1/2: TMS Transcranial magnetic stimulation

What is TMS?

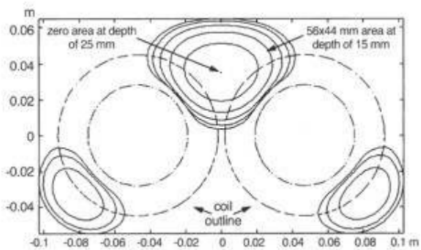
- Transcranial Magnetic Stimulation is a “Noninvasive” technique to create virtual cortical “lesions” (Lesion impared functionality)
- Studies on patients with real lesions have informed cognitive science for a long time as they allow studying what patients can't do anymore
- E.g Phineas Gage (1823-1860), suffered a serious injury by an iron rod piercing his head and frontal cortex. This lead to severe changes in his personality
- Temporary and reversible, localised lesions (at small minimal scale) could allow for better understanding the function of specific brain regions

Why are they not always using patients?

- Removing most parts of his hippocampus, parahippocampal gyrus and amygdala in the famous patient H.M led to severe anterograde amnesia
- In the same way, lesions in Broca and Wernicke areas have been linked to impairments of speech production and language comprehension, respectively
- However, there might not be enough patients with circumscribed lesions to study all cognitive functions
- Lesions in single, specialised areas are rare
- Recovery and brain plasticity might compensate for lesions over time → patients might become quite “special” overtime\

How is TMS done?

- TMS can be applied externally, using a coil placed on the scalp that produces a rapidly changing magnetic field to induce electrical currents in the brain.
- These currents can depolarise neurons to fire randomly. Acting as “neural noise”, thereby masking the neurons that are firing correctly
- Fritsch & Hitzig (1870) were the first to electrically stimulate the cortex of animals
- D’Arsonval (1896) discovered that's the magnetic stimulation of the visual cortex can elicit “phosphenes”
- Magnusson & Stevens (1911) developed the first “head coil” covering the entire head



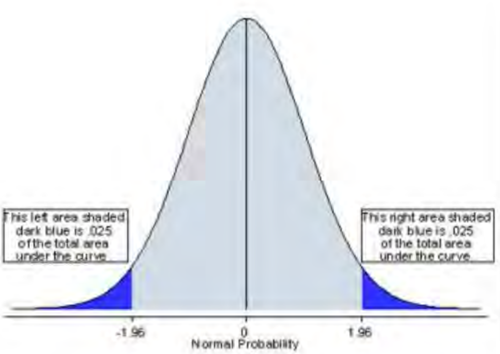
How TMS is used at present

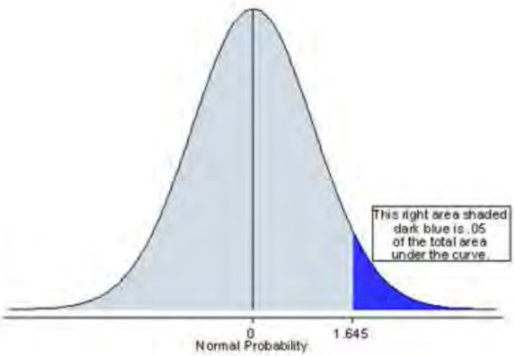
- Barker, Jalinous and Freestone (1985) developed the current TMS technique, which had the great advantage of not being painful
- In order to create the current pulse, which is required to generate the magnetic field, a capacitor is charged and then suddenly discharged.
- This process can be modified such that it creates a fast sequence of pulses instead of a single pulse (Repetitive TMS or rTMS)
- In order to create a magnetic field strong enough for stimulation, very fast loading times (~100-200 µs) and short discharge durations (< 1ms) are required

- In our one tailed *t*-test example this would be something like:
  H_1 = our sample is drawn from a population $\mu > 10$ OR $\mu < 10$
- In words that might sound like:
  - It was hypothesised that there would be a significance difference in MEPs between performing a mental imagery task and at a baseline
  - Of course this does not really make sense for this experiment, but there are other experimental questions where you would use a non directional hypothesis

Directional hypothesis

- For a directional hypothesis, we would use a one-tailed test (this is what we had in our original example):
  H_1 = Our sample is drawn from a population $\mu > 10$
- In words this would look like:
- It was hypothesised that MEPs would be significantly higher when performing a mental imagery task, compared to baseline.
- Of course it does not make sense to hypothesise the reverse in our example experiment, but there are other experiments where you may also be interested in a lower difference



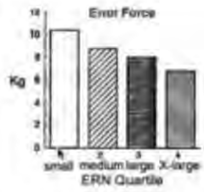
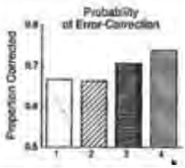
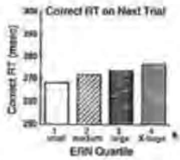


For a **non directional** hypothesis we would use a **two tailed test**	For a **directional hypothesis** we would use a **one tail test**

Caution of one tailed test!

- It may be tempting to always want to use a directional hypothesis: you have an idea of how things will turn out and more area under the curve means more power to detect an effect, right?
- It is important to first evaluate whether, theoretically, an effect in the other direction would be likely/ important!
- If in doubt, use a two-tailed test!
- Moreover, if missing an effect in the opposite direction would be in any way negligible/unethical/irresponsible you should not use a one-tailed test
  - Returning to our psychological treatment example, it is also important to know whether our treatment is significantly LESS effective than the industry standard, not just significantly more effective

- The ERNs from the entire experiment can be divided into quartiles from “small” to “extra large” (X-large)
- They then investigated how ERNs of different sizes were related to response parameters, which might in turn be related to correcting or avoiding errors

	- The **greater the ERN, the lower the response forces** - → trying to correct for the error
	- The **greater the ERN, the higher the probability to get it right on the next trial** - → successful learning from errors
	- The **greater the ERN, the slower the response on the next trial** - → successful learning from errors

7: fMRI Functional Magnetic resonance imaging: Methods

Why would we want to use fMRI as psychologists?

- To **draw conclusions about cognitive processes from the presence of activation**
- We usually want to know something about cognitive processes, and we know cognition “happens” in the brain.
- One method to scan the brain was positron emission tomography (PET), which involves administering a radioactive isotope to the patient (e.g. oxygen-15). Thereby exposing the patient to a significant amount ionizing radiation
- fMRI is now far more commonly used than PET as it does not involve radiation

Scanners, head coils and magnetic fields

- 1.5 - 9 Tesla magnetic field (usually 3T for most functional imaging)
- Earth magnetic field: 65 microtesla
- Participant is place on the bed and moved into the magnet
- Experiments can be controlled from outside the scanner room
- No metal is to be taken into the scanner

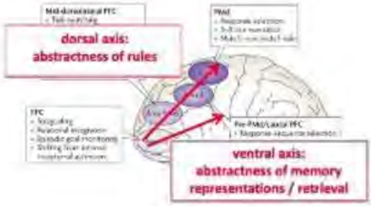
- Participants can see a projection (usually computer controlled experiment) via mirror mounted on the head coil
- Responses can be given via scanner-compatible keys, joystick, or a touchpad
- The head coil is used to send radio frequency pulses and also functions as a receiver
- Head position is fixed to avoid any movement

Interpretation of fMRI data

→ From BOLD fMRI to understanding cognitive functions

- The previous experiments highlight a big issue: when we interpret fMRI results, we are confronted with the problem of *reverse inference*
- As psychologists we (usually) do not want to understand where cognitive functions are located , but we want to understand the *mental architecture* underlying these functions
- We want to use neuroimaging as another *tool to gather evidence* for the engagement of mental / cognitive processes in a particular task
- However -- is that *valid* ?

- We usually apply the following logic:
    - 1. In this study when task **A** , then brain region **Z** is active
    - 2. In other studies, when cognitive process **X** , brain region **Z** is active
    - 3. Thus, in this study activity in **Z** → engagement of cognitive process **X**



One problem is that (2.) is *not exclusive:* brain region **Z** may be active for many tasks

- For example, the regions in the prefrontal cortex are notoriously difficult to "understand"
- Some researchers have concluded from looking at results from many studies that more anterior regions (Towards the front of the brain) represent more abstract information, and more posterior regions (towards the back) represent more specific content

- Others concluded that most regions in the frontal cortex can actually be found to be activated in many different tasks
- **Duncan (2001; 2010; 2013)** argued that the frontal cortex shows *relative* , but not absolute specialisation
- This means, prefrontal regions might just be recruited "more strong" if the task at hand becomes more difficult
- This according to Duncan, is true for other regions as well
    - **The "multi-demand" network:** remembering word/non-word strings, arithmetic, spatial working memory, verbal memory and three version of resisting response conflict
- **The problem now is that, if we find activation in a region which is part of this "multiple-demand" network, we still don't really know what the region is doing..**

If brain region is activated by many cognitive functions, we learn very little from observing activation in those areas

"If the experimental setup fails to manipulate the cognitive process of interest, it cannot provide useful information about that process"

The second problem is that we need to know how suitable task A is for understanding cognitive process X

If the tasks measure more than one cognitive function, we also don't learn much!

- **Poldrack (2006)** expressed these problems with reverse inference in probabilistic terms. The probability that we really learn from our fMRI results that cognitive process X is involved depends on:
    - The *quality of the task* to measure the cognitive process
    - The *specificity of the region* for this cognitive process

Another problem is the overinterpretation of null results

- What does it mean if you find that *no region* was significantly stronger activated from task A vs.