Music and Neuroscience

Issues and Music and Sciences

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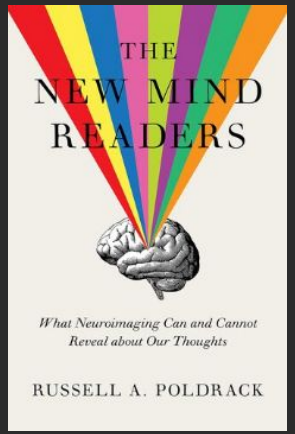
Outline

I. Neuroscience gets huge amount of attention in scientific world
II. We dive into how fMRI works to give you an idea of how some neuroscience is conducted with musical examples
III. The distance between a brain lighting up and a theory is large, many things can and do go wrong
IV. Example of Reading with Lesion Paper

Introduction to Neuroscience

Introduction to Neuroscience



Neuroscience: Brief History

- Neuro ~ brain
- Science ~ systematic inquiry/study of subject
- Neuroscience = study of the brain and associated behavior
- Has existed long before latest technical innovations of 1990s (fMRI)
- Goal is to link changes in physical organism with changes in behavior
- Classic studies illustrate this connection

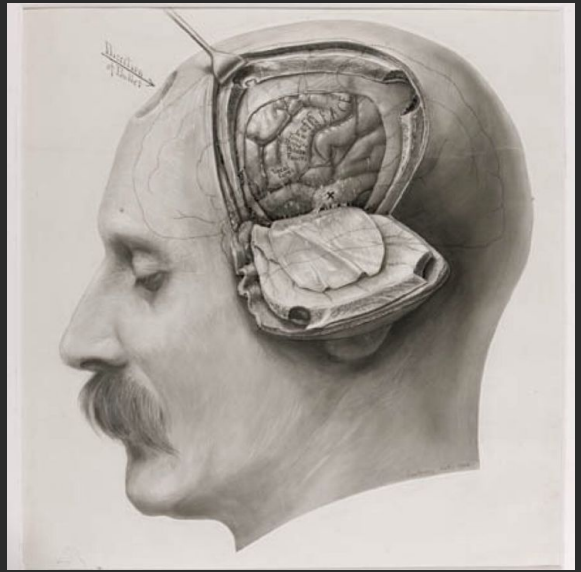
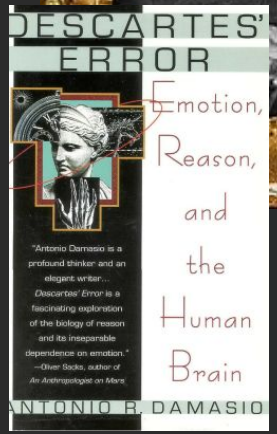


Image: https://www.techexplorist.com/brain-science-finding-secrets-century-old-brains/7643/

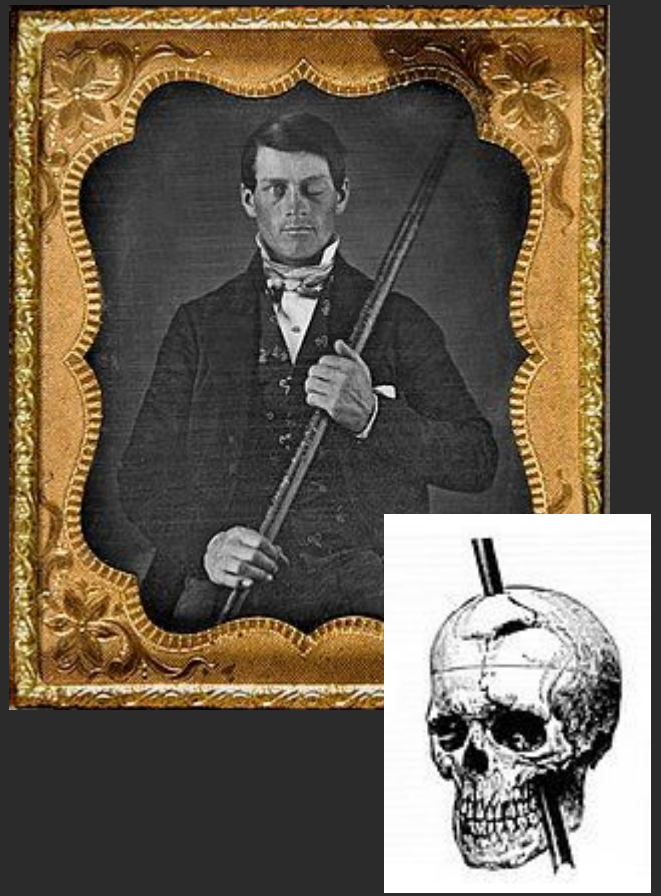
Phineas Gage

- Railway worker in 19th century
- Suffered traumatic brain injury to the head
- Recovered from head trauma
- Went to to display change in behavior documented in various sources
- Theorized to have damaged medial pre-frontal cortext (mPFC), area of brain responsible for impulse control
- Used as common case study to demonstrate early example of link between brain structure and behavior



Phineas Gage Caveats

- Foreshadowing later, reasons for change in personality might be manifestations of traumatic injury
- Many discussions exaggerate claims of negative behavior



Michele Bertino -- 1877

- Brick dropped on head in 1877
- Survived, hole in skull exposing brain
- Angelo Moss-- University of Turin
  - Method to measure blood pressure on brain through hole in skull
- When thinking, Bertino's wrist pulse did not change whereas it did in his brain
- Brain responds to mental activity 1880s
- Published in *On the Circulation of the Blood in the Human Brain*

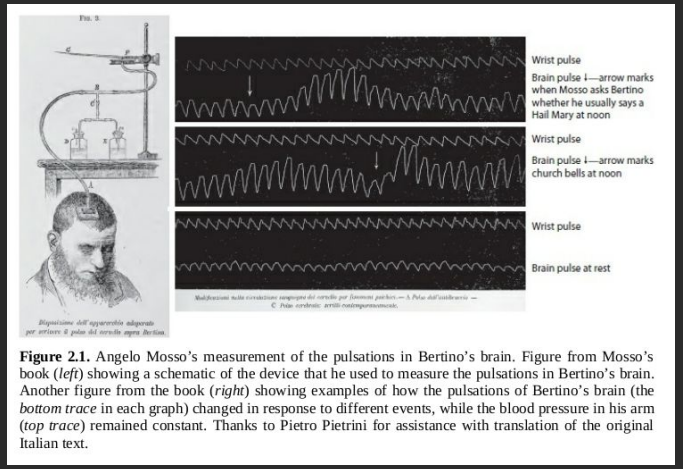


Figure 2.1. Angelo Mosso's measurement of the pulsations in Bertino's brain. Figure from Mosso's book (*left*) showing a schematic of the device that he used to measure the pulsations in Bertino's brain. Another figure from the book (*right*) showing examples of how the pulsations of Bertino's brain (the *bottom trace* in each graph) changed in response to different events, while the blood pressure in his arm (*top trace*) remained constant. Thanks to Pietro Pietrini for assistance with translation of the original Italian text.

Take Aways

- Link change in brain state with change in behavior
- Increase in activity in brain is associated with changes in cognition
- Rationale uses subtraction method
  - F.C. Donders in 19th Century
  - Establish baseline with one condition
  - Add others to reason out length of process
- Brain has both electrical and chemical ways of communicating
- Logic is to present stimuli to individuals, observe change in brain
  - EEG
  - fMRI
  - TMS

Subtraction Method

- Ask individual to process meaning of word
- Prompt of name vs vegetable

Carrot

Marquis

Soup

Subtraction

- Carrot ~ 800ms
- Marquis ~ 800ms
- Soup ~ 800ms
- Meaning of word takes 800ms?
  - See word
  - Think about word
  - Find button
  - Choose button
  - Press button
- Word vs no Word

piglet

flxvbd

Subtraction

- Carrot ~ 800ms
- Marquis ~ 800ms
- Soup ~ 800ms
- Meaning of word takes 800ms?
  - See word
  - Think about word
  - Find button
  - Choose button
  - Press button
- Word vs no Word
- Piglet ~ 200ms
- Flxbvd ~! 200ms
- Subtract to find word comprehension

Subtraction in Neuroscience

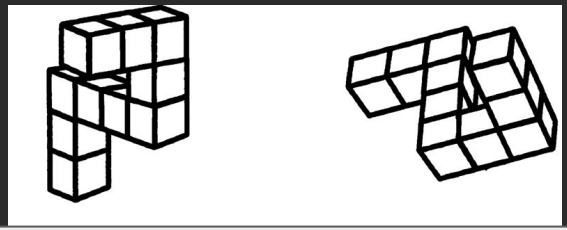
- How could you use this logic in a neuroscientific setting?

Subtraction in Neuroscience

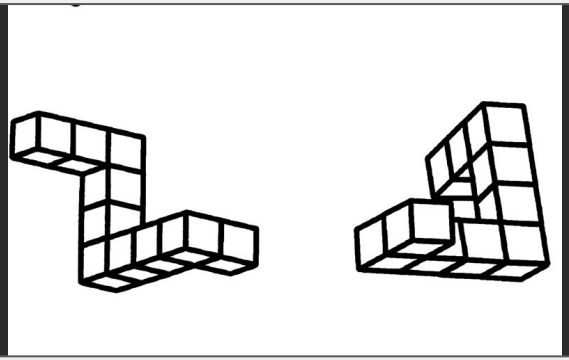
- How could you use this logic in a neuroscientific setting?
  - Fixation Point
  - Activity
  - Average across individuals in both conditions

Mental rotation

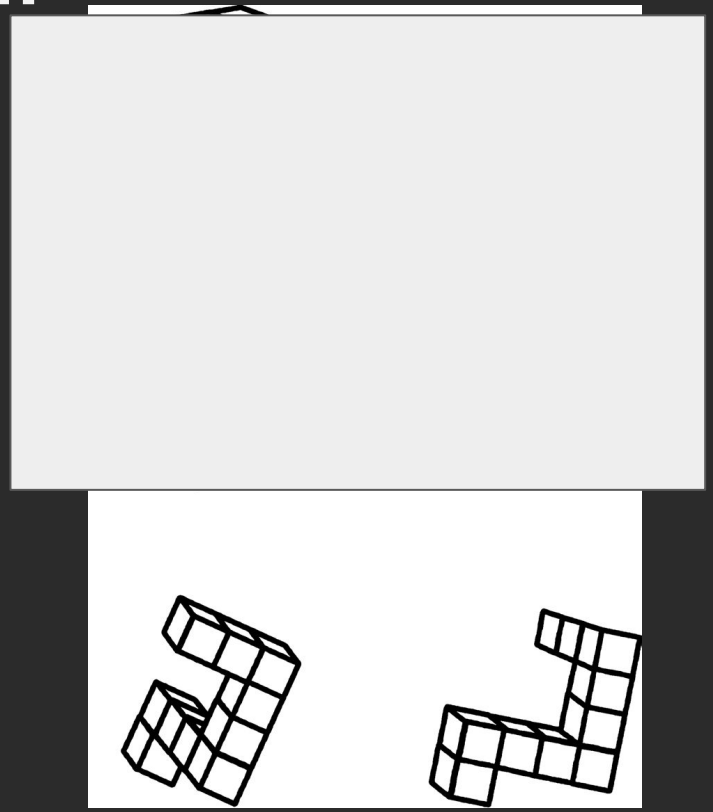
Mental rotation



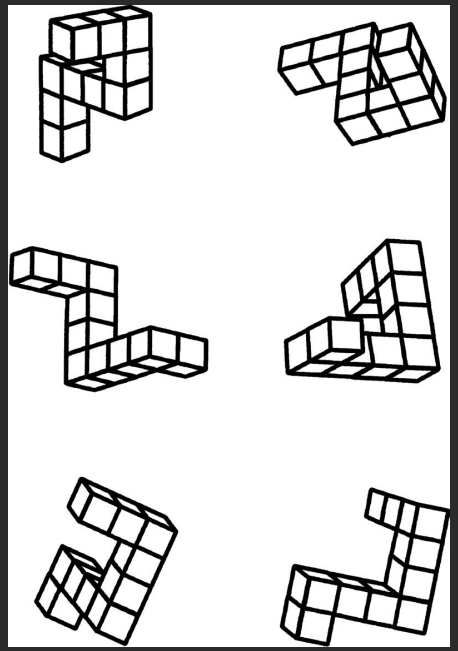
Mental rotation



Mental rotation



Mental Rotation



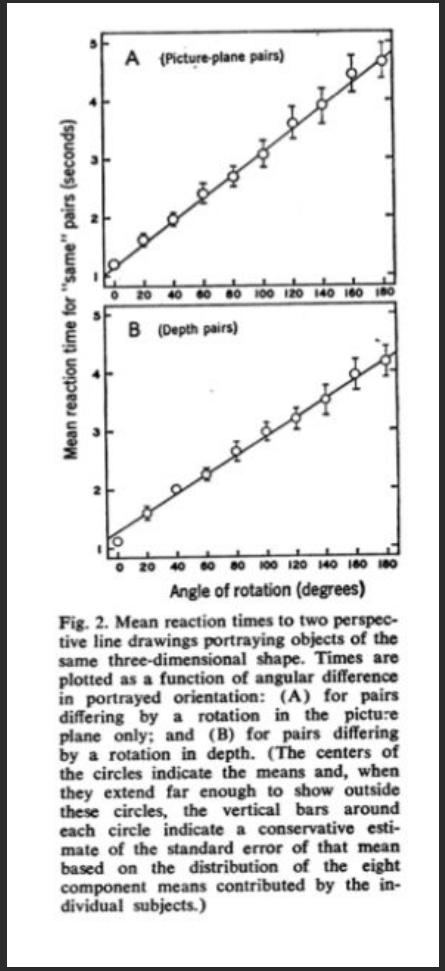
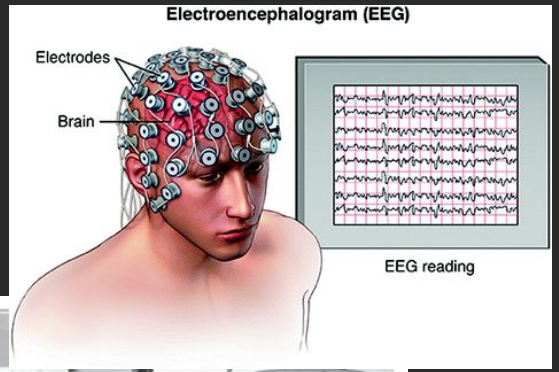
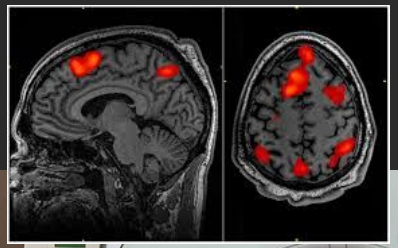


Fig. 2. Mean reaction times to two perspective line drawings portraying objects of the same three-dimensional shape. Times are plotted as a function of angular difference in portrayed orientation: (A) for pairs differing by a rotation in the picture plane only; and (B) for pairs differing by a rotation in depth. (The centers of the circles indicate the means and, when they extend far enough to show outside these circles, the vertical bars around each circle indicate a conservative estimate of the standard error of that mean based on the distribution of the eight component means contributed by the individual subjects.)

Shephard and Metzler 1971

The Tools of Neuroscience





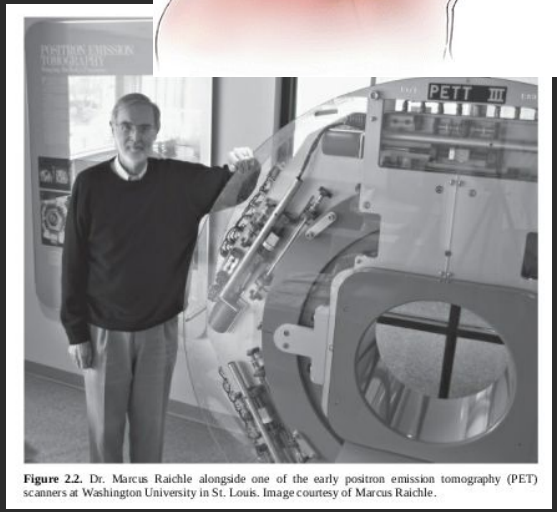


Figure 2.2. Dr. Marcus Raichle alongside one of the early positron emission tomography (PET) scanners at Washington University in St. Louis. Image courtesy of Marcus Raichle.

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fMRI

- Functional Magnetic Resonance Imaging
- Detect sensitivity to blood flow
- BOLD -- blood oxygenation level dependent
- Increase in blood activity → Increase in cognition in that area
- High spatial resolution
- Low temporal resolution (delay of ~4 seconds)

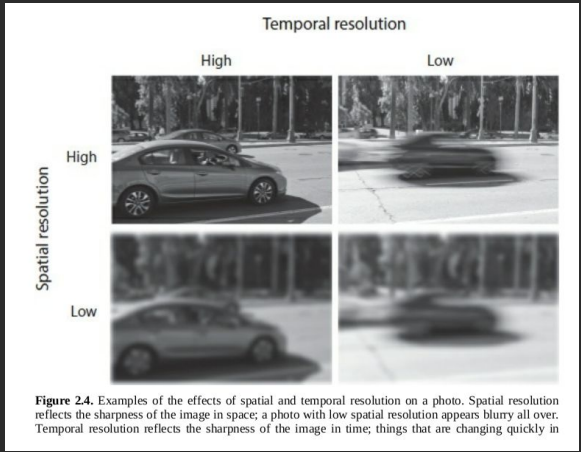

Figure 2.4. Examples of the effects of spatial and temporal resolution on a photo. Spatial resolution reflects the sharpness of the image in space; a photo with low spatial resolution appears blurry all over. Temporal resolution reflects the sharpness of the image in time; things that are changing quickly in

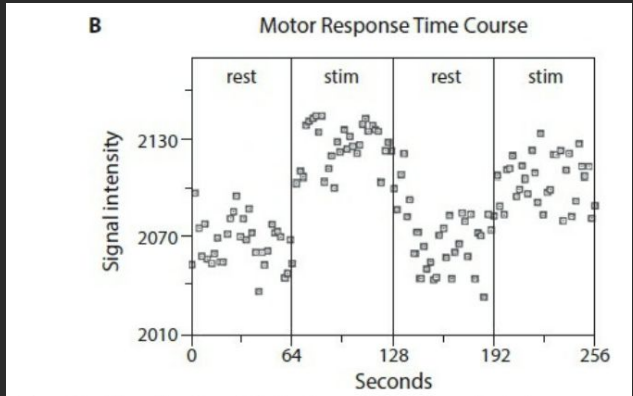

Figure 2.5. A figure from Kwong's landmark paper, showing that activity in the motor cortex

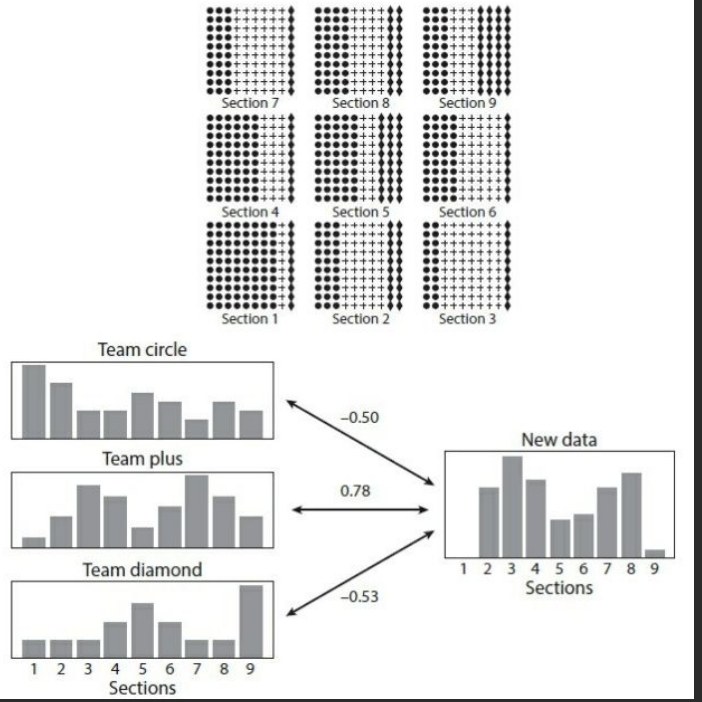

Figure 3.1. An example of how fMRI decoding works, using the analogy of the audience reaction to three different political candidates. The *top panel* depicts nine sections of the audience (which are analogous to voxels in fMRI); each section is made up of many individuals, each of whom claps for only one candidate (denoted by three different shapes: circle, plus, and diamond). These individuals represent the neurons within a voxel in fMRI. The *bottom left panel* shows a graph of the relative amount of clapping for each of the candidates across the nine sections; you can see that each candidate has a very different pattern of clapping across the sections. Now pretend that we have a new measurement of clapping (*bottom right*) and we want to decode which candidate is speaking. We can compute the correlations between the new pattern and each of the known patterns (which are the numbers presented next to the arrows); in this case, the new pattern is most highly correlated with the pattern that we observed when candidate plus was speaking, and thus we would predict that candidate plus was speaking when these data were collected.

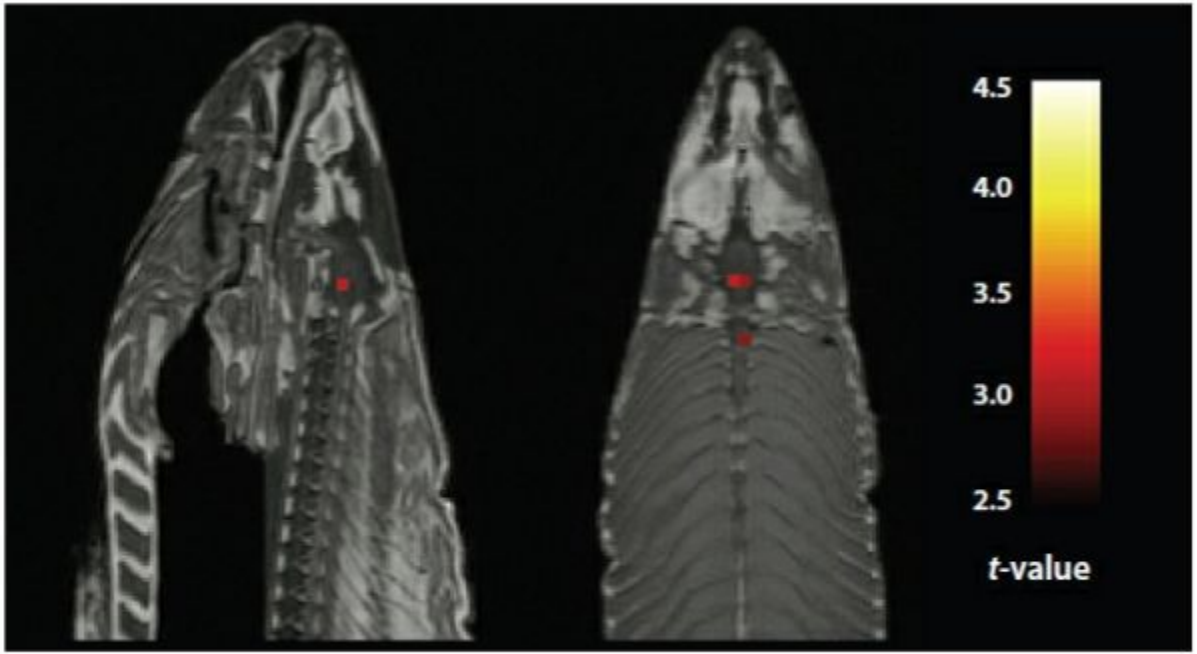

Plate 5. The image of brain activation in a dead salmon from Craig Bennett's 2009 poster. The tiny red spot was the location of significant activation found when the proper correction for multiple comparisons was not applied. Image courtesy of Craig Bennett.

Check for Understanding

Subtractive logic

How does this work with fMRI?

Reverse Inference

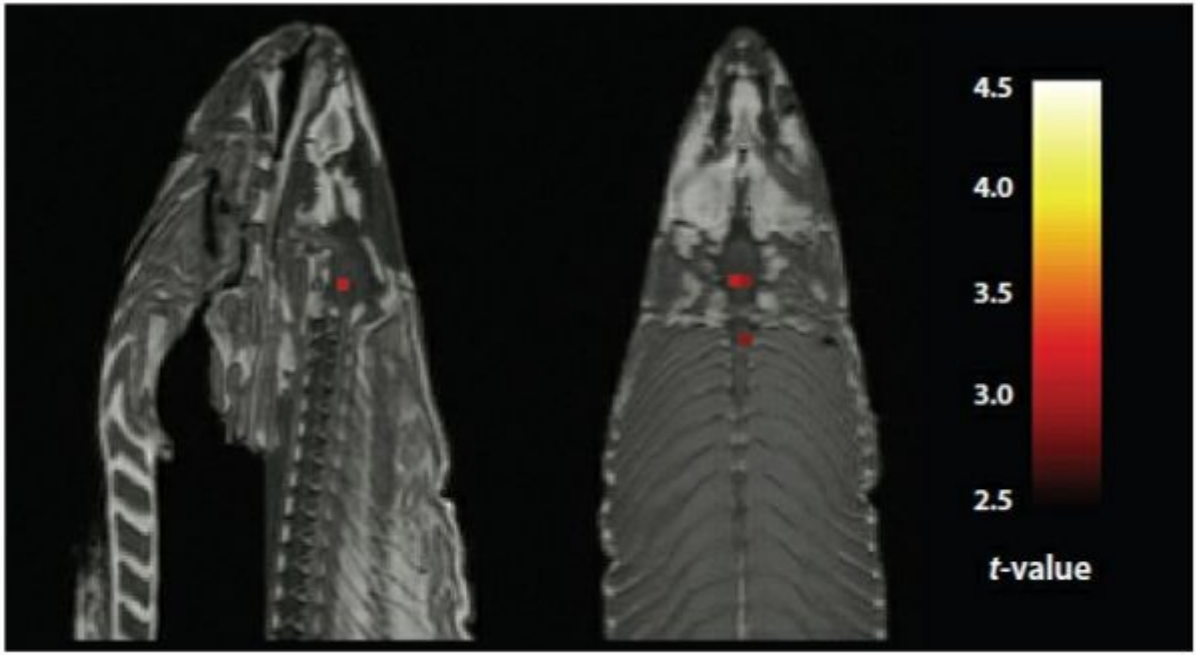

Plate 5. The image of brain activation in a dead salmon from Craig Bennett's 2009 poster. The tiny red spot was the location of significant activation found when the proper correction for multiple comparisons was not applied. Image courtesy of Craig Bennett.

Problem of Reverse Inference

As I read this piece, my blood began to boil. My research has focused on what kinds of things we can and cannot learn from neuroimaging data, and one of the clearest conclusions to come from this work is that activity in a particular region in the brain *cannot* tell us on its own whether a person is experiencing fear, reward, or any other psychological state. In fact, when people claim that activation in a particular brain area signals something like fear or reward, they are committing a basic logical fallacy, which is now referred to commonly as *reverse inference*. My ultimate fear was that the

Problem of Reverse Inference

Emotions about Hillary Clinton are mixed. Voters who rated Mrs. Clinton unfavorably on their questionnaire appeared not entirely comfortable with their assessment. When viewing images of her, these voters exhibited significant activity in the anterior cingulate cortex, an emotional center of the brain that is aroused when a person feels compelled to act in two different ways but must choose one. It looked as if they were battling unacknowledged impulses to like Mrs. Clinton. Subjects who rated her more favorably, in contrast, showed very little activity in this brain area when they viewed pictures of her.

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Mr. Obama was rated relatively high on the pre-scan questionnaire, yet both men and women exhibited less brain activity while viewing the pre-video set of still pictures of Mr. Obama than they did while looking at any of the other candidates. Among the male subjects, the video of Mr. Obama provoked increased activity in some regions of the brain associated with positive feeling, but in women it elicited little change.

Problem of Reverse Inference

Throughout this book, I will return to the fact that there is no simple one-to-one mapping between psychological states and activity in specific brain areas. As we will see, it is possible sometimes to decode the contents of a person's mind using fMRI, but it requires sophisticated statistical analyses along with careful interpretation.

What's the problem with reverse inference? Take the example of a fever. If we see that our child has a fever, we can't really tell what particular disease he or she has, because there are so many different diseases that cause a fever (flu, pneumonia, and bacterial infections, just to name a few). On the other hand, if we see a round red rash with raised bumps, we can be fairly sure that it is caused by ringworm, because there are few other diseases that cause such a specific symptom. When we are interpreting brain activation, we need to ask the analogous question: How many different psychological processes could have caused the activation? If we knew, for example, that mental conflict was the only thing that causes the anterior cingulate cortex to be active, then we would be fairly safe in concluding from anterior cingulate activity that the person is experiencing conflict when viewing images of Hillary Clinton. On the other hand, if many different things can cause the region to be active, then we can't safely draw that conclusion. Figure 1.5

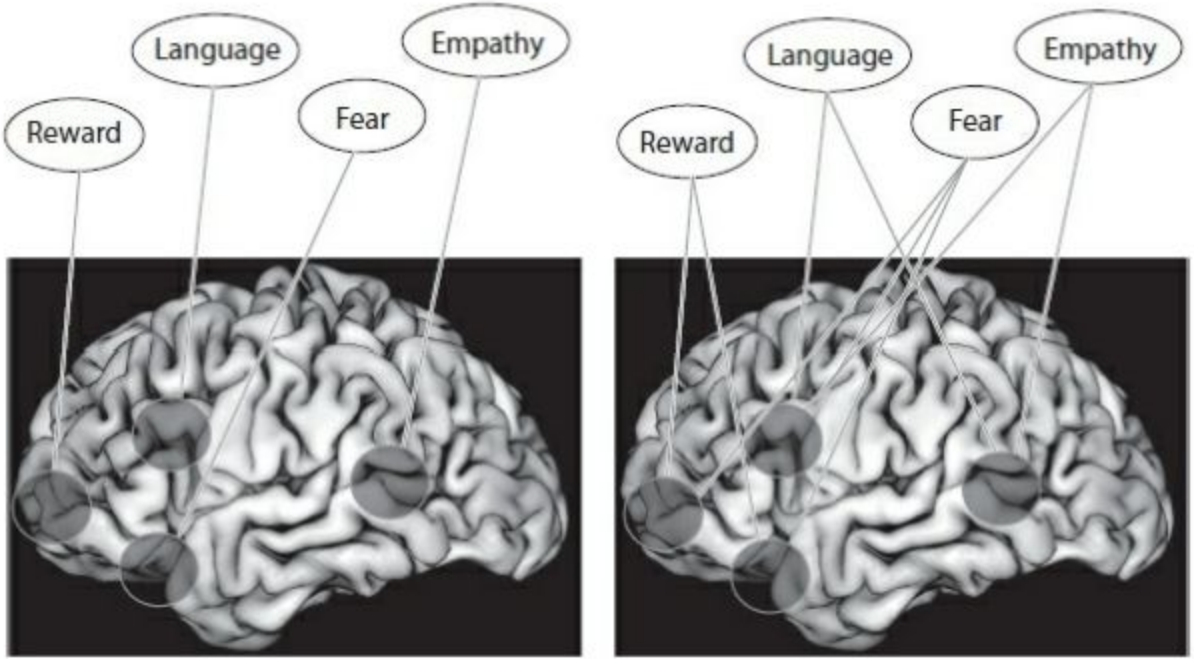

Figure 1.5. Can you infer cognitive function from areas of brain activation? If there was a one-to-one mapping between brain areas and cognitive functions, as shown in the *left panel*, then reverse inference based on activation in those areas would be possible—activation in the amygdala would imply fear, and activation in the ventromedial prefrontal cortex would imply reward. However, the brain is actually organized more like the *right panel*—any mental function involves a combination of many different brain regions, that are combined in different ways to support different mental functions.

Reverse Inference ~ Only Association

- With association problem, can only get correlation
- Correlation ~ causation
- How to manipulate brain?
  - Make cut ~ possible with surgery
  - Record cells directly, unethical with humans bc kills cells
  - Done with animal research
  - Temp disable with TMS
  - Find patterns where nature has take course

Lesions

- Similar to first two, sometimes life happens
- Have stroke, loose function
- Idea is that if part of brain is theorized to do some task, stroke kills it, have evidence in favor of that working
- Works on general level, but brain repairs itself (doidge)
- Look at this with musical example

Paper

Summary

- Summary
- Start with figures
- Questions
- Show DAG of sex and rock and roll next
- What is DAD of belfi ?
- Reverse inference?

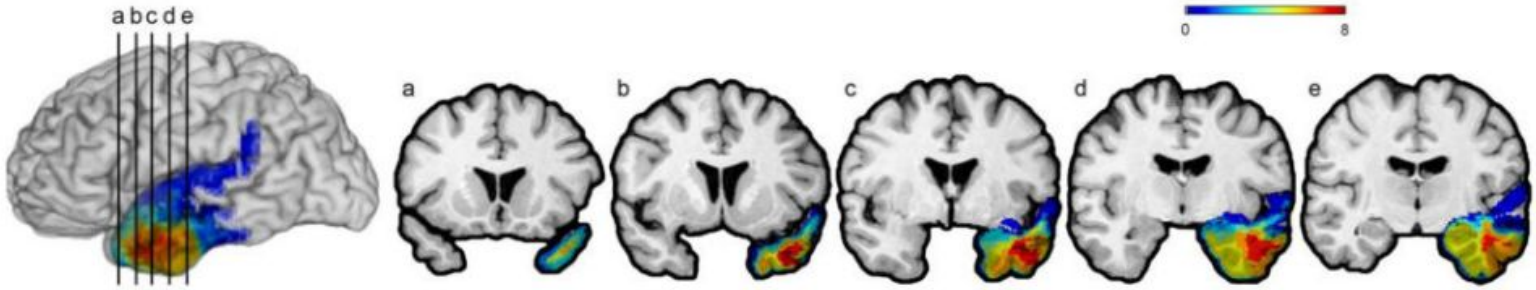

Figure 1.
Lesion overlap map of patients with left temporal polar lesions. The left panel depicts a lateral view of the left hemisphere. The five panels to the right depict coronal cuts (a-e) through the left anterior temporal region. Images are shown in radiological convention, with the left hemisphere on the right. The color bar codes maximal lesion overlap, with “hotter” colors (red, yellow) representing higher numbers of lesion overlap.

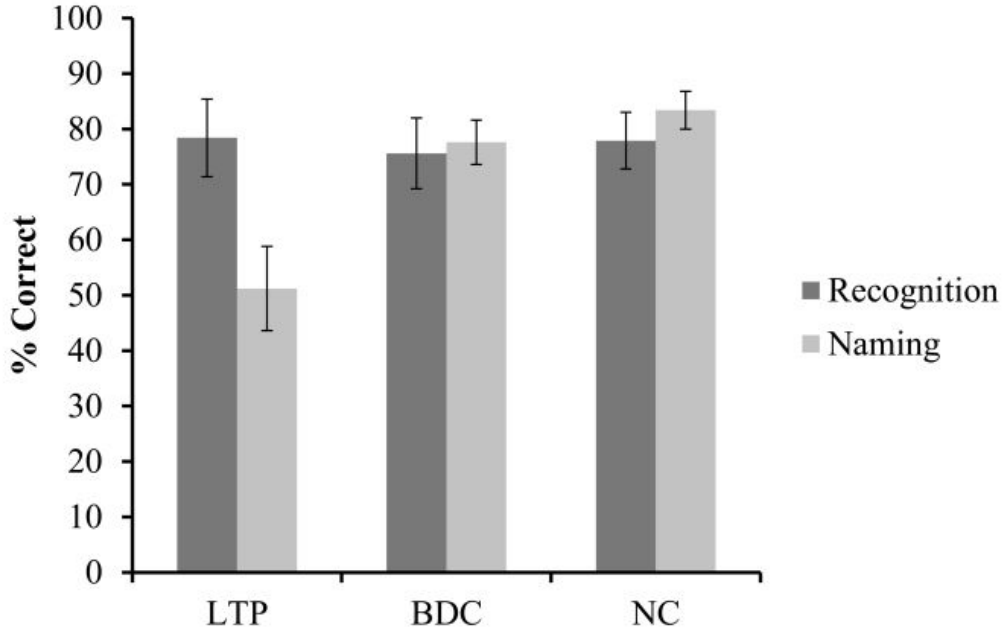

Figure 2.
Performance on recognition and naming for each group. Error bars represent standard error of the mean. The naming score for the LTP group was significantly lower than the naming scores for the BDC and NC groups, per one-way $F(7,27) = 10.2$, $p < .001$, $\eta^2 = .43$. There was no significant group difference for the recognition score $F(7,27) = .055$, $p = .947$, $\eta^2 = .003$.

Terms to Review

- Additive
- Reverse Inference
- Type I Error