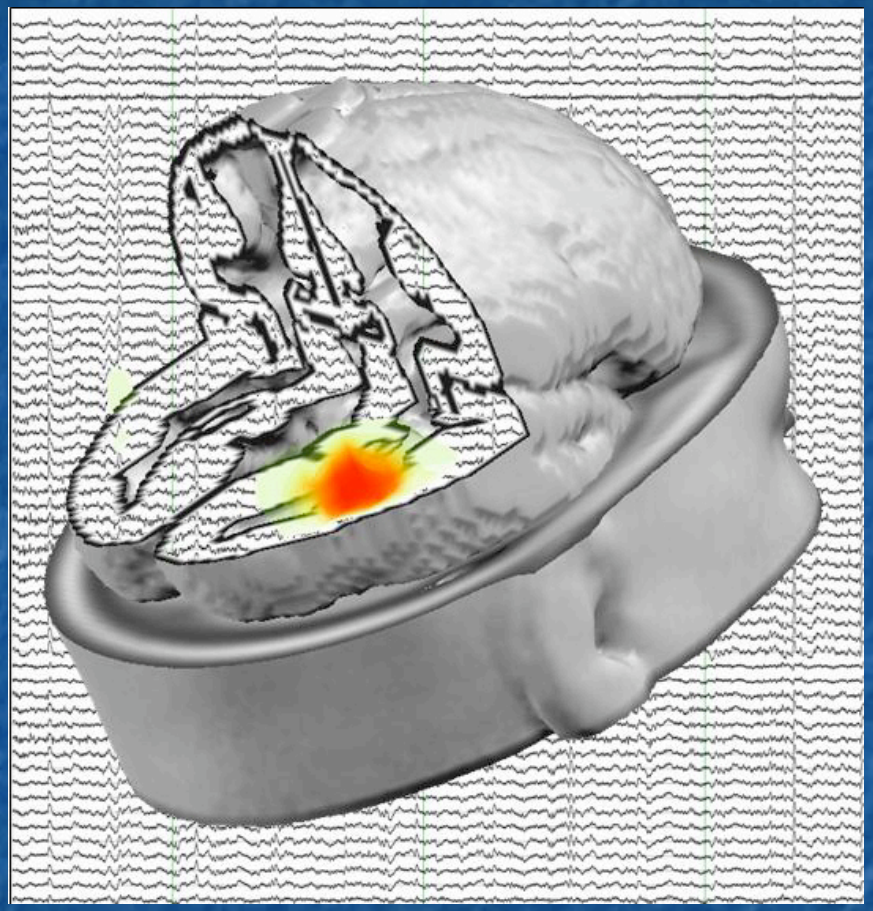
Cognitive Neuroscience of Language: 4: Imaging Technologies, Language, and the Brain

Richard Shillcock

Goals

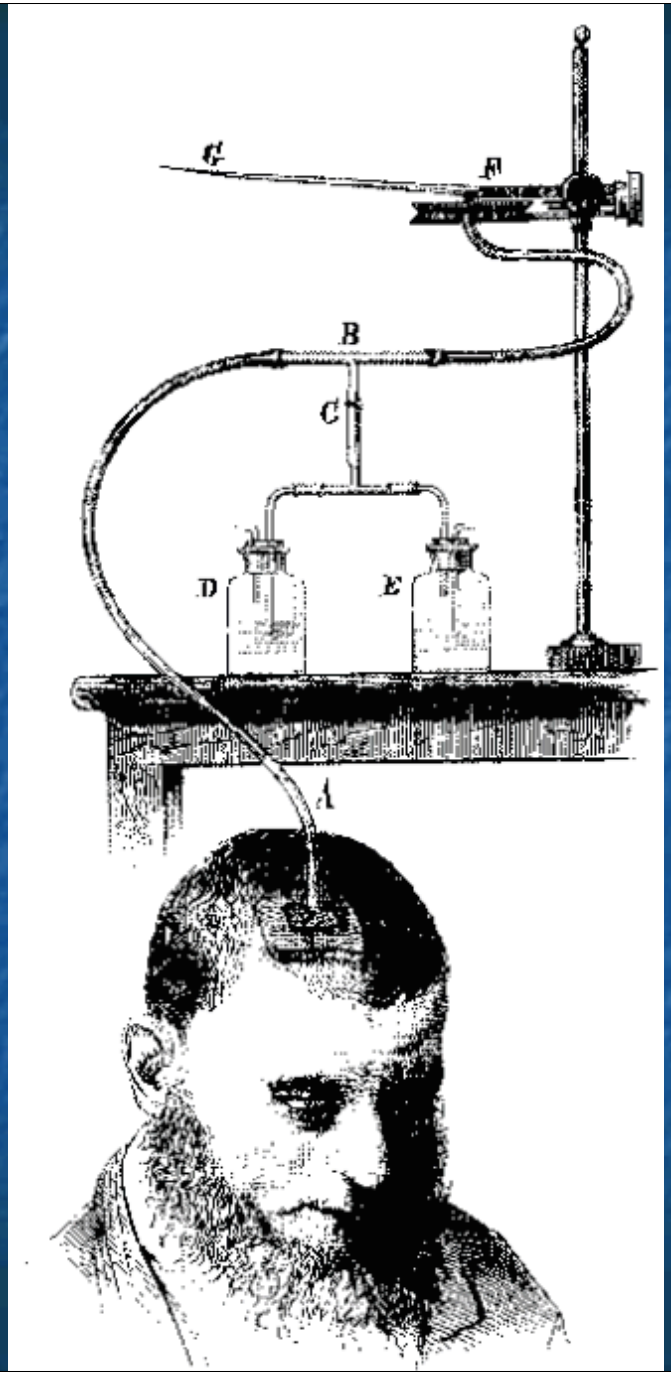


- Understand the principles of brain imaging and the kinds of data that can be revealed

Reading

Page, M. (2006). What can't functional neuroimaging tell the cognitive psychologist? *Cortex*, *42*, 428-443.

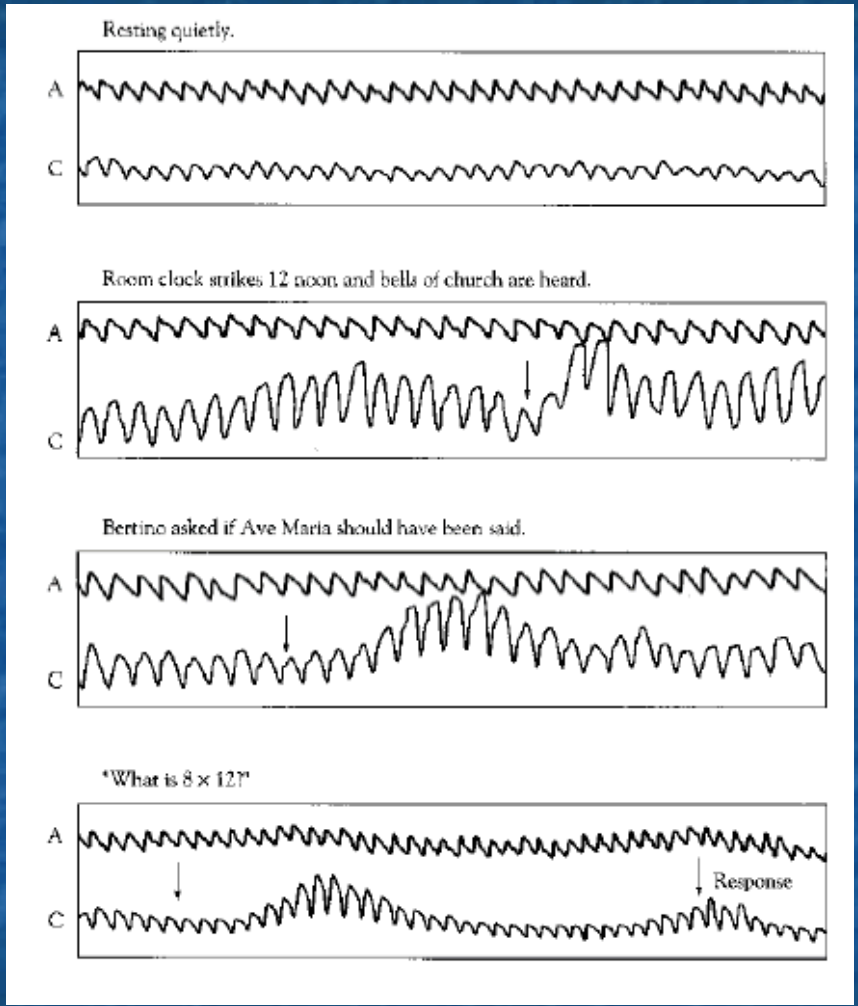
Coltheart, M. (2006). Perhaps functional neuroimaging has not told us anything about the mind (so far). *Cortex*, *42*, 422-427.



History

Mosso (1881) concludes that behaviour changes cause changes in blood flow to the brain, measuring a pulse in an abnormality in Bertino's skull

History



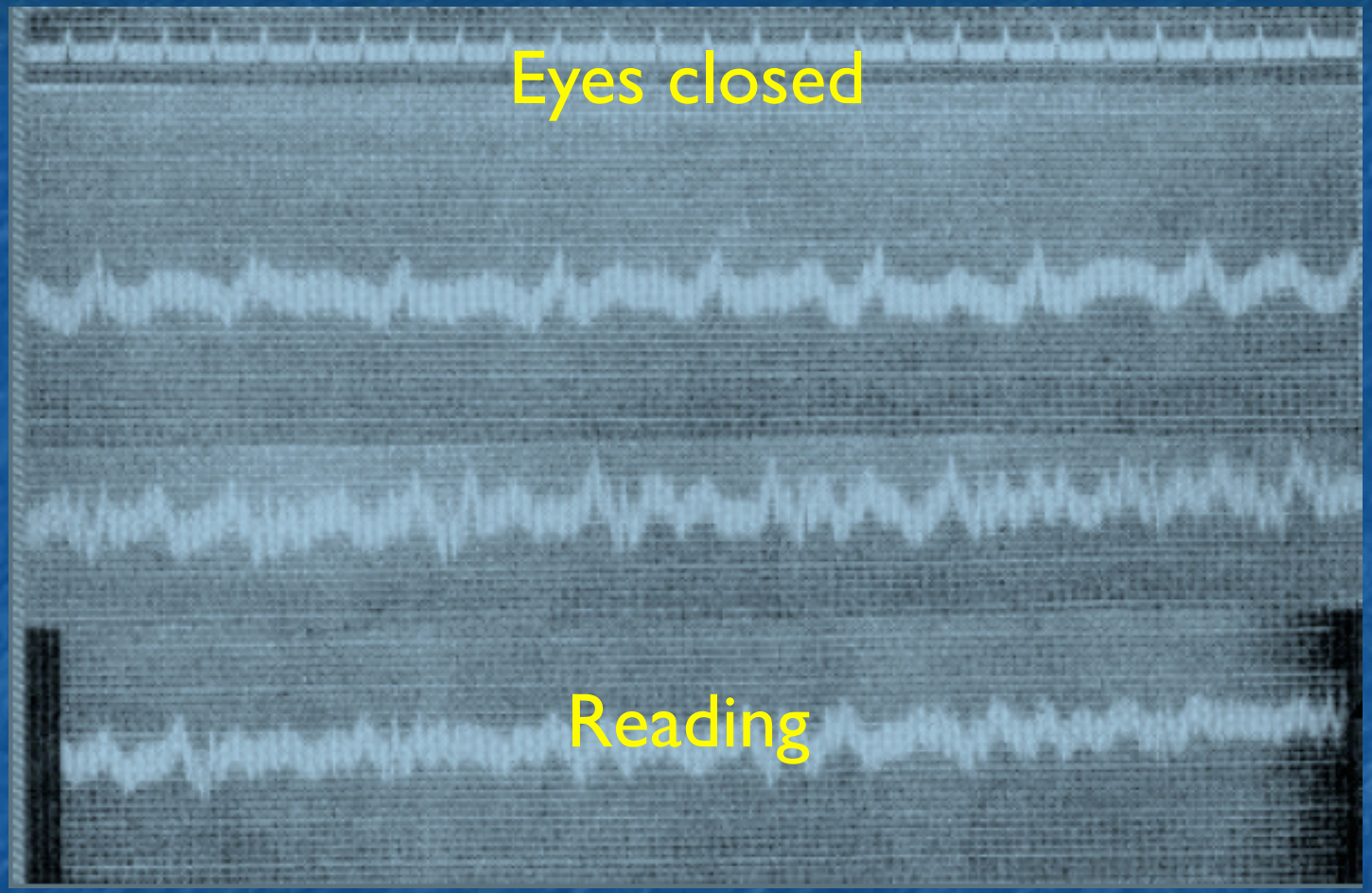
Mosso (1881) concludes that behaviour changes cause changes in blood flow to the brain, measuring a pulse in an abnormality in Bertino's skull

(A = forearm, C = brain)

History

Fulton (1928) listens to the arteriovenous malformation in patient Walter K's skull.

History

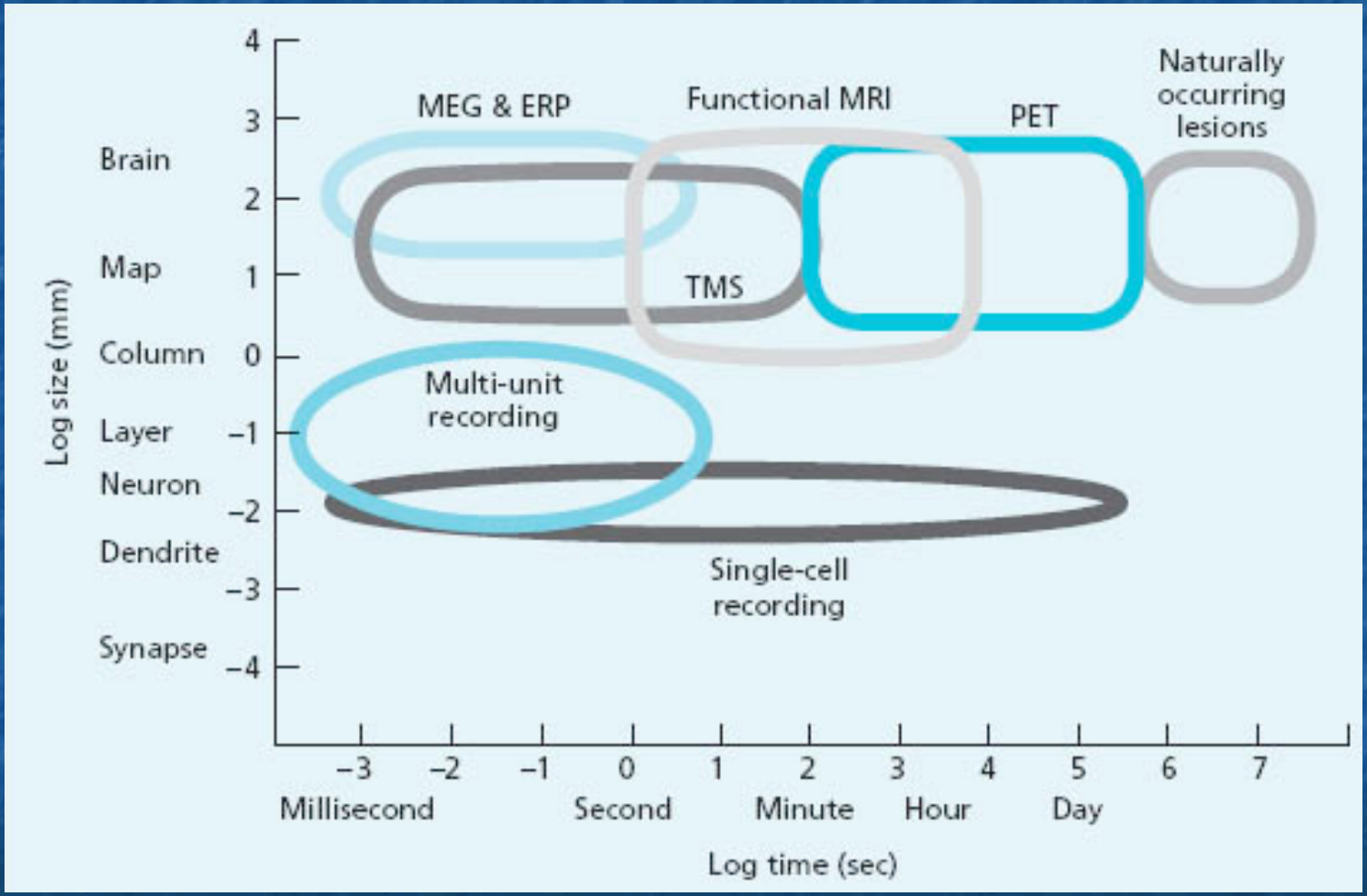


Fulton (1928) listens to the arteriovenous malformation in patient Walter K's skull.

Imaging techniques

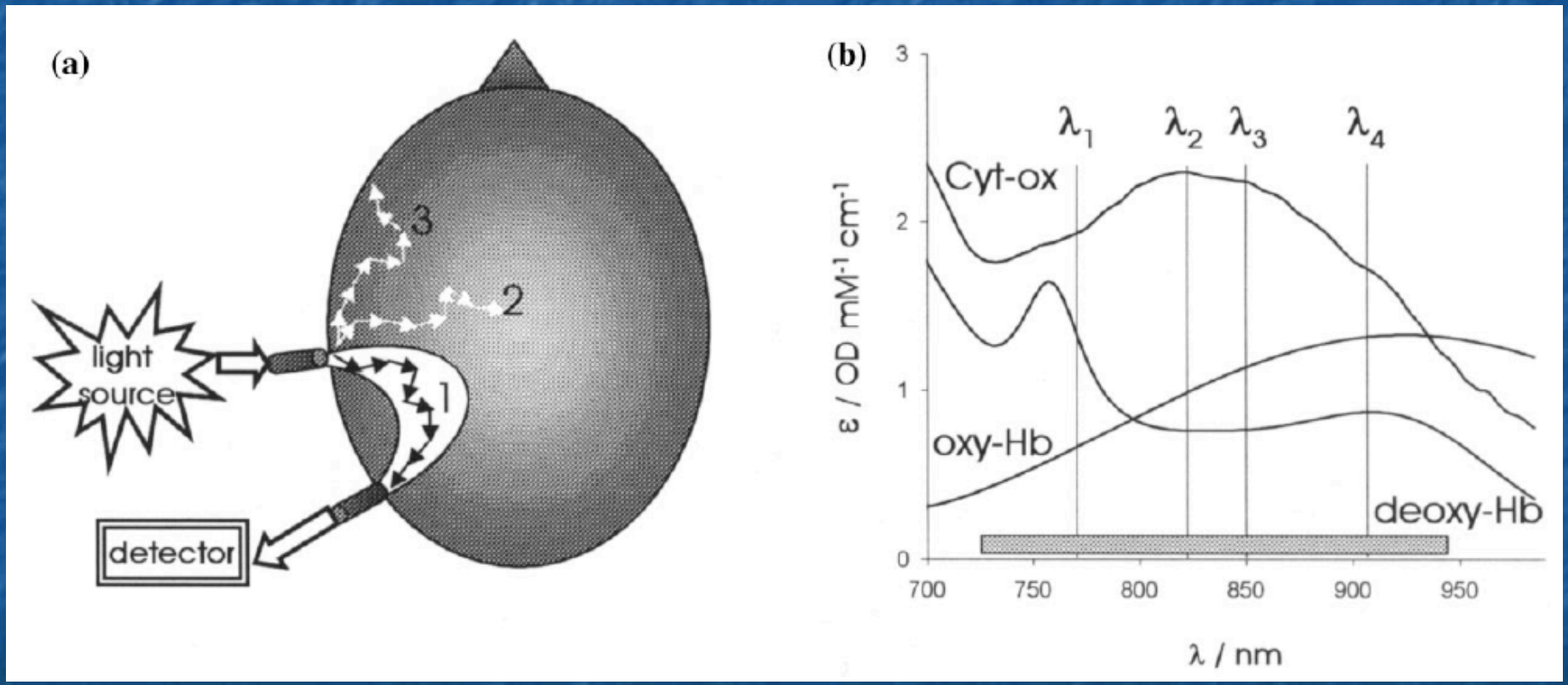
- Near Infra-Red Spectroscopy (NIRS)
- Doppler sonography
- Positron Emission Tomography (PET)
- Magneto-Encephalography (MEG)
- Functional Magnetic Resonance (fMRI)
- Electro Encephalography (EEG)
- Diffusion tensor tractography
- Transcranial Magnetic Stimulation (TMS)

Specificity of imaging techniques



Near Infra-Red Spectroscopy

Obrig *et al.* (2000)



Near Infra-Red Spectroscopy

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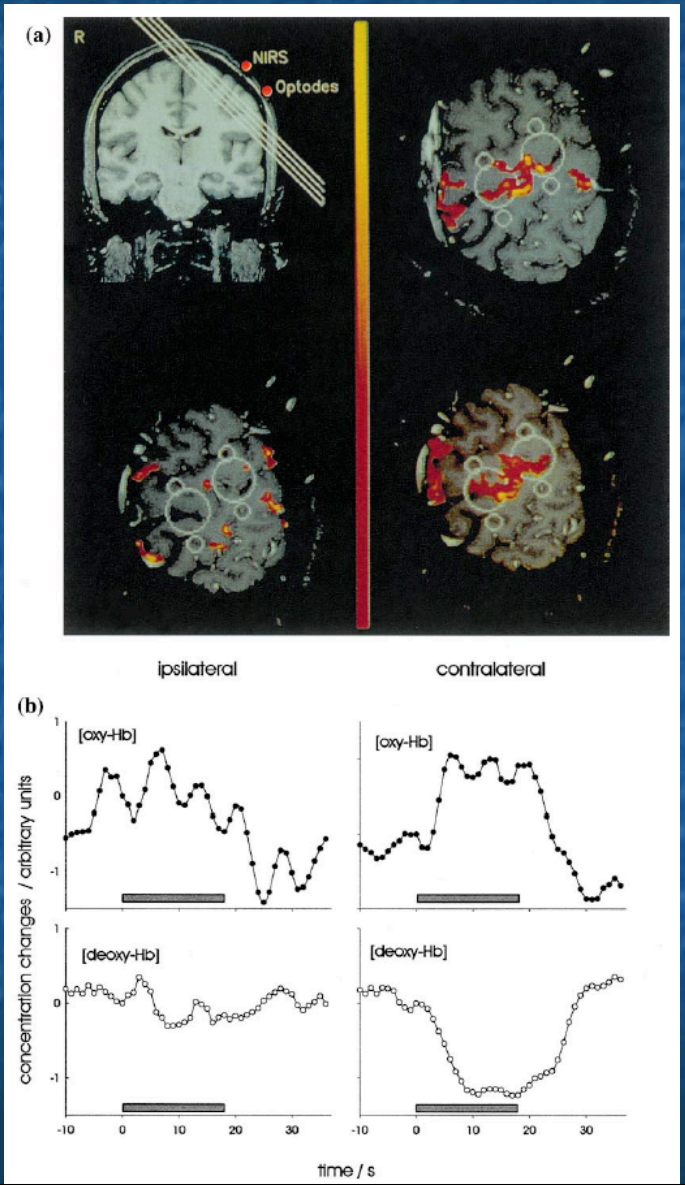


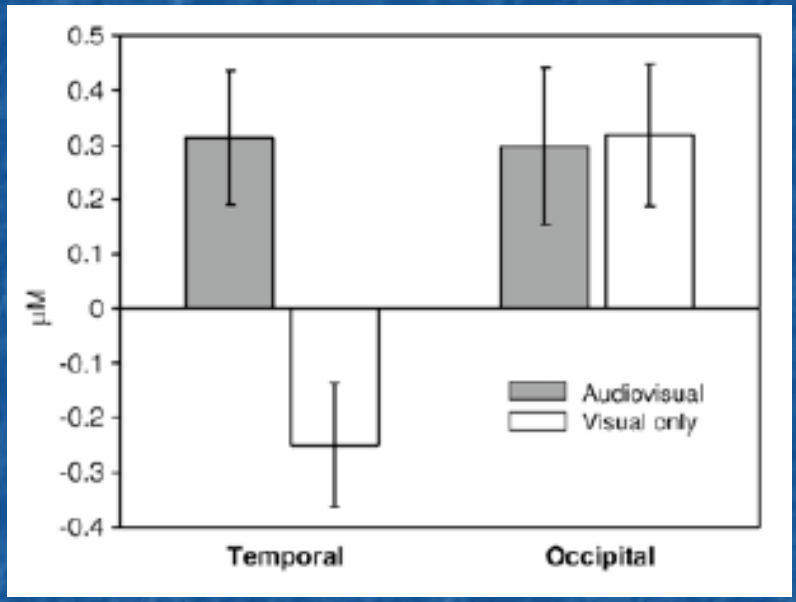
fMRI

NIRS

Near Infra-Red Spectroscopy

Bortfeld *et al.* (2007)

(b)



Doppler sonography

Knecht *et al.* (1998)

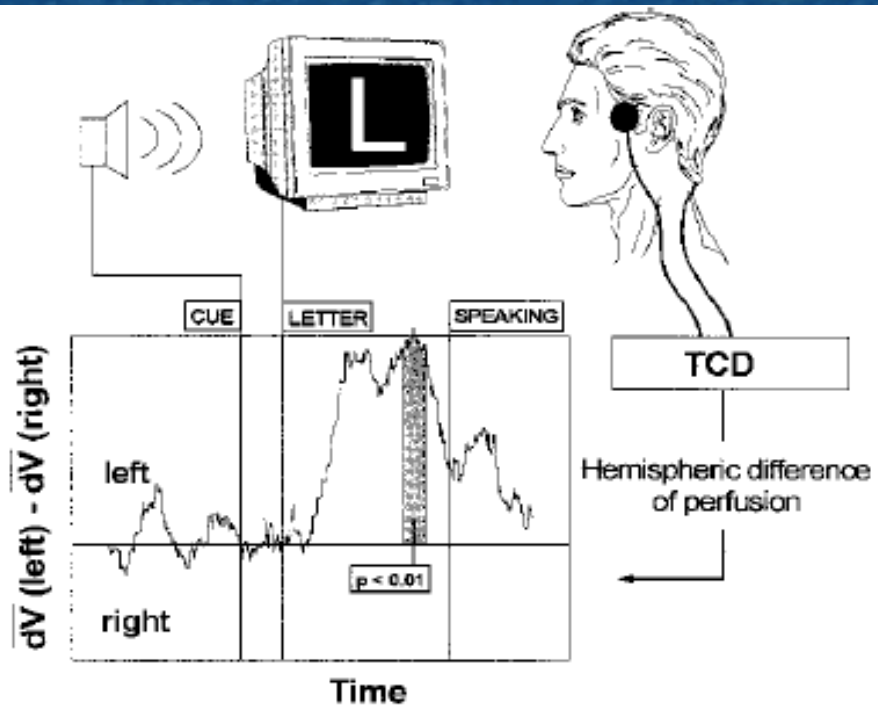
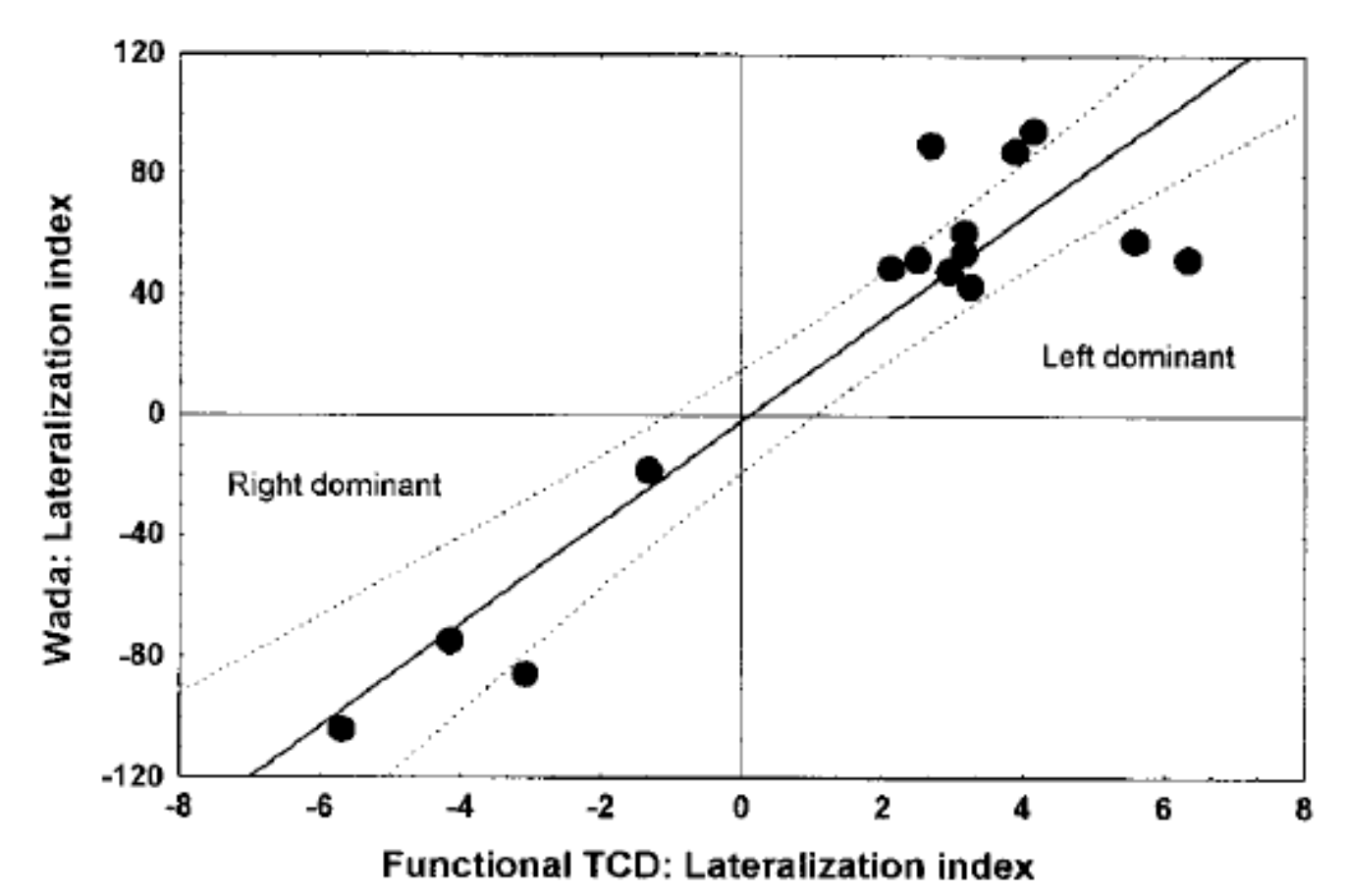


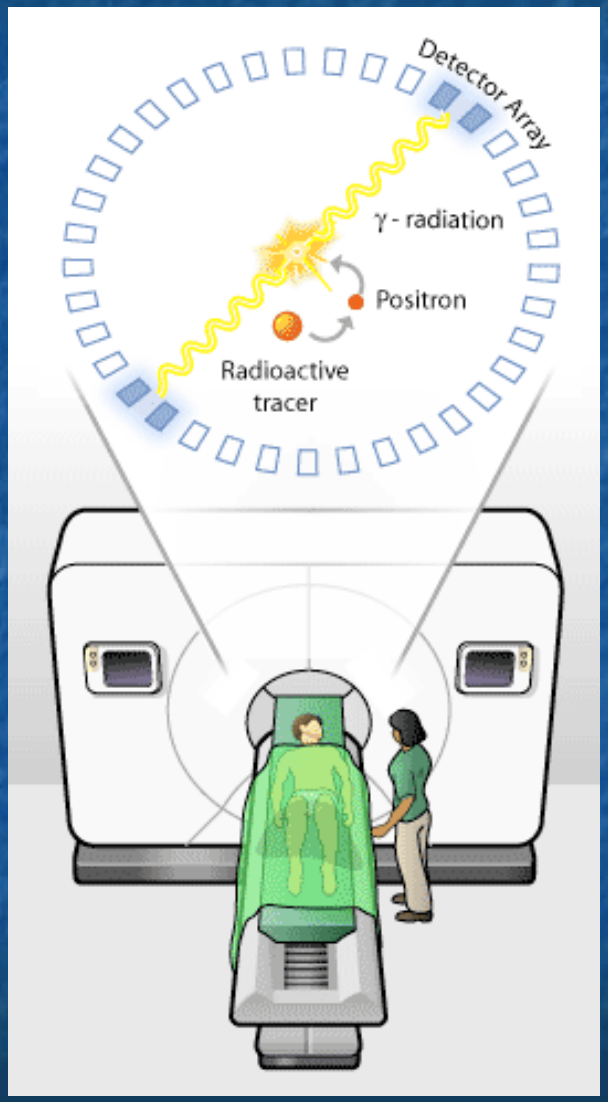
Figure 1. Experimental setup of language dominance assessment by fTCD. Displayed data represent the averaged results from 20 letter presentations in a single subject. Note the delay of approximately 4 to 7 seconds before the maximal hemispheric difference is reached. dV indicates relative CBFV changes.

Doppler sonography

Knecht *et al.* (1998)

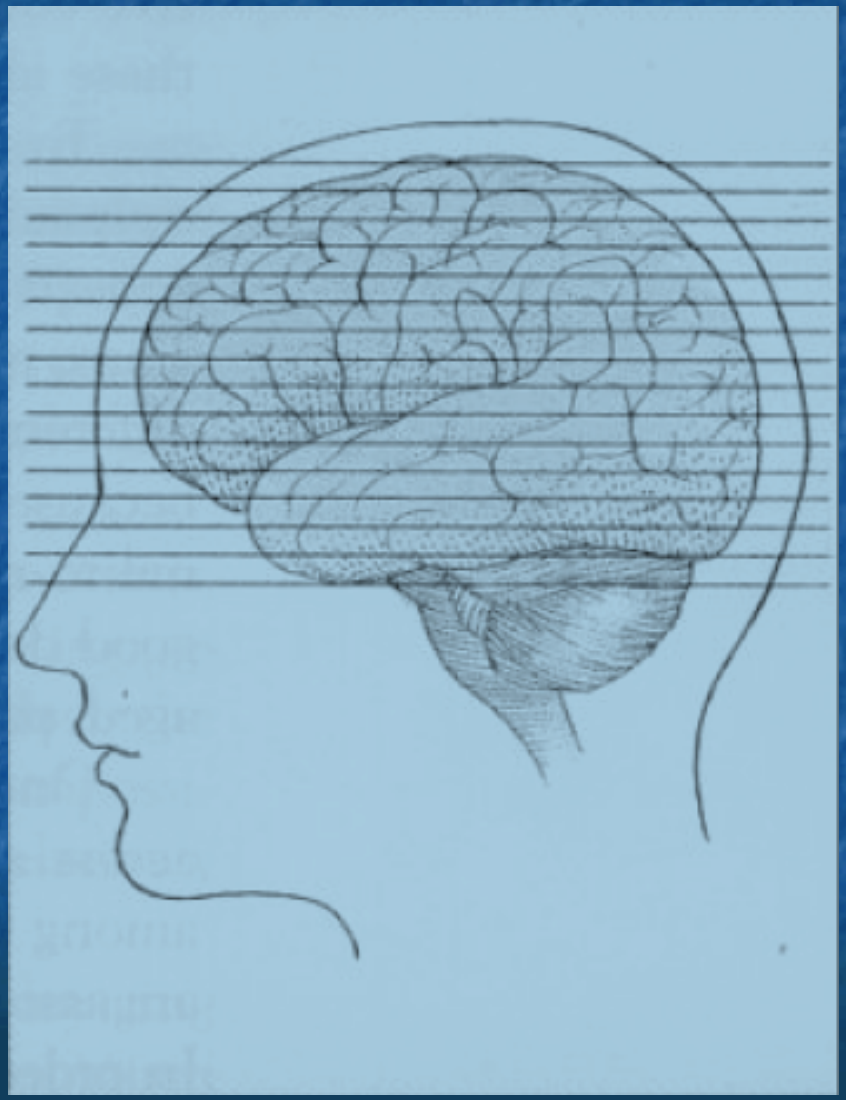


Haemodynamic methods: PET



Radioactive water is injected into the participant and radioactive decay releases pairs of high-energy photons that leave the skull and are monitored

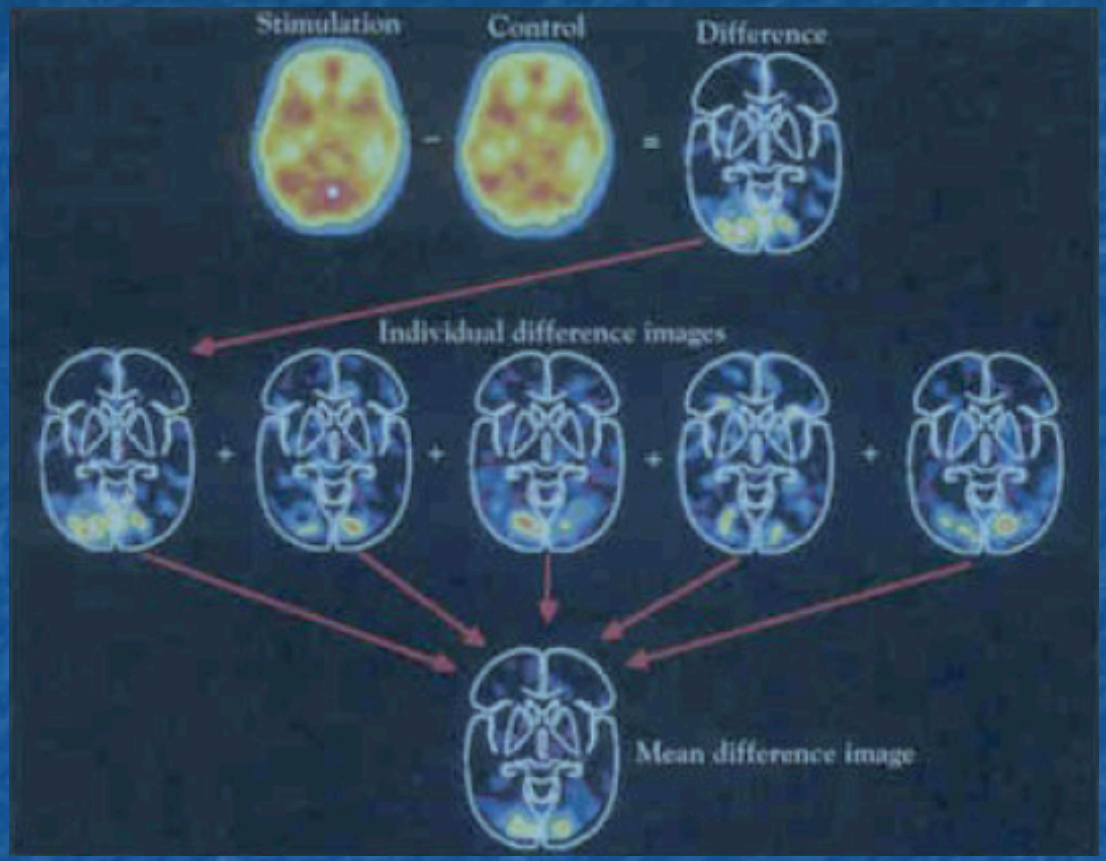
Haemodynamic methods: PET



Parallel slices are imaged

Such methods necessarily produce a partial view

Haemodynamic methods: PET

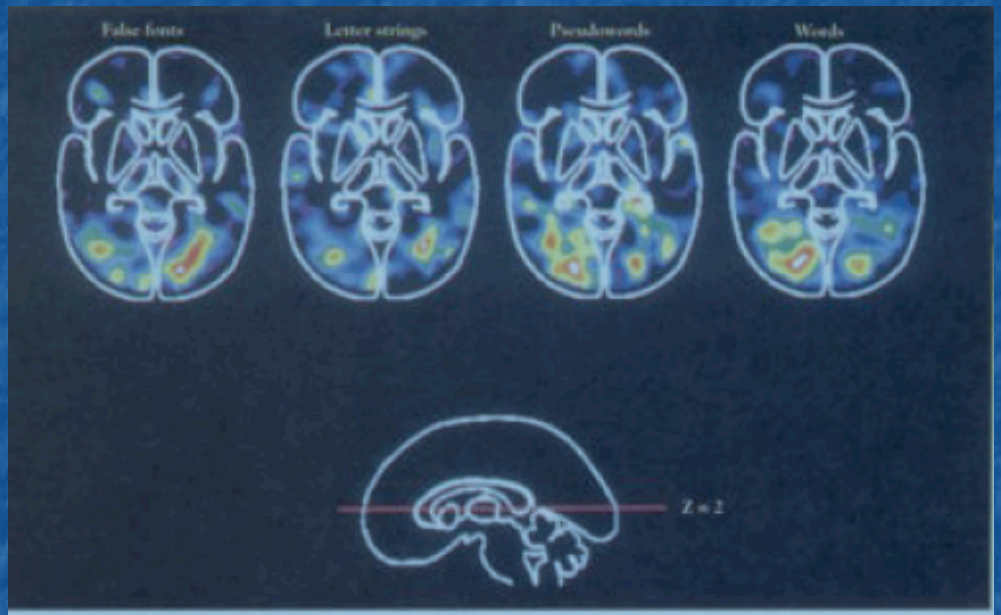


The control condition is subtracted from the experimental condition (*e.g.* low-level vision task *versus* reading.

Data are averaged over several participants.

PET: localization of function

Posner & Raichle (1994)



Example of the Four Types of Visual Stimuli

False Fonts	Letterstrings	Pseudowords	Words
ƎЯƎ	VSFFHT	GEEL	ANT
ꓤ9ꓤЯ	TBBL	IOB	RAZOR
ЯƆ٩Я	TSTFS	RELD	DUST
⊦ꓤ⊃Π	JBTT	BLERCE	FURNACE
ЯЯƎꓤS	STB	CHELDINABE	MOTHER
ƘʎƆЯ	FFPW	ALDOBER	FARM

More LH activity for more word-like stimuli

Haemodynamic methods: PET

The K family — Vargha-Khadem *et al.* (1995)

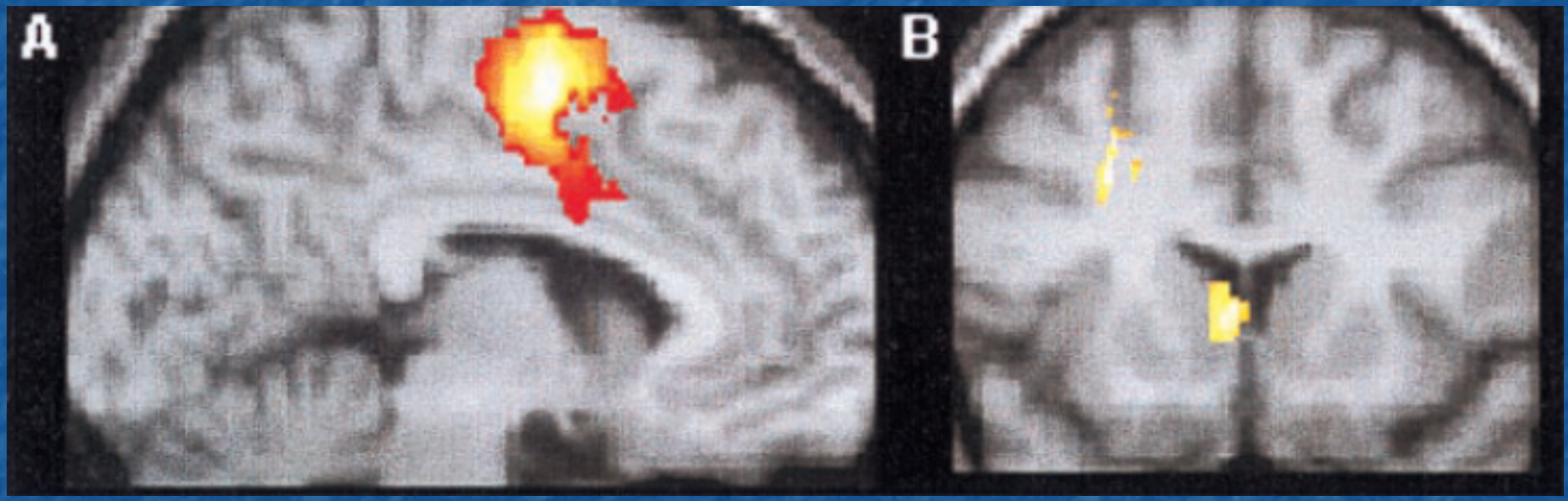


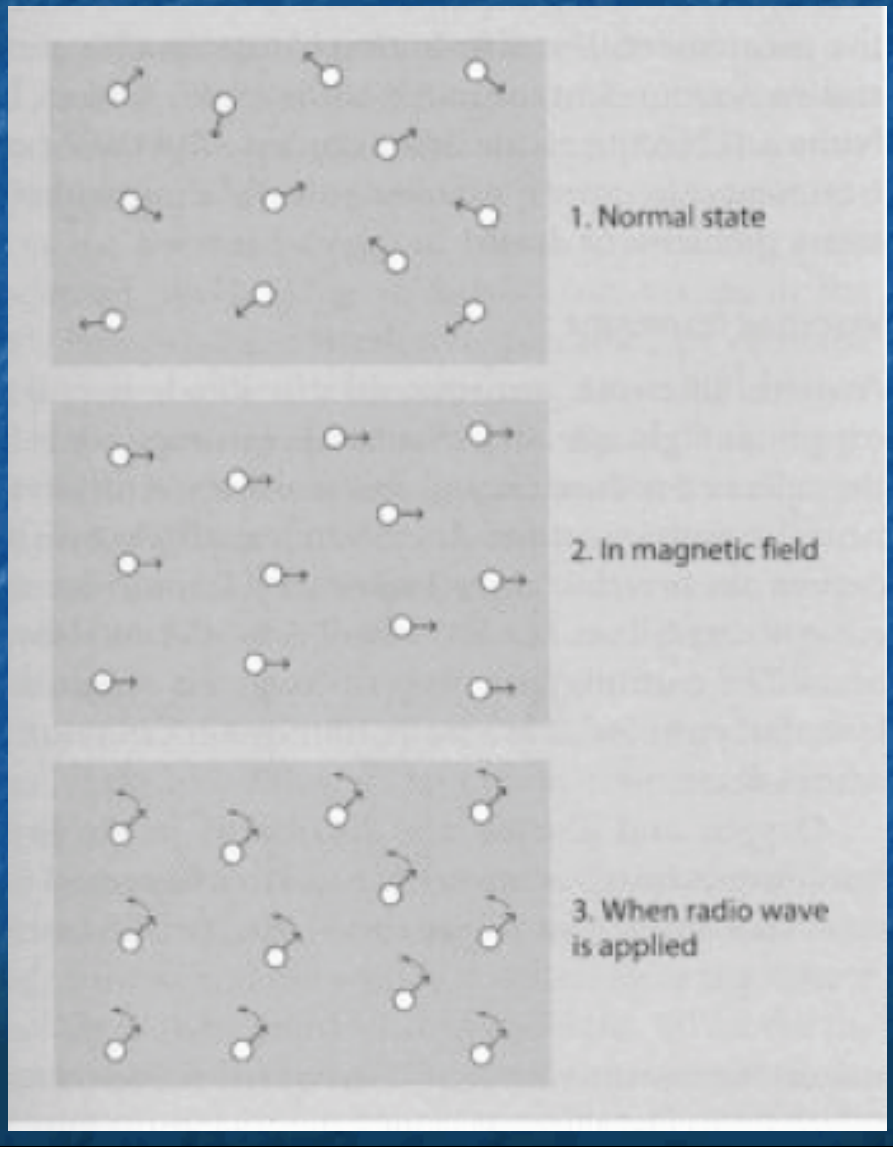
FIG. 3. Results of SPM analysis of PET data (*A* and *B*; see also Table 1) and MRI data (*C*; see also Table 2). (*A*) Parasagittal section through left hemisphere, 6 mm from midline. Colored area, encompassing parts of SMA, preSMA, and cingulate cortices, indicates a region that was less active in the affected family members than in the controls. (*B*) Coronal section, 14 mm in front of the coronal plane through the anterior commissure. Colored areas, located in the head of the left caudate nucleus and left premotor cortex, indicate regions that were more active in the affected family members than in the controls. (*C*) Transverse section, 2 mm above the transverse plane through the anterior and posterior commissures. Colored

Haemodynamic methods: MRI

In magnetic resonance imaging, a powerful magnetic field aligns the protons (mostly relying on the hydrogen in the body).

An electromagnetic pulse then perturbs the alignment and causes photons to be emitted

Haemodynamic methods: MRI



These are monitored by the device

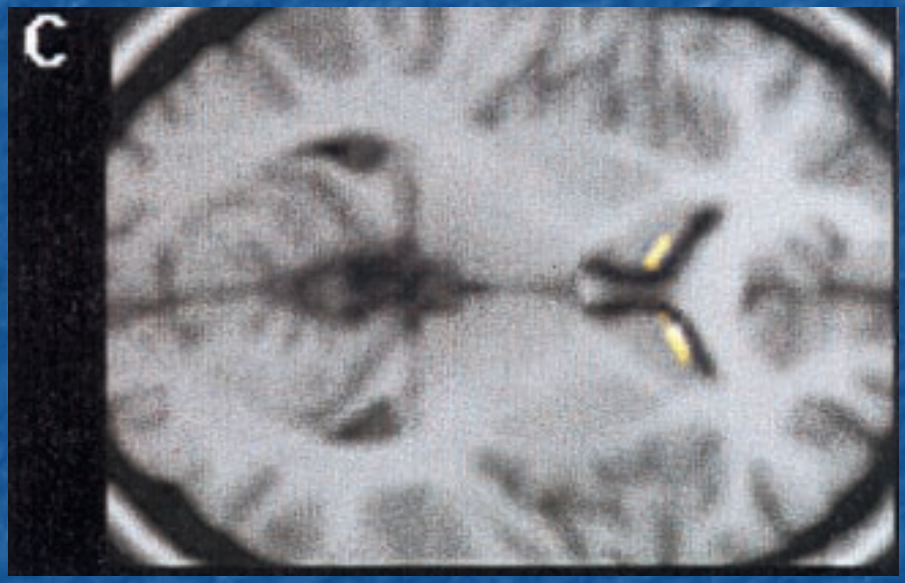
Volumes can be imaged

Changes in blood flow over time reveal function

The blood-oxygen level dependent (BOLD) method reveals oxygen supply

Haemodynamic methods: MRI

Vargha-Khadem *et al.* (1995)



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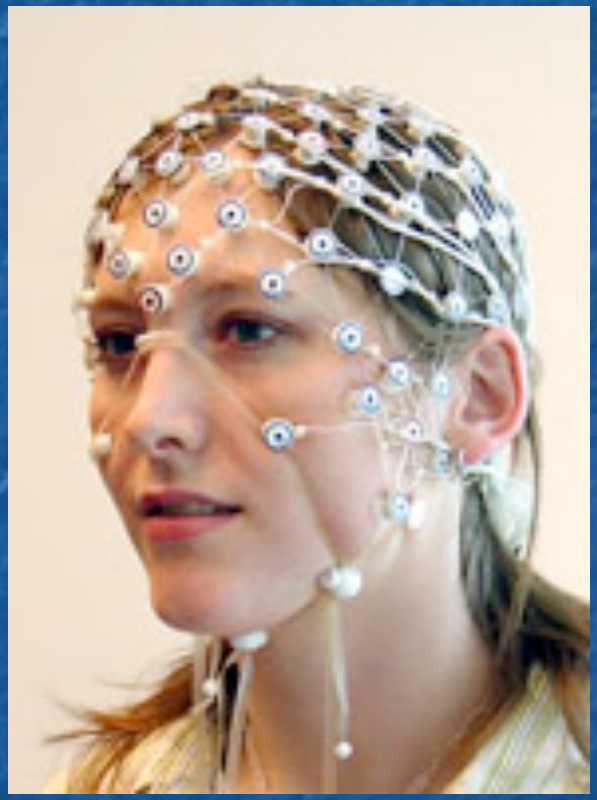
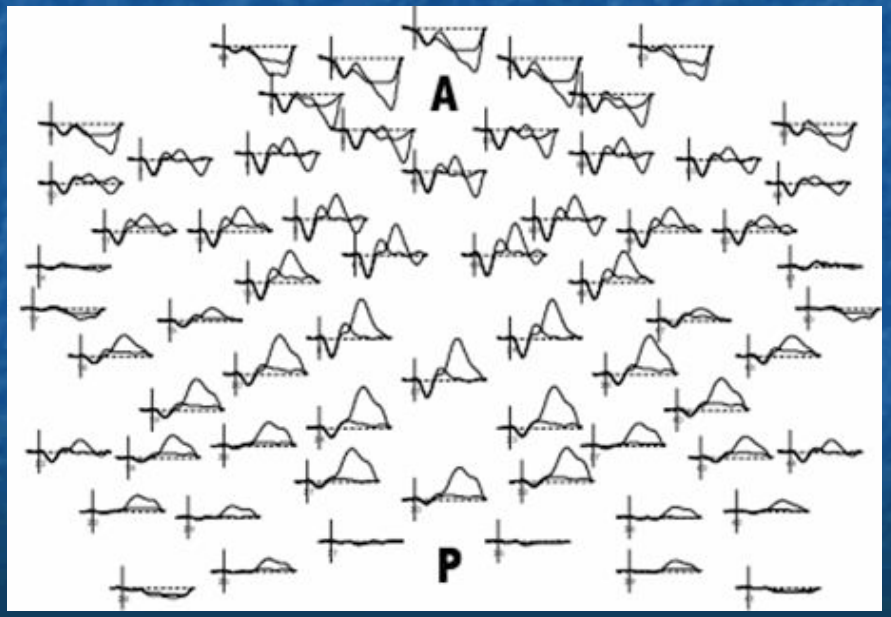
Electrical activity on the scalp : ERP



Neurons produce electrochemical activity.
The sum of their activity is detectable on the scalp.



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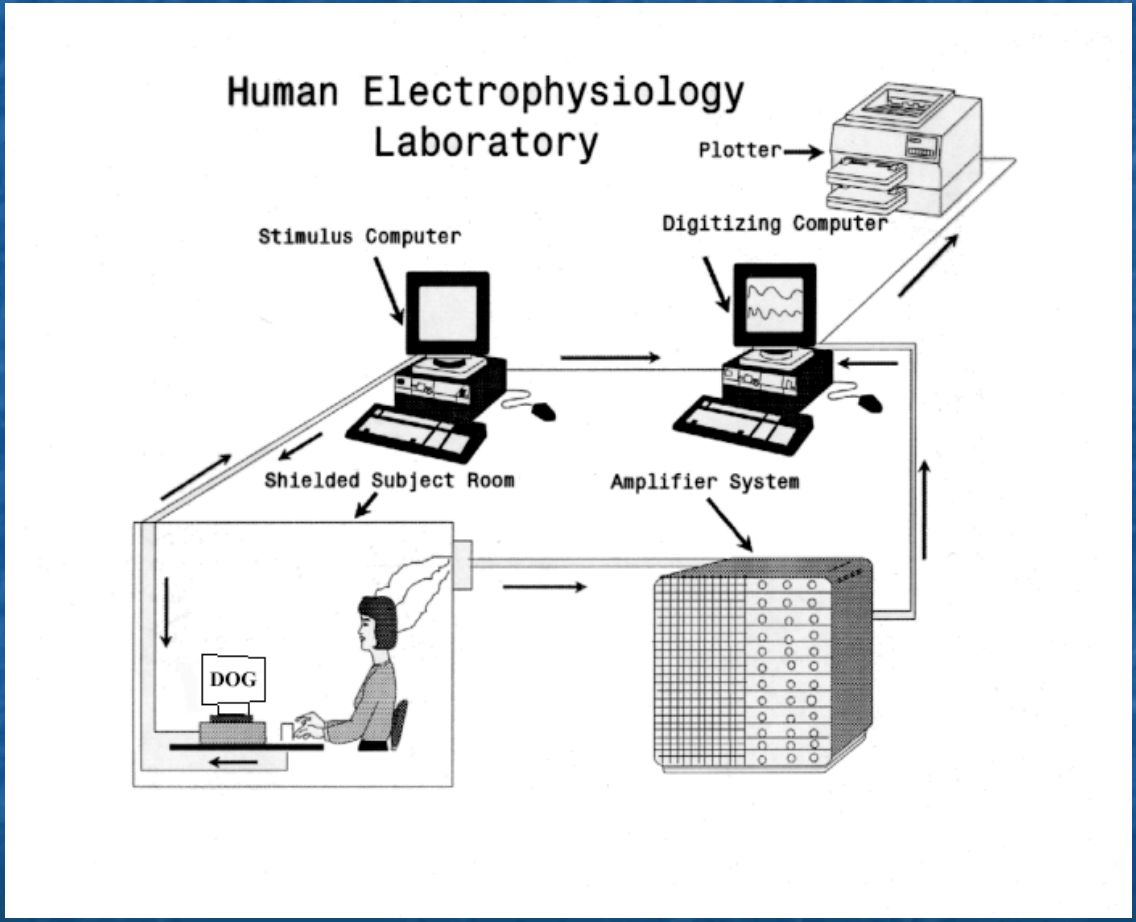
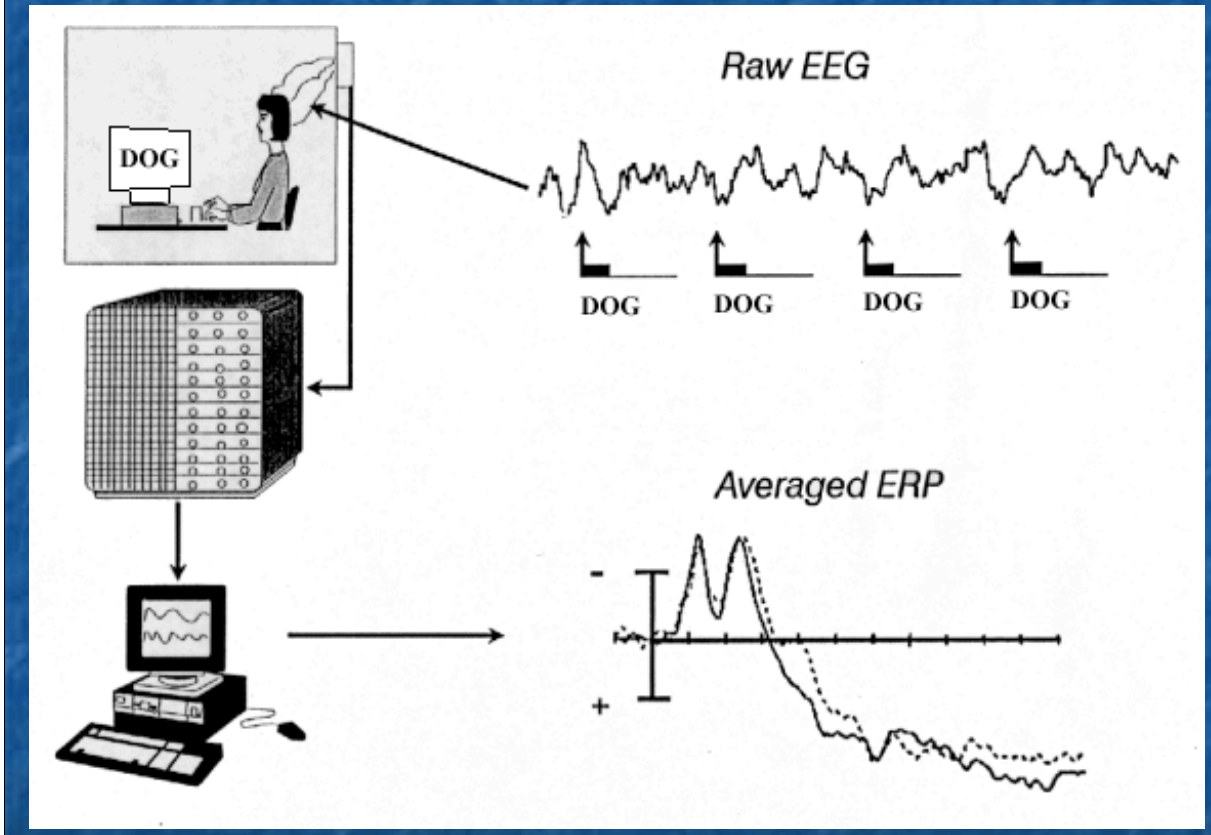


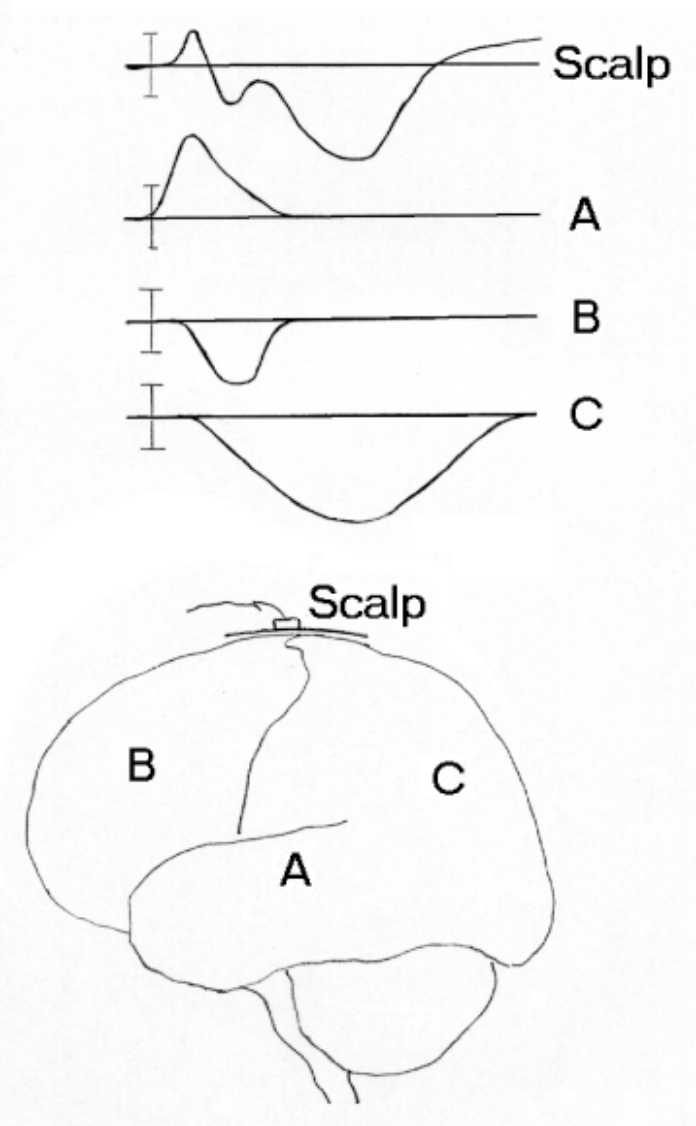
The EEG is the raw activity. There is a relatively small event-related activity (ERP) as the participant responds to stimuli.

Electrical activity on the scalp : ERP



Repeated raw EEG data are averaged to create an averaged ERP

Electrical activity on the scalp : ERP

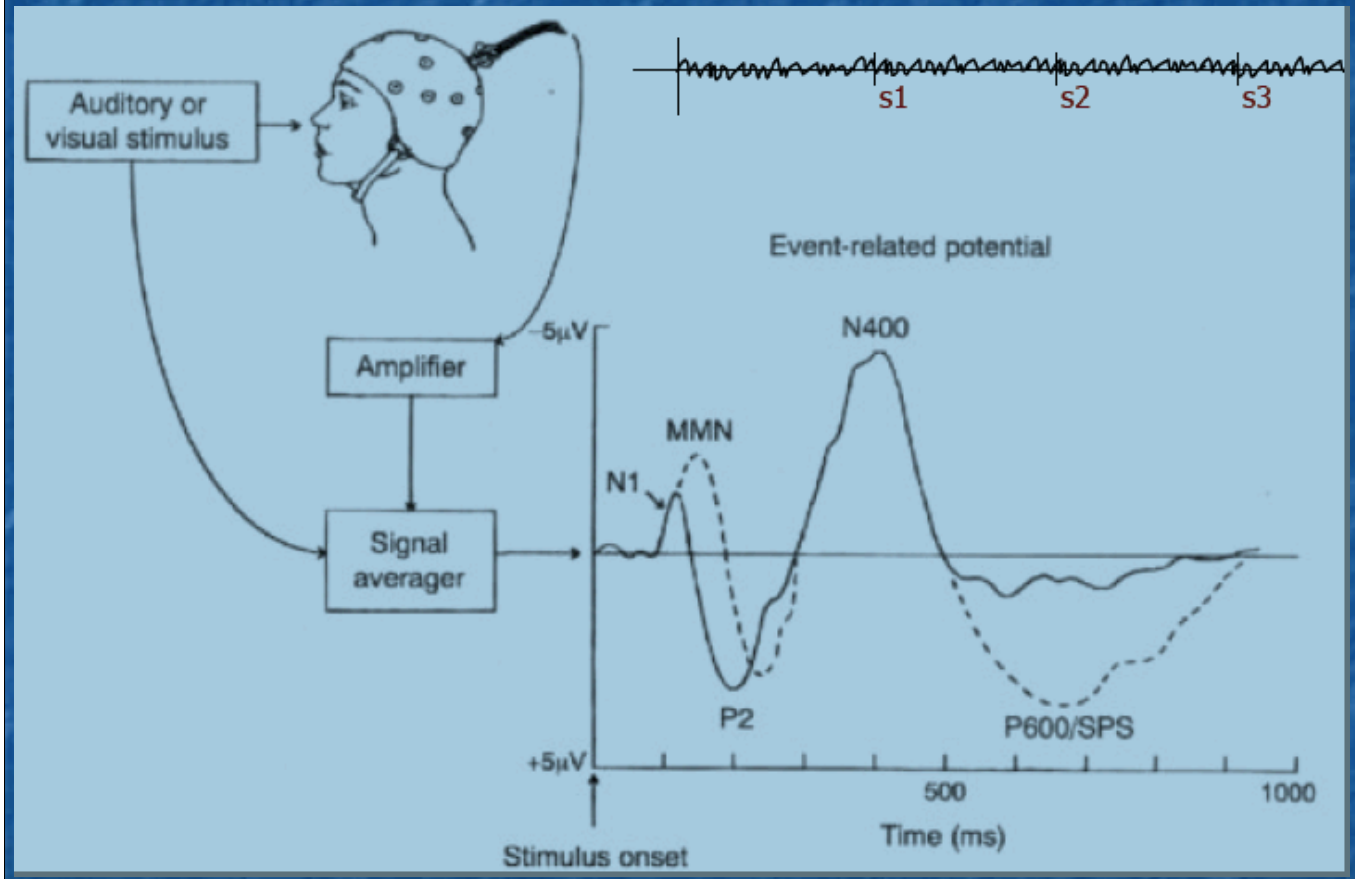


Different generators in different parts of the brain can combine to create the ERP at the scalp.

Nevertheless, location information can be revealed.

Timing is accurate.

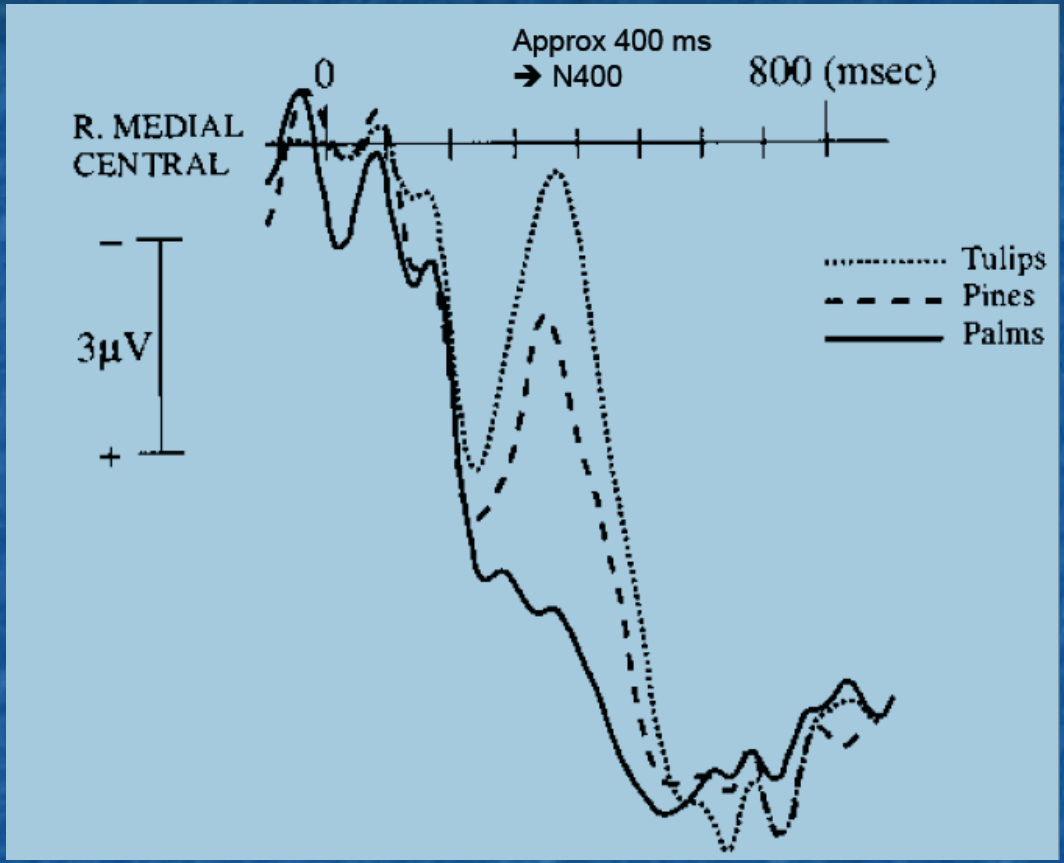
Electrical activity on the scalp : ERP



ERPs are referred to as N (negative) or P (positive).

Numbers indicate order or occurrence after the stimulus.

ERPs and incongruity



Kutas *et al.*(1999)

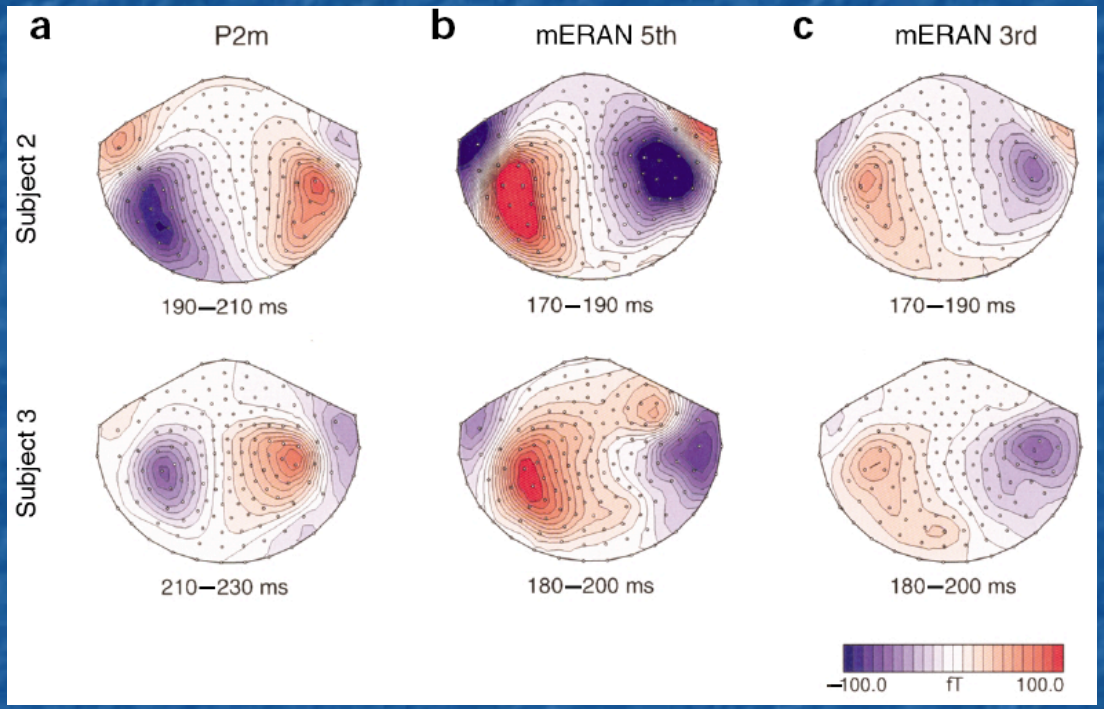
They wanted to make the hotel look like a tropical resort. So along the driveway they planted rows of ...

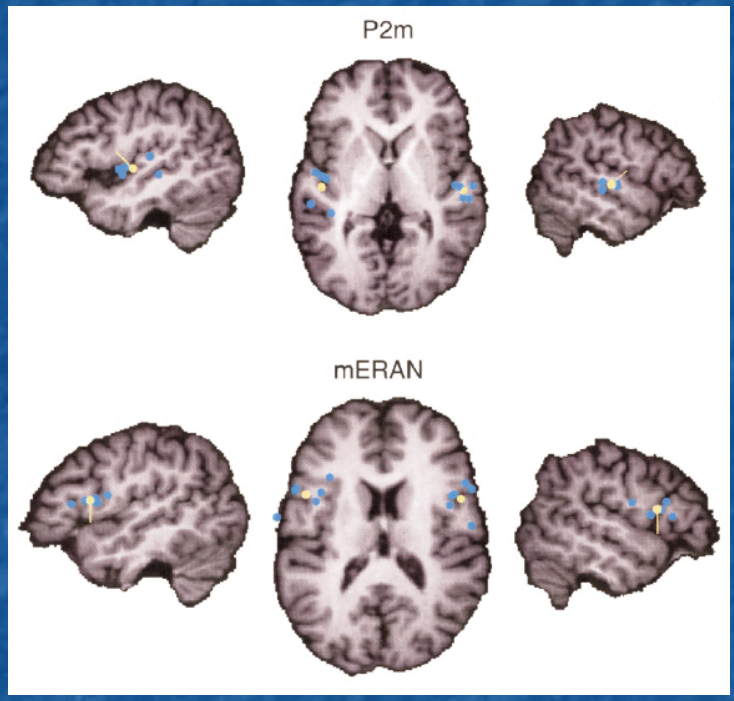
Magneto-encephalography (MEG)

MEG picks up tiny magnetic disturbances outside the skull. It is non-invasive.

Magneto-encephalography (MEG)

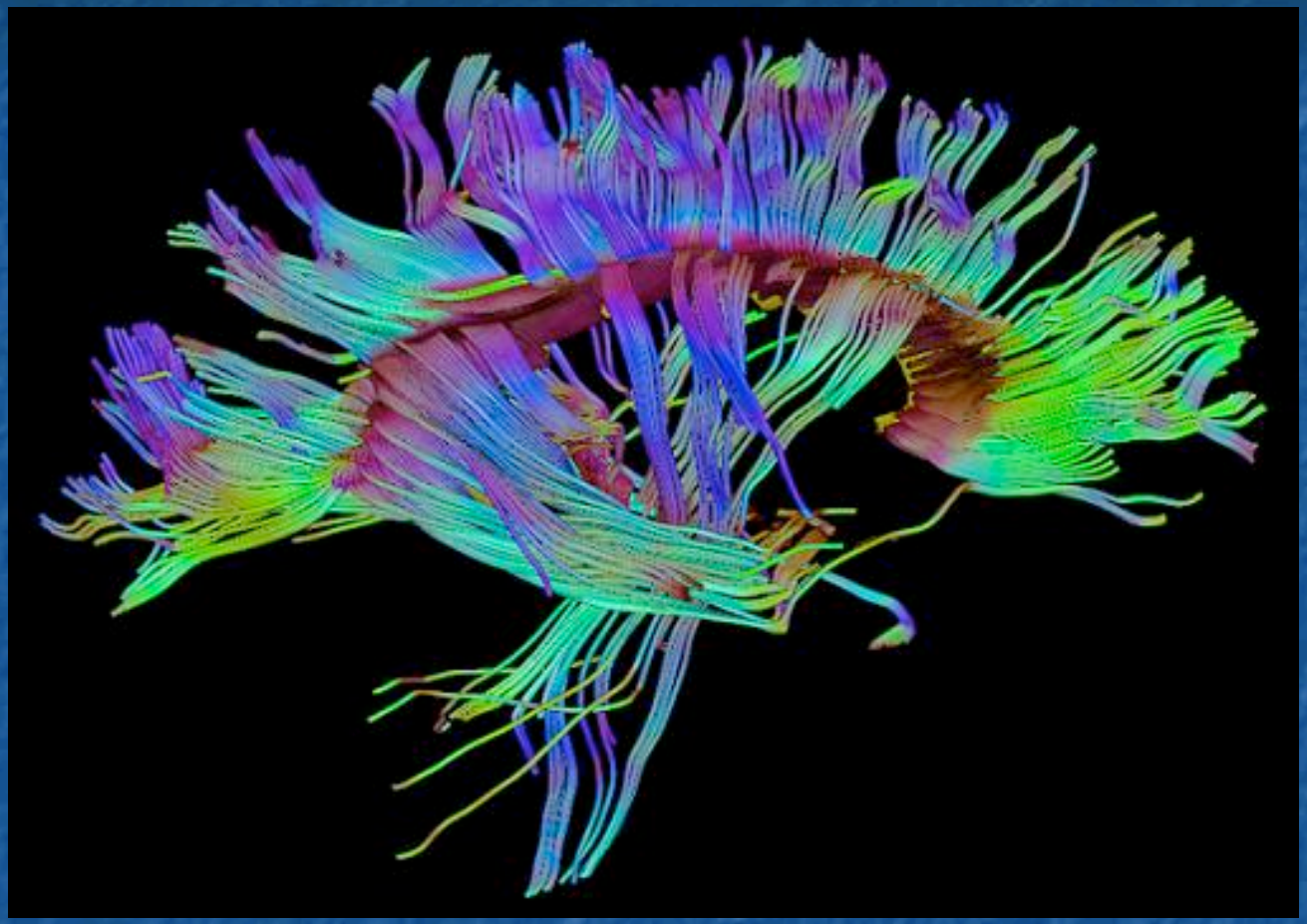
Maess *et al.* (2001)





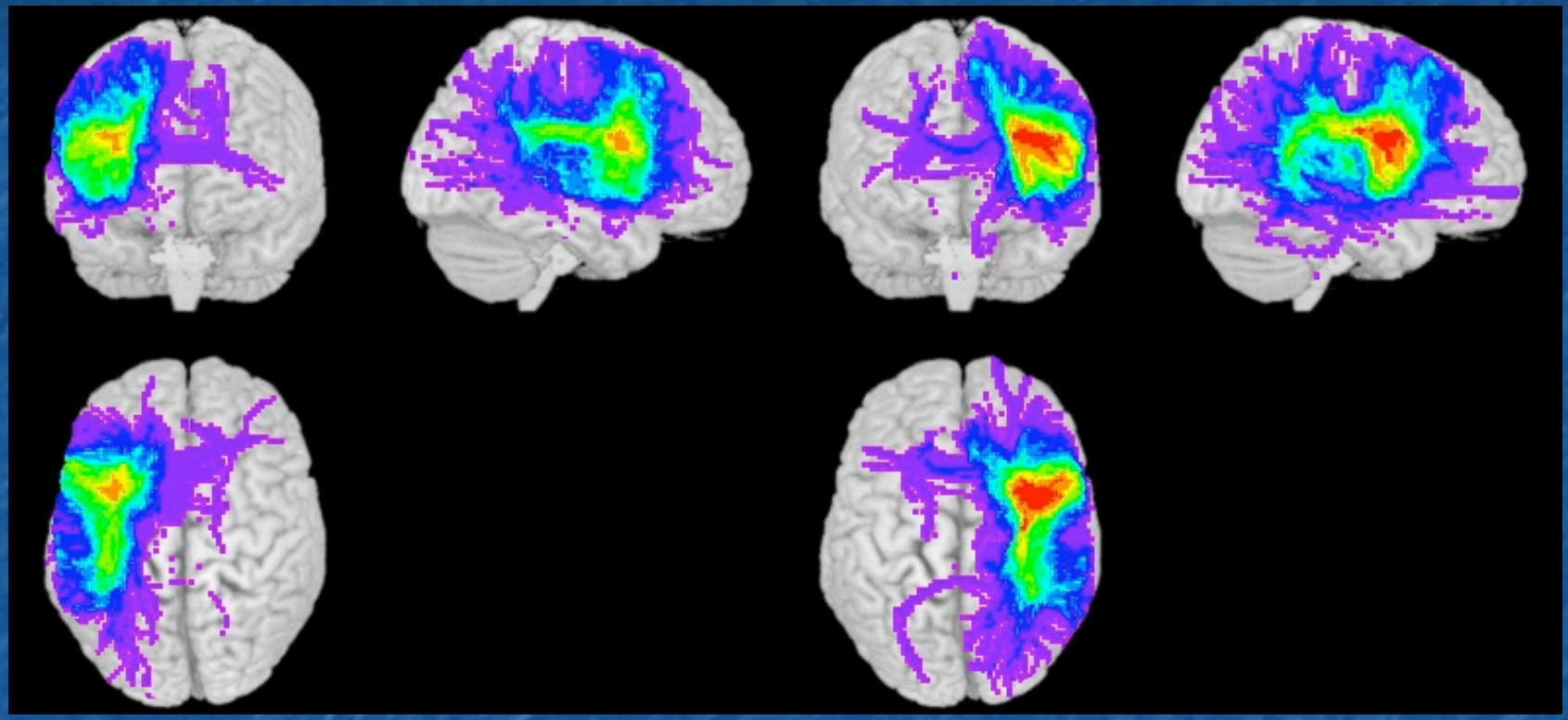
MEG study showing that musical syntax is processed in Broca's area.

Diffusion tensor imaging



Diffusion tensor imaging tracks the paths of fastest diffusion of water molecules in white matter fibres

Diffusion tensor imaging



Diffusion tensor imaging shows that the white matter connections from Broca's area are more extensive in the LH (Powell, *et al.*, 2006)

Transcranial Magnetic Stimulation

TMS disrupts the electrical activity of the superficial cortex, using a powerful magnetic field.

rTMS does this repetitively.

Function can be localized, in conjunction with a behavioural task.

Summary

Neuro-imaging can provide unique and detailed information about language processing.

These techniques are distorting research funding.

“Activity” – or lack of it – needs to be interpreted.

Convergent evidence is typically desirable.