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# Cognition and Emotion

## Lecture 4: Cognitive Neuroscience

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# Lecture Overview

- ▶ What is Cognitive Neuroscience
- ▶ Key terminology
- ▶ Organisation of the brain
- ▶ Techniques for studying the brain
- ▶ Strengths
- ▶ Limitations

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# What is Cognitive Neuroscience?

- ▶ Involves studying the brain
  - ▶ IN DETAIL!
- ▶ Uses imaging techniques to view the brain and its functions whilst performing various tasks.
- ▶ Attempts to link brain processes with how they relate or give rise to cognitive functioning.



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## What is Cognitive Neuroscience?

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- ▶ If a part/process in the brain becomes active, it suggests involvement in the aspect of cognition under investigation.
- ▶ However! Before discussing what it entails, we must first understand key terms and the organisation of the brain.
- ▶ The brain is an exceptionally complicated organ –
  - ▶ It consists of about 100 billion neurons
    - ▶ Cells that receive and send electrochemical signals
    - ▶ Each of which can make thousands of connections.



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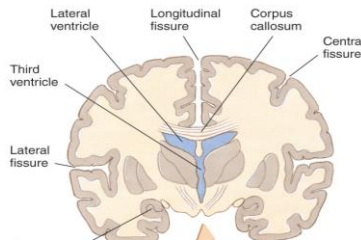
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## Key terminology

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- ▶ The brain can be divided into the left & right hemisphere.



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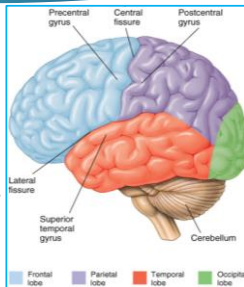
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## Key terminology

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- ▶ Within each hemisphere there are four divisions/lobes:
  - ▶ **Frontal lobe:** complex cognitive & motor functions
  - ▶ **Parietal lobe:** body sensations, attention, perceive object location
  - ▶ **Temporal lobe:** hearing, language, identifying complex visual patterns
  - ▶ **Occipital lobe:** analyse visual info
  - ▶ But! They are not separate functioning units



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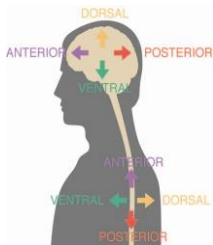
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## Key terminology

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- **Anatomical directions:** • Anatomical directions ignore that humans walk upright.



- Therefore, top of the head is both "dorsal" (back) and "superior" (top)
- Other directions:
  - Medial: middle (inwards)
  - Lateral: side (outwards)
  - Proximal – close
  - Distal – far

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## Organisation

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- 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 (52 in total) to various areas of the brain that are distinguished by their cellular arrangement.
  - Often high correlations between Brodman's areas and their underlying function.
  - There are regions responsible for vision and motor function that have distinguishable cellular arrangements.

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## Organisation

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- Based upon principles of:
- **Cost Control:** Short connections better to reduce energy & space
  - **Efficiency:** Long/complex connections better to integrate info across the brain
- To deal with these differences, the brain has achieved a near-optimal trade-off between cost and efficiency.
- Within the brain are modules and hubs.

**Bullmore and Sporns (2012)**

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# Techniques

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- Technological advances mean we can obtain detailed information about the brain's structure **AND** functioning.
- We can work out where and when specific cognitive processes occur.
- We can determine the order in which different parts of the brain become active when someone performs a task.
- We can investigate whether two different tasks involve the same parts in the same way or whether they differ.

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# Techniques

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

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# Techniques

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## Why so many?



- They may be focusing on measuring the structure of the brain
- They may be focusing on measuring the function of the brain
- They may be capturing images of the brain
- They may be recording electrical activity of the brain
- They vary in precision of identifying areas (spatial resolution)
- They vary in precision of identifying time course of activity (temporal resolution)

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Techniques

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Which is best?

- No simple answer – each have strengths and limitations.
- The best technique will depend on the research question.
- High spatial and temporal resolutions are better when a detailed account of brain *functioning* is required.
- Low resolution techniques are useful when an overview of brain activity throughout the duration of a whole task is required.

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Single-unit recording

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- Enables the study (activity) of single neurons
- Micro-electrode is inserted into the brain

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Electroencephalogram (EEG)

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- Measure of gross electrical activity of the brain
  - Including action potentials & postsynaptic potentials.
- Uses electrodes attached to scalp (individually or in cap)
- Good temporal resolution but not good spatial resolution.

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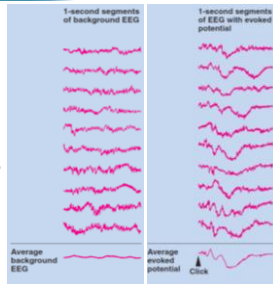
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## Event-related potentials (ERP)

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- ▶ EEG waves that accompany certain events (ERP).
- ▶ The same stimulus is presented repeatedly and pattern of electrical brain activity is averaged to produce a single wave form.
- ▶ Allows researchers to work out timings of various cognitive processes.



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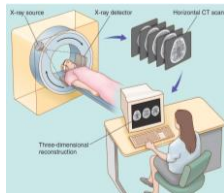
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## X-Ray Computed Tomography (CT)

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- ▶ Head placed in cylinder: x-ray tube projects x-ray beam to x-ray detector.
- ▶ Tube & detector rotate & take no. of photographs.
- ▶ Each photograph combined on PC to create a CT scan of horizontal section of the brain.
- ▶ Beam & detector move to another level of brain.
- ▶ Process repeated until 8/9 horizontal sections obtained & combine to create 3D image.



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## Positron emission tomography (PET)

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- ▶ Involves detection of positrons: atomic particles emitted from radioactive substances.
- ▶ Person injected with radioactive glucose, which is taken up by metabolically active cells.
- ▶ Radioactive particles emit positrons detected by scanner.
- ▶ Areas of brain high in metabolic activity produce more gamma rays because they take up more glucose.
- ▶ This is transformed to a colour coded 3D image indicating regions of increased blood flow.
- ▶ Good spatial resolution but not good temporal resolution.
- Only provides indirect measure of neural activity.
- Images are not of the brain: only produces coloured map of radioactivity in tiny cubic voxel (a pixelated area) from scan superimposed on image of brain.



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## Functional magnetic resonance imaging (fMRI)

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- ▶ Provides images of brain structure *and* activity.
- ▶ Uses strong magnetic field
  1. Active areas of brain take up more oxygenated blood than actually needed.
  2. Oxygenated blood has magnetic properties through iron.
- ▶ Structure is imaged using waves emitted by hydrogen ions
- ▶ Function is imaged using signal created from interaction between oxygen and iron in the blood
  - Blood Oxygenated Level Dependent (BOLD)
- ▶ Good spatial and temporal resolution
- ▶ Produces 3D images of activity over the whole brain.
- ▶ But only provides indirect measure of neural activity through BOLD.
- ▶ Also, 2 to 3 seconds to create image is too slow to capture neural responses



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## Magneto-encephalography (MEG)

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- ▶ A measure of neural activity
- ▶ Measures changes in magnetic fields on the surface of the scalp produced by underlying patterns of neural activity
- ▶ Fast temporal resolution



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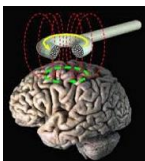
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## Transcranial magnetic stimulation (TMS)

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- ▶ NOT a measure of neural activity
- ▶ Provides experimental probe to alter neural activity
- ▶ Involves placing figure of 8 coil close to the head and then running a brief pulse of current
  - Produces a brief, strong magnetic field that alters neural activity
  - Can either activate or "deactivate" brain structures
  - Then observe changes in behavior



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# Strengths

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- Can help resolve theoretical debates not possible from behavioural studies alone (White & Poldrack, 2013).
- E.g., some suggest knowledge of presented speech influences understanding early in the process, thus affecting the process itself.
- Others suggest understanding of speech perception occurs after basic auditory processing is complete.

(Mattys et al., 2012)



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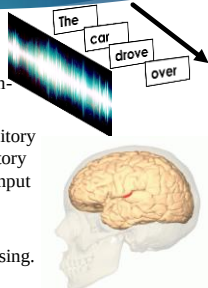
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# Evidence...

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- Wild et al. (2012): Using fMRI
  - Ps heard degraded speech of sentences accompanied by either matching or non-matching text.
  - Findings: More activity in primary auditory cortex, which is involved in early auditory processing, when auditory and visual input matched.
  - Conclusion: Knowledge of what is presented affects basic auditory processing.



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# Evidence...

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- Kosslyn (2005) has argued that visual imagery uses the same processes as actual visual perception.
- Meta-analysis of functional neuroimaging studies found visual imagery is associated with activation in primary visual cortex, which suggests similar processes are used for imagery and perception (Kosslyn & Thomas, 2003).



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# Strengths

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- ▶ 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.

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# Strengths

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- ▶ Data obtained from research can help enable construction of cognitive models.
- ▶ It is a self-correcting approach:
  - ▶ Data showing activation of the fusiform face area during the presentation of faces now also recognises that a **network** of brain regions are also involved (Atkinson & Adolphs, 2011).
- ▶ It acknowledges both functional specialisation AND functional integration (coordinated activity across regions).

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# Limitations

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- It relies too much on **reverse inference**: arguing backwards that brain activation reveals presence of cognitive process.
  - Many regions are involved in several cognitive processes, thus activation is not informative (Brown, 2012).
- E.g., lighting-up of Amygdala during a threat related task does not mean it only processes fear info (Sander, 2009).
- It also processes other emotions (Lindquist et al., 2012)



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## Does brain imaging actually tell us anything about cognition? 28

- Difficult to find the bridge between a psychological process and the physical activation of the brain (Harley, 2012).
- E.g., the prefrontal cortex becomes active when performing a reasoning task –
  - But what does this actually mean?



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## Limitations 29

- Do patterns of brain activation actually provide us with direct evidence of cognitive processing?
- Patterns of brain activation are 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.

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## Does brain imaging actually tell us anything about cognition? 30

- This association basically shows a *correlation* –
  - As one thing happens something else happens.
  - It does not necessarily show brain regions activated are needed for that task.
- That brain area may become activated because the person decided to use a particular strategy.
- Or a person worrying about task performance will lead to areas involved in the worry lighting up.

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# Limitations

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- ▶ 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?
- ▶ Research studies are **underpowered**: usually involving less than 20 Ps.
- ▶ Can lead to false positives: mistakenly taking random activity as evidence of a cognitive process

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# Limitations

- ▶ Bennett et al. (2009):
  - ▶ fMRI of **dead** salmon showed brain activity when it was presented with pictures of people.
  - ▶ Voxel/Statistics issue
    - ▶ Raises questions for the role of fMRI in studying brain processes
    - ▶ Not the be-all and end-all some thought



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# Limitations

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- ▶ When researchers say a given brain region is activated, what they mean is that it is active relative to a baseline.
- ▶ We could argue that an appropriate baseline is when the participant is in a resting state, but is this a suitable baseline?
- ▶ The brain is never resting - there will always be processing.
- ▶ Thus, all imaging does is show an increase in brain activity from the demands of the task.
- ▶ Some have even found a decrease in brain activity in certain regions during a task, suggesting activity and cognitive functioning is far more complex than we think.

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# Lecture Summary

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- ▶ Cognitive Neuroscience attempts to link brain processes with how they relate or give rise to cognitive functioning.
- ▶ It uses brain imaging and other techniques to understand the structure of the brain and how it functions when performing certain tasks.
- ▶ All techniques have strengths and limitations.
- ▶ Overall, the approach can only suggest associations between the brain and cognitive processes.

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