

What can neuroimaging tell us about the mind?

Kelly Alexandra Roe

2008

*Presented to Tempo and Mode, centre for Macroevolution and Macroecology,
hosted by the Australian National University*

Acknowledgment

- I would like to thank Martin Davies for introducing me to the *Cortex* debate with his pre-talk and seminar presentation to the Philosophy Society of the Australian National University.

The Challenge

- In a special edition of the Journal *Cortex* the Australian Cognitive Psychologist Max Coltheart issued a challenge:
- What has functional magnetic resonance imaging (*fMRI*) told us about the mind so far?
- Or:
- When has functional neuroimaging provided data that has adjudicated between two rival cognitive psychological theories?

Structure of the talk

- Set up the background
- Get clearer on the rules of the game
- - What is it for a theory to be a ‘cognitive’ theory?
- - What is it for data to ‘adjudicate’ between two theories?
- An ‘in principle’ (logical) objection
- An ‘in practice’ (empirical) objection
- Consider what would have to be the case in order for neuroimaging to tell us about the mind (aka adjudicate between two cognitive psychological theories)

Background

- *‘Rather a lot of people believe you can’t learn anything about cognition from studying the brain (Harley, Coltheart, Colby, Morton, van Orden and Paap, Uttal, Fodor)’*

- Some philosophers have claimed that neuroscience can't show us anything about the structure of mental processes *in principle*
- E.g., if you want to learn about the structure of a Microsoft Word document then learning about the hardware that the programme is implemented on is *irrelevant*
- *'How might these people be shown the error of their ways? All that is needed to do this is to provide them with actual examples where neuroimaging data have successfully been used to distinguish between competing psychological theories. They all claim that this cannot happen. Has it ever happened?'*
- In contrast to this view, many cognitive neuroscientists maintain that fMRI (in particular) has much to show us about the nature of mental processes
- Cognitive neuroscience textbooks typically say that we have made significant advances in understanding the mind as the result of advances in neuroimaging
- *'if it turns out that none of this work [so far] can be used to distinguish between competing psychological theories, the in-principle question of whether cognitive neuroimaging data can ever serve this function will deserve much more attention than it has so far been given'*

Coltheart's challenge

- Coltheart presents his challenge in the form of a request for examples of when fMRI data has been successfully used to adjudicate between two rival cognitive theories
- We need to get clearer on the rules of the game that Coltheart invites respondents to play in order to understand what would be required for a successful case

Rules of the game: Cognitive psychological theories

- Cognitive psychology is a well developed research programme within psychology

- It is the science of mental processes
- - Perception, attention, language, memory
- Cognitive psychological theories predict (and are answerable to) behavioural data
- - Accuracy of responses, kinds of errors, response time

Rules of the game: Adjudication by data

- Let Theory A and Theory B (Ta and Tb) be theories of the structure of mental processes
- - Ta
- - Tb
- Let Ta and Tb predict different patterns of behaviour data (e.g., response time, accuracy etc) such that:
 - - Ta predicts Bx and
 - - Tb predicts that Bx **will not occur**
- If Bx were found, then this would adjudicate between the theories by providing support for Ta over Tb

Example

- Ta - Irregular word reading requires access to semantics (Plaut *et al.*, Rogers *et al.*)
- Tb - Irregular word reading does not require access to semantics (Goodall and Phillips, Patterson and Shewell, Lytton and Brust, Coltheart *et al.*, etc)
- Ta predicts *all* patients with impairments to the semantic system will be impaired at irregular word reading (Bx)
- Tb predicts *some* patients (at least one) with impairments to the semantic system will have normal irregular word reading (**not** Bx)
- There are patients with impairments to the semantic system who have normal irregular word reading (**not** Bx)

- So the behavioural data strongly favours Tb over Ta .

The Challenge

- Coltheart's challenge is thus for people to provide examples where neuroimaging data has adjudicated between two rival cognitive theories in the same way that behavioural data adjudicated in the example
- Coltheart restricts the challenge to what has been found *so far*
- - Failure to find a case doesn't (by itself) entail that there won't be cases in future
- Coltheart restricts the challenge to *fMRI*
- - Failure to find a case doesn't (by itself) entail that other neuroimaging techniques have been similarly unsuccessful
- Restricted to what it can tell us about *mental processes*
- - Concerned with data *adjudicating between* cognitive theories and explicitly not concerned with *localisation of cognitive psychological processes*

Logical structure

- Ta and Tb must be two otherwise plausible cognitive psychological theories
- Coltheart cashes out 'otherwise plausible' in terms of theories that have been seriously entertained by cognitive psychologists
- Ta and Tb need to predict incompatible patterns in behavioural data in order to count as rival cognitive psychological theories
- - Ta predicts Bx
- - Tb predicts not Bx

Logical structure that seems to be required

- Ta and Tb must predict incompatible patterns in neuroimaging data (Nx) in order for neuroimaging data to be relevant to adjudicate between two theories

- - Ta predicts Nx
- - Tb predicts **not** Nx
- The relevant pattern of neuroimaging data needs to be univocal (speak with one voice) so that we have clear support for either Ta or Tb and not both

Logical structure that isn't allowed

- But when people provide examples of the form:
 - - Ta predicts Nx
 - - Tb predicts **not** Nx
- Coltheart maintains that the theories are not cognitive psychological theories!

Example

- Ta - Endogenous and exogenous attention are governed by a single cognitive system
- Tb - Endogenous and exogenous attention are governed by separate cognitive systems
- Imaging has revealed that endogenous attention activates a dorsal parietofrontal network whereas exogenous attention activates a ventral parietofrontal network
- This is taken as evidence that supports Tb and *not* Ta

The logical objection

- *'I think one can show that the two theories he considers are not psychological because nothing in his paper would be changed if he stated the two theories thus:*
 - *Ta endogenous and exogenous attention are governed by a single brain system*
 - *Tb endogenous and exogenous attention are governed by separate brain systems*

They are not theories about cognitive processes they are theories about the brain'

...the theory that the process of rehearsal is cognitively independent of the process of speech production does not predict that different regions of the brain will be activated by these processes'

- Coltheart's main objection to his critics is that their cases fail because the neuroimaging data doesn't adjudicate between *cognitive psychological* theories
- In particular, he seems to be maintaining that cognitive psychological theories don't predict anything at all about neural localisation and, insofar as critics think it does, they have failed to understand what he means by a *cognitive psychological theory*

What to make of the 'in principle' objection

- While Coltheart presents the claim as an *empirical* one, his constraints on the logical form of a case seem to make it a *logical impossibility* that there will be a case
- While Coltheart presents the claim as one that is restricted to *fMRI*, the same point would apply to *any neuroimaging technique* (or any data about neurological processes)
- One might conclude: So much the worse for cognitive psychological theory!
- In particular, one might conclude: If cognitive psychology regards neurological data to be irrelevant (as a matter of principle, no less) then surely a *better* theory of the structure of mind would be one that was answerable to more kinds of, hence neurological, data
- *'provided one makes the assumption that there is some "systematic" mapping from psychological function to brain structure, then functional neuroimaging data simply comprise another dependent variable, along with behavioural data, that can be used to distinguish between competing psychological theories (Henson, 2005 p.194)'*
- *'I want to challenge this argument directly. I fully accept Henson's assumption that there is some systematic mapping*

from psychological function to brain structure. Nevertheless, I'll claim that no functional neuroimaging research to date has yielded data that can be used to distinguish between competing psychological theories'

- Coltheart thus grants that there is a mapping from psychological function to neurological processes. His other (empirical) objections to the examples provide clues as to why he isn't willing to regard cognitive psychological theorising as being answerable to fMRI data

What would have to be the case for neuroimaging to tell us about the mind?

The empirical objections

- It might not be enough to grant that there is 'some systematic mapping', it might be that there has to be some specific mapping in order for neuroimaging data to be able to adjudicate between two cognitive theories
- While Coltheart states that he is *not* concerned with localisation, some of his responses seem to take issue with the specific mappings that are relied on
- For example: Three theories of how number transcoding tasks such as reading aloud Arabic numerals are performed:
 - - *Ta* - such transcodings always require passing through a semantic level
 - - *Tb* - such transcodings bypass the semantic level so make no use of it
 - - *Tc* - such transcodings can make use of both a semantic and nonsemantic route (with various factors biasing the route)
- Coltheart accepts these as rival cognitive theories
- *'The next step is to nominate the intraparietal sulcus (IPS) as a region of the brain that is activated when semantic tasks are being performed. Let's accept this nomination, and measure IPS activation when people are performing number transcoding tasks. The predictions seem clear'*

Ta - IPS will always be activated when such tasks are being performed

Tb - IPS will never be activated when such tasks are being performed

Tc - IPS will sometimes be activated and other times not as a function of the factors biasing the use of the route

- The IPS is activated in tasks that don't require access to number semantics
- So it doesn't follow from *Tb* and *Tc* that there will be no occasions when a numeral doesn't activate IPS
- Thus the finding that IPS is always activated when subjects perform a transcoding task is compatible with all three theories and can't be used to distinguish between them
- Similarly, in response to another case, Coltheart objects:
 - *'This reasoning required that covert shifting of visual attention and activation of the right posterior parietal region be co-extensive... Thus the claim that the sole function of this brain region is control of covert shifting of visual attention; unless that is so, the reasoning about Ta and Tb does not follow'*
- Research has shown that covert shifting of visual attention is *not* the sole function
- In 'Brain Imaging, Connectionism, and Cognitive Neuropsychology' (2004), Coltheart maintains:
 - *'I don't know of any examples in which there is current consensus as to the cerebral localisation of any module of any cognitive system on the basis of cognitive neuroimaging data'*
- He maintains that if we view cognitive processing as cascaded (rather than thresholded) and interactive (rather than purely feedforward) this poses
 - *'grave difficulties for the use of imaging to discover the cerebral localisation of cognitive modules'*

What do we make of this?

- It might turn out that there is a case in the existing literature that hasn't been unearthed yet
- It might turn out that there are localisations accessible to *fMRI* that haven't been discovered yet (or put to good use in adjudicating between cognitive psychological theories)
- It might turn out that *fMRI* is simply at the wrong grain to find the needed correlations between neurology and cognitive mechanisms
- Or it might be that cognitive processes are multiply realised and distributed such that localisation attempts will fail (I think this would be to deny systematic mapping)
- Before I said that it might be tempting to conclude 'so much the worse for cognitive psychology' if it was ruling neuroimaging out as providing inadmissible data as a matter of principle
- It would be especially tempting to conclude this if neuroimaging had been successful in finding the neural correlates of cognitive psychological mechanisms
- Insofar as neuroimaging hasn't been successful in finding neural correlates for cognitive psychological mechanisms it is hard to see how neuroimaging data is useful for adjudicating between cognitive psychological theories, however!
- If the IPS is always active during semantic processing (necessary for it) then if we were to find that with lesion to the IPS number semantics could still be processed sometimes (contrary to *Tc*) or always (contrary to *Tb*) or never (contrary to *Ta*) then this would seem to provide evidence in support one of these theories rather than the others
- This hasn't been done. But it might be that neuroimaging in conjunction with other methodologies such as neurological damage can provide information that could be used to adjudicate
- Of course, cognitive psychologists would be able to reach similar conclusions by observing behavioural data (e.g., the ability to process numbers in the absence of semantic ability)
- But different findings converging on the same result is often considered a virtue rather than a vice (even if one of the methods is considerably more expensive)

- It is unclear whether neuroimaging will be placed to adjudicate between two cognitive theories where behavioural data cannot
- Until localisations (or neural correlations) are agreed upon... Why should cognitive psychologists look to cognitive neuroscience in order to find evidence to adjudicate between cognitive psychological theories?