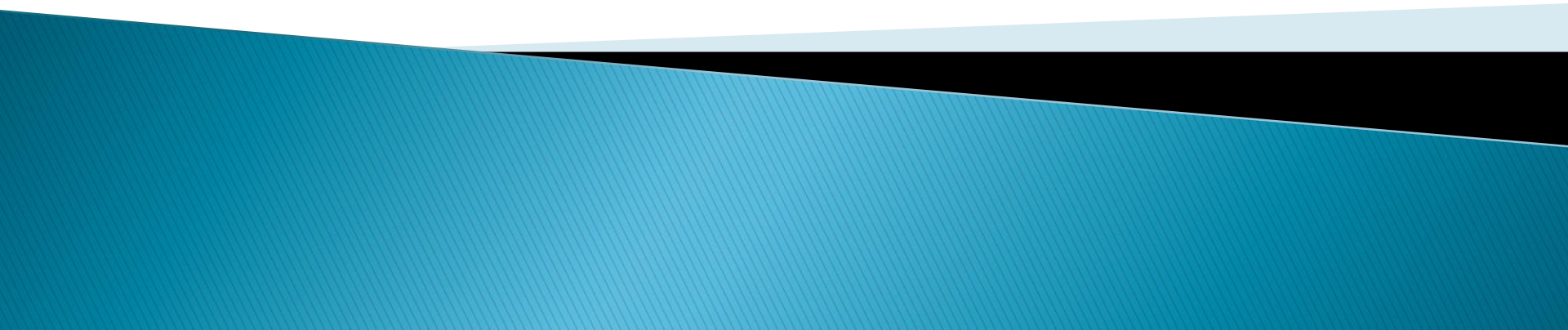


# **Experimental Psychology**

## **Lecture 7: Cognitive Neuropsychology and Cognitive Neuroscience**

**Dr. Kate Williams**



# Approaches to Human Cognition

## 1. Experimental Cognitive Psychology

- Uses behavioural evidence

## 2. Computational Cognitive Science

- Uses computational models (takes account of our knowledge of behaviour and the brain).

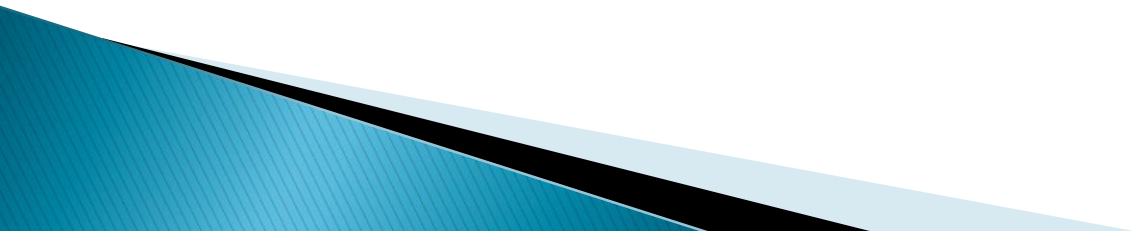
## 3. Cognitive Neuropsychology

- Involves studying brain-damaged patients

## 4. Cognitive Neuroscience

- Uses behavioural evidence *along with* evidence from the brain

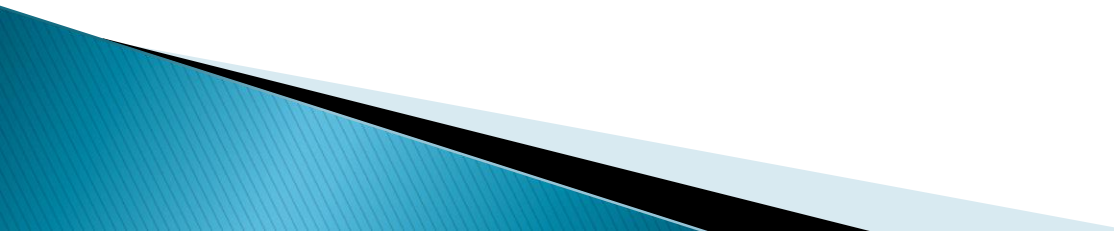
# Cognitive Neuropsychology

- ▶ Examines cognitive performance of brain-damaged patients.
  - ▶ Damage caused to brain by **Lesions** (either from injury or disease).
  - ▶ Aims to see whether studying brain-damaged patients can tell us anything about normal human cognition.
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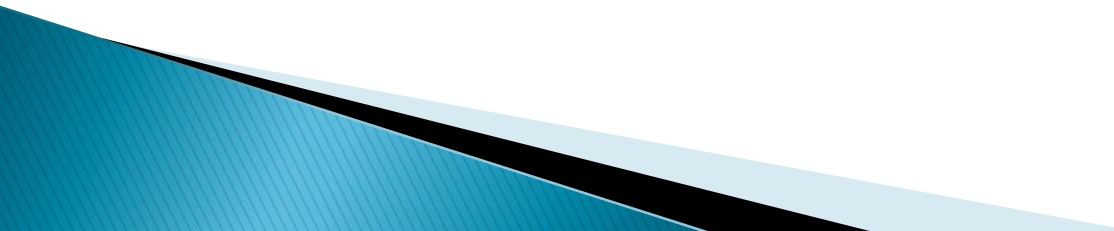
# Cognitive Neuropsychology: Development

- ▶ Edwin Smith Surgical Papyrus: ancient manuscript (3000-2500 BC) discovered in Luxor (1862) details the effects of brain damage on functioning - thought to be the first documentation of detail relating to various parts of the brain.
- ▶ Neuropsychology crops up again between 4<sup>th</sup> - 14<sup>th</sup> century with the early theorists of function arguing that types of behaviour mediated by the brain were based on activity of the ventricles.
  - Ventricles: hollow parts in an organ - in our brain we have 4 connected fluid-filled cavities.
  - At the beginning of the 4<sup>th</sup> century Church Fathers or elders suggested the anterior ventricles (ones towards the front) were responsible for perception, the middle ventricles for reasoning, and the posterior (ones at the back) were responsible for memory.

# Cognitive Neuropsychology: Development

- ▶ The renaissance: focus on the seat of the soul.
  - ▶ Descartes: the pineal gland was the location where the soul was situated and connected the mind to the brain.
  - ▶ But by 18<sup>th</sup> and 19<sup>th</sup> century ventricle hypotheses no longer considered valid due to the discoveries in anatomy and neurophysiology.
  - ▶ One of these discoveries was that the brain was composed of cells (neurons) that had various parts that played different functions. Some of these parts of the cell included the cell body, dendrites, and axons.
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# Cognitive Neuropsychology: Development

- ▶ Physician Camillo Glogi: discovered a way of tracing the structure of these cells through a technique called staining.
  - ▶ Pathologist Santiago Ramon y Cajal: discovered the brain comprises a network of communication neurons.
  - ▶ Physician Luigi Galvani: discovered that nerve cells produced electricity, this led to Helmholtz finding nerve cells communicated with each other using electrical signals.
  - ▶ Discovery in psychopharmacology that the surface of neurons, known as their receptor sites, were responsive to various chemicals called neurotransmitters.
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# Cognitive Neuropsychology: Development

- ▶ Two important figures in the 19<sup>th</sup> C: Surgeon Pierre Paul Brocca and neurologist Carl Wernicke.
- ▶ Anthropological society meeting (1861) to discuss **equipotentiality** (any part of an intact piece of the brain can still carry out the functions from a part that has been damaged) versus the **localisation** theory (only that part of the brain can deal with a certain function).
- ▶ Broca gave an account of an epileptic patient paralysed on one side of the body who had not spoken for over 20 years.
  - Post mortem on the brain revealed damage to the 2nd and 3rd left frontal convolution (basically there was a hole on the front left side of the brain that had filled up with fluid).
  - The patients speech production deficit then became known as Broca's aphasia (aphasia means a communication disorder).

# Cognitive Neuropsychology: Development

- ▶ As only one hemisphere was damaged, it suggested brain did not work in equipotential way (otherwise the patient would produce words as other parts of the brain would take on the functions of the damaged area).
- ▶ So, localisation deemed more appropriate of how the brain is structured and functions.
- ▶ The region responsible for speech production became known as Broca's area.
- ▶ But although speech production deficits are associated with Broca, Hippocrates had already noted an association between brain damage and aphasia and had also suggested that damage to one side of the brain resulted in paralyses of the opposite side of the body.

# Cognitive Neuropsychology: Development

- ▶ Other important discovery: some aphasics unable to comprehend speech - sensory aphasia (now known as Wernicke's aphasia).
- ▶ Associated with left hemisphere of the brain and would lead to inappropriate word use in the middle of a sentence or inability to name objects.
- ▶ Writing was also very impaired.
- ▶ Wernicke: not only were specific regions responsible for specific functions but connections between regions also responsible for function.
- ▶ He further argued that Broca's area was the region of the brain responsible for the motor representations of speech, while his area was the region responsible for storing 'sound images' - phonological representations of speech.

# Modularity of mind/Mapping brain functions

- ▶ Clinical evidence from the 15<sup>th</sup> C suggested localisation of some functions of the brain, especially language.
- ▶ In 1870 two German physicians, Gustav Fritsch and Eduard Hitzig discovered that the neocortex (part of the cerebral cortex, the grey outer layer of the brain), is not just excitable by electrical stimulation but that its selectively excitable.
- ▶ When an electric current placed on the anterior part of a dogs brain certain parts of the dog's body would move.
- ▶ Four years later application of electrical current to the brain was done on a human.

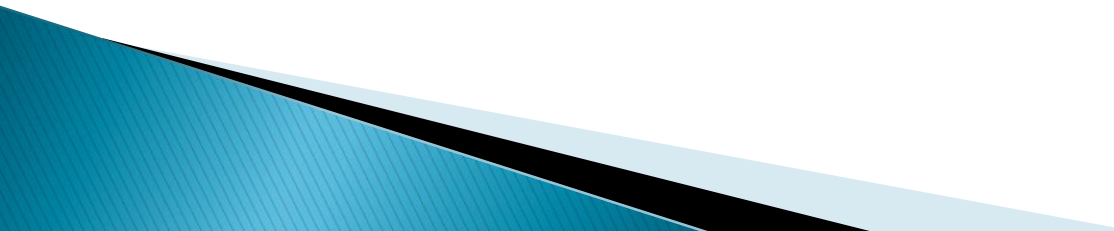
# Modularity of mind/Mapping brain functions

- ▶ With evidence of localisation growing, researchers attempted to map out functions of the brain.
- ▶ By the end of the 19<sup>th</sup> C neuropsychology was truly established.
- ▶ Ribot reported that there was a distinction between types of memory loss depending on whether an injury occurred before or after an event – retrograde and anterograde amnesia.
- ▶ He was the first to show that despite someone suffering from amnesia, they could still learn new material.
- ▶ Neuropsychological tests use to measure cognitive ability: e.g., verbal ability, visuospatial awareness, and memory.
- ▶ These aspects of cognition may be sensitive to brain damage - if a person with brain damage performs badly on one of these types of tests, then depending where that injury has occurred could tell us whether that part of the brain is involved in that particular type of cognitive functioning.

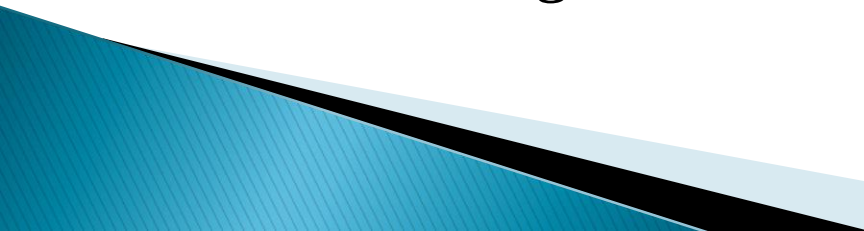
# Research

- ▶ Understanding cognitive functioning through dissociation:
  - when a patient performs normally on one type of task but is impaired on another - E.g., amnesiacs perform normally on STM task but are impaired on LTM tasks.
- ▶ However, it doesn't necessarily mean the tasks involve different processing modules.
- ▶ Comparing different tasks is an issue – maybe one is more difficult than the other and even normal control patients would perform differently on the two types of tasks.
- ▶ Instead look for a double dissociation: when one patient performs normally on task X but is impaired on task Y, while another patient performs normally on task Y, but is impaired on task X.

# Limitations with double dissociation?

- ▶ Dunn and Kirsner: ideal if one module in the brain is only required for task X while only another required for task Y, with some patients only having damage to one of the modules and other patients only having damage to the other
  - ▶ In reality this is never the case.
  - ▶ Also, double dissociation is only useful for showing differences between 2 systems, what about 4 or 5 systems?
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# To illustrate...

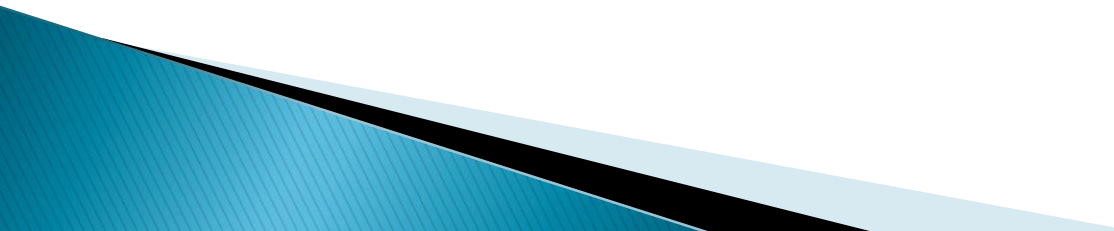
- ▶ Coltheart et al (2001) – 67 year old who had suffered several strokes leading to severe problems with knowledge of objects.
  - ▶ If only one system controlled object knowledge then he should have been impaired on all aspects of object knowledge.
  - ▶ However, he did not possess any ability on the visual information of objects (e.g., what colour a certain animal is), but he was able to classify whether animals were dangerous or not.
  - ▶ Conclusion: there cannot be a single object knowledge system.
  - ▶ Studies like this also show we can have an understanding of how object knowledge is stored (the organisation of knowledge) without knowing where in the brain that knowledge is stored.
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- ▶ Key assumptions of cognitive neuropsychology.
    - Cognitive system made up of many modules/processing modules that operate relatively independently/separately from other modules.
    - Domain specific: they only respond to one type of stimuli.
    - Anatomical modularity: each module is located in a particular area of the brain - E.g., visual processing system.
    - Coltheart (2001): “uniformity of functional architecture across people” – if these modules do exist, they are the same for everyone.
    - So, comparisons between brain damaged patients and healthy controls can be achieved.
    - Finally, the assumption of subtractivity: brain damage can delete or remove modules or the connections between them but it cannot introduce new ones. This is important because if a patient's brain damage did produce a new module then it would make understanding normal cognitive functioning very difficult.
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# Research

- ▶ Case Study approach – someone already with brain damage.
  - Advantages:
    - Allows cognitive neuropsychologists to explore behavioural consequences following brain damage to make inferences about the principles that underlie cognitive functioning.
    - Allows for examination of brain lesions that could not be done experimentally, and allows for study over a long period of time.
  - Limitations:
    - cannot control specific area of damage – multiple sites may be damaged, making it difficult to work out whether deficit is due one of more of the areas damaged.
    - Likely to be the only person with that type of brain damage.
    - Pinpointing areas involved in cognitive functioning can take a long time to achieve. Also, the person in question would need to be studied over a long period of time to see if any changes occur.

# Famous case studies:

- ▶ **Phineas Gage**: 3cm thick 109cm long iron rod went through his face, skull and brain when laying down train tracks.
  - ▶ After the accident his personality appeared to change, he lost all sense of responsibility and disregarded acceptable social conventions.
  - ▶ Damasio (1994) examined his skull and estimated that the iron rod must have produced lesions to the left frontal lobe.
  - ▶ A number of other studies of frontal cortex damage suggest they produce disturbances in personality.
  - ▶ **HM**: Had surgery to remove the medial temporal lobe on both sides of his brain in an attempt to stop his seizures. Following the surgery, seizures were alleviated however he suffered severe anterograde amnesia - he was able to converse but could not remember anything that had happened after 1953.
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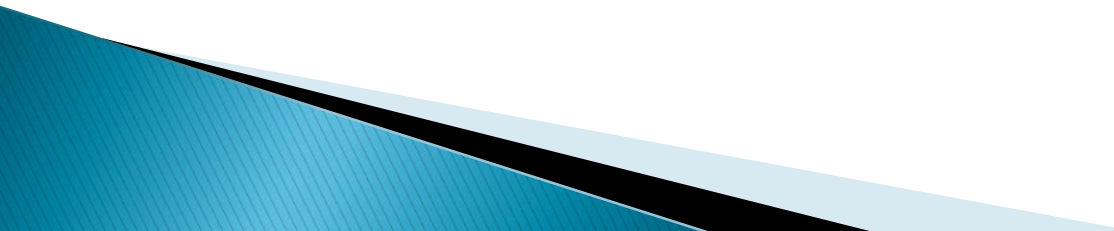
# Research

- ▶ However, we should be cautious when interpreting case studies.
  - ▶ Would need to consider the persons behaviour before injury:
    - E.g., before injury a person may have scored 150 on an IQ test and then only 110 following brain damage, but with the norm of the population being 100 on IQ tests anyway, the patient although showing a detriment in their performance is still performing above the norm.
  - ▶ Also, they are subject to individual differences, the accuracy of the area of damage may be variable, and other damaged brain regions not known about could be causing the deficits.
    - E.g., a patient presenting some deficit in cognitive ability following an accident that damaged a brain region on the left side of the brain may actually be because of disease on the right which they were not aware of.
  - ▶ Finally, other confounding variables such as medication should be considered.
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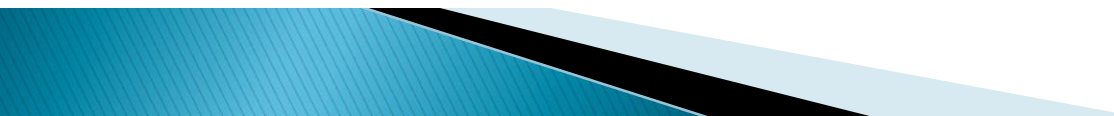
# Group studies – are they any better?

- ▶ Examine patients who display the same symptoms together.
- ▶ Would make sense to gather large amounts of data.
- ▶ But this comes with its own problems.
- ▶ Can you think why trying to study a group of patients who display the same cognitive deficits might not be appropriate?
- ▶ Showing a similar deficit doesn't necessarily mean the exact same areas of the brain are damaged.
- ▶ The extent/area of damage is going to vary between patients.
- ▶ We cannot control for individual differences between the patients before the brain damage.
- ▶ Group studies can be used as a basis with a general overarching idea, which can then be followed up by single case studies to fill any gaps.

# Limitations of Cognitive Neuropsychology

- ▶ Can conclusions from brain-damaged patients tell us how normal cognitive functioning works?
  - ▶ Assumes seriality (we discussed this last week)
  - ▶ Brain damage tends to not be restricted to one area
  - ▶ Differences between patients despite having similar types of brain damage.
  - ▶ Only focuses on certain types of cognitive functioning (e.g., language and memory)
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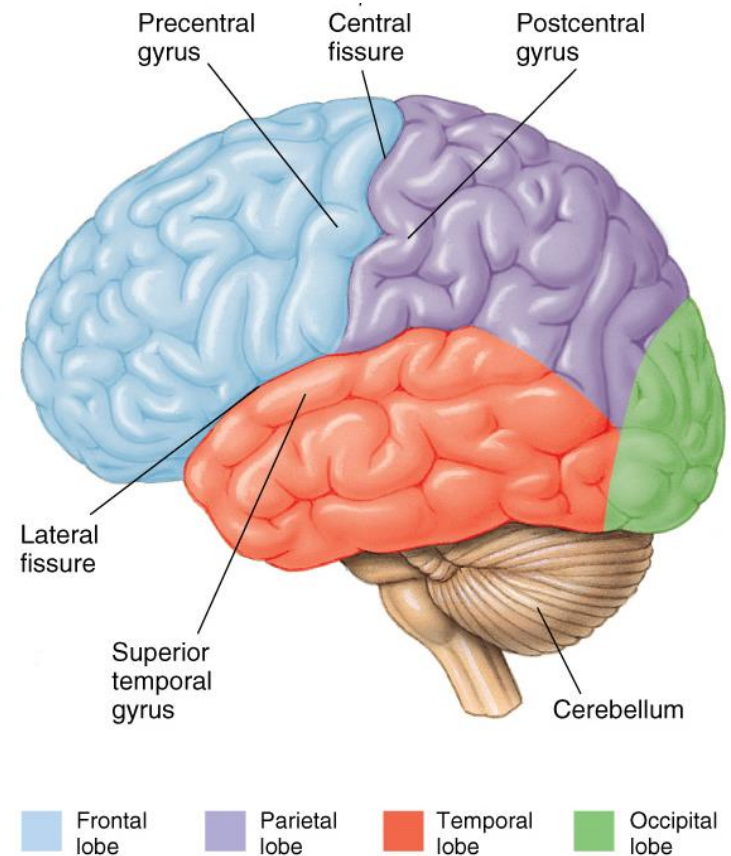
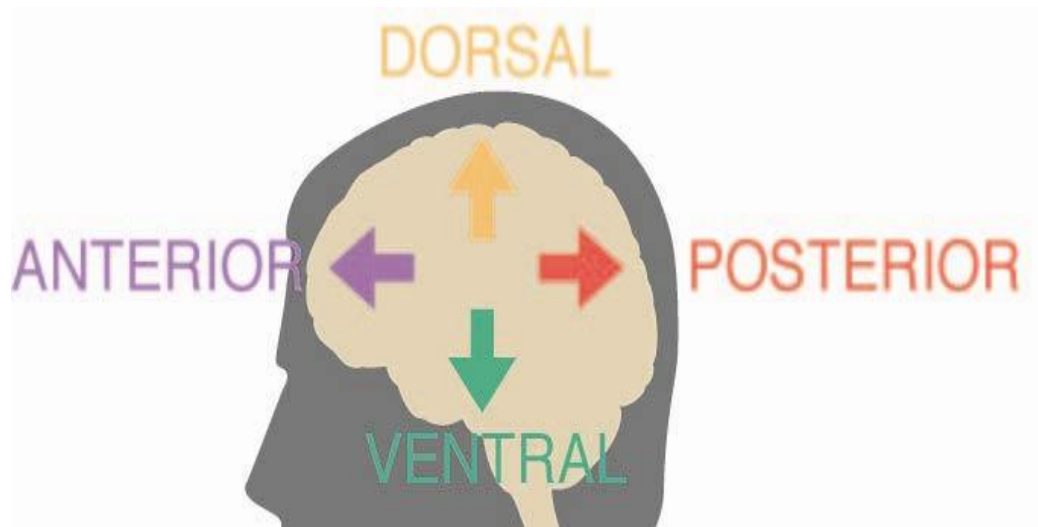
# Cognitive Neuroscience

- ▶ Trying to link the processes of the brain and how they relate or give rise to cognitive functioning has been an arduous task, but one thing that has paved the way for accomplishing this task is the advent of modern technology.
  - ▶ If we want to say how things happening in the brain relate to our cognitive functioning and how we behave, then its a good idea for us to first understand how the brain works.
  - ▶ The brain is an exceptionally complicated organ – e.g., the brain consists of about 50 billion neurons each of which can connect with up to 10,000 other neurons.
  - ▶ Understanding how the brain is organised and how different areas are described is key before we move on to look at how these areas relate to certain aspects of behaviour.
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# Cognitive Neuroscience

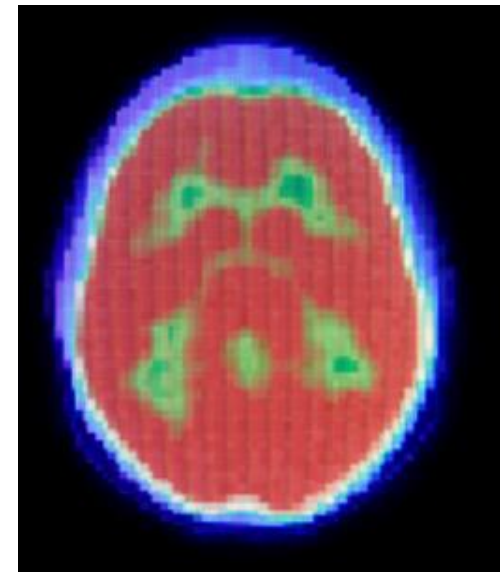
- ▶ The brain can be described by the division of the 4 lobes:
    - frontal lobe, parietal lobe, temporal lobe, and occipital lobe.
  - ▶ Another way is through Brodman's Cytoarchitectonic map:
    - A complicated atlas constructed according to the types of cells and the density of the cells that exist in specific regions of the brain.
    - Assigns numbers to the various areas of the brain that are distinguished by their cellular arrangement.
    - Often high correlations between Brodman's areas and their underlying function.
    - E.g., Area 44 corresponds to Broca's area.
    - There are regions responsible for vision and motor function that have distinguishable cellular arrangements.
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- Technological advances means we can obtaining detailed information about the brain's functioning and the structure.
- We can start working out where/when in the brain specific cognitive processes occur and we can determine the order in which different parts of the brain become active when someone performs a task.
- Also allows us to find out whether 2 different tasks involve the same parts of the brain in the same way or whether they differ.



# Techniques

- ▶ Electroencephalogram (EEG)
- ▶ Single-unit recordings (single-cell recordings)
- ▶ Event related potentials (ERPs)
- ▶ X-ray Computerised Tomography (CT)
- ▶ Positron emission tomography (PET)
- ▶ Functional magnetic resonance imaging (fMRI)
- ▶ Event-related functional magnetic resonance imaging (efMRI)
- ▶ Magneto-encephalography (MEG)
- ▶ Transcranial magnetic stimulation (TMS)



# Combining Cognitive Neuropsychology and Neuroimaging

- ▶ Neuroimaging studies highlight brain regions required for specific tasks.
  - ▶ Whereas studying individuals with brain damage shows how the damage disrupts specific functions.
  - ▶ By combining the two, researchers can see how these things converge.
  - ▶ What could be done is examining whether a certain area of the brain that should become active while performing a certain task doesn't actually show any activation in the area in which a patient has sustained brain damage.
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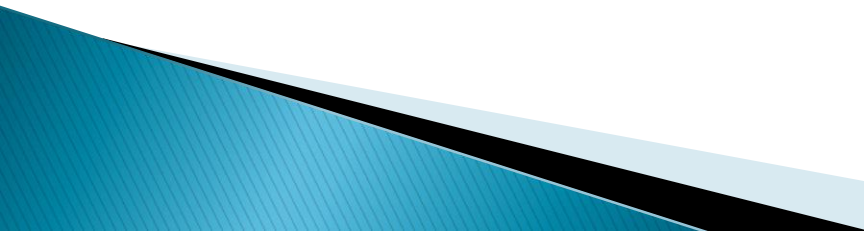
# Do brain imaging studies actually tell us anything about cognition?

- Do patterns of brain activation actually provide us with direct evidence of cognitive processing?
- Patterns of brain activation are seen as dependent variables:
  - They are sources of information about human cognition that need to be interpreted within the context of other relevant information.
- Brain-imaging techniques only reveal **associations** between patterns of brain activation and behaviour.
  - E.g., the prefrontal cortex becomes active when performing a reasoning task - but what does this actually mean?
- This association between what you're doing and the lighting up of that brain area on a researcher's screen basically shows a correlation - as one thing happens something else happens, it doesn't necessarily show that the brain regions activated are needed for that task performance.

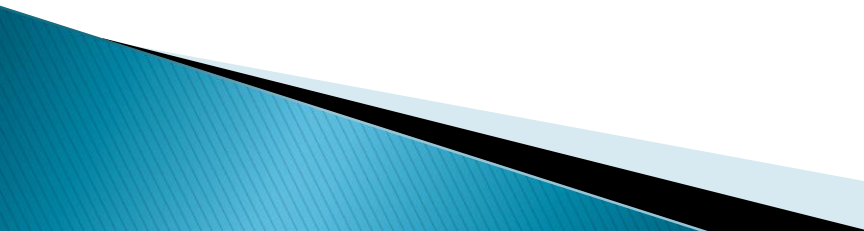
# Do brain imaging studies actually tell us anything about cognition?

- ▶ That brain area may have become activated because the participant decided to use a particular strategy.
- ▶ Some brain areas may become active because people worry about task performance and those areas involved in the worry are also lighting up.
- ▶ Although there is evidence for functional specialisation, this may only be the case for lower-level/basic processing, and not the case for higher-order or more complex cognitive functions.
- ▶ There's an acceptance of integration/co-ordination across the brain that functional specialisation may not always be found.
  - Functional integration: studied by correlating activity across different brain regions - if a network of brain regions is involved in a particular process then activity in all of them should be positively correlated when that process occurs.

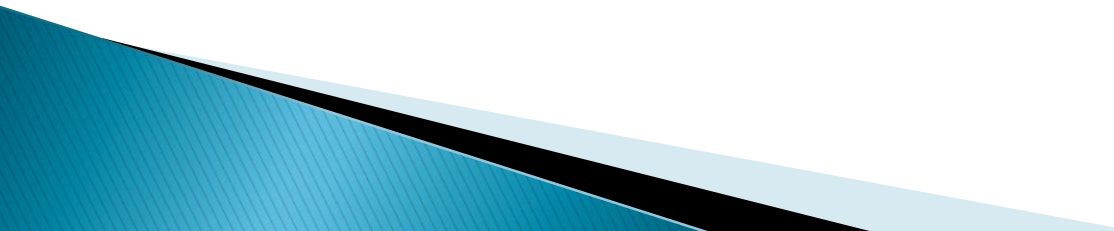
# Do brain imaging studies actually tell us anything about cognition?

- ▶ Some have even questioned whether functional neuroimaging research is actually relevant to test cognitive theories.
  - ▶ How does an image of the brain give us an idea of the cognitive theory it supports?
  - ▶ However, Kosslyn has argued that visual imagery, for example, uses the same processes as actual visual perception.
    - Meta-analysis of functional neuroimaging studies found visual imagery is associated with activation in the primary visual cortex, which would suggest that similar processes are used for imagery and perception (Kosslyn and Thomas).
    - But the behavioural evidence for this is inconclusive.
- 

# Do brain imaging studies actually tell us anything about cognition?

- ▶ Neuroimaging findings from studies on the processing of unattended stimuli have also helped with theoretical issues.
  - ▶ Deutch and Deutch: argued that unattended stimuli is thoroughly processed - but, ERP studies show unattended stimuli are not thoroughly processed and receive significantly less processing than attended stimuli.
  - ▶ When researchers say a given brain region is activated during the performance of a particular task, what they mean is that it is active relative to a baseline.
  - ▶ So we may argue that an appropriate baseline is when the participant is in a resting state, but is this a suitable baseline?
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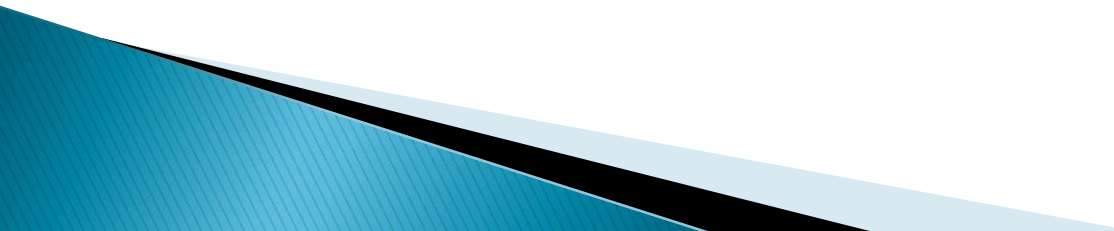
# Do brain imaging studies actually tell us anything about cognition?

- ▶ The brain is never really resting - there will always be some sort of process happening.
  - ▶ So, it is argued that all imaging does is show an increase in brain activity from the demands of performing a task.
  - ▶ Some have even found a decrease in brain activity in certain brain regions during a tasks, suggesting brain activity and cognitive functioning is far more complex than we think.
  - ▶ Finally, there is low ecological validity. When in our daily lives do we lay down in a long metal tube whilst trying to remember a series of words or numbers?
- 

Inside your head is the most complex instrument in the (known) universe!

## Your Mind

The aim of cognitive psychology is to develop experimental tools and techniques for probing how the mind works



# Next Week...

- ▶ Lecture: Issues with Experimental Psychology
  - We will discuss issues of replication, the file-drawer problem, and consider the potential strengths and limitations of carrying out experimental research.
- ▶ Seminar: Consciousness and Mental Representation