What can Neuroimaging tell us About the Mind?

Tempo and Mode, 2008

The Challenge

- What has functional neuroimaging told us about the mind so far?’
- When has functional neuroimaging provided data that has adjudicated between two rival cognitive psychological theories?

Structure of 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 (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 the Microsoft Word program then learning about the hardware *is irrelevant*

Background

- ‘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?’

Background

- In contrast to this 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 a result in advances in neuroimaging

Background

- ‘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 respondants to play in order to understand what would be required for a successful case

The Rules of the Game:
Cognitive Psychological Theories

- Cognitive psychology is a well developed research program within psychology
- It is the science of mental processes
  - Perception, attention, language, memory
- Cognitive psychological theories predict (and are answerable) to behavioral data
  - Accuracy of responses, kinds of errors, response times

The Rules of the Game:
Adjudication by Data

- Let Ta and Tb be theories of the structure of mental processes
  - Ta
  - Tb
- Let Ta and Tb predict different patterns of behavioral data (response time, accuracy etc)
  - Ta -> Bx
  - Tb -> -Bx
- If Bx were found to be the case 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 with impairments to the semantic system will have normal irregular word reading (-Bx)

Example

- There are patients with impairments to the semantic system who have normal irregular word reading (-Bx)
- So the behavioral data strongly favors 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 the behavioral data adjudicated in the example

Some Restrictions on the Challenge

- Restricted to what has been found *so far*
  - Failures to find a case don't (by themselves) entail that there won't be cases in the future
- Restricted 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 *localization 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 behavioral data in order to count as rival cognitive psychological theories
  - Ta -> Bx
  - Tb -> -Bx

Logical Structure that Seems to be Required

- Ta and Tb must predict incompatible patterns in neuroimaging data in order for neuroimaging data to be relevant to adjudicate between the two theories
  - Ta -> Nx
  - Tb -> -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 -> Nx
  - Tb -> -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 Logical Objection

- ‘…the theory that the process of rehersal is cognitively independent of the process of speech production does not predict that different regions of the brain will be activated by these processes’

The Logical Objection

- 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 about neural localization and insofar as critics think it does they have failed to understand what he means by *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 one

- 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)

What to Make of the ‘In Principle’ Objection

- One might conclude ‘so much the worse for cognitive psychological theory!’
- In particular one might conclude that if cogntiive psychology regards neurological data to be irrelevant as a matter of principle then surely a better theory of the structure of mind would be one that was answerable to 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 behavioral 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 theorizing as being answerable to neuroimaging data

What Would Have to be the Case in Order for Neuroimaging to tell us About the Mind?

The Emprical 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 to adjudicate between two cognitive theories

- While Coltheart states that he is *not* concerned with localization some of his responses question the legitimacy of the specific mappings that are relied on

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

Example

- ‘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:’

Example

- 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 Emprical Objection

- 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 occasions when a numeral doesn't activate IPS
- Thus the findings 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

Example

- Similarly in response to another case Coltheart objects:

- ‘This reasoning required that covert shifting of visual attention and activation of this 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

The Empirical Objection

- 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 to 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 localizations accessible to fMRI that haven't been discovered yet (or put to good use in adjudicating between cognitive psychological theory)
- 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 realized and distributed such that localization attempts will fail (I think is would be to deny systematic mapping)

A Vindication?

- 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!

A Vindication?

- If the IPS is always active during semantic processing (necessary for it)…
- Then If we were to lesion the IPS and we found that number semantics could still be processed okay sometimes (contrary to Tc) or always (contrary to Tb) or never (contrary to Ta) then this would seem to support one of these theories against 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

A Vindication?

- Of course cognitive psychologists would be able to reach similar conclusions by observing behavioral data (e.g., ability to process numbers in the absence of semantic ability)
- But different methods converging on the same results 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 behavioral data cannot

A Vindication?

- Until localizations (or neural correlations) are agreed upon…
- Why should cognitive psychologists look to cognitive neuroscience in order to find evidence to adjudicate between two cognitive theories?