STUDYING THE BRAIN

Specification: Ways of studying the brain: scanning techniques, including functional magnetic resonance imaging (fMRI); electroencephalogram (EEGs) and event-related potentials (ERPs); post-mortem examinations.

WHAT YOU NEED TO KNOW
1. Outline and evaluate fMRI as a way of studying the brain
2. Outline and evaluate EEG & ERP as a way of studying the brain
3. Outline and evaluate post-mortem examinations as a way of studying the brain
4. Compare the different ways of studying the brain

KEY TERMS	DEFINITIONS
Functional Magnetic Resonance Imaging (fMRI)	**Functional magnetic resonance imaging (fMRI)** is a brain-scanning technique that measures blood flow in the brain when a person performs a task. fMRI works on the premise that neurons in the brain which are the most active (during a task), use the most energy. An fMRI creates a dynamic (moving) 3D map of the brain, highlighting which areas are involved in different neural activities.
Electroencephalogram (EEGs)	An **electroencephalogram (EEG)** works on the premise that information is processed in the brain as electrical activity in the form of action potentials or nerve impulses, transmitted along neurons. EEG ners measure this electrical activity through electrodes attached to the scalp. Small electrical charges that are detected by the electrodes are graphed over a period of time, indicating the level of activity in the brain.
Event-Related Potentials (ERPs)	**Event-Related Potentials (ERP)** use similar equipment to EEG, i.e. electrodes attached to the scalp. However, the key difference is that a stimulus is presented to a participant (for example a picture/sound) and the researcher looks for activity related to that stimulus.
Post-Mortem Examination	A **post-mortem examination** is when researchers study the physical brain of a person who displayed a particular behaviour while they were alive that suggested possible brain damage. An example of this technique is the work of **Broca**, who examined the brain of a man who displayed speech problems when he was alive. It was subsequently discovered that he had a lesion in the area of the brain important for speech production. This area later became known as Broca's area.

Introduction – Studying the Brain

Studying the brain allows psychologists to gain important insights into the underlying foundations of our behaviour and mental processes. A range of methods are available that involve scanning the living brain, and looking at patterns of electrical activity. However, a post-mortem examination is another possible approach.

1. Functional Magnetic Resonance Imaging (fMRI)

Functional magnetic resonance imaging (fMRI) is a brain-scanning technique that measures blood flow in the brain when a person performs a task. fMRI works on the premise that neurons in the brain that are the most active during a task use the most energy.

Energy requires glucose and oxygen. Oxygen is carried in the bloodstream attached to haemoglobin (found in red blood cells) and is released for use by these active neurons, at which point the haemoglobin becomes deoxygenated.

Deoxygenated haemoglobin has a different magnetic quality from oxygenated haemoglobin. An fMRI can detect these different magnetic qualities and can be used to create a dynamic (moving) 3D map of the brain, highlighting which areas are involved in different neural activities. fMRI images show activity approximately 1-4 seconds after it occurs and are thought to be accurate within 1-2 mm. An increase in blood flow is a response to the need for more oxygen in that area of the brain when it becomes active, suggesting an increase in neural activity.

Evaluation of fMRI

- **Invasive or Non-Invasive:** An advantage of fMRI is that is non-invasive. Unlike other scanning techniques, for example Positron Emission Tomography (PET), fMRI does not use radiation or involve inserting instruments directly into the brain, and is therefore virtually risk-free. Consequently, this should allow more patients/participants to undertake fMRI scans which could help psychologists to gather further data on the functioning human brain and therefore develop our understanding of localisation of function.

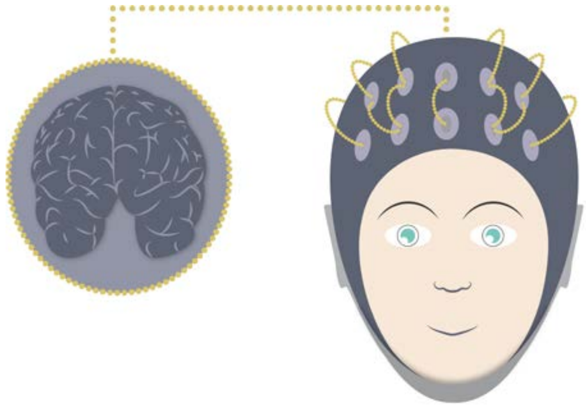
- **Spatial Resolution:** fMRI scans have good spatial resolution. Spatial resolution refers to the smallest feature (or measurement) that a scanner can detect, and is an important feature of brain scanning techniques. Greater spatial resolution allows psychologists to discriminate between different brain regions with greater accuracy. fMRI scans have a spatial resolution of approximately 1-2 mm which is significantly greater than the other techniques (EEG, ERP, etc.) Consequently, psychologists can determine the activity of different brain regions with greater accuracy when using fMRI, in comparison to when using EEG and/or ERP.

- **Temporal Resolution:** fMRI scans have poor temporal resolution. Temporal resolution refers to the accuracy of the scanner in relation of time: or how quickly the scanner can detect changes in brain activity. fMRI scans have a temporal resolution of 1-4 seconds which is worse than other techniques (e.g. EEG/ERP which have a temporal resolution of 1-10 milliseconds). Consequently, psychologists are unable to predict with a high degree of accuracy the onset of brain activity.

- **Causation**: fMRI scans do not provide a direct measure of neural activity. fMRI scans simply measure changes in blood flow and therefore it is impossible to infer causation (at a neural level). While any change in blood flow may indicate activity within a certain brain area, psychologists are unable to conclude whether this brain region is associated with a particular function.
    - In addition, some psychologists argue that fMRI scans can only show localisation of function within a particular area of the brain, but are limited in showing the communication that takes place among the different areas of the brain, which might be critical to neural functioning.

2. Electroencephalogram & Event-Related Potentials

Electroencephalogram (EEG)



An **electroencephalogram (EEG)** works on the premise that information is processed in the brain as electrical activity in the form of action potentials or nerve impulses, transmitted along neurons. EEG scanners measure this electrical activity through electrodes attached to the scalp. Small electrical charges detected by the electrodes are graphed over a period of time, indicating the level of activity in the brain. There are four types of EEG patterns including alpha waves, beta waves, theta waves and delta waves. Each of these patterns has two basic properties that psychologists can examine:

1. Amplitude: the intensity or size of the activity
2. Frequency: the speed or quantity of activity

Also, EEG patterns produce two distinctive states: synchronised and desynchronized patterns. A synchronised pattern is where a recognised waveform (alpha, beta, delta and theta) can be detected, whereas a desynchronized is where no pattern can be detected.

Fast desynchronized patterns are usually found when awake and synchronised patterns are typically found during sleep (alpha waves are associated with light sleep, and theta/delta waves are associated with deep sleep). Furthermore, EEG scanning was responsible for developing our understanding of REM (dream) sleep, which is associated with a fast, desynchronized activity, indicative of dreaming.

EEG can also be used to detect illnesses like epilepsy and sleep disorders, and to diagnose other disorders that affect brain activity, like Alzheimer's disease.

Event-Related Potentials (ERP)

Event-Related Potentials (ERP) use similar equipment to EEG, electrodes attached to the scalp. However, the key difference is that a stimulus is presented to a participant (for example a picture/sound) and the researcher looks for activity related to that stimulus. However, as ERPs are difficult to separate from all of the background EEG data, the stimulus is present many times (usually hundreds), and an average response is graphed. This procedure, which is called 'averaging', reduces any extraneous neural activity which makes the specific response to the stimulus stand out.

The time or interval between the presentation of the stimulus and the response is referred to as latency. ERPs have a very short latency and can be divided into two broad categories. Waves (responses) that occur within 100 milliseconds following the presentation of a stimulus are referred to as sensory ERPs, as they reflect a sensory response to the stimulus. ERPs that occur after 100 milliseconds are referred to as cognitive ERPs, as they demonstrate some information processing.

Evaluation of EEG & ERP

- **Invasive or Non-Invasive:** An advantage of EEG and ERP is that both techniques are non-invasive. Unlike other scanning techniques, such as Positron Emission Tomography (PET), EEG and ERP do not use radiation or involve inserting instruments directly into the brain and are therefore virtually risk-free. Furthermore, EEG and ERP are much cheaper techniques in comparison with fMRI scanning and are therefore more readily available. Consequently, this should allow more patients/participants to undertake EEG/ERPs, which could help psychologists to gather further data on the functioning human brain and therefore develop our understanding of different psychological phenomena, such as sleeping, and different disorders like Alzheimer's.

- **Spatial Resolution:** However, one disadvantage of EEG/ERP is that these techniques have poor spatial resolution. Spatial resolution refers to the smallest feature (or measurement) that a scanner can detect, and is an important feature of brain scanning techniques. Greater spatial resolution allows psychologists to discriminate between different brain regions with greater accuracy. EEGs/ERPs only detect the activity in superficial regions of the brain. Consequently, EEGs and ERPs are unable to provide information on what is happening in the deeper regions of the brain (such as the hypothalamus), making this technique limited in comparison to the fMRI, which has a spatial resolution of 1-2mm.

- **Temporal Resolution:** An advantage of the EEG/ERP technique is that it has good temporal resolution: it takes readings every millisecond, meaning it can record the brain's activity in real time as opposed to looking at a passive brain. This leads to an accurate measurement of electrical activity when undertaking a specific task.
    - However, it could be argued that EEG/ERP is uncomfortable for the participant, as electrodes are attached to the scalp. This could result in unrepresentative readings as the patient's discomfort may be affecting cognitive responses to situations. fMRI scans, on the other hand, are less invasive and would not cause the participants any discomfort, leading to potentially more accurate recordings.

- **EEG:** Another issue with EEG is that electrical activity is often detected in several regions of the brain simultaneously. Consequently, it can be difficult pinpoint the exact area/region of activity, making it difficult for researchers to draw accurate conclusions.

- **ERP:** However, ERPs enable the determination of how processing is affected by a specific experimental manipulation. This makes ERP use a more experimentally robust method as it can eliminate extraneous neutral activity, something that other scanning techniques (and EEG) may struggle to do.

3. Post-Mortem Examination

The final method of investigating the brain is post-mortem examination, where researchers will study the physical brain of a person who displayed a particular behaviour while they were alive that suggested possible brain damage. An example of this technique is the work of **Broca**, who examined the brain of a man who displayed speech problems when he was alive. It was subsequently discovered that he had a lesion in the area of the brain important for speech production. This later became known as Broca's area. Similarly, **Wernicke** discovered a region in the left temporal lobe, which is important for language comprehension and processing, which is now known as Wernicke's area.

This method of investigation has successfully contributed to the understanding of many disorders. **Iverson** examined the brains of deceased schizophrenic patients and found that they all had a higher concentration of dopamine, especially in the limbic system, compared with brains of people without schizophrenia, highlighting the importance of such investigations.

Furthermore, post-mortem studies allow for a more detailed examination of **anatomical** and **neurochemical** aspects of the brain than would be possible with other techniques. They also enable researchers to examine deeper regions of the brain such as the hypothalamus and hippocampus, something that is not as easy with other methods of investigation.

Evaluation of Post-Mortem Examination

- **Causation**: One of the main limitations of post-mortem examination is the issue of causation. The deficit a patient displays during their lifetime (e.g. an inability to speak) may not be linked to the deficits found in the brain (e.g. a damaged Broca's area). The deficits reported could have been the result of another illness, and therefore psychologists are unable to conclude that the deficit is caused by the damage found in the brain.
    - In additional, another issue is that there are many extraneous factors that can affect the results/conclusions of post-mortem examinations. For example, people die at different stages of their life and for a variety of different reasons. Furthermore, any medication a person may have been taking, their age, and the length of time between death and post-mortem examination, are all confounding factors that make the conclusions of such research questionable.

- However, one strength of post-mortem examinations is that they provide a detailed examination of the **anatomical** structure and **neurochemical** aspects of the brain that is not possible with other scanning techniques (e.g. EEG, ERP and fMRI). Post-mortem examinations can access areas like the hypothalamus and hippocampus, which other scanning techniques cannot, and therefore provide researchers with an insight into these deeper brain regions, which often provide a useful basis for further research. For example, Iverson found a higher concentration of dopamine in the limbic system of patients with schizophrenia which has prompted a whole area of research looking into the neural correlates of this disorder.

- While post-mortem examinations are 'invasive', this is not an issue because the patient is dead. However, there are **ethical issues** in relation to informed consent and whether or not a patient provides consent before his/her death. Furthermore, many post-mortem examinations are carried out on patients with severe psychological deficits (e.g. patient HM who suffered from severe amnesia) who would be unable to provide fully informed consent, and yet a post-mortem examination has been conducted on his brain. This raises severe ethical questions surrounding the nature of such investigations.

4. Compare Ways of Studying the Brain

TECHNIQUE	OUTLINE	INVASIVE OR NON-INVASIVE	TEMPORAL RESOLUTION	SPATIAL RESOLUTION
fMRI	fMRI measures blood flow when a person performs a task and creates a dynamic (moving) 3D map of the brain, highlighting which areas are involved in different neural activities.	Non-Invasive	1-4 s	1-2 mm
EEG	**EEG** measures electrical activity through electrodes attached to the scalp. Small electrical charges are detected by the electrodes that are graphed over a period of time, indicating the level of activity in the brain.	Non-Invasive (although uncomfortable)	1-10 ms	Superficial general regions only
ERP	**ERP** uses similar equipment to EEG. However, the key difference is that a stimulus is presented to a participant and the researcher looks for activity related to that stimulus.	Non-Invasive (although uncomfortable)	1-10 ms	Superficial general regions only
Post-Mortem Examination	A **post-mortem examination** is when researchers study the physical brain of a person who displayed a particular behaviour while they were alive that suggested possible brain damage.	N/A (Invasive - although the person is no longer alive)	N/A	N/A

Exam Hint: Questions 9 and 10 in the possible exam questions section are tricky, as they require you to compare/contrast different ways of studying the brain. The table above can help you find the similarities and differences between the different techniques.

Possible Exam Questions

1. **Short Answer:** Outline fMRI as a way of studying the brain. (4 marks)
2. **Short Answer:** Outline EEGs as a way of studying the brain. (4 marks)
3. **Short Answer:** Outline ERPs as a way of studying the brain. (4 marks)
4. **Short Answer:** Outline post-mortem examinations as a way of studying the brain. (4 marks)

5. **Short Answer:** Outline one strength and one limitation of fMRI. (6 marks)
6. **Short Answer:** Outline one strength and one limitation of EEGs. (6 marks)
7. **Short Answer:** Outline one strength and one limitation of ERPs. (6 marks)
8. **Short Answer:** Outline one strength and one limitation of post-mortem examinations. (6 marks)

9. **Short Answer:** Outline one difference between EEG and ERP (2 marks)
10. **Short Answer:** Outline one difference between fMRI and EEG. (2 marks)

11. **Essay:** Discuss ways of studying the brain. (16 marks)