

Neuroimaging in the study of the brain and its functions

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1. State of the art in neuroimaging

- Computed tomography (CT)
- Anatomical Magnetic Resonance Imaging (MRI)
- Functional MRI, tractography
- Positron emission tomography (PET), single proton emission tomography (SPECT)
- EEG
- MEG
- Transcranial magnetic imaging (TMS)

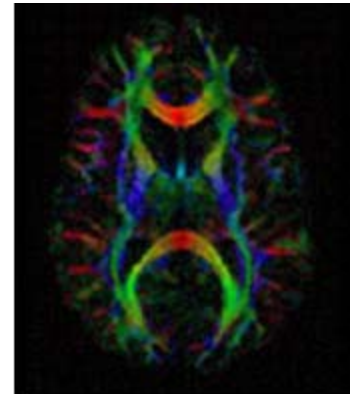
fMRI



AMI Centre, Aalto University

fMRI

- Measures blood oxygenation level changes during tasks
- Source localization relatively reliable
- Time resolution seconds, link to neuronal activation not understood
- Variable between subjects, thresholding of the signal needed to decide what is a true activation
- White matter tracts
- Resting-state fluctuations
- Directionality analyses
- Decoding of fMRI signals to conclude properties of stimuli producing activation
- Increasing field strength to improve signal-to noise ratio
- Availability very good



fMRI decoding

- Combining neuroscience and data mining
- Trying to define the stimulus, attention or emotional state from fMRI signals
- Create an encoding model with stimuli utilizing machine learning
- Utilize the encoding model to reverse the interpretation to brain signals
- Identify the picture seen amongst other pictures or a section of the movie
- Usually an individual model is needed
- The material fed for encoding influences the reconstruction result
- Generalized models?

fMRI decoding

Target image

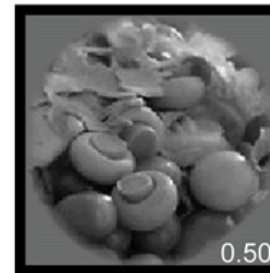


Reconstructions with natural image prior

Structural model only



Structural and semantic models (hybrid method)



Naselaris et al.
Neuron 2009

Perspective

- Despite experimental complexity, the scenarios remain relatively simple
- guessing what you are seeing, doing or planning within a pre-defined set of possibilities.
- The number of thoughts is infinite. A “mind reading experiment” in a broader context much more complex.
- Based on a direct relationship between stimulus feature (e.g., the locations, frequencies and orientations in an image) and a neuroanatomical location. This relationship is clear for some functions (somatotopy, retinotopy, tonotopy), more than uncertain for other functions.

PET



PET, SPECT

- Measures tissue metabolism or receptor densities
- Better localization ability in PET than SPECT
- Averaging over subjects generally needed
- Repeated measurements difficult due to radiation
- Radioisotopes needed, availability limited

EEG

- Long experience
- Excellent time resolution, poor localization of activated areas, repeatable
- Increased number of electrodes utilized to improve source localization
- Availability good



EEG and pilots

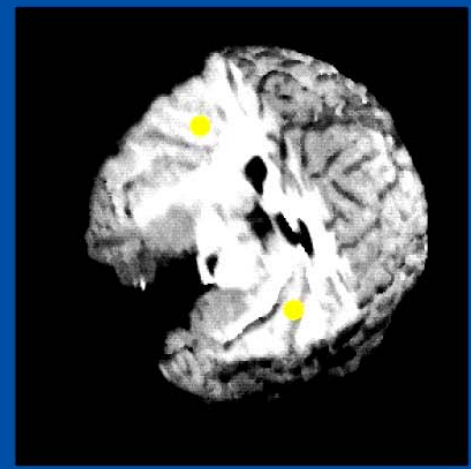
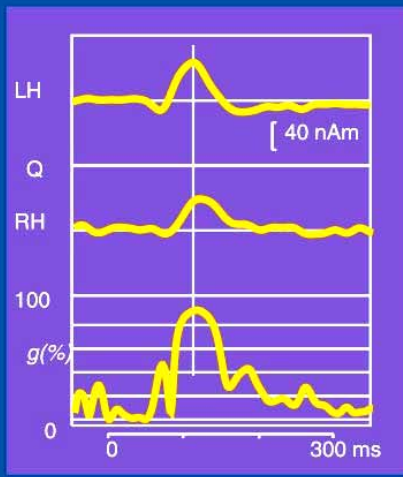
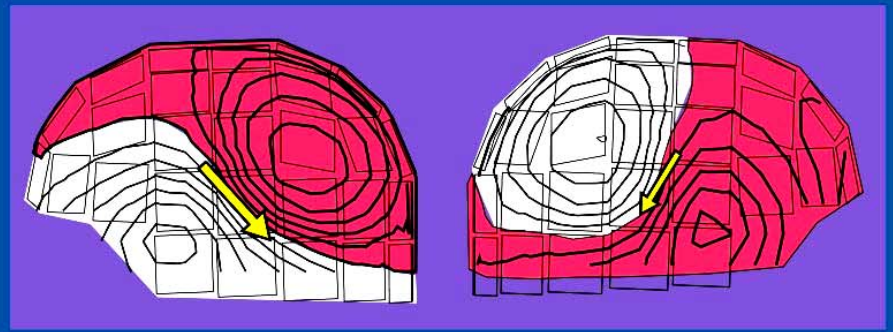
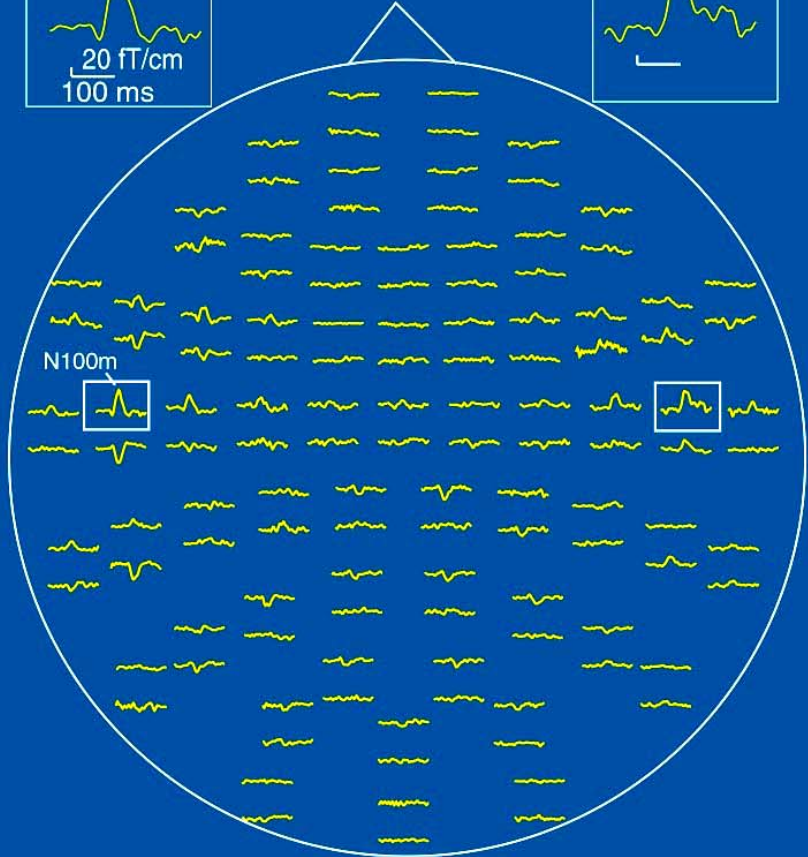
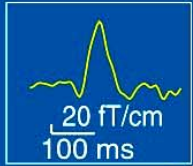
- In UK, 13 568 EEG:s for pilots; 65 (0.5%) had epileptiform phenomena
- Follow-up 5-29 yrs (38 subjects); one epilepsy, one unclear collision
- USAF: 2947 EEGs for flying cadets, 14 abnormal
- Follow-up 10-15 yrs: no epilepsy

Magnetoencephalography (MEG)

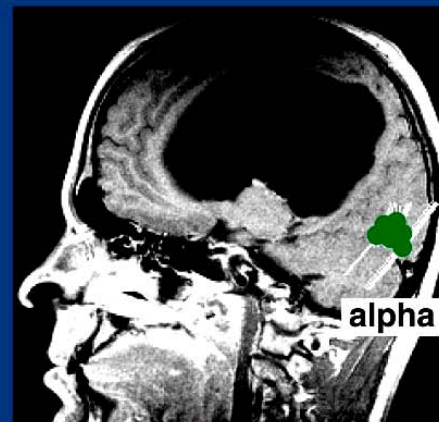
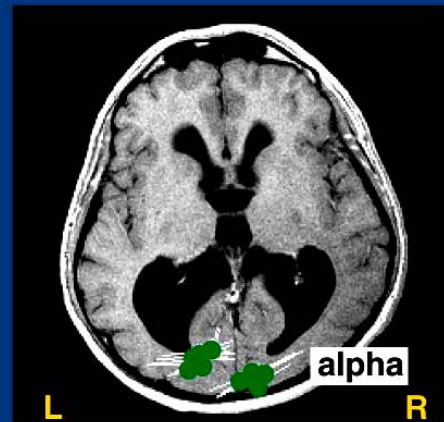
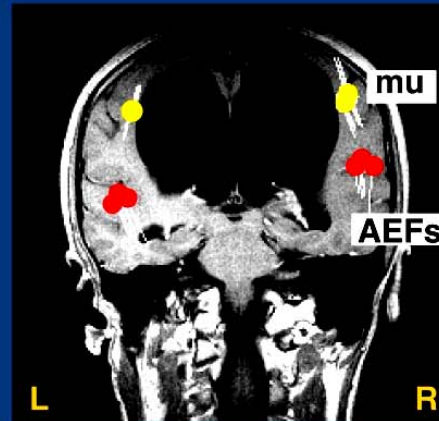
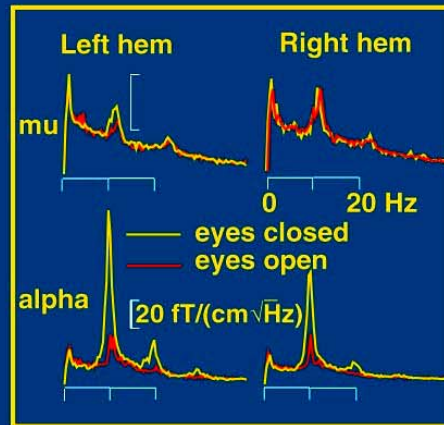
- Excellent time resolution, moderate localization of sources
- Deep activations not easily visualized
- Easily repeatable
- Availability limited



RESPONSES TO TONES

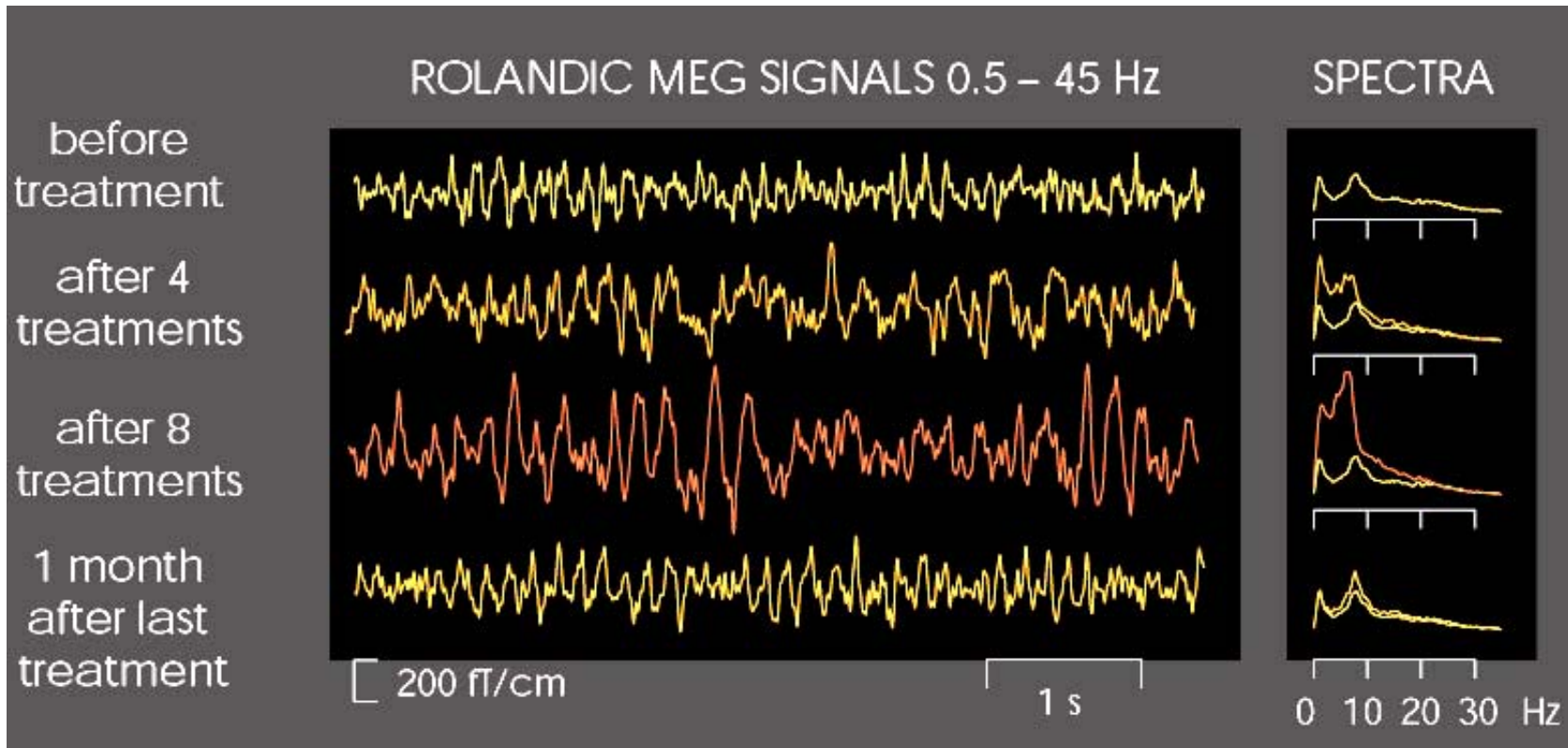


SPONTANEOUS ACTIVITY AND AEFs IN HYDROCEPHALUS



JM 2/94

Spontaneous activity after ECT



Heikman et al. J ECT 2001

Navigated brain stimulation nTMS

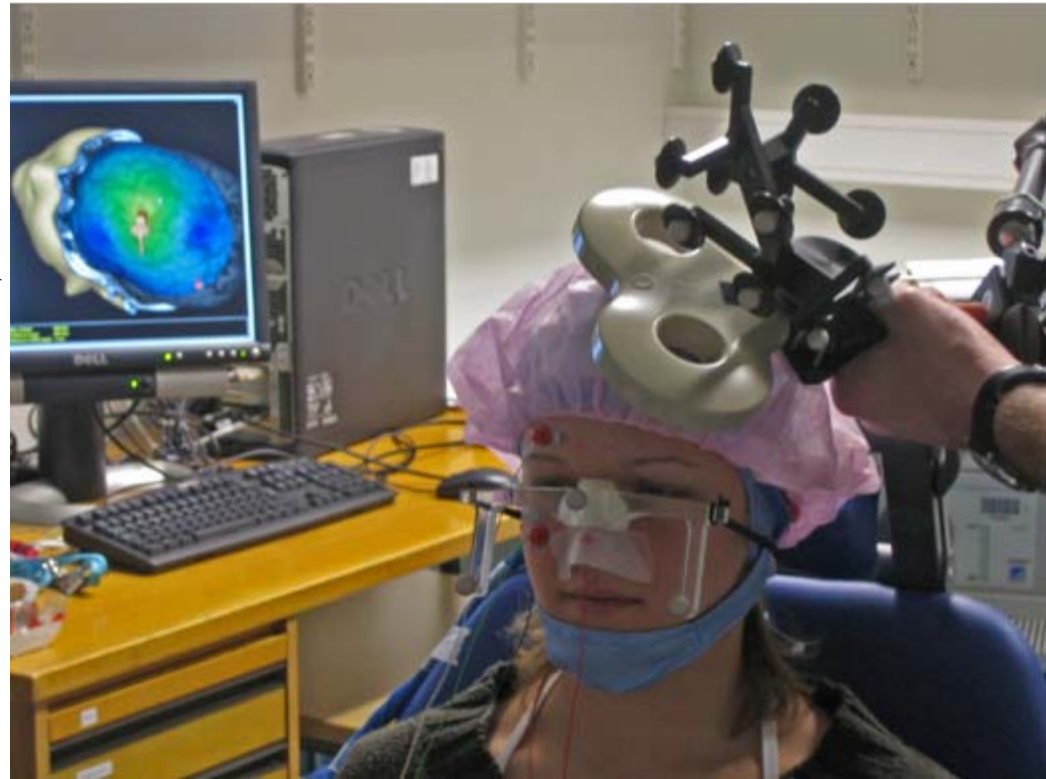
Strong magnetic field (0-2 T in
100 microsec)

Weak electric current in the brain

TMS is focused accurately with
the anatomic MR images

Reactions to TMS are measured
by EEG

Deep structures progressively less
activated



Psychological studies in neuroimaging

- Targeted towards general brain mechanisms
- Individual variation considerable; outliers often excluded
- Correlative measures to behaviour: correlation does not imply causality

Brain imaging ready to detect terrorists, say neuroscientists

NATURE | Vol 437 | 22 September 2005

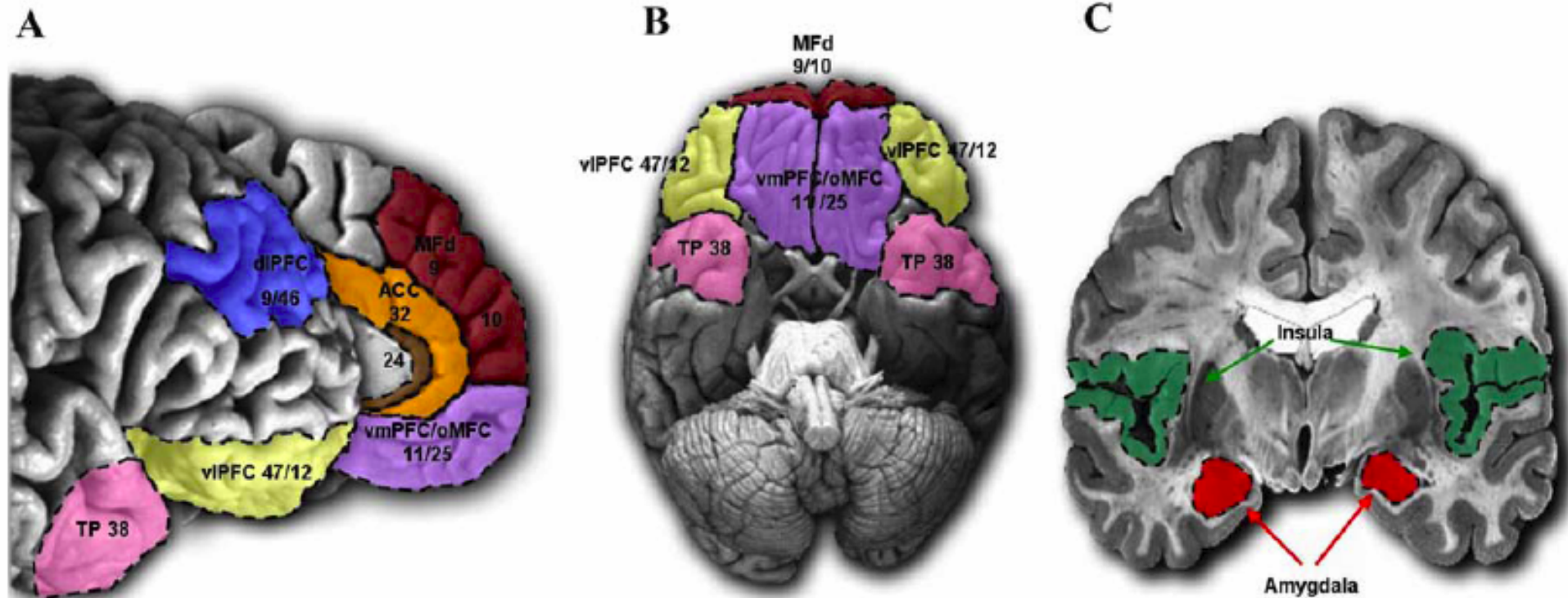
- “Interrogating the grey matter”
 - to detect deception etc
 - without subject’s permission?
- Guilty or not-guilty? Case from Iowa Supreme Court:

was introduced through the testimony of Dr. Lawrence Farwell, who specializes in cognitive psychophysiology. Dr. Farwell measures certain patterns of brain activity (the P300 wave) to determine whether the person being tested recognizes or does not recognize offered information. This analysis basically ‘provide[s] information about what the person has stored in his brain.’ According to Dr. Farwell, his testing of Harrington established that Harrington’s brain did not contain information about Schweer’s murder. On the other hand, Dr. Farwell testified, testing did confirm that Harrington’s brain contained information consistent with his alibi.²⁷

Lesion studies of aggressive and violent behaviour

- Emotional behaviour regulated by a neural circuit including prefrontal cortex, anterior cingulate gyrus, insular cortex, amygdala, hippocampus, thalamus
- Patients with early onset lesion in ventromedial prefrontal cortex experience an insensitivity to future consequences (Damasio et al.)
- Patients with orbitofrontal cortical damage tend to exhibit poor impulse control, aggressive outbursts
- Patients with damage in anterior cingulate cortex feel pain but report it as less distressful

Relevant brain areas



doi:10.1371/journal.pbio.0050103.g001

Figure 1. Regions Associated with Normal and Atypical Social Behaviour

(A) Medial and lateral view of the PFC.

(B) View of the ventral surface of the PFC and temporal poles.

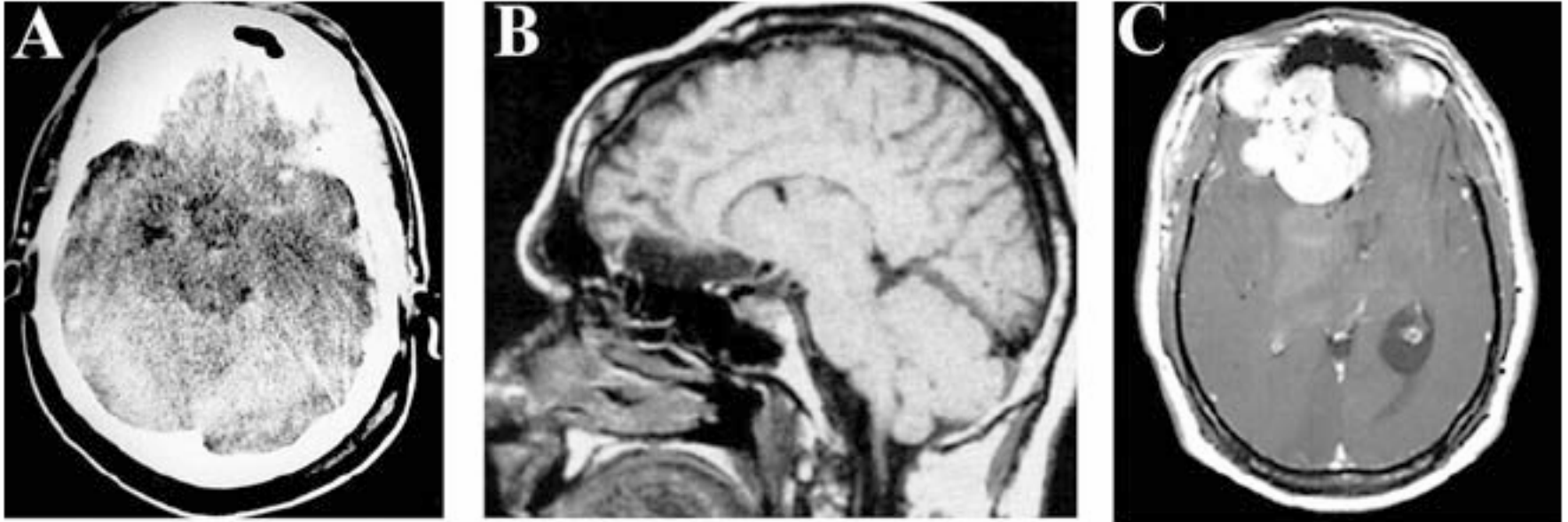
(C) Coronal slice illustrating the amygdalar and insular cortex.

See also Table 1.

ACC, anterior cingulate cortex; dIPFC, dorsolateral PFC; MFd, medial PFC; oMFC, orbitomedial PFC; TP, temporal pole; vIPFC, ventrolateral PFC; vmPFC, ventromedial PFC.

Dean Mobbs*, Hakwan C. Lau, Owen D. Jones, Christopher D. Frith

Brain Pathology and behaviour?

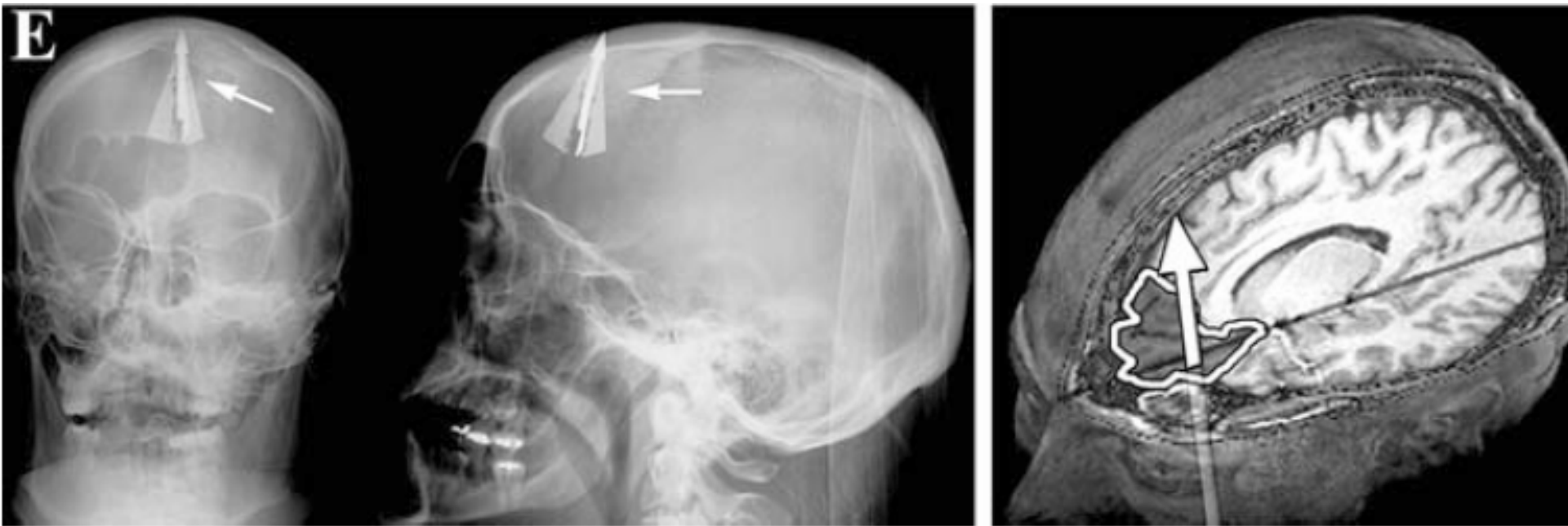


(A) Brain scan of patient J. S., who exhibited sociopathic behaviour [5]. The image shows a lesion in the orbital frontal cortex.

(B) fMRI sagittal slice of the brain of patient J. Z., showing a lesion that was caused by the resection of pituitary tumour [4]. This lesion led to anti-social conduct, which was not exhibited before the surgery.

(C) Orbitofrontal damage associated with symptoms of paedophilia and sexual misconduct in the case of a 40-year-old male patient.

Brain Pathology and behaviour?



(E) Cranial X-ray of a man who attempted suicide with a crossbow. Although the individual exhibited premorbid APD, the PFC damage caused by the crossbow arrow resulted in reversal of anti-social conduct [54].

Neuroimaging studies of aggressive and violent behaviour

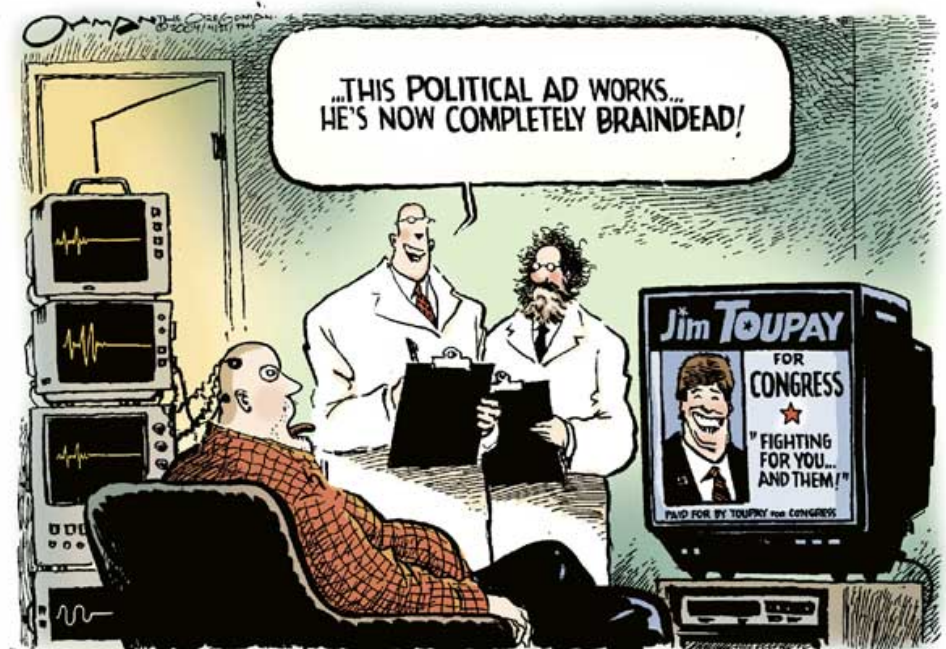
- SPECT, PET, fMRI on subjects from prisons, psychiatric hospitals and non-institutionalized violent offenders: 17 reports (Bufkin and Luttrell 2005)
- Frontal and temporal abnormalities as a group finding
- (1/14 patients; up to 50% of the patients...)
- Reported also in a wide variety of psychiatric and neurological disorders not associated with violence
- Retrospective findings

Points to be considered

- Imaging methods relatively new
- Significance of activation unclear
- fMRI measures blood flow, which can be increased by neural excitation or inhibition; thresholding required because of a large individual variation
- MEG/EEG measures coherent activity of large neuronal populations; significance of coherent vs. non-coherent activity?
- What type of tests bring information about psychopathology/aggressiveness; co-operation?
- "We need to know much more before firm conclusions can be drawn on antisocial and psychopathic traits from brain imaging data" (Wahlund and Kristiansson, Int J Law Psychiatr. 2009)

Something to hide?

- Activation of emotion-related brain areas may tell something that we would like to hide
 - (the information depends on experimental setup)
 - racial prejudices
 - sexual attitudes
 - shopping preferences
 - voting behaviour
- BUT the same can be studied



Courtesy of Riitta Hari

Problems in imaging psychopathy

- "Champagne, if you are seeking the truth, is better than a lie-detector. It encourages a man to be expansive, even reckless, while lie-detectors are only a challenge to tell lies successfully"

*Graham Greene, Travels with my aunt
1969*