PSYC 10004-6 – FOUNDATIONS OF PSYCHOLOGY
Introduction to Cognitive Psychology

Lecture 2 – Methods in Cognitive Science

Prof Markus Damian

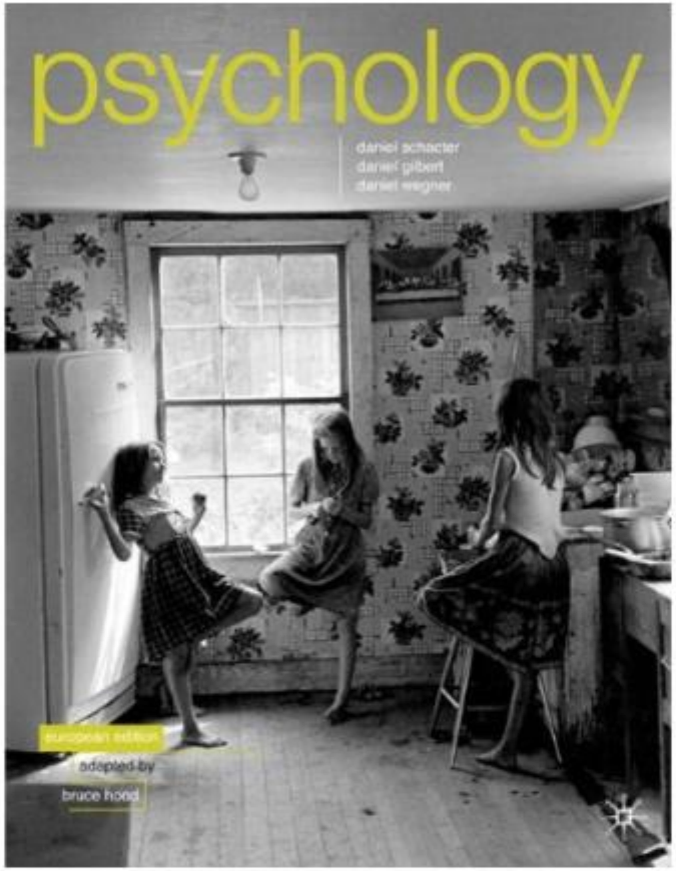
University of BRISTOL

Aims of this lecture

- How to study the brain/mind?
  - acquired brain damage
  - experimental studies
  - neuroimaging

Additional recommended reading – not required:

- Schacter, Gilbert, Wegner & Hood (2012), Psychology. Palgrave Macmillan. European Edition.
  - Chapter 2 (“The methods of psychology“)



How are mind and brain related?

- Western thought strongly influenced by “dualism” – mind and body occupy two entirely different spheres, one cannot be reduced to the other
- If so, mental phenomena may be forever outside the realm of natural sciences
- By contrast, modern science holds a strongly naturalistic view, according to which “the mind is what the brain does”

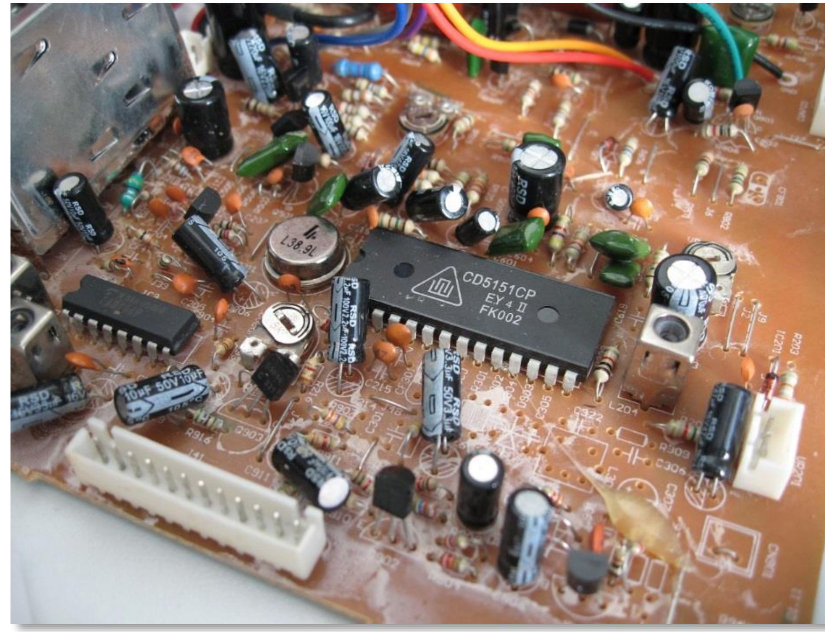
Rene Descartes
(1596-1650)

How are mind and brain related?

- What looks like something fundamentally different “from the inside” (your thoughts, beliefs, desires, emotions, etc.) is really just the functioning of an extremely complex biological system created by evolutionary history
- Is this true? Is consciousness really just neural activity? Is the mind completely created by the brain? Etc.
- In any case, mind and brain are evidently very closely related…

How does the brain function?

- like an (old-fashioned) TV set, with lots of “discrete components”?
- probably not – if you remove a random single component, the TV just stops working altogether
- (typically) not the case for brains – many individuals with severe brain damage in one area are (relatively) unimpaired in many, or most, others



How does the brain function?

- entirely “holistically” - all areas of the brain participate in every mental activity (e.g., Flourens’ “aggregate field theory”)?
- if so, damage to a particular proportion of the brain would result in corresponding mental impairment *across all cognitive domains* (reasoning, language, memory, motor skills)
- clearly wrong: many case studies show fairly selective deficits in one particular area, but preserved abilities in others

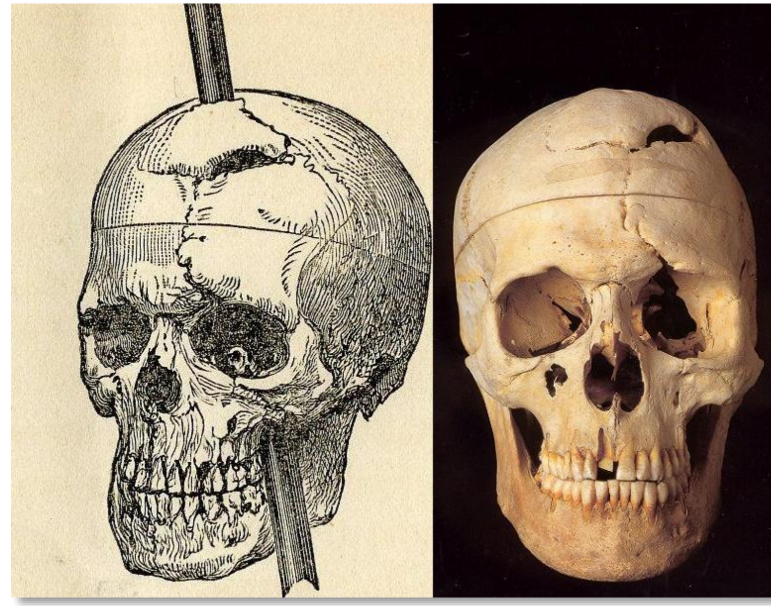
Jean Pierre Flourens
(1794-1867)

How does the brain function?

- neither completely “discrete”, nor entirely “holistic”
- specific areas of the brain support corresponding mental functions (e.g., vision: occipital cortex; executive control: frontal cortex, etc.) even though most mental activities involve much of the brain
- “graceful degradation” – system is protected against total wreckage
- this makes it instructive to look at cases of acquired brain damage…

How do brains get damaged? Lots of reasons…

- trauma/injuries
- gunshot wounds
- tumours
- encephalitis
- neurosurgery (!)
- cardiovascular accidents (strokes)
- dementia…
- “ablation” in animal research



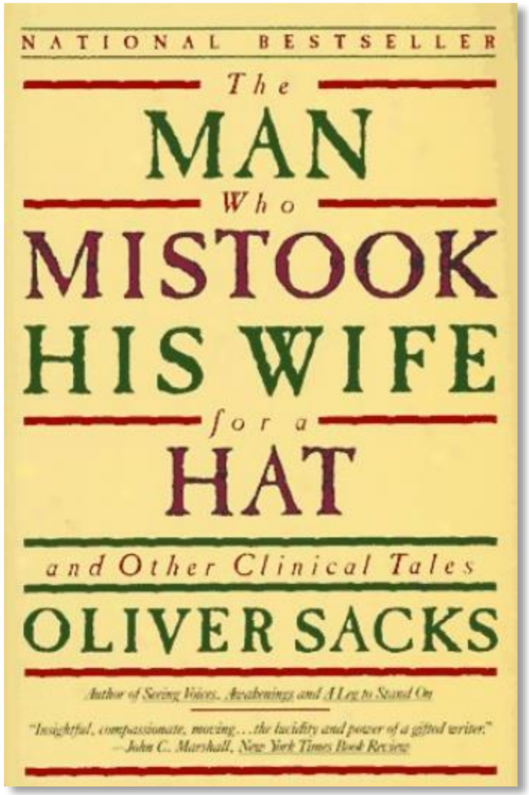
Phineas Gage
(1823-1860)

Selectivity of impairment

- The more *selective* a cognitive impairment (i.e., the more specifically a particular cognitive domain can be identified which is impaired while others are spared) the more instructive the case is for cognitive science

Neuropsychological impairments (random selection)

- *Aphasia* – specific language impairment (in the absence of intellectual impairment)
- *Visual agnosia* – loss of ability to recognise objects (despite vision being intact)
- *Prosopagnosia* – inability to recognise faces (but objects can be recognised)
- *Amusia* – deficit in musical pitch processing, music memory and recognition (but auditory system is intact)



Single vs double dissociations

- In all cases, suggests that the brain implements neural systems which specialise in a particular mental function
- Documenting patients suffering from deficit X, whereas most (or all) other cognitive functions are spared, suggests that <u>specialised</u> brain areas support music processing ("*single dissociation*")
  - E.g., patient suffering from amusia, but not from aphasia (musical abilities are selectively impaired; language is spared; Peretz, 1993)
- Even stronger evidence is generated if complementary cases can be found
  - E.g., aphasia without amusia (language difficulties, but entirely intact musical abilities; Tzortzis et al., 2000)
- If *double dissociation* can be demonstrated, we can strongly infer that the two mental domains are carried out in different underlying brain systems

Psychological scales

- Strictly speaking, it is scientifically problematic to "measure" mental states, but we can certainly measure individuals' self-report, e.g., in "scales"

Dimension	High scorers are ...	Low scorers are ...
Extroversion	Outgoing, enthusiastic and active; you seek novelty and excitement.	Aloof, quiet and independent; you are cautious and enjoy time alone.
Neuroticism	Prone to stress, worry and negative emotions.	Emotionally stable but can take unnecessary risks.
Conscientiousness	Organised, self-directed and successful, but controlling.	Spontaneous, careless, can be prone to addiction.
Agreeableness	Trusting, empathetic and compliant, you are slow to anger.	Uncooperative and hostile, find it hard to empathise with others.
Openness	Creative, imaginative, eccentric and open to new experiences.	Practical, conventional, sceptical and rational.

	Very unlikely	Moderately unlikely	Neither likely or unlikely	Moderately likely	Very likely	Score
1 Start a conversation with a stranger						
2 Make sure others are comfortable and happy						
3 Use difficult words						
4 Prepare for things in advance						
5 Feel blue or depressed						
6 Plan parties or social events						
7 Insult people						
8 Think about philosophical or social questions						
9 Let things get into a mess						
10 Feel stressed or worried						

Experimental studies

- Is it possible to scientifically measure mental states?
- From Wikipedia: "An experiment is an orderly procedure carried out with the goal *of verifying, refuting, or establishing* the *validity of a hypothesis*. Controlled experiments provide insight into *cause-and-effect* by demonstrating what outcome occurs when a particular *factor* is *manipulated*."
- Physics, chemistry, biology, pharmacology, etc.

E.g., does a new cancer drug work?

- assign participants randomly to either a “treatment” group (which receives the drug) or a “control” group (which receives a placebo)
- as much as possible is held constant (e.g., the pill-taking procedure) whereas the rest is randomised (e.g., assignment of individuals to either treatment or control group)
- after a particular time period, quantitatively measure success rate (perhaps some mortality statistic), typically via “inferential statistics” (more on this later)
- if results show that drug works better than placebo, accept the hypothesis that the outcome is not due to chance (or at least, consider further studies)

Psychological experiments

- Does a similar method work in psychology?
- Yes! Strictly speaking, it is scientifically problematic to “measure” mental states, but we can certainly measure overt behaviour

A sample experiment

- Individuals have permanent knowledge about all the words in their native language (“mental lexicon”)
- But – words differ in their frequency of occurrence: some occur very often whereas others are rarely encountered:

A sample experiment

- is the "mental lexicon" organised according to frequency? Wouldn't be implausible…
- if so, is processing time in a task which requires word processing affected by frequency of occurrence?
- can be tested in an experimental task, such as the "lexical decision task"
  - H_1: speed of lexical decisions is affected by frequency
  - H_0: speed is not affected – all words are created equal

A sample experiment

- we choose the lexical decision task: on a computer, individuals are presented with a series of letter strings
- on each “trial” (individual instance) the letter string is either

a *word*

TABLE

or a *non-word*

BOARP

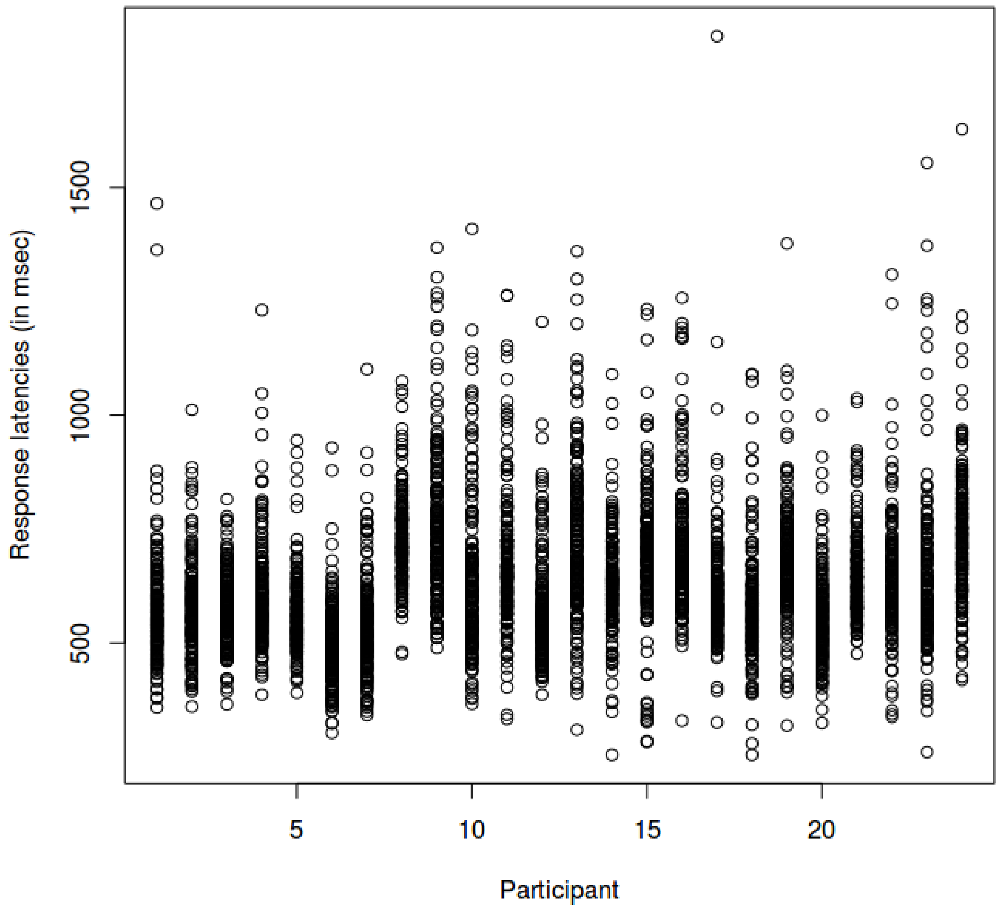
- words and nonwords are randomly intermixed
- participants press one key if they think it’s a word, and another key if it’s a nonword
- reaction times on each trial (time period from presentation of letter string, to response) are measured by specialised software, to the nearest millisecond (1/1000 of a second)

A sample experiment – we need…

- *words* – select 100 words low in frequency (less than 10 occurrences per 1 million of printed text) and 100 words high in frequency (more than 100 occurrences per 1 million of printed words)
- matching number of *nonwords* – take existing words, chance one or more letters around ("board" -> "boarp")
- "frequency" (high or low) represents *the factor which is being manipulated* in our experiment
- software which randomly mixes words and nonwords, and accurately measures response latencies
- decent number of participants – say, N = 24

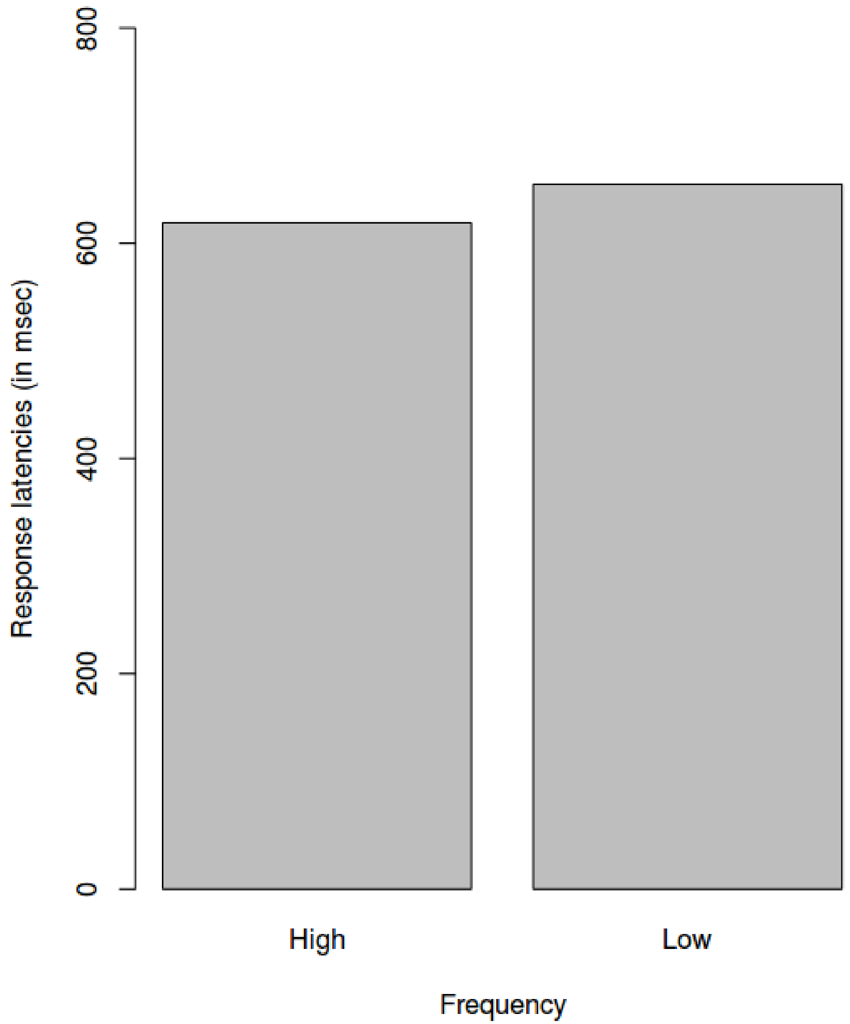
Results

- Human performance tends to be *noisy*!



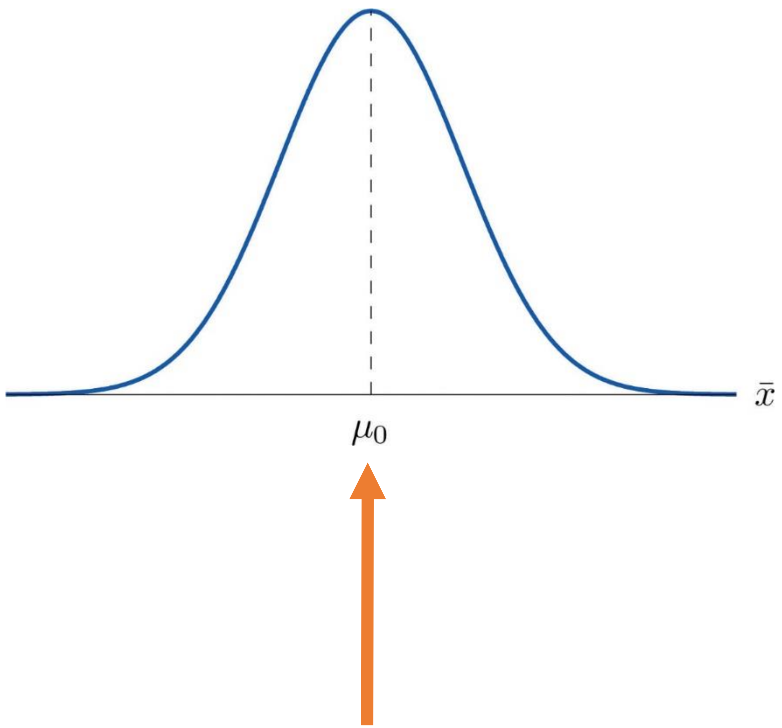
Averaging

- averaging gets rid of most of the noise
- in this experiment, average latencies in the “high frequency” condition are 36 msec faster than in the “low frequency condition – seems to go in the right direction…
- To obtain these results, we averaged across numerous words, as well as across participants
- Is this interesting/relevant/important? Could it be just random fluctuation?



Inferential Statistics

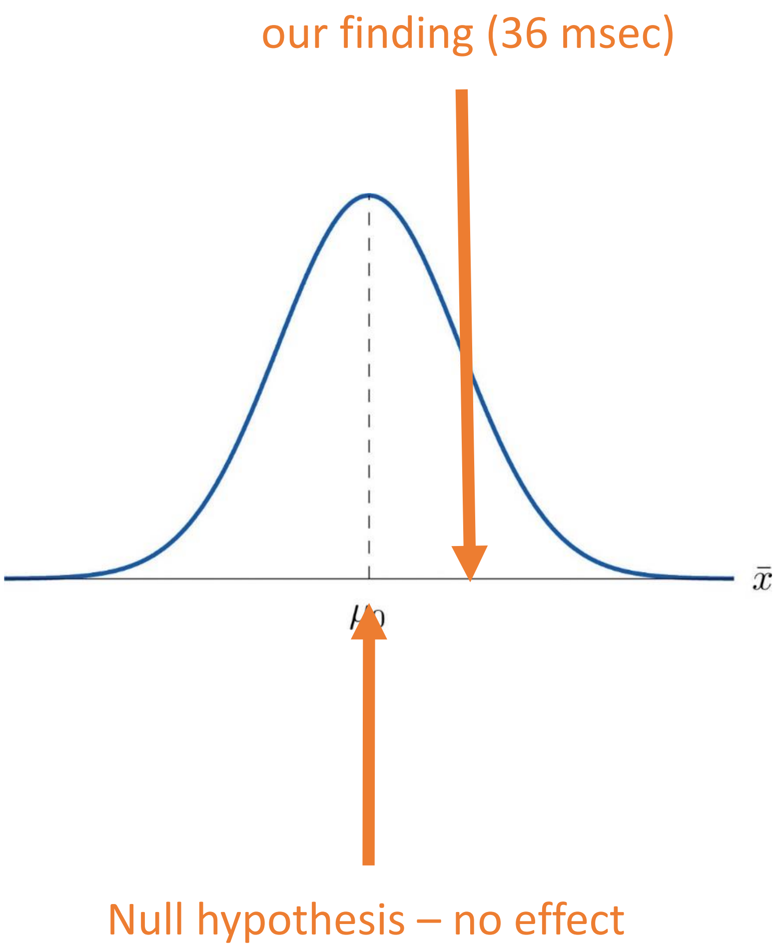
- "Null Hypothesis Significance Testing" (NHST)
- remember: null hypothesis (H_0) states that there is <u>no</u> effect
- assuming for the time being that the null hypothesis is true (i.e., there is really no effect), doing the same experiment over and over again would result in a distribution of results which centre around zero



Null hypothesis – no effect

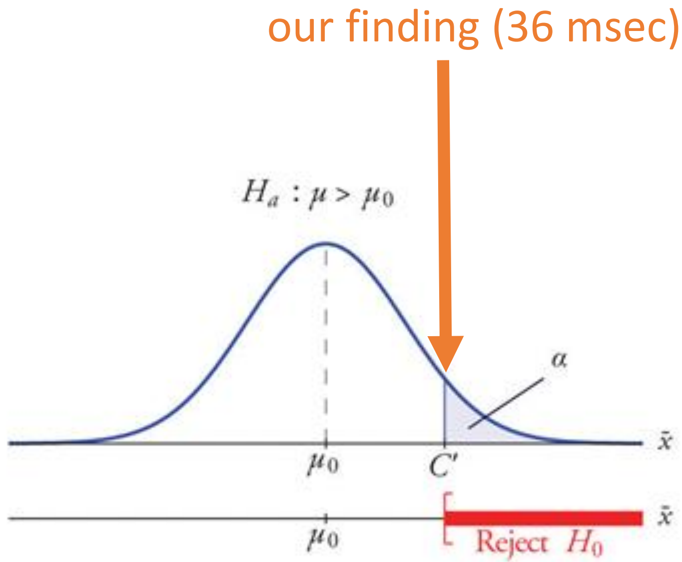
Testing the null hypothesis

- but, we cannot run multiple replications of one and the same study – it's costly!
- so, given a particular finding in our study, what is the *likelihood of that finding under the assumption that the null hypothesis is true* (that there is really no effect)?
- obviously, we would want that probability to be quite low!
- i.e., we want to be reasonably sure that, under the assumption that there is no effect, our results are quite unlikely



Rejection of null hypothesis

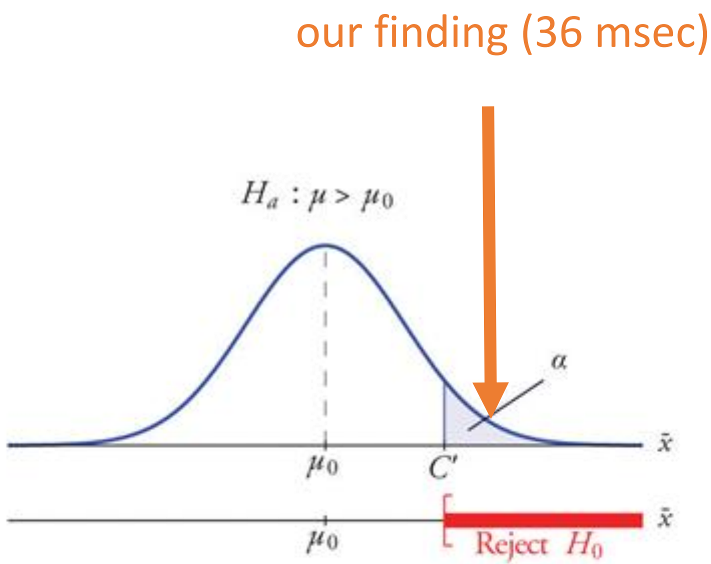
- we can calculate the probability that, assuming the null hypothesis, *a result such as ours, or more extreme,* would have been found:



- statistical procedure (software) results in a *p-value* (error probability)
- e.g. statistical test results in p = .02 - implies a 2% chance that the particular result (frequency effect of ≥ 36 msec) would have been found under the assumption that there really is no frequency effect (the null hypothesis)

Statistical significance

- in everyday parlance, “significance” means “importance”
- in statistical terms, it means something different. Conventions:
  - p ≤ .05: “statistically significant” – the chance (5%) of obtaining a result like ours (or more extreme) under the assumption that the null hypothesis was true
  - p ≤ .01: “highly significant” – chance of 1% obtaining a result like ours (or more extreme) under the assumption that the null hypothesis was true



- “statistically significant” means that there is at most a 5% chance that the result could have been due to chance, under the assumption that the null hypothesis is true
- accept, or at least consider further studies investigating, H_1

Statistical significance

- what's so special about 5%?
- nothing really – represents a compromise between cost and benefit in social sciences
- it means that we can be reasonably sure that our result was not due to chance…
- … but it also means accepting that 5% of our studies (1/20) will result in a "significant" outcome which was due to chance
- whether that's acceptable has to be judged in context – e.g., wouldn't want to build a bridge with a 5% probability of collapsing…

Our experiment on frequency…

```
    Paired t-test

data:  rt[cond == "Low"] and rt[cond == "High"]
t = 8.6, df = 2236, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 28 44
sample estimates:
mean of the differences
                     36
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- for our experiment, *p* value is very small: < .001.
- frequency effect in our lexical decision task is significant – odds of obtaining a result such as ours (or more extreme) under the assumption of H_0 (there is no frequency effect) is vanishingly small
- Results warrant further research… we (tentatively) conclude that the mental lexicon is indeed organised according to frequency of occurrence of words
- NHST technique is shared across all of life sciences (psychology, biology, economics, public health, medical research, etc.)

Bottom line

- virtually all psychological studies report tests of statistical significance
- although a variety of methods exist, it boils down to *p* values
- small is good (*p* values of ≤ .05 are typically required to render a result publishable)

Results

As shown in Figure 2, performance was superior in the familiar-target condition, when the spouse's voice was the target (and the masker voice was novel), compared with the novel-baseline condition, in which both voices were novel. This finding provides a measure of the benefit that people obtain when their spouse's voice is the focus of attention. Performance was also better in the familiar-masker condition, when the spouse's voice was the masker (and the target voice was novel), than in the novel-baseline condition, at least when the familiar masker was at least as loud as the target message (i.e., TMR of 0 dB or less).

The trends described above were confirmed by an analysis of variance (ANOVA) with age group and sex as between-subjects factors, and condition and TMR as within-subjects factors. The effect of TMR was significant, $F(2.396, 100.615) = 98.35$, $p < .001$, $\eta_p^2 = .70$: Performance differed significantly among all TMRs ($p < .05$) except for −3 dB versus 0 dB. The effect of condition was also

fered among all conditions only at −3 and 0 dB TMR ($p < .05$). In contrast, at TMRs of +3 and +6 dB, performance was very similar in the familiar-masker and novel-baseline conditions, and at a TMR of −6 dB, the difference between the familiar-target and familiar-masker conditions was not significant. The effects of age group and sex, and the interactions involving these factors, were not significant.

Despite the lack of any interaction with age, treated as a categorical variable, we were interested to know whether age was related systematically to performance in any of the conditions. We therefore performed an additional analysis, the results of which showed that the correlation between performance and age depended on condition; see Figure 3. Specifically, performance (averaged across TMR) decreased with increasing age in the novel-baseline condition ($r = -.44$, $p < .005$) and familiar-masker condition ($r = -.35$, $p < .025$), but not in the familiar-target condition ($r = -.032$, n.s.).To compare these correlations, we computed 95% confidence intervals (CIs) for the difference between the correlations

- *P* values tell us little or nothing about whether a particular result is *important*!

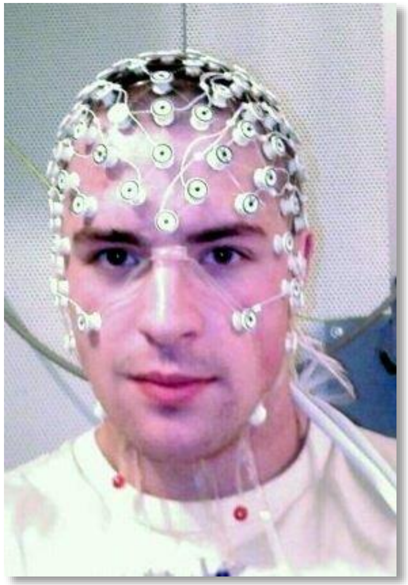
Experimental studies

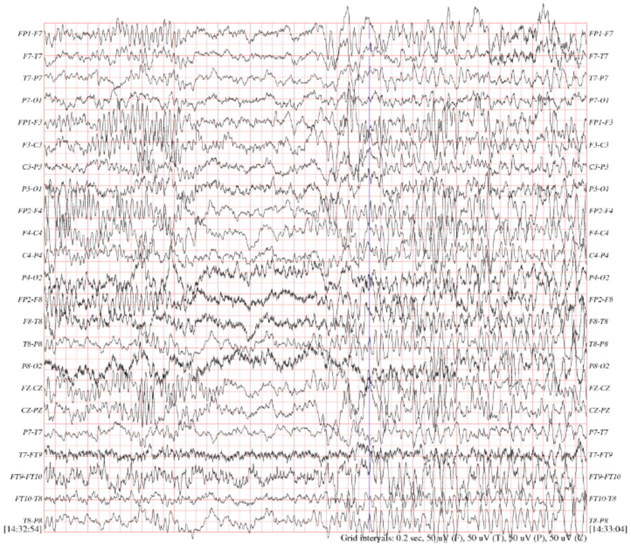
- sample experiment on frequency represents "mental *chronometry*" – measuring the time that mental processes take to be carried out
- pioneered by Donders in the 19th Century
- still widely used…

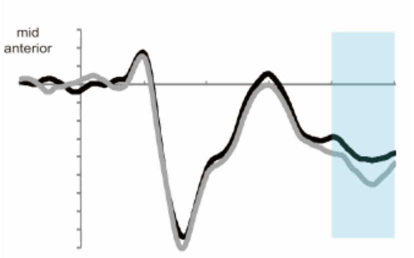
F C Donders (1818-1889)

More recent techniques

- Electroencephalography (EEG)



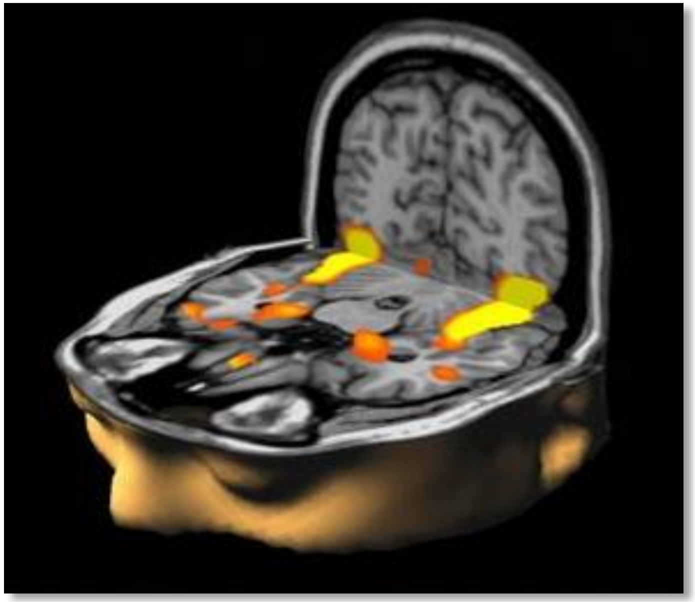




- similar experiments as those done with chronometry
- but looking at electrical activity along the scalp
- averaging out of noise, statistical analysis on wave forms

MRI and PET

- fMRI (magnetic resonance imaging) and PET (positron emission tomography)
- measures brain activity by detecting increases in cerebral blood flow in response to a particular mental activity
- good for localising particular mental tasks in the brain



Summary and key points

- a rich arsenal of techniques exists to study the mind and brain
- neuropsychological case studies of acquired brain damage
- studies on healthy individuals
- experimental work
  - null hypothesis significance testing (NHST)
- mental chronometry
- brain imaging

References

Peretz, I. (1993). Auditory atonalia for melodies. *Cognitive Neuropsychology*, *10*(1), 21-56.

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