

# Cognition and Consciousness: Is There a Fundamental Link?

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# Overview

- Three related issues
  - Neural parallelism
  - Modular theories of mind
  - The frame problem
- Global workspace theory (GWT)
- Applying GWT to the three issues



# First Issue

# Neural Parallelism

- An animal's nervous system is massively parallel
- Massive parallelism surely underpins human cognitive prowess
- So how are the massively parallel computational resources of an animal's central nervous system harnessed for the benefit of that animal?
- How can they orchestrate a coherent and flexible response to each novel situation?
- What is their underlying architecture?
- Nature has solved this problem. How?



# Second Issue

# Modular Theories of Mind (1)

- Many cognitive scientists advocate modular theories of mind (Gardner, Tooby & Cosmides, Fodor, Mithen, Carruthers)
- The mind comprises (or incorporates) an assemblage of distinct specialist *modules*
- Fine-grained horizontally modular theories (eg: Tooby & Cosmides) posit specialists for particular behaviours (eg: foraging)
- More coarse-grained vertically modular theories (eg: Fodor) posit specialists for certain input and output processes (eg: parsing, low-level vision)

# Modular Theories of Mind (2)

- In addition to the specialist modules, all modular theories demand (for humans) some overarching faculty, central system, super-module, meta-representational facility, or whatever
- This addition is capable, when required, of transcending modular boundaries to produce flexibly intelligent behaviour rather than an automatic, preprogrammed response to a novel situation
- But nobody has a very convincing account of this



# Third Issue



# The Frame Problem (1)

- The frame problem originated in classical AI

How can we formalise the effects of actions in mathematical logic without having to explicitly enumerate all the trivial non-effects?

- This is tricky, but was more-or-less solved in the mid 1990s
- Our concern is the wider interpretation given to the frame problem by philosophers, notably Dennett and Fodor

# The Frame Problem (2)

- Fodor's version:

How do *informationally unencapsulated* cognitive processes manage to select only the information that is relevant to them without having to explicitly consider everything an agent believes ?

- A cognitive process is *informationally unencapsulated* if it has the potential to draw on information from any domain
- Analogical reasoning is the epitome of informational unencapsulation

# Computational “Infeasibility”

- Fodor claims that informationally unencapsulated cognitive processes are computationally infeasible

“ The totality of one’s epistemic commitments is *vastly* too large a space to have to search ... *whatever* it is that one is trying to figure out. ”

(Fodor, 2000)

- Fodor believes that this is a fatal blow for cognitive science as we know it because it entails we cannot find a computational explanation of the human mind’s “central systems”

# Fodor's Modularity of Mind

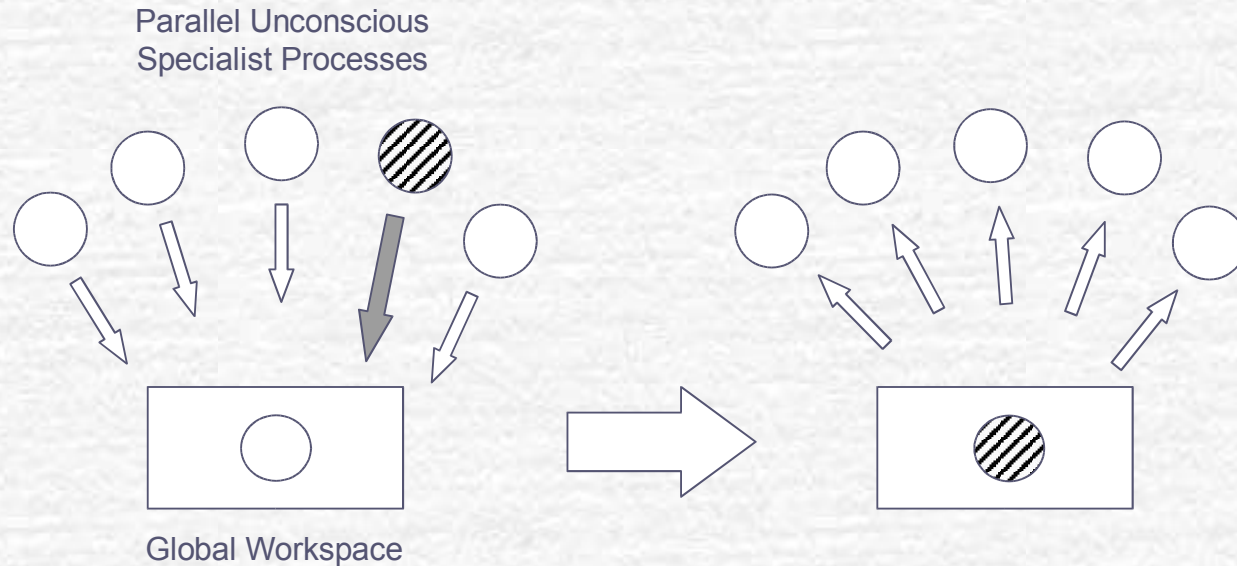
- The mind's *peripheral* processes are special purpose, do things like parsing and low-level vision, and are computational
- The mind's *central* processes are general purpose, do things like analogical reasoning, are informationally unencapsulated, and (probably) *aren't computational*

“... it probably isn't true that [all] cognitive processes are computations. ... [so] it's a mystery, not just a problem, what model of the mind cognitive science ought to try next. ” (Fodor, 2000)



# The Solution

# Global Workspace Architecture



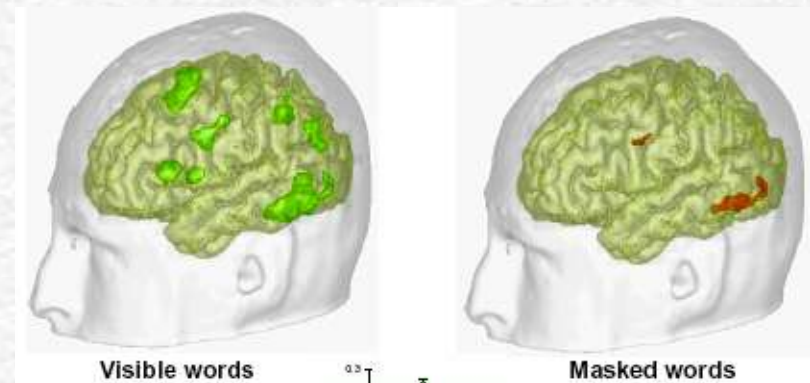
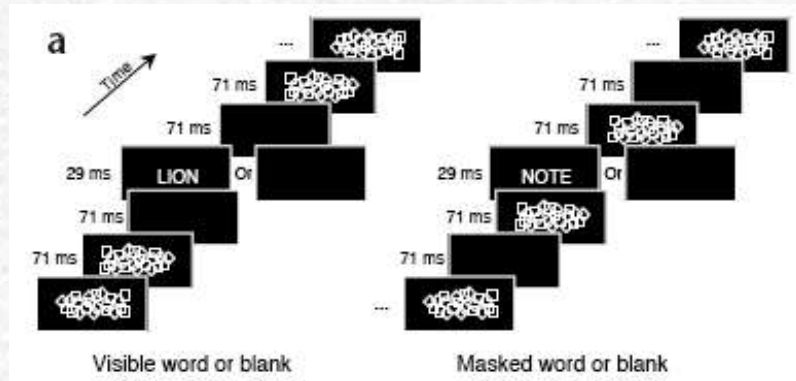
- Multiple parallel *specialist* processes compete and co-operate for access to a *global workspace*
- If granted access to the global workspace, the information a process has to offer is *broadcast* back to the entire set of specialists

# Conscious vs Non-Conscious

- Global workspace theory (Baars) hypothesises that the mammalian brain instantiates such an architecture
- It also posits an empirical distinction between conscious and non-conscious information processing
- Information processing in the parallel specialists is non-conscious
- Only information that is broadcast is consciously processed

# Empirical Evidence

- Contrastive analysis compares and contrasts closely matched conscious and unconscious brain processes
- Dehaene, *et al.* (2001)
  - Imaged subjects being presented with “masked” words
  - Masked and visible conditions compared



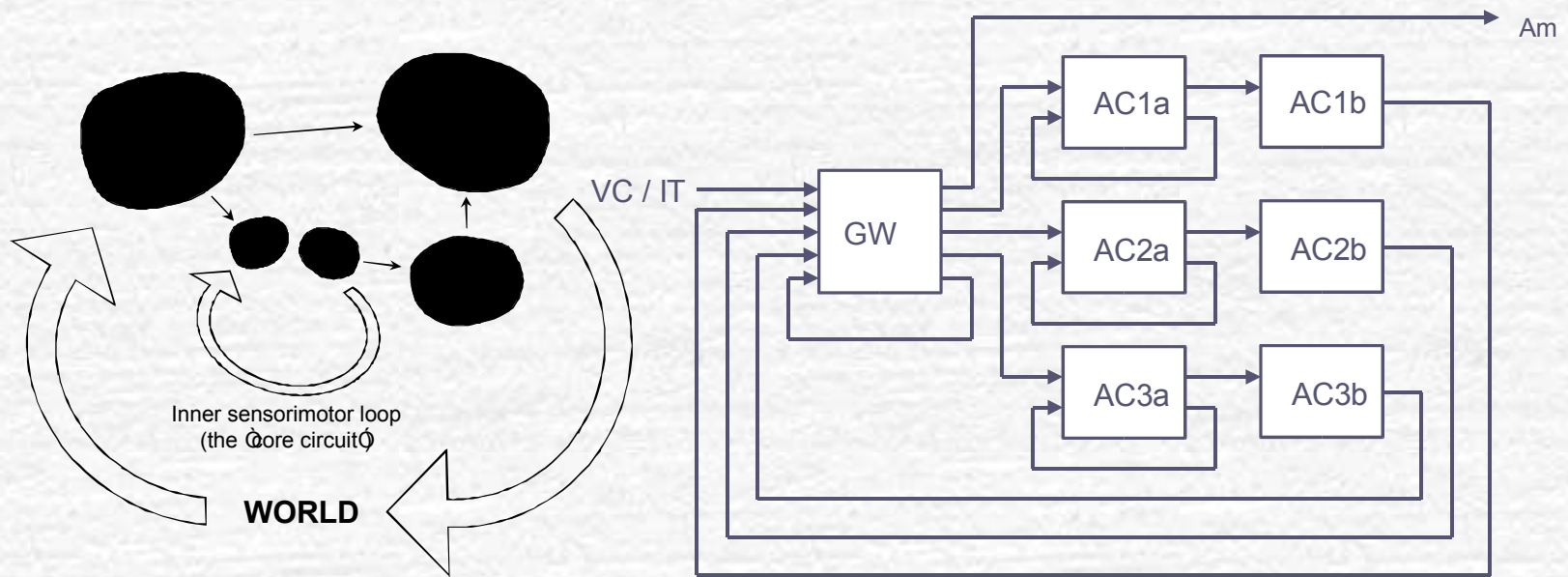
- Such experiments suggest that conscious information processing recruits widespread brain resources while unconscious processing is more localised



# Embodiment

- According to GWT, only something that instantiates a global workspace architecture is capable of conscious information processing
- But this is a necessary not a sufficient condition
- I have argued (Shanahan, 2005) that the architecture must direct the actions of a spatially localised body using a sensory apparatus fastened to that body
- This allows the set of parallel specialists a shared viewpoint, from which they can be indexically directed to the world and fulfil a common remit

# Combining GWT with Internal Simulation



This “core circuit” combines an internal sensorimotor loop with mechanisms for broadcast and competition, and thereby marries the *simulation hypothesis* (Cotterill, Hesslow) with *global workspace theory* (Baars)



# Applying the Solution

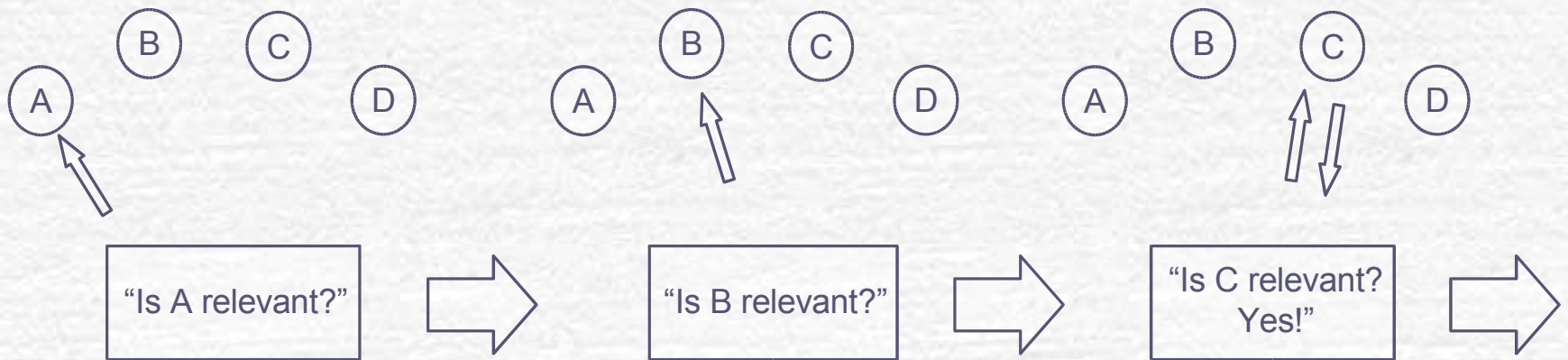
# Serial from Parallel / Unity from Multiplicity

- The global workspace architecture harnesses the power of massively parallel computation
- The global workspace itself exhibits a *serial* procession of states
- Yet each state-to-state transition is the result of filtering and integrating the contributions of huge numbers of *parallel* computations
- The global workspace architecture thereby distils unity out of multiplicity
- This is perhaps the essence of consciousness, of what it means to be a singular, unified subject

# GWT and the Frame Problem (1)

- Both Fodor and Dennett seem to have a strictly serial architecture in mind when they characterise the frame problem

Peripheral Processes (Modules)



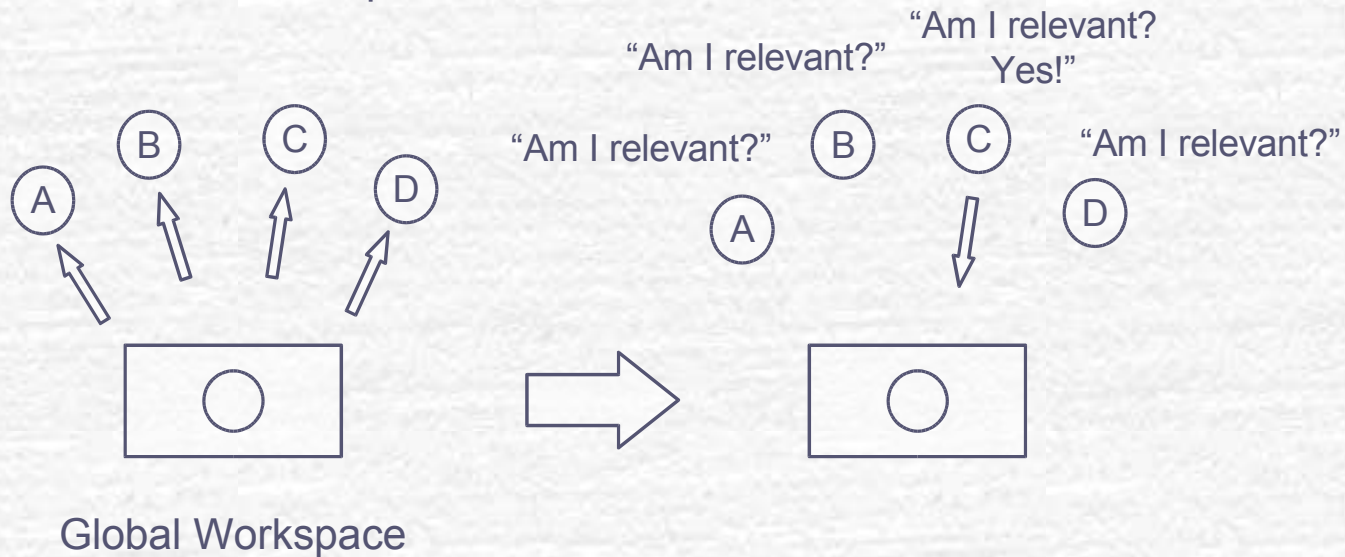
Central Processes

- This certainly looks computationally infeasible

# GWT and the Frame Problem (2)

- But global workspace architecture offers a parallel alternative

Parallel Unconscious Specialists



- In the context of an appropriate parallel architecture, the frame problem looks more manageable

# Analogical Reasoning (1)

- Analogical reasoning is informational unencapsulation in its purest form

“Analogical reasoning depends precisely upon the transfer of information among cognitive domains previously assumed to be irrelevant ” (Fodor)

- Computational models of analogical reasoning distinguish between
  - *retrieval* – the process of finding a potential analogue in long-term memory for a representation already in working memory – and
  - *mapping* – the subsequent process of finding correspondences between the two

# Analogical Reasoning (2)

- Retrieval is the locus of the frame problem in analogical reasoning
- The most psychologically plausible computational model is currently LISA (Hummel & Holyoak), which mixes serial and parallel computation, and also fits a global workspace architecture very closely





# Reinventing Modularity

- The global workspace architecture can be appropriated by any of the modular theories of mind
- It potentially supplies the means of transcending modular boundaries required to realise human-level, flexible, creatively intelligent cognition
- Its application to the frame problem in general, and to analogical reasoning in particular, is an example of this

# Conclusion

*Is there a fundamental link between cognition and consciousness?*

There is plentiful support for an affirmative reply

So perhaps an understanding of cognition has to go hand-in-hand with an understanding of consciousness

# References

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