Brain Imaging in the Courtroom:
Admissibility and Future Directions

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COLLEGE OF LAW
THE UNIVERSITY OF UTAH

Training Leaders to Confront
the Issues of Our Time

Outline

1. How Neuroimaging is Being Used in Court

2. Introduction to three types: EEG; QEEG; fMRI

3. 702 and 403 Analysis of fMRI

4. Possibly (?): Future Directions

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3. Admissibility of QEEG and fMRI

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How Brain Imaging is Being Used in Court

1. To demonstrate a structural or functional disability for **government entitlements** SSA, SSI, ADA, Workman's Comp benefits

1. To demonstrate injury in **civil personal injury cases** (car accidents, etc)
   - Structural injury
   - Functional deficits for medical and pain and suffering

How Brain Imaging is Being Used in Court

3. **Criminal Trials**
   - Deciding whether defendants are competent
   - Deciding whether to punish (the guilt phase)
   - Deciding how much to punish (the sentencing phase)
     - Brian Dugan case (serial killer in IL)
     - To show developmental population differences (adolescents are less capable of impulse control, should not be executed or subjected to life without parole) i.e., *Roper, Jackson, Graham*
   - After punishment, ineffective assistance of counsel claims

4. **Lie Detection** in civil, criminal and probate trials
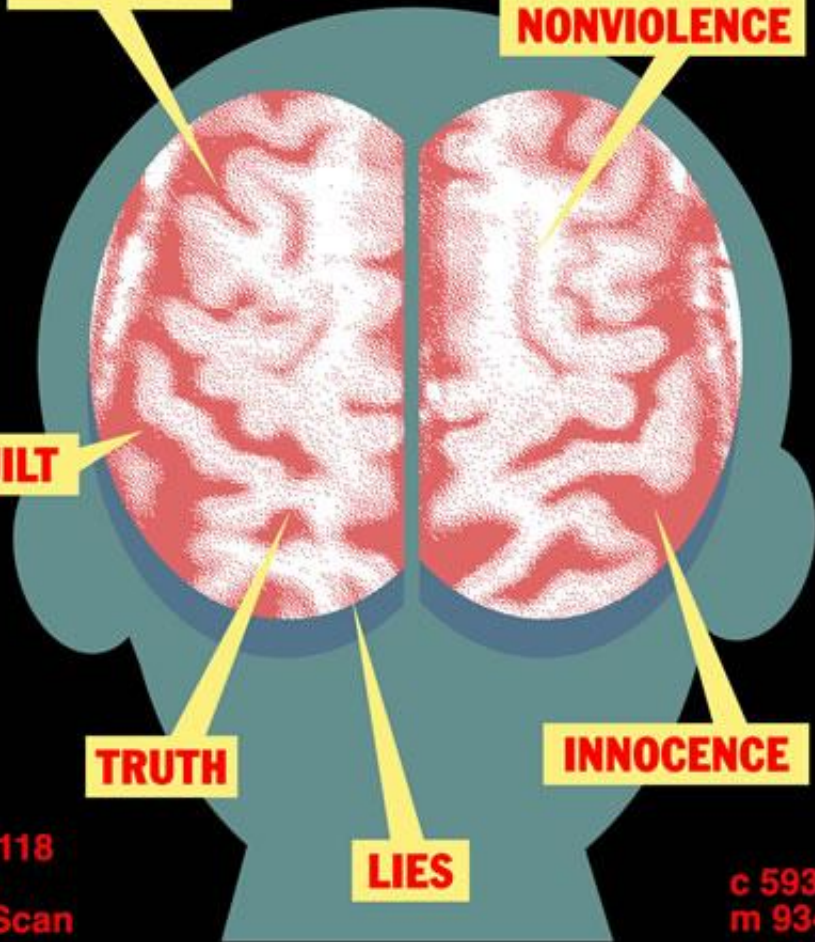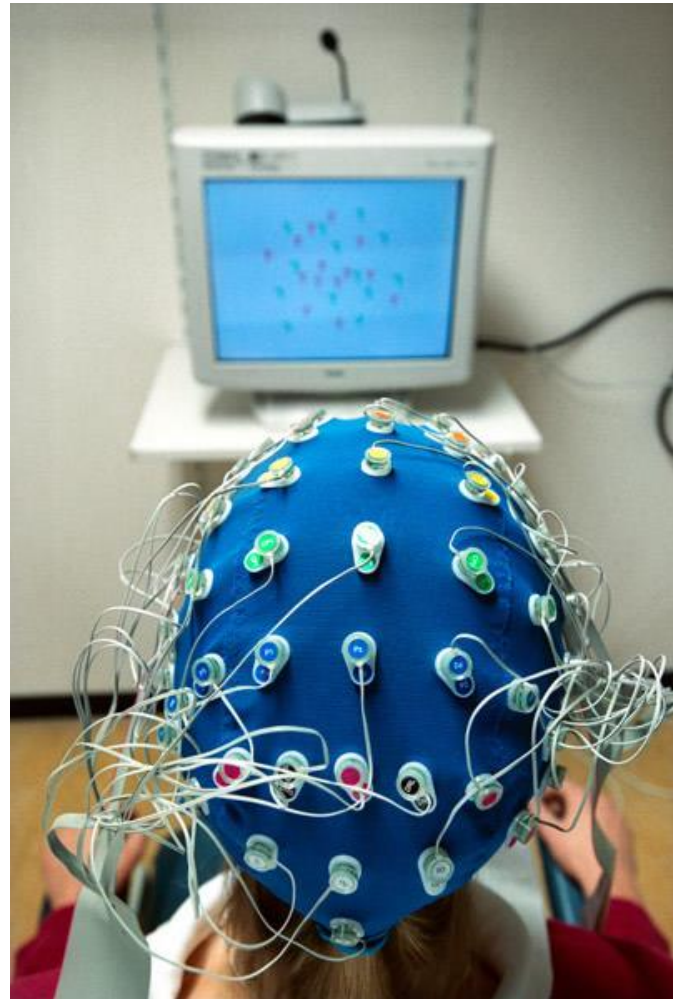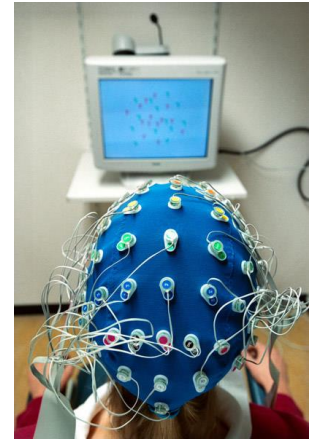
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EEG

EEG

- Discovery in 1800s that brain produces electricity
- Cortical activity can be measured on the surface of the scalp with standard sensors, some subcortical
- EEG has remained a crucial clinical and research tool
- Does not require exposure to external radiation (fMRI) or radioactive tracers (like PET/SPECT)

EEG

- Requires subject compliance
- Susceptible to countermeasures
- Less expensive than fMRI
- More mobile
- Great temporal specificity
- Poor spatial and depth resolution
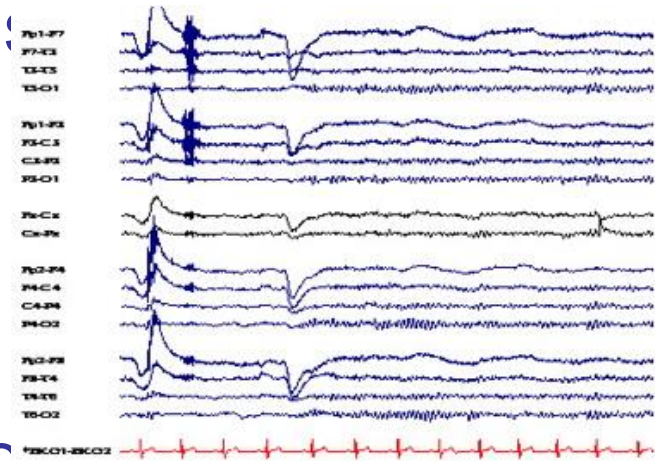
EEG – Clinical Use

- Diagnose epilepsy, coma, brain death
- With digital EEG, all signals are typically digitized and stored in a particular reference base
- The EEG can be viewed by the technician in any display format that is desired (comparing one recording channel with average of those around it; comparing individual to reference class of "normals")

QEEG (Quantitative EEG)

- A computational analysis of EEG output, using around 20 channels of EEG recordings;

- Compare activity to database of "neurotypicals"

- Show relative differences in wave/patterns/strength
  - For example, some research shows increased beta waves in left tempo-parietal and right occipital lobes in psychopaths (small studies and can't diagnose just one person, but can

QEEG: generally NOT accepted for these purposes

- To demonstrate TBI for personal injury claims and insurance coverage
  - Greene v. State Farm; 2008 WL 6667445
  - Smith v. Ryan; 2012 WL 6019055
- For criminal mitigation at sentencing
  - Mendoza v. State, 87 So. 3d 644 (Fla. 2011)
- For post-conviction habeas and *Atkins* hearings
  - United States v. Williams, CR 06-00079 DAE-KSC, 2009 WL 424583 (D. Haw. Feb. 20, 2009)
  - Smith v. Ryan, CV-87-234-TUC-CKJ, 2012 WL 6019055 (D. Ariz. Dec. 3, 2012)

QEEG: generally NOT accepted for explaini[ng] Individual Behavior or Mental Function

"[T]he Academy of Neurology and the American Clinical Neurophysiology Society *do not consider QEEG brain mapping to be a useful technique for assessing neurobehavioral or psychological issues* and recommend against its use in the courtroom setting. [Describing] interpretation and database problems, [the expert noted] that QEEG testing flags as statistically abnormal a lot of things in normal individuals that are not attributable to injury or disease. In his opinion, neither QEEG nor MRI and CT scans would be reliable tests for determining the presence of mental retardation [for an Atkins hearing]."

Smith v. Ryan, 2012 WL 6019055 (D. Ariz. Dec. 3, 2012)

QEEG: Admitted!

- Grady Nelson, stabbed his wife 61 times, raped her and her daughter
- Judge agreed to allow QEEG results at his sentencing hearing. The jurors were split 6-6 in sentencing; resulting in automatic life sentence
- Some jurors said QEEG did influence their move from the death penalty to a life sentence

QEEG

- Reference class can be manipulated (who defendant is being compared to)
- Proprietary algorithms used for converting electrical signals to pictures need to be scrutinized
- Error rates not standardized or known
- Similar problems as with fMRI
  - (data change if subject moves, blinks or hears a noise, or variations in the placement or pressure of the sensors on the scalp)

fMRI: the "f" stands for *function*

fMRI

- Requires voluntary compliance of subject
- Contraindicated: metal plates / powerful magnets
- Scanning time is expensive (~$450/hour?)
- Post-scanning analysis is expensive (~$250/study)
- Great spatial resolution, not great temporal resolution

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Federal Admissibility Standards

- FRE 403 – probative and not overly prejudicial (or a waste of time, misleading, or cumulative)

- FRE 702 – *Daubert*
  - Valid and reliable data?
    - Peer-reviewed
    - Falsifiable
    - Error rate
    - Fit for this purpose (*Joiner*)

Utah Admissibility Standards

- Expert can testify if the specialized knowledge will assist the trier of fact;

- And there is there is a threshold showing that the principles or methods that are underlying in the testimony (1) are reliable,(2) are based upon sufficient facts or data, and (3) have been reliably applied to the facts.

- Generally accepted principles and methods may be admitted based on judicial notice. Expert may explain abstract methods and leave it up to jury to apply to facts of this case.

Utah Admissibility Standards

"[J]udge must take care to direct her skepticism to the particular proposition that the expert testimony is offered to support. The *Daubert* court characterized this task as focusing on the "work at hand"…The foundation of reliability presented for it [should] reflect that consideration."

- Mangrum And Benson On Utah Evidence; 1 UTPRAC RULE 702

Utah Admissibility Standards

The greatest hurdle for most brain imaging evidence in being admitted is this problem of "fit"; or *Joiner* standard in federal courts

Perfectly valid research studies using fMRI, EEG, or QEEG for tracking stroke victims, seizure patients, or localizing speech centers before brain surgeries are being used in inappropriate contexts to say something about the criminal defendant's criminal mental state (such as competence to stand trial or *mens rea*)

Because you cannot evaluate admissibility without knowing what the evidence is being introduced to prove, I will focus my remaining remarks on using fMRI to prove a criminal defendant's past mental state (*mens rea* or provocation)

Legal Claims Made About fMRI

- "It's magical!"
- "Computerized and therefore objective"
- "Capable of reading our innermost thoughts"
- "Impossible to game"
- "Provides a colorful video in real-time of someone's thoughts"
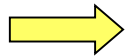
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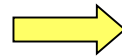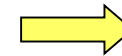
What do we know?

Functional scans: fMRI

Cognition/ Behavior

Functional Brain Anatomy

arterial   HbO₂   Hb
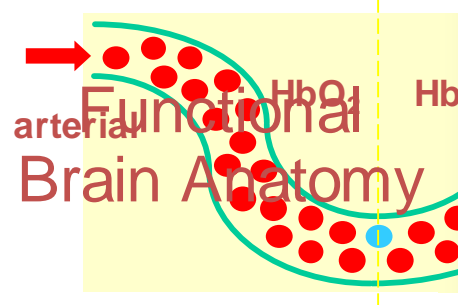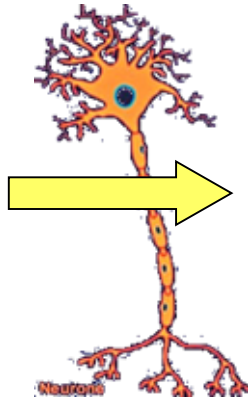
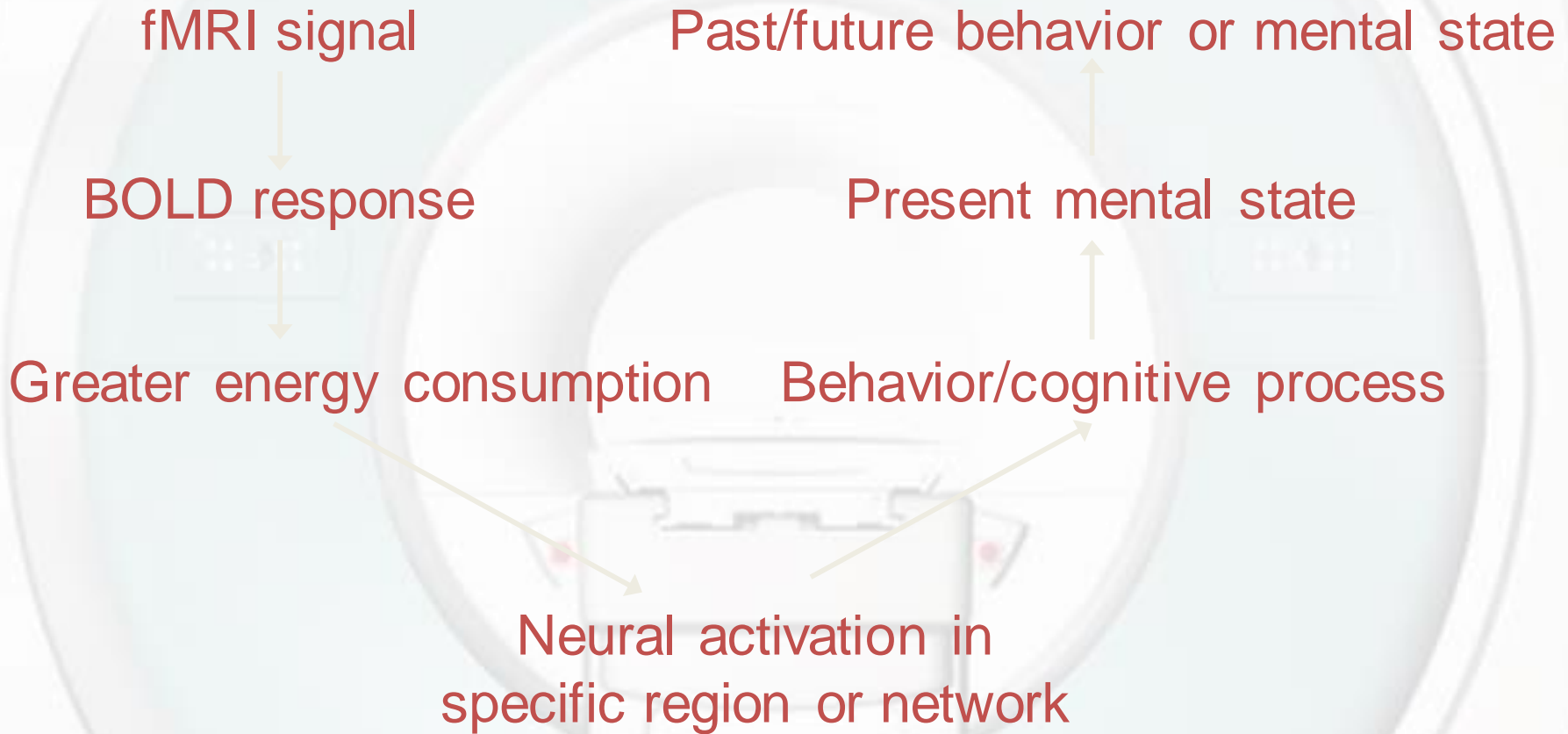| Perform a Task | → | Increased Neuronal Activity | → | Increased Oxygenated Blood Flow | → | Activation Map |

fMRI measures oxygenated blood flow, not neuronal activity directly.

Low Probative Value: "Epistemic Mismatch"

fMRI signal   Past/future behavior or mental state

↓   ↑

BOLD response   Present mental state

↓   ↑

Greater energy consumption   Behavior/cognitive process

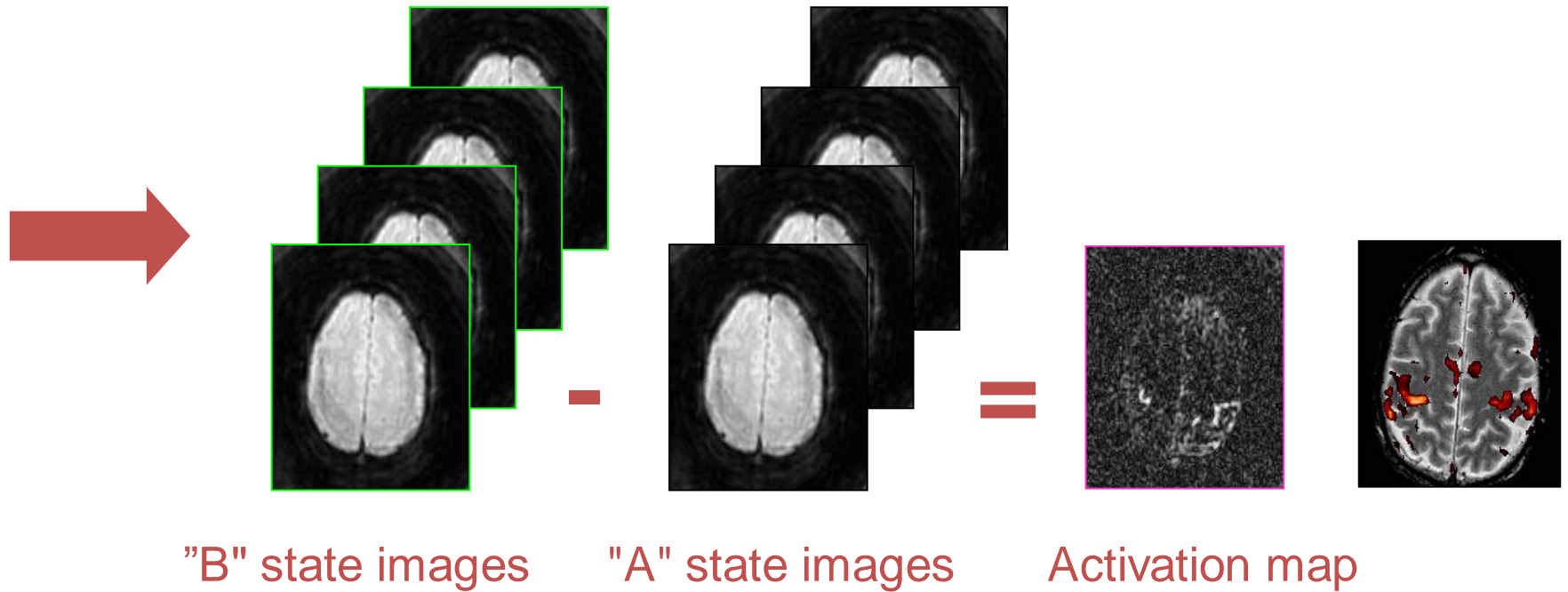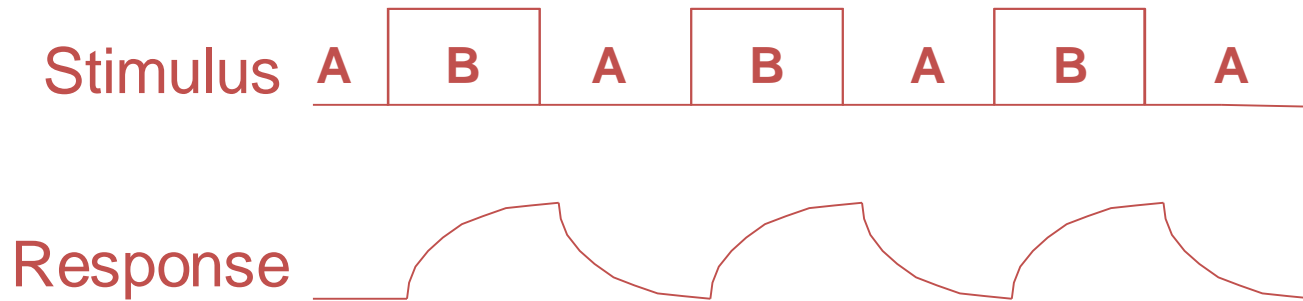Neural activation in
specific region or network

Plausible? Yes.

Potential for Prejudice

- Encourage an overly emotional response?
- Confuse the jury?
- **Waste the court's time/resources**
- **Cumulative of other evidence**
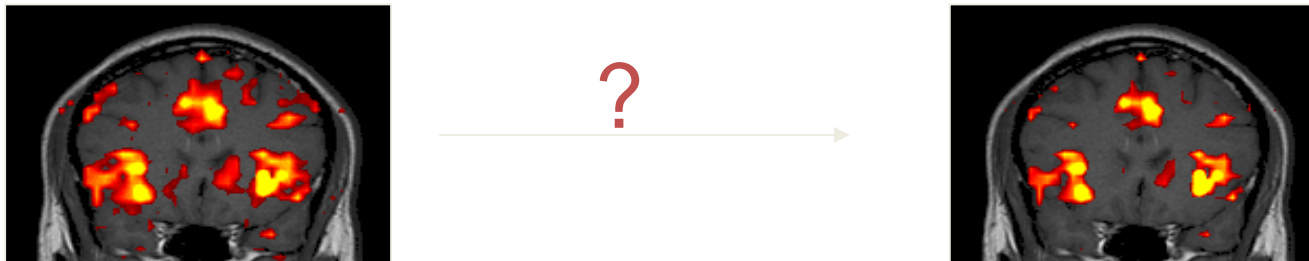
Cumulative of Behavioral Evidence?

Stimulus A B A B A B A

Response

"B" state images   "A" state images   Activation map

Images courtesy of Gary Glover, Stanfor

What is normal? Base rates and reference classes

Make a database of "normal brains"

Comparing an individual subject to the "norm"

?

**"Normal" is a statistical creation**

Individual Differences

- People have different memories and reference points

- People perform tasks in the scanner at different speeds and with different skills

- People have different brain architecture

- People have different molecular signaling pathways (based on genes and environment)

- People use what they have in different ways

Individual Differences

Miller et al., *J of Cognitive Neuroscience*
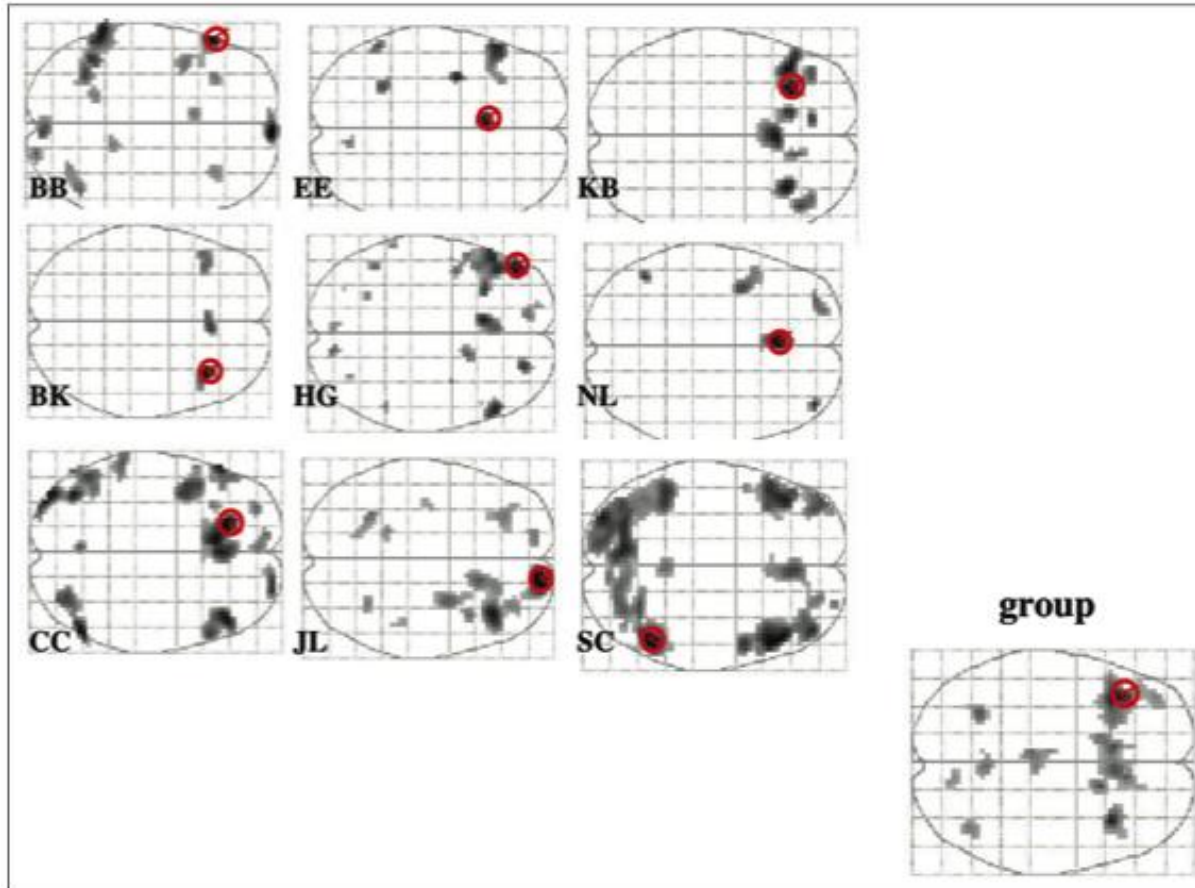
Lies, damn lies, and statistical thresholds

"Dialing a defect"
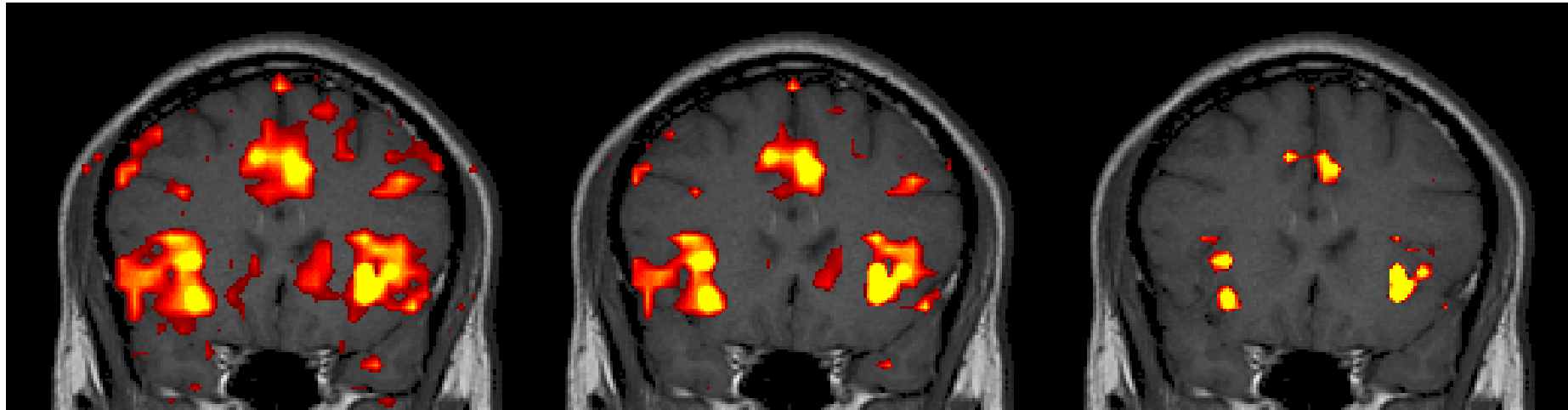
P < 0.05   P < 0.01   P < 0.001

# Which brain has processing deficits?

Neural correlates of interspecies perspective taking in the post-mortem Atlantic Salmon: An argument for multiple comparisons correction

Craig M. Bennett[1], Abigail A. Baird[2], Michael B. Miller[1], and George L. Wolford[3]

[1] Psychology Department, University of California Santa Barbara, Santa Barbara, CA; [2] Department of Psychology, Vassar College, Poughkeepsie, NY;
[3] Department of Psychological & Brain Sciences, Dartmouth College, Hanover, NH

GLM RESULTS
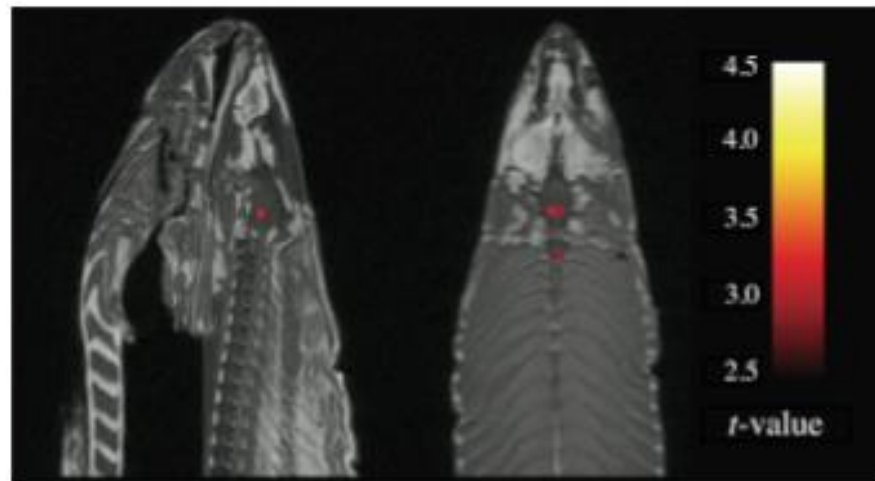
A t-contrast was used to test for regions with significant BOLD signal change during the photo condition compared to rest. The parameters for this comparison were $t(131) > 3.15$, p(uncorrected) < 0.001, 3 voxel extent threshold.

The Danger of Not Correcting for Chance

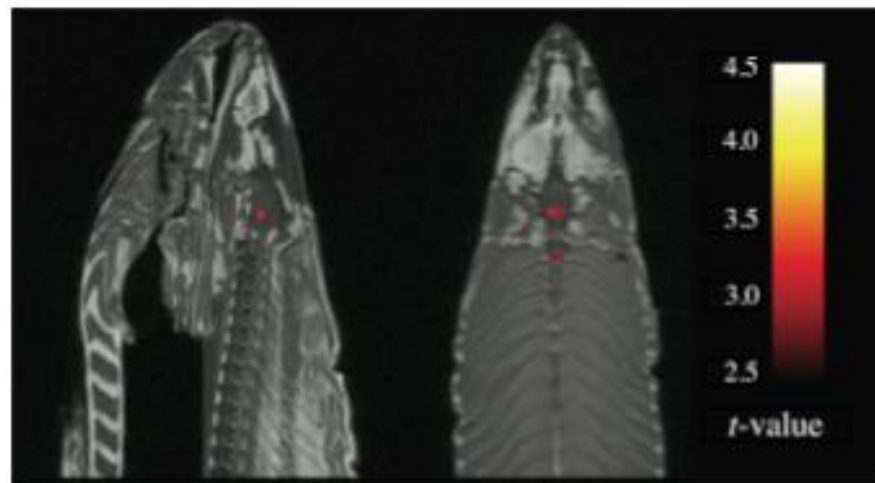# How could a dead fish exhibit brain function?

GLM RESULTS

A *t*-contrast was used to test for regions with significant BOLD signal change during the photo condition compared to rest. The parameters for this comparison were $t(131) > 3.15$, p(uncorrected) < 0.001, 3 voxel extent threshold.

The Danger of Not Correcting for Chance

The BOLD Response

The brain's energy budget

Legend:
- Evoked Activity
- Intrinsic Activity
- Other
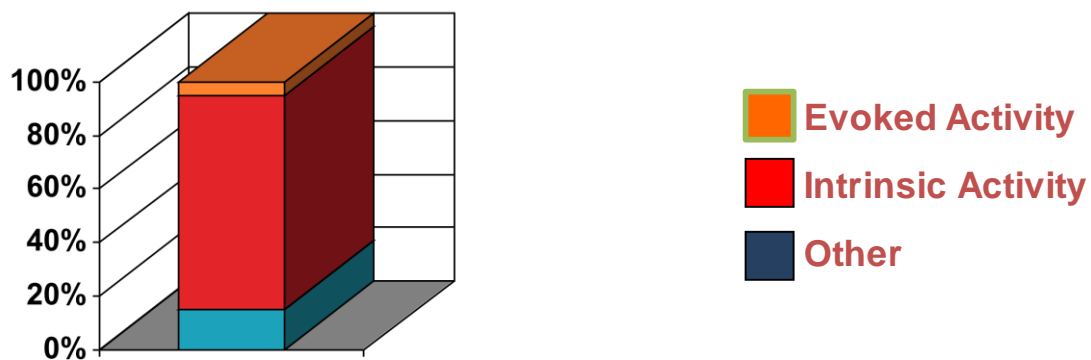
fMRI relies on a very noisy and subtle signal, and is best used as a research tool

Ecological Validity

- The images are only as good as the precision and relevance of the task the subject is asked to perform

- If the subject performs a task that is not related to the relevant legal behavior (such as the specific intent to kill, deception, feel pain) then the image will have little probative value and will not be reliably applied to the facts

- Impossible to replicate criminal behavior in a scanner

Why "Accuracy" in a Vacuum is Useless

- We first need to know something about the baserate of the phenomenon we are testing

- If the baserate is low, the positive predictive value (PPV) will also be low (because of false positives)

- PPV is critical when you REALLY want to know if someone possesses a trait, like legally relevant mental state or mental abnormality

Try this:

Should a fMRI-based "test" with 90% specificity and sensitivity pass 702?

Security screening example:

1000 travelers going through SLC airport security

10 of them are lying about carrying explosives (1%)

Brain scan with 90% specificity, 90% sensitivity

Scan result

Reality	Allow	Detain	Total
Truth			990
Lying			10

Positive predictive value: At 90% specificity and 90% accuracy, but a 1% prevalence rate, the scan incorrectly says to detain 99/108 people: wrong 91.7% of the time!

Positive Predictive Value

- Need to know something about baserates to say anything meaningful about the PPV

- What is the baserate of a mild traumatic brain injury? Of psychopathy? Of schizophrenia?

- Compare to men, of the same age, using the same meds, sleeping the same amount, with the same background IQs?

General questions to ask counsel before admitting fMRI:

- What is the particular behavior assessed during the scan?

- Why was the particular behavioral task chosen?

- Is it well supported in the psychological literature as best capturing this type of mental state?

- Did the subject perform the behavioral task adequately?

- Is the task vulnerable to manipulation, countermeasures, or malingering?

- Are the subject's behavioral data within or significantly outside the normal distribution of performance on the task?

General questions to ask counsel before admitting fMRI:

- How were the controls selected to be in the control group? Are they the correct reference class? What sort of testing was done on the controls to make sure that they were in fact, "normal"? Is the sample size large enough to capture normal variance between subjects?

- Can you show us the brain scans of the control group, and are there significant differences among the individuals in this group? How much difference between individuals do we see?

- What are possible alternate explanations for this behavior and corresponding neural activation correlates (i.e., expertise in the task, medication status, drug abuse history, hormonal fluctuations, language or motor limitation, etc.)?

For List of Questions to Ask Before Admitting fMRI Evidence

- See the Appendix in

  Teneille Brown and Emily Murphy, *Through a Scanner Darkly: Functional Neuroimaging as Evidence of a Criminal Defendant's Past Mental States*, 62 Stanford Law Review 1119 (2010)

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fMRI for Sentencing & Risk Prediction

- Using fMRI to infer mental states requires drawing a conclusion about an individual:
  - Did *defendant* intend to defraud? Is plaintiff in pain? Is defendant telling the truth?
  - What is the cost of getting this wrong? Jail time? Not receiving damages?

- Risk prediction, on the other hand, deals with probabilities for populations
  - Not about retribution, but deterrence
  - How do we predict which classes of people are most likely to reoffend?

Neuroprediction of Future Rearrest

- The odds that an offender with relatively low ACC activity would be rearrested were approximately **double** that of an offender with high activity in this region, holding constant other observed risk factors.

- These results suggest a potential neurocognitive biomarker for persistent antisocial behavior.

Aharoni et al, 110 PNAS 6223 (2013)

Neuroprediction of Future Rearrest

- Brain activity elicited during performance of an inhibitory task (Go/No-Go) prospectively predicted subsequent rearrest among adult offenders within 4 yr of release ($N = 96$).

- Inmates were given a simple test asking them to press a button when the letter "X" appeared on a computer screen but to refrain from pressing the button when a "K" appeared.

- Inmates who made mistakes and exhibited low brain activity in the ACC afterward had a harder time controlling their impulses and were more prone to apathetic or aggressive behavior

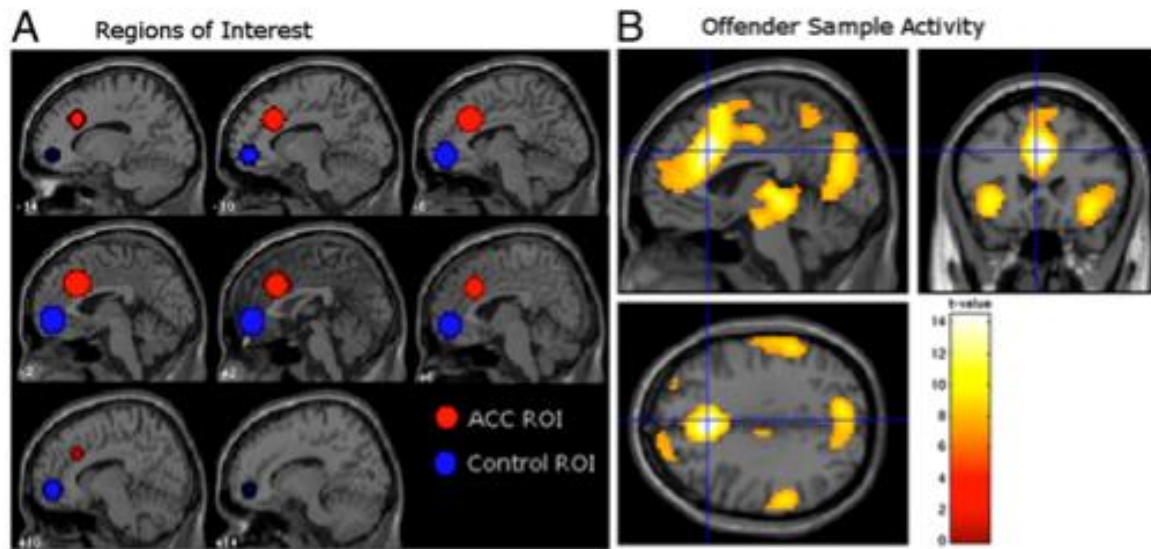Aharoni et al, 110 PNAS 6223 (2013)

Risk Prediction

Fig. 2. (A) A priori seed region (red) for BOLD response to commission errors vs. correct hits in anterior cingulate from a GNG task with an independent sample of 102 healthy adult nonoffenders; peak voxel $x = -3$, $y = 24$, $z = 33$; radius = 14 mm sphere; $t(94) = 13.38$, $P < 0.0001$, FWE. A priori control region (blue) embodying anterior portion of the medial prefrontal cortex (peak voxel: 0, 51, −6; radius = 14 mm sphere). (B) Mean hemodynamic response change in offender sample ($n = 96$) during commission errors vs. correct hits from sagittal (*Upper Left*), coronal (*Right*), and axial (*Lower Left*) orientations. Peak activation located at $x = 3$, $y = 24$, $z = 33$ within the ACC ROI ($P < 0.00001$, FWE).

Neuroprediction of Future Rearrest

- What are the benefits of this approach?
- What are the concerns?

Aharoni et al, 110 PNAS 6223 (2013)

Use of fMRI at Sentencing

- *The Double-Edged Sword: Does Biomechanism Increase or Decrease Judges' Sentencing of Psychopaths?* 337 Science 846 (2012)
    - Lisa G. Aspinwall,Teneille R. Brown, James Tabery
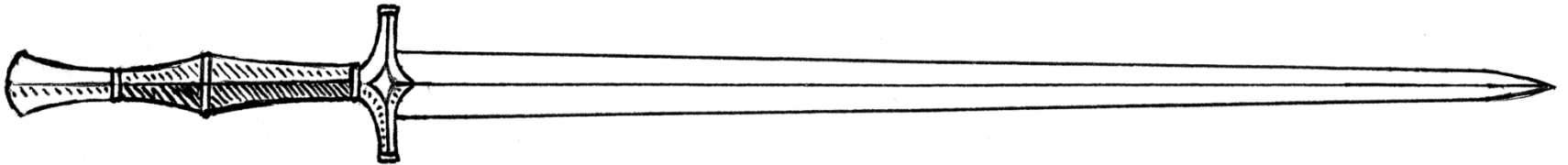
Thanks!

Questions? Email me at: Teneille.Brown@law.utah.edu