulation and Unified Cognitive Science

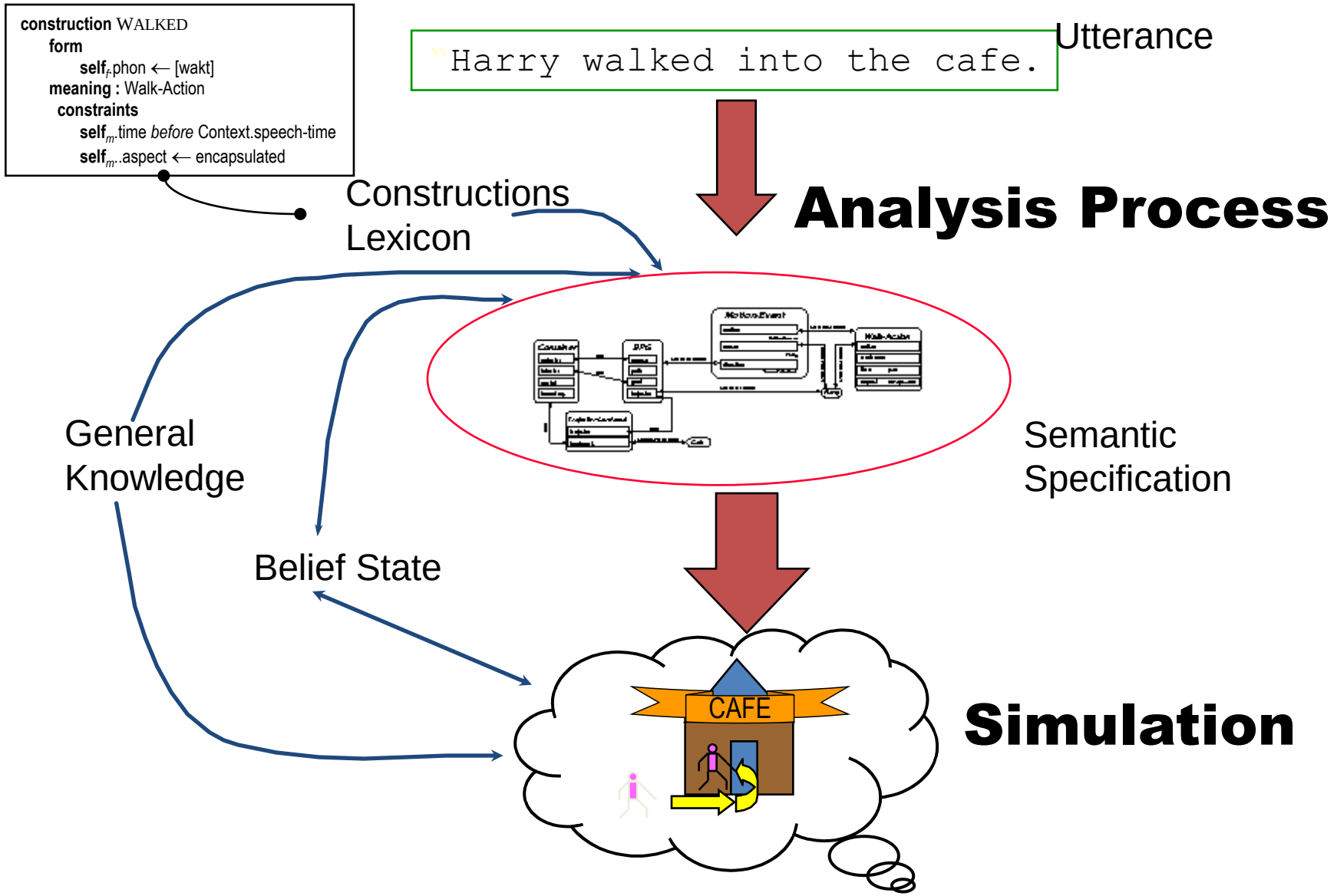
1) Action is evolutionarily much older than symbolic thought, belief, etc.; also developmentally earlier
2) Only living things act (in our sense); natural forces, mechanisms act by metaphorical extension.
3) Fitness is nature's assessment of actions; we define ***actionability*** as an organism's internal assessment of its available actions in context.
4) Actionability, not non-tautological truth, is what an agent/animal can actually compute.
5) Communication is action and is needed for cooperation – from pheromones to language
6) Actions include persistent change of internal state: self-concept, memory, world models, learning, etc.
   *The external world (e.g., other agents) is not static - internal models need **simulation***
7) The brain is not a set of areas that represent things, rather a network of circuits that do things.
8) In animals, perception is best-fit, active, and utility/**affordance** based.
9) Mysteries remain; subjective experience, binding, self, free will, robots, etc.
10) One crucial divide/cline is *volitional* action and communication – boundary not clear, but birds are above the line; protozoans, plants below. Assume, in nature, neurons are necessary for volition.
11) Volitional actions have automatic components and influence, e.g., speech
12) Cognitive Science is bounded by [neurons, individuals]; unify with related sciences.
13) Overall goal of the effort is consistency with all experimental findings.
14) Theory remains central; multiple formalisms are needed – theories should cohere
    Control, probability, computation, logic, dynamics, utility, process, system, learning,
15) Formulation is multi-level in three ways:
    Standard divisions by scale, complexity - synapse, neuron, circuit, etc.
    System formulation – whole and parts inseparable, body-environment coupling essential
    Higher level sciences describe the phenomena, e.g., linguistics, psychology.
16) Action models are multi-modal: describe execution, recognition, planning, language.
17) Volitional simulation proposed as the mechanism of planning, mind-reading, etc. *With an appropriate formalism, simulation can yield both causal and predictive inferences*.
18) Biological, social, and cultural co-evolution, including language.
19) Linguistics based on embodied simulation semantics as the foundation of language and thought.
20) Additional mechanisms include construction grammar, mental spaces, mappings, etc.
21) Rationalization and other mental illusions

Simulation hypothesis

We understand utterances by mentally simulating their content.

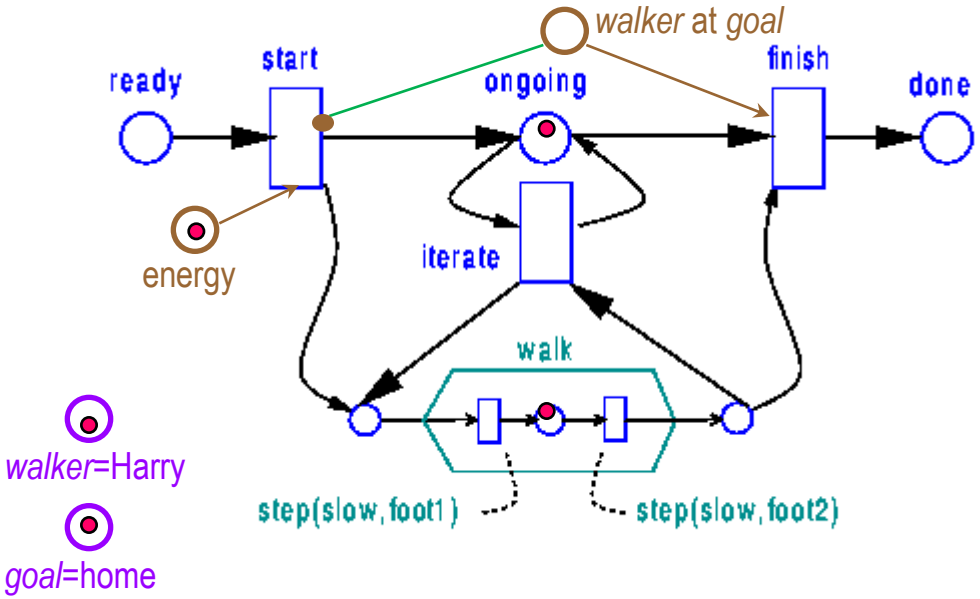
- Simulation exploits some of the **same neural structures** activated during performance, perception, imagining, memory…
- Linguistic structure **parameterizes** the simulation.
  - Language in context gives us enough information to simulate
  - Linguistic structure includes constructions , frames (http://framenet.icsi.berkeley.edu), embodied schemas, metaphor, mental spaces. Formalized in Embodied Construction Grammar, ECG.
  - Understanding involves running the *best fitting* simulation for the linguistic input.
    - Analysis involves finding the best simulation specification (Bryant 2008).

Language understanding: analysis & simulation



Active representations

- Many inferences about actions derive from what we know about executing them
- X-net representation based on stochastic Petri nets captures dynamic, parameterized nature of actions
- Used for acting, recognition, planning, and language



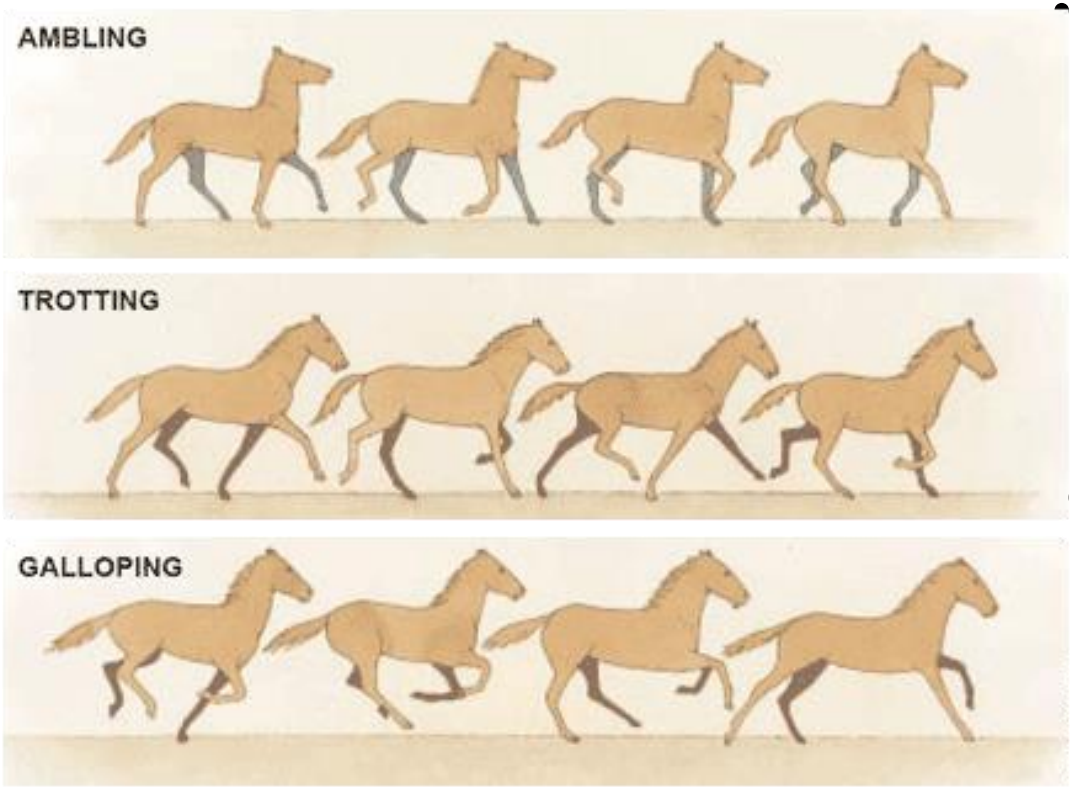
Walking: bound to a specific *walker* with a direction or *goal*

consumes resources (e.g., energy)

may have termination condition (e.g., *walker* at *goal*)

ongoing, iterative action

Active/Procedural Semantics circuits versus program semantics



Actions are:

- parameterized
- Interruptable
- Coordinated
- Hierarchical

Parameterized

- Speed
- Direction
- Step size
- Distance off the ground

An integrated System for Computing with Natural Language

- An integrated system combining
  - Deep semantic analysis of language in context with
  - A scalable simulation model
- Best-fit Language Analyzer
  - Embodied Construction Grammar (ECG)
    - Construction Parser
      - John Bryant PhD Thesis 2008
      - Eva Mok PhD Thesis 2009
      - Ellen Dodge PhD Thesis 2010
- Scalable Domain Representation
  - Event Models
      - Steve Sinha PhD Thesis 2008
      - Joe Makin PhD Thesis 2008
  - Coordinated Probabilistic Relational Models
      - Leon Barrett PhD Thesis 2010

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Brains ~ Computers

- 1000 operations/sec
- 100,000,000,000 units
- 10,000 connections/
- graded, stochastic
- embodied
- fault tolerant
- evolves, learns

- 1,000,000,000 ops/sec
- 1-100 processors
- ~ 4 connections
- binary, deterministic
- abstract
- crashes
- designed, programmed

100 Step rule: Reaction times ~ 100 milliseconds

Variable Binding

Variable Binding ~ Neural Reasoning

In behavior

- Grasping motion depends on object to grasp
- Drive away in a rental car

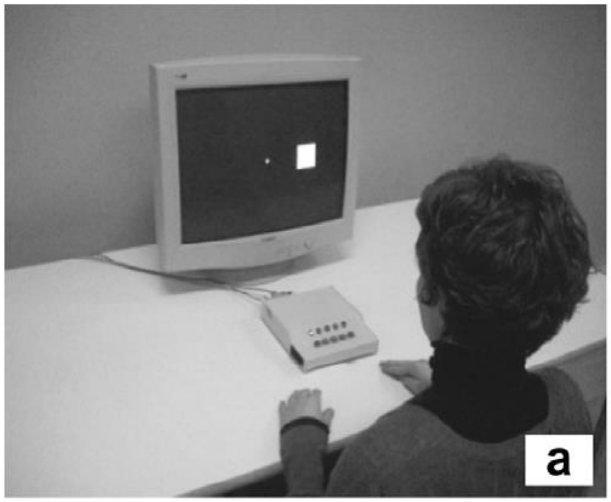
In inference, language

- Human(x) -> Mortal(x)
- Must bind a variable to x
- Unification : *One cows, one/two sheep
- Pronouns, Antecedents: He moved her hand

Proposals for Neural Binding

- Brute-force enumeration ~ crossbars
  - Does not scale to human knowledge, variability
  - No learning model
- Signature propagation (direct reference)
  - Implausible to pass enough information to directly reference each item (~ 20 bits)
  - Unifying bindings (e.g. agreement) is difficult
- Temporal synchrony (e.g.SHRUTI)
  - Weak biological evidence, unification unsolved

Hummel JE (2011) Getting symbols out of a neural architecture. Connection Science 23:109-118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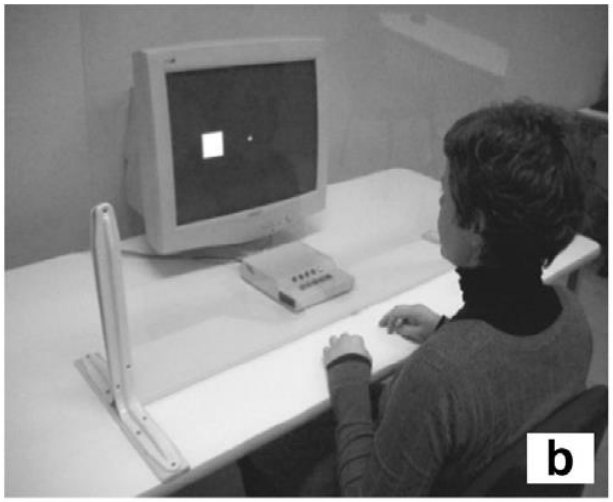
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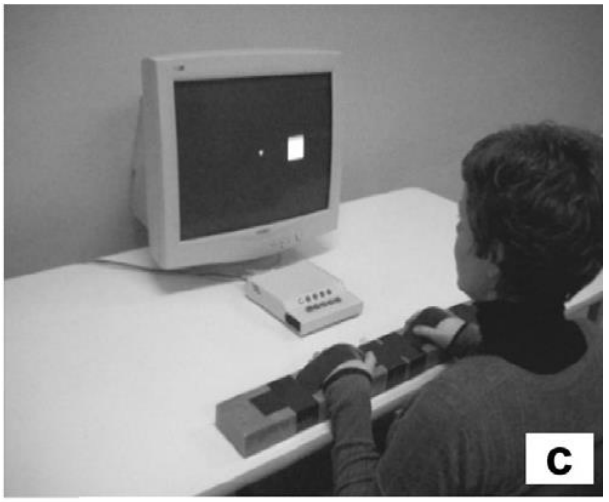
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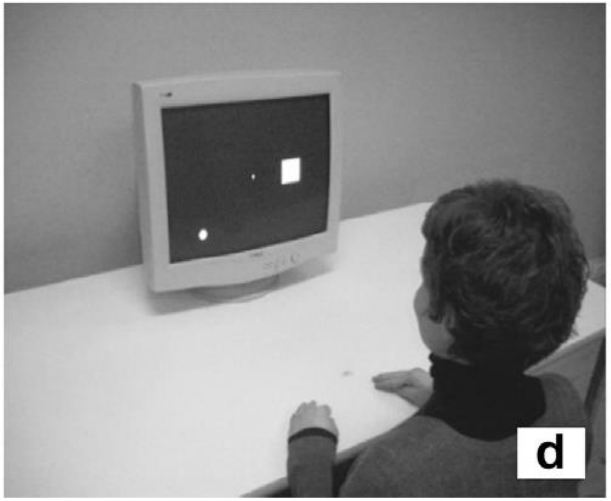
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Actionability in Integrated Cognitive Science

1. All living things *act*; acting is what living things do.
2. Natural selection constrains the fitness (*utility*) of these actions.
3. *Volition* is the key concept; *agents* perform volitional as well as automatic actions.
4. *Actionability* is an agent's assessment of the *expected utility* of an external or internal action.
5. This defines, but does claim to solve, actionability as a *integrating issue* for Cognitive Science.
6. No answers are suggested for hard *mind-brain* problems like subjective agency.
7. Actionability calculation often involves *simulation* of action and its consequences.