CGSC6501F (**Neuroimaging)**

Week 2 (Conceptual Issues)

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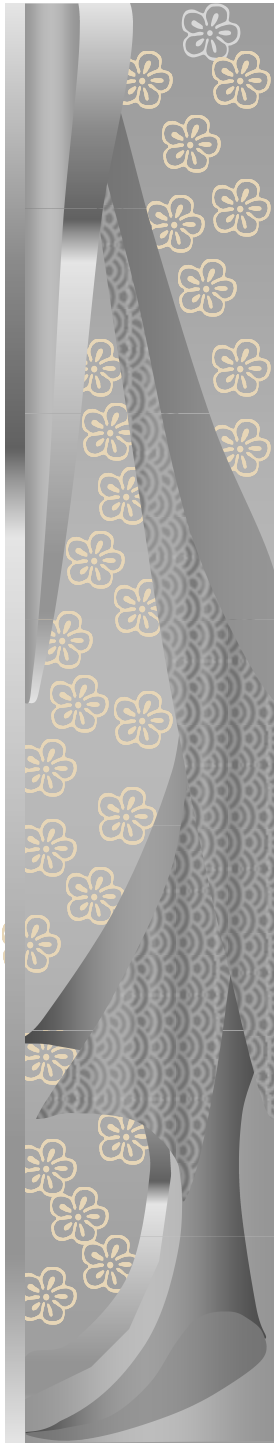


Localization vs. Distribution

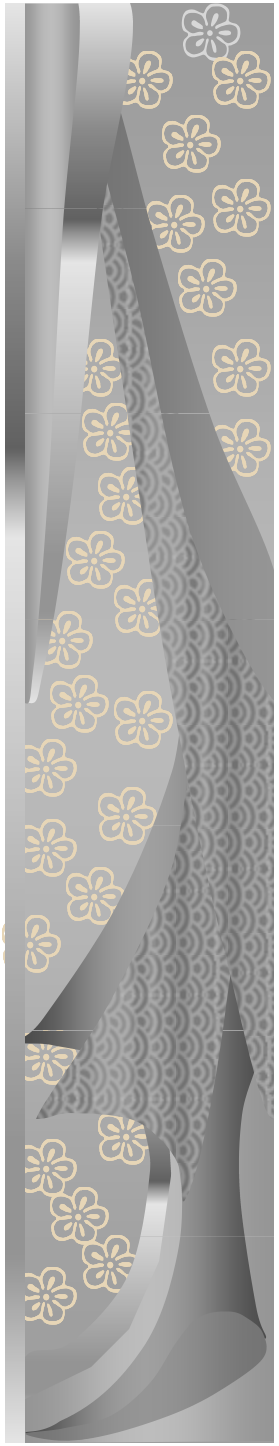
- **What is localization?**

  Cognitive functions (mind?) are modular and located in specific modular regions of the brain.

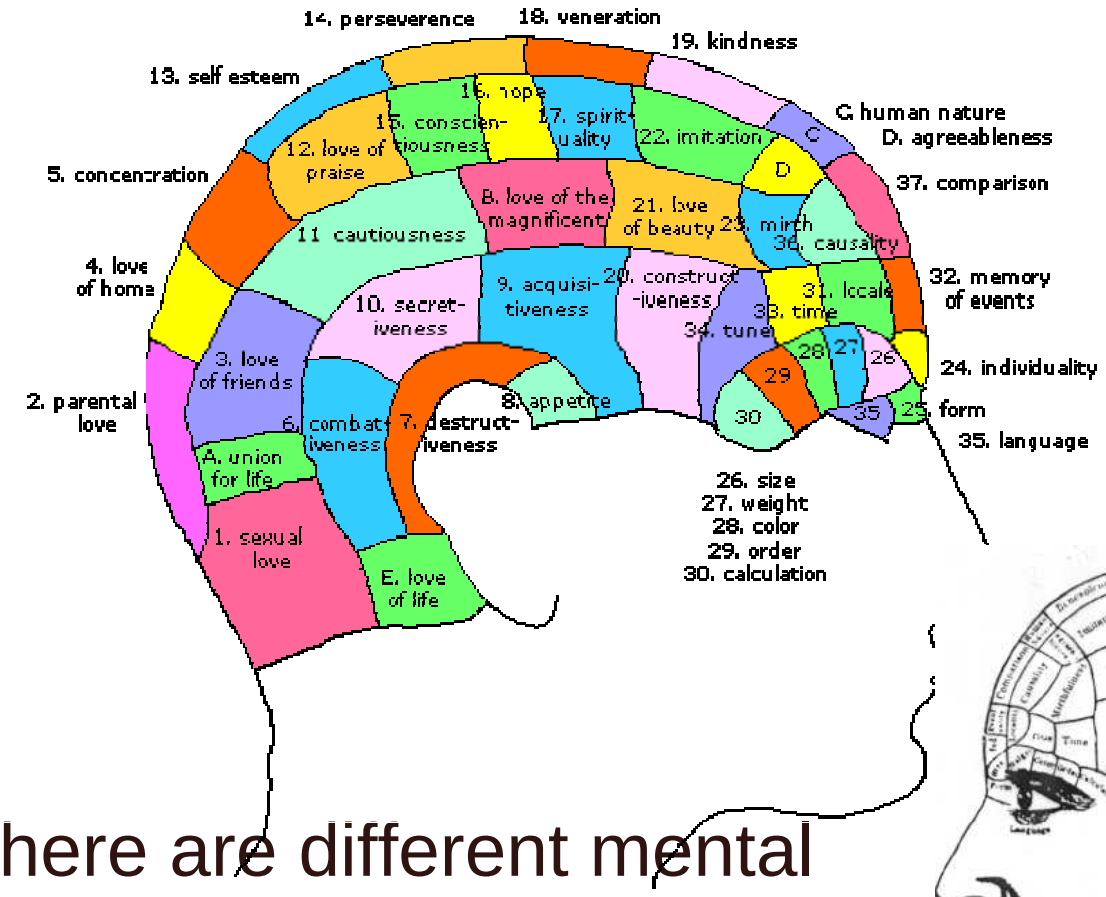
- **Opposed to Descartes' unified mind?**

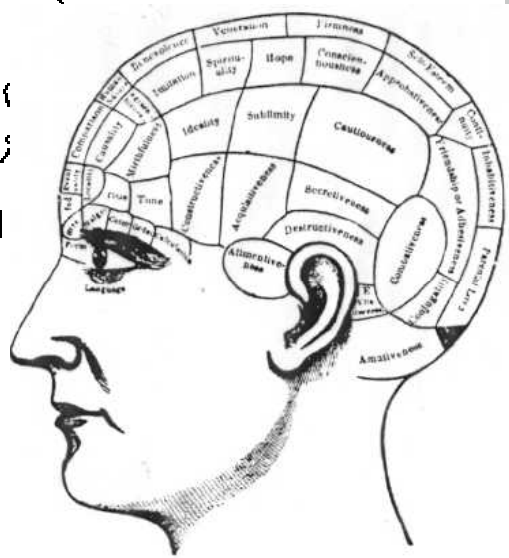
  (which still includes automatic vs. soul driven)

- **Issues related to localization are very important for cognitive science (Hubbard 2003).**



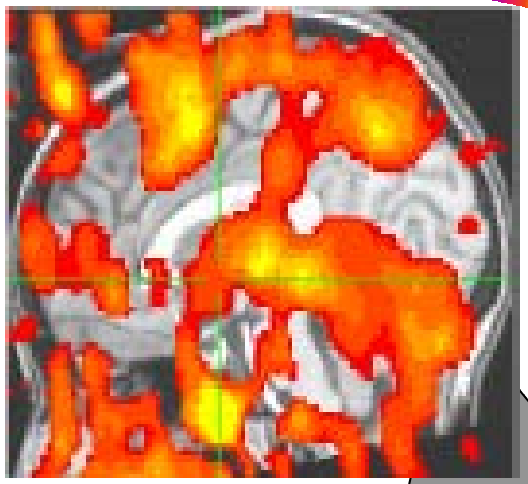
Phrenology-19th century: Gall



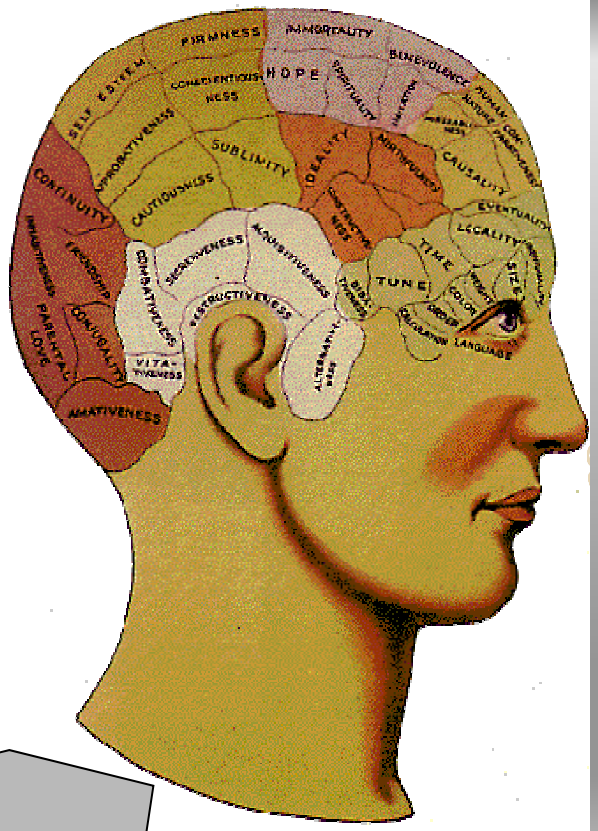


There are different mental faculties located in specific areas of the brain, detectable by looking at skull bumps

FUNCTIONAL
Magnetic Resonance Imaging



Phrenology



For example, Snow (2003):

Four Locations

1: “social mind” for emotional intelligence (BA9)

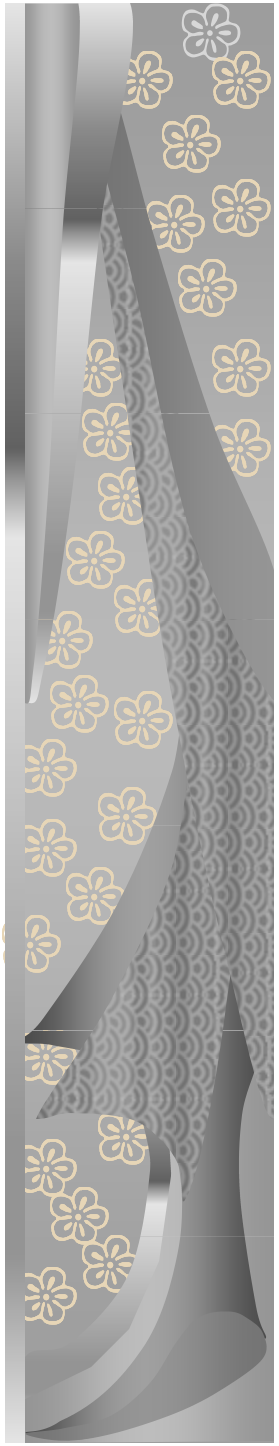
2: “temporal mind” for the future and goal (BA10)

3: the “material mind” for practicality (BAs 45 and 47),

4: and finally the “abstract mind” for hypotheses generation (BA46).

Snow argued that these areas are heritable and their sizes determine the personality differences.

The current flexibility of cognition is not consistent with strong localization and modularity.



Uttal: The New Phrenology 2001

Debates

- There are debates even on the localization of well known specific domains such as face processing (e.g., Gauthier et al., 1999; see also Price and Friston, 2005 for a strong argument against a specific area for word recognition) and numerical cognition (e.g., Shuman and Kanwisher, 2004).

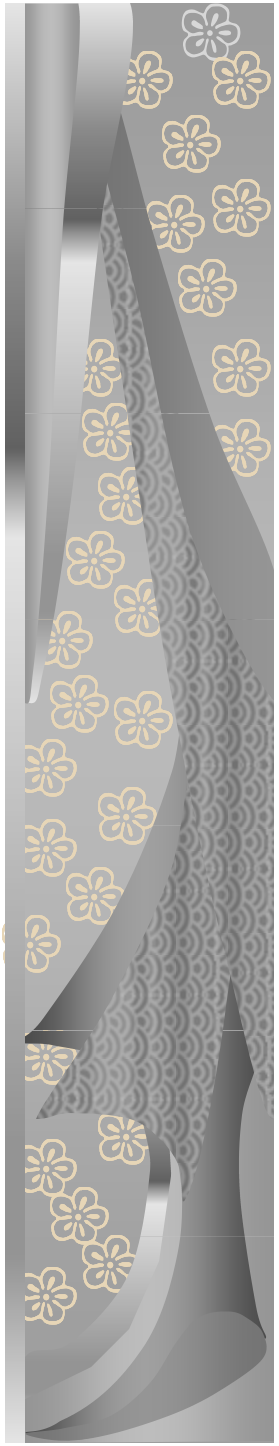
Uttal contd.

- Uttal reviews the history of localization then critiques that idea and finally he lists a number of technical and conceptual problems.
- History has shown that localization has failed excepts a few specific success.
- The complexity of methods, processes and equipments leads to misunderstanding and misinterpretation.

Technical problems

- Poor regional demarcation, distributed and dynamic processes, and complex interconnection:

“beyond the old distinction (input-associative-output module), other divisions have been arbitrary” Using “the idea that glucose consumption is associated with neural activity to the final conclusion that a particular area of the brain *IS* the locale of such an intangible entity as, say, executive decision making” Is not acceptable.

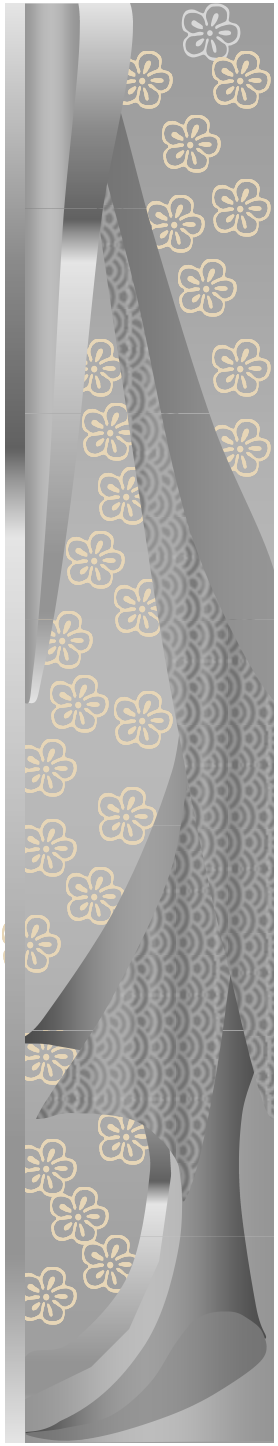


Technical contd.

- Some are more serious and some can be replied
- Methodological and Technical problems are not very serious and can be overcome.

e.g., BOLD is an indirect measure:

- Despite some controversies, the BOLD responses relatively an acceptable measure of the neural activities (e.g., Huettel et al., 2004; Logothetis et al., 2001, 2004).



Main problem

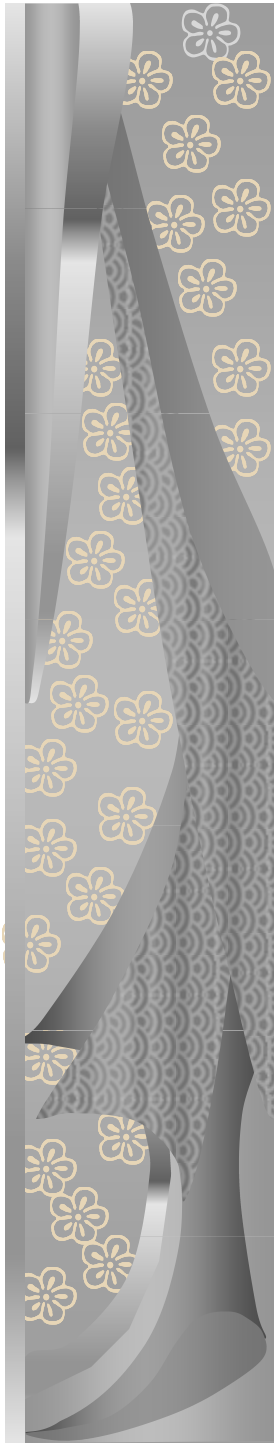
- There is no agreement on the definition of ognitive/mental/psychological components.
- Arbitrary experimental operations have become the definition of cognitive processes.
- **“Is it possible to localize such phantoms–such elusive ‘hypothetical constructs’ – in the brain?** ”

Conceptual issue

- Necessity is not sufficiency:

  the argument that a study places the cognitive process X in the Y brain region in most cases is much too strong.

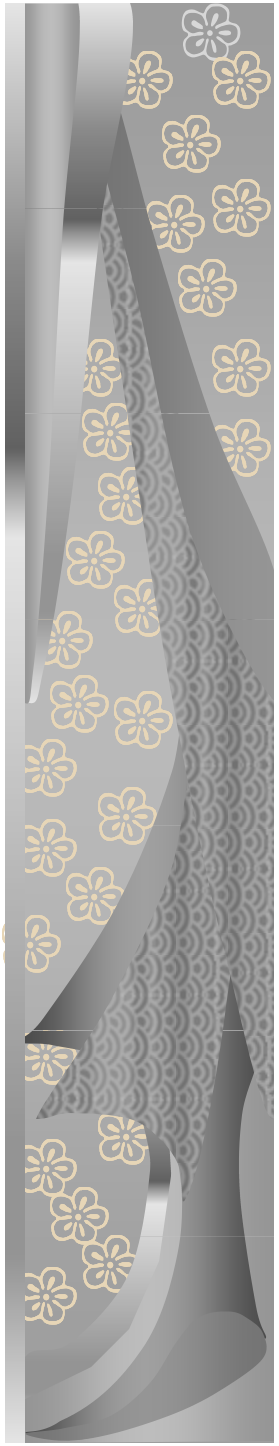
- “Replication is rare, vaguely defined cognitive modules have been attributed to virtually every area of the brain.”



Uttal's conclusion:

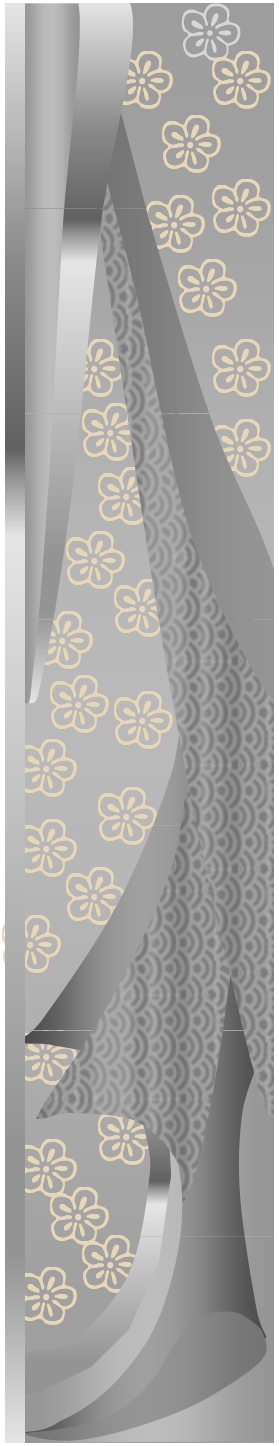
- We are not close to solve these problems.

  "It's just too easy to use localization assumption as a vehicle for misleading, but convenient, research studies."
- Suppose we are able to localize, so what?
- Knowing the huge investment, "Ignoring these and claim we must make progress is irresponsible."
- Back to a sort of behaviorist functionalism?



Posner 2003

- There is some overlap (multiple realizations?) but also consensus on results.
- No one accept Fodorian (encapsulated) module challenged by Uttal.
- e. g., word recognition area: Controversies are related to the depth of languages used, different instruction, and teaching methods. That area is also involved in other similar processes.
- Attention is not a unified process; automatic and controlled attention are related to different areas.

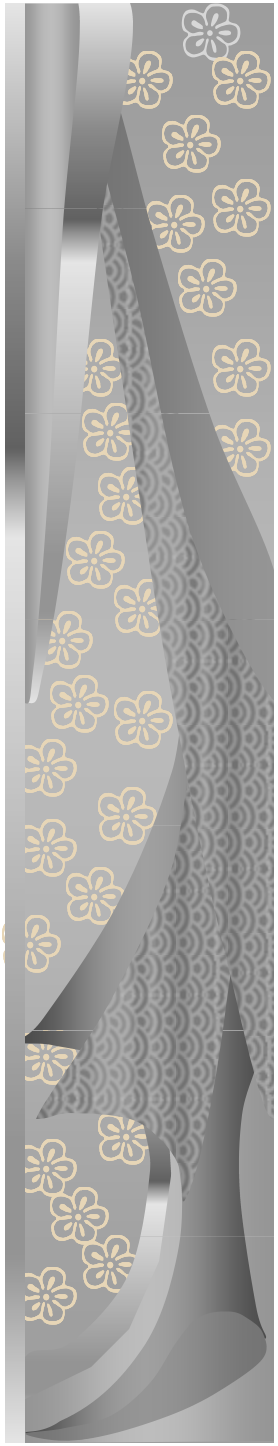


Donaldson 2004

- Using new methods in neuroimaging we are not only looking for “where” the process is in the brain but also “what” is that process.
- We also believe that current methods such as fMRI are not the ultimate or ideal tools.

Proper use

- The neuroimaging studies can also be used for evaluating debatable theories such as ‘central processing bottleneck’ (e.g., Jiang & Kanwisher, 2003) or for comparing two competing theories (e.g., Corlett et al., 2004).
- For example, Corlett et al. (2004) compared two theories, probabilistic (e.g., Macho and Burkhard, 2002) and predictive (e.g., Dickinson and Burke,1996) learning, and argued in favor of the latter instead of just looking for localization.
- More importantly, neuroimaging can be used along with computational models and cognitive theories to guide and support each other (e.g., Anderson et al., 2004; Corlett et al., 2004).



Interconnected networks

- Some statistical methods are available such as multivariate analysis (e.g., Harrison et al., 2005) and especially the Dynamic Causal Modeling (DCM) (Friston et al., 2003) that go beyond simple subtraction methods and static patterns of activations.
- Finally, whereas phrenology was based on the correlational methods, in neuroimaging many interventions and manipulations are possible (c.f., Henson, 2005).

Poldrack 2006

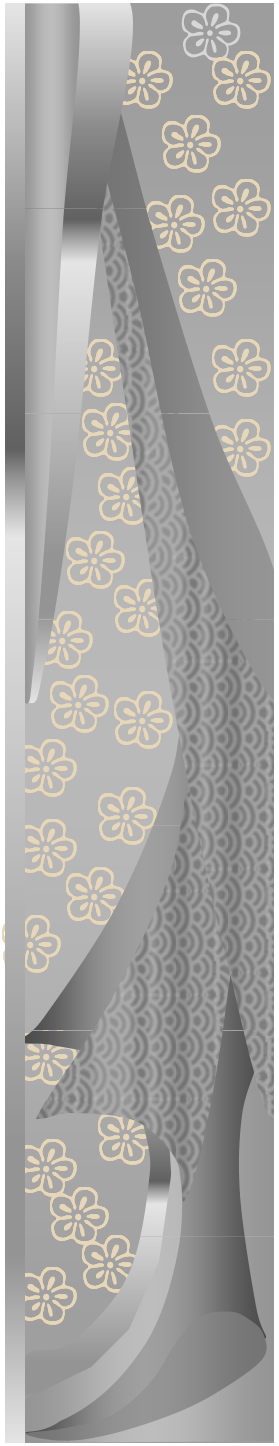
- Neuroimaging: to infer something about the role of particular brain regions in cognitive function.
- However, there is increasing use of neuroimaging data to make the opposite inference: to infer the engagement of particular cognitive functions based on activation in particular brain regions.
- This is a ‘reverse inference’, in that it reasons backwards from the presence of brain activation to the engagement of a particular cognitive function.

Bayes and inverse problem

- It could be deductively valid if it were exclusive, such that area Z was active if and only if cognitive process X is engaged.
- **$P(COG_X|ACT_Z)$**

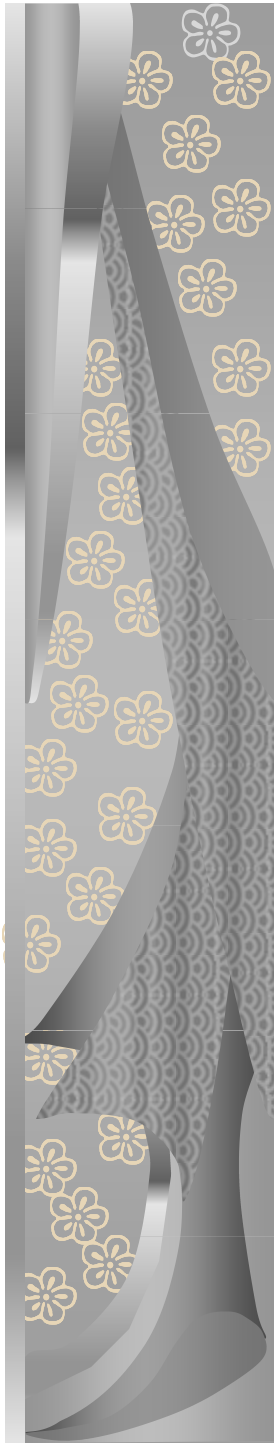
$$= \frac{P(ACT_Z|COG_X)P(COG_X)}{P(ACT_Z|COG_X)P(COG_X) + P(ACT_Z|\sim COG_X)P(\sim COG_X)}$$

- **$P(COG_X|TASK_Y)$**

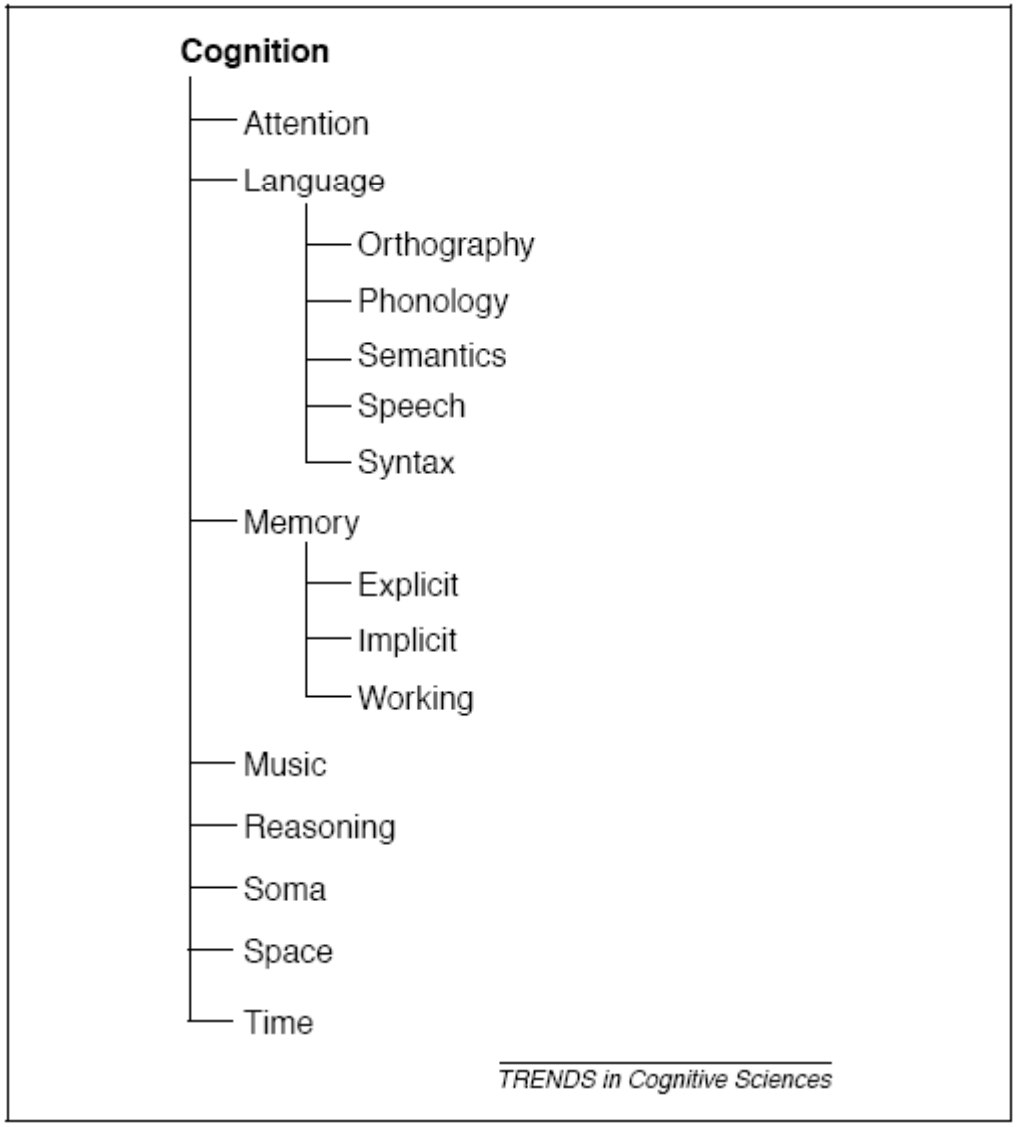


BRAINMAP

- Activation in “Broca’s area” implies engagement of language function
- The Bayes factor for the reverse inference discussed above is 2.3, meaning that the inference provides a positive but relatively weak increase in confidence over the prior.
- The cognitive ontologies in BrainMap and other databases such as Brede and fMRI Data Center are all **coarse**.



Cognition in BrainMap



Suggestions

- Enhance selectivity by looking at literature
- The analysis of “sets of regions” might provide greater selectivity than the analysis of single regions, to the degree that specific processes engage specific networks.
- The size of the region of interest will also affect selectivity, suggesting that reverse inference to smaller regions will provide more confidence.
- Choose experimental tasks that maximize the prior probability of a particular process being engaged.

Greene et al.

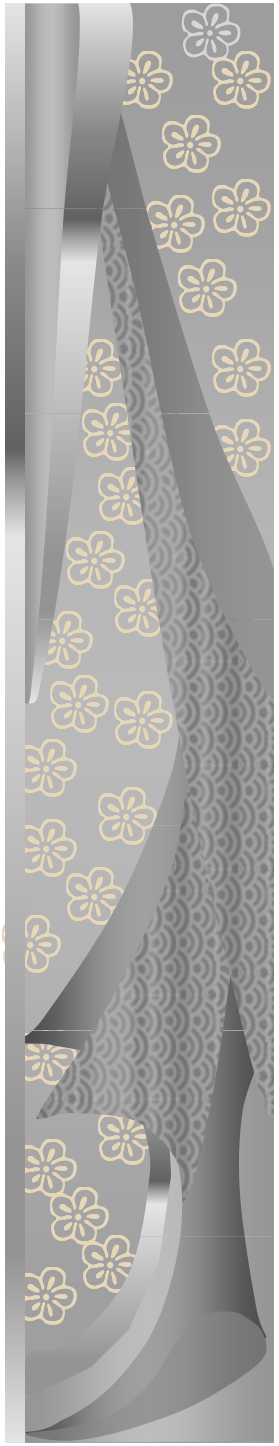
- Personal or impersonal moral dilemmas
- RTs for personal dilemmas were longer when the subjects responded ‘appropriate’ than when they responded ‘inappropriate’, impersonal dilemmas had opposite pattern.
- They argued that this behavioral effect reflected emotional conflict for the personal but not the impersonal dilemmas.

Poldrack's Conclusion

- Powerful reverse inference awaits the development of a detailed cognitive ontology.

Box 4. Questions for future research

- How do brain regions differ in their selectivity?
- Are networks more selective than individual regions?
- Can cognitive psychology support a detailed formal ontology of cognitive proceses?
- How are selectivity estimates from neuroimaging databases biased by selection biases on database entries?



Henson 2006

"forward inference:"

- The use of qualitatively different patterns of activity over the brain to distinguish between competing cognitive theories (model/hypotheses/explanation).

'pure insertion' assumption:

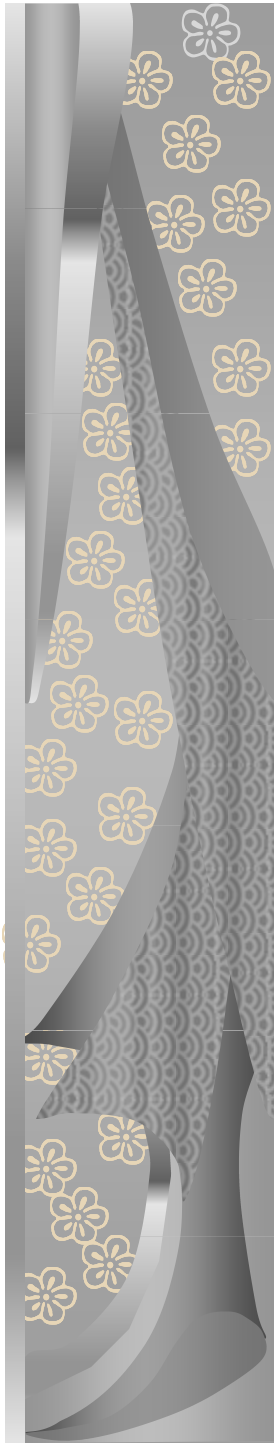
- Having experimental conditions that differ only in one component that is supported by a theory not by another.

Henson contd.

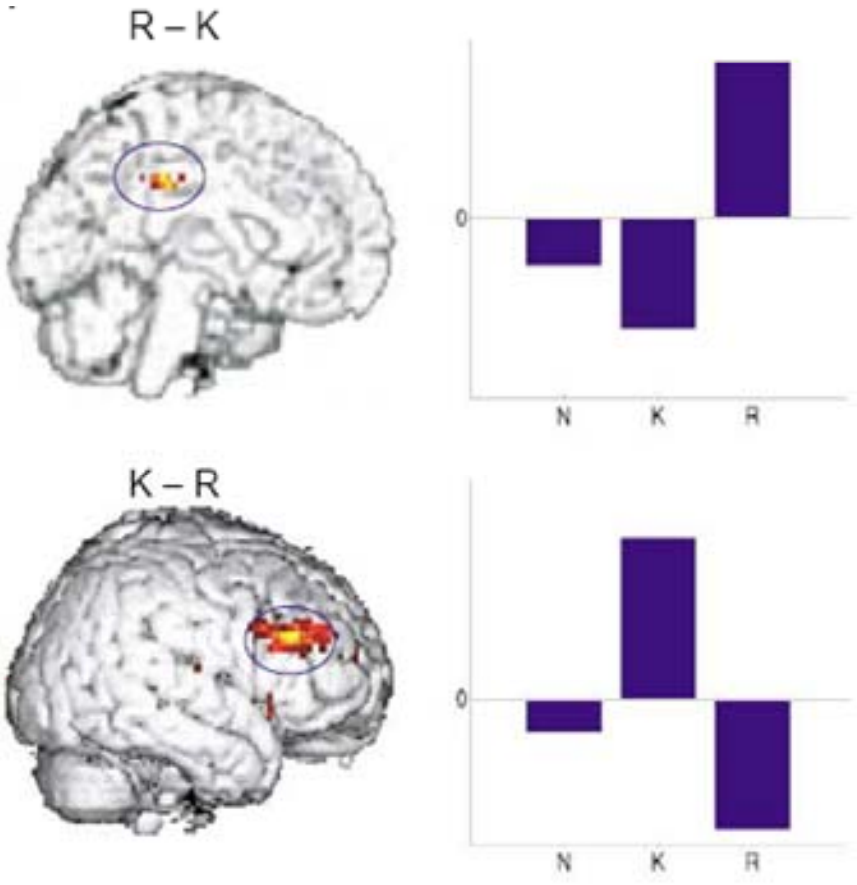
- “if one can design experimental conditions that differ in the presence of a cognitive process according to one theory, but not according to another, then the observation of distinct patterns of brain activity associated with those conditions constitutes evidence in favour of the first theory.”
- An Example:
- ‘single-process’ versus ‘dual-process’ theories of recognition memory
- Henson et al. used fMRI to compare brain activity for items that subjects said they ‘remembered’ with that for items that subjects said they just ‘knew’

The two theories

- According to single-process models, such ‘Remember’ and ‘Know’ judgments differ only in the strength of memory for an item.
- According to dual-process models however, the two judgments differ in the relative contributions of two distinct forms of memory (e.g. recollection and familiarity.
  - Henson et al. found that a region in posterior cingulate (among other regions) was more active for Remember than Know judgments, whereas a region in right lateral frontal cortex was more active for Know than Remember judgments.



Henson et al.



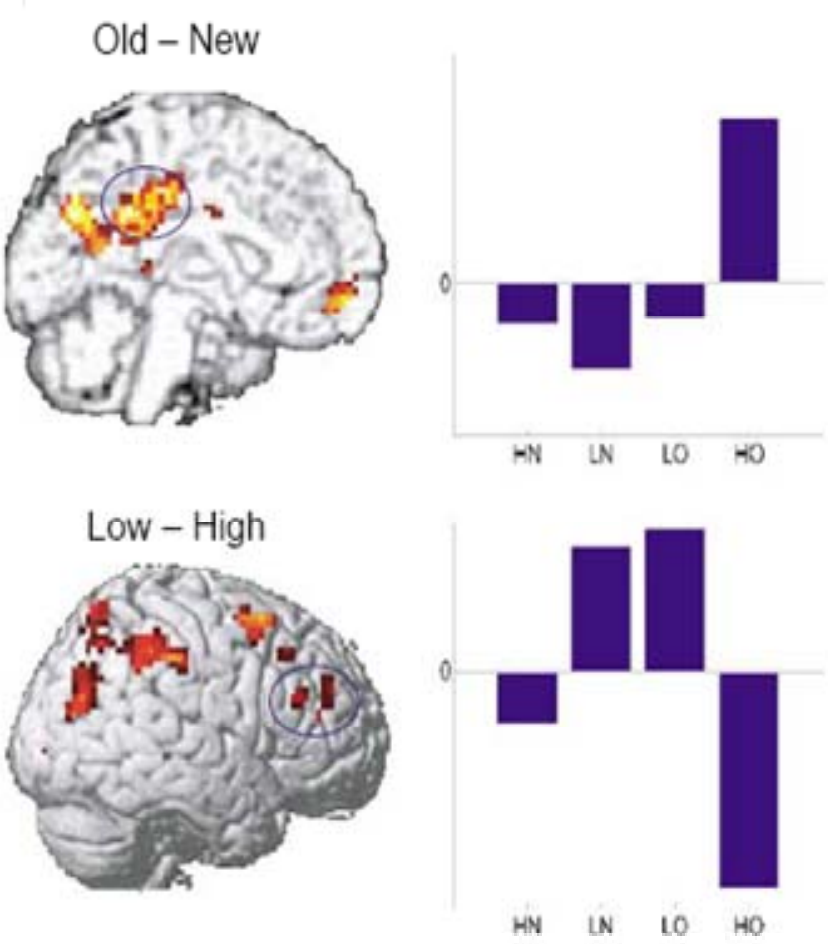
Dissociations

- Here,the neuroimaging data are simply being treated as an additional dependent variable with which to find functional dissociations (cf. reaction times or accuracy). Similar to ‘dissociation logic’ in cognitive neuropsychology e.g., lesion studies
- One feature of forward inference is that it does not require strong selectivity of brain regions

Henson 2006

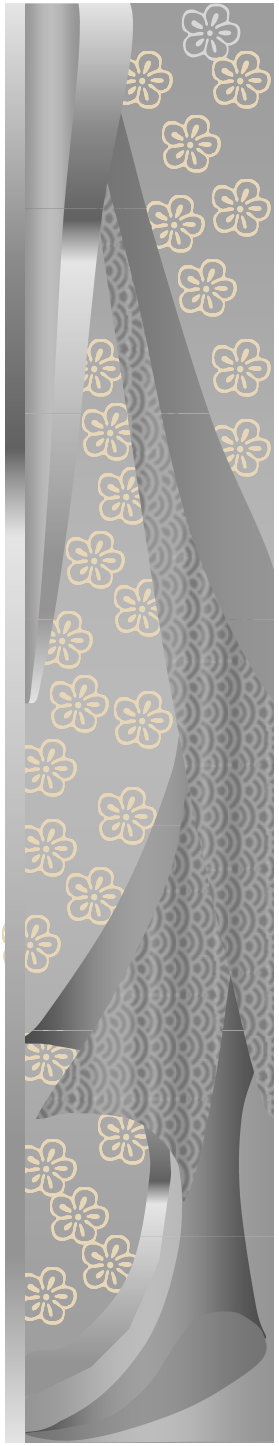
- But, it is not clear whether the right frontal activation for Know relative to Remember judgments had more to do with decision processes, rather than reflecting memory strength per se.
- For example, when an item seems familiar, but details of its previous occurrence are not remembered, subjects might engage in greater checking or ‘monitoring’ of retrieved information.

Henson et al.



New explanation

- **Right lateral frontal activity reflects confidence of the decision, rather than memory strength**
- **The posterior cingulate region, on the other hand, continued to show greatest activity for 'high confidence old' decisions.**
- **Now interpretable in terms of a new model in which decisions are based on a single-continuum of memory strength, and memory strengths close to a response criterion entail additional cognitive processes, such as 'monitoring', before a decision is made.**

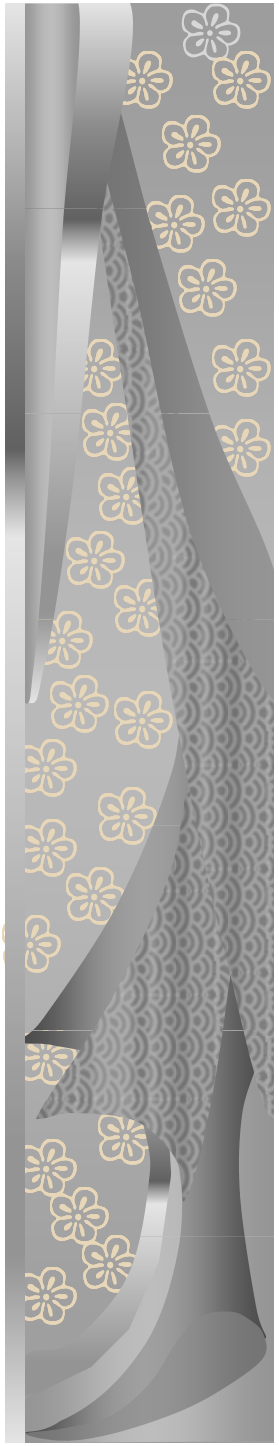


Dissociation logic critics

- Dissociations can only result in further fractionation of cognitive processes.
It is also closely tied to the ‘modularity’ assumption that is prevalent in cognitive science.
- So associations are also necessary, for example by the reverse inference (Poldrack)

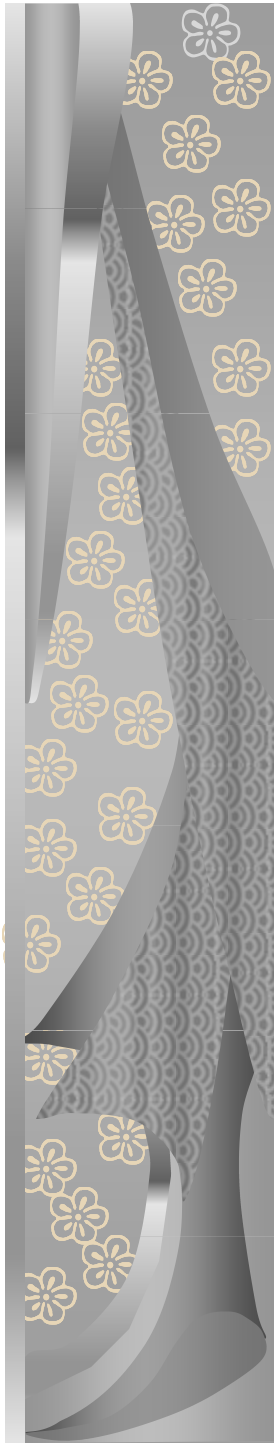
Box 3. Questions for further research

- Is it a reasonable assumption that the same cognitive process cannot activate different brain regions within different conditions of the same experiment?
- What exactly is meant by a cognitive process (consider, for example, the case of 'selective attention' in relation to the above question)?
- Are some cognitive processes invisible to current neuroimaging techniques (even putting aside issues related to spatial resolution), for example, by being realised by rapid changes in communication between brain regions, without changes in the mean metabolic activity within those regions?
- Are the criteria for a qualitative difference in brain activity (outlined in Box 2) necessary and sufficient?
- How are the criteria for a qualitative difference generalizable to multiple brain regions/voxels?
- Have we made any progress in cognitive theory to date using functional neuroimaging data?



Final Conclusion

- Strong version of localization has failed.
- Good theories and definitions are needed for using neuroimaging.
- Combining neuroimaging with other techniques is needed.
- Knowing “where a process occurs” doesn’t tell us “what that process is”.
- It seems that cognitive functions are multiply realized but with different activational, distributional, and temporal patterns



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