tutor2u

LOCALISATION AND LATERALISATION

Specification: Localisation of function in the brain and hemispheric lateralisation: motor, somatosensory, visual, auditory and language centres; Broca's and Wernicke's areas, split brain research. Plasticity and functional recovery of the brain after trauma.

WHAT YOU NEED TO KNOW
1. Outline and evaluate what research has shown about localisation of function in the brain, with reference to the following regions: a. Motor area b. Somatosensory area c. Visual area d. Auditory area
2. Outline the role of language centres in the brain, including: a. Broca's area b. Wernicke's area
3. Outline and evaluate research into lateralisation and/or the split brain.
4. Outline and evaluate evidence for plasticity and/or functional recovery of the brain after trauma.

KEY TERMS	DEFINITIONS
Localisation of Function	Localisation of function is the idea that certain functions (e.g. language, memory, etc.) have certain locations within the brain.
Hemispheric Lateralisation	Lateralisation is the fact that the two halves of the brain are functionally different and that each hemisphere has functional specialisations, e.g. the left is dominant for language, and the right excels at visual motor tasks.
Motor Area	The motor area is responsible for voluntary movements by sending signals to the muscles in the body.
Somatosensory Area	The somatosensory area receives incoming sensory information from the skin to produce sensations related to pressure, pain, temperature, etc.
Visual Area	The visual area receives and processes visual information. The visual area contains different parts that process different types of information including colour, shape or movement.
Auditory Area	The auditory area is responsible for analysing and processing acoustic information.
Broca's Area	The Broca's area is found in the left frontal lobe and is thought to be involved in language production.
Wernicke's Area	The Wernicke's area is found in the left temporal lobe and is thought to be involved in language processing/comprehension.

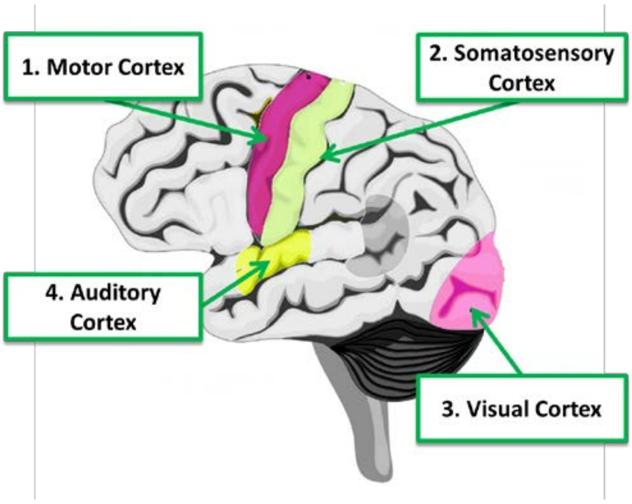
Split-Brain Research	Split-brain patients are individuals who have undergone a surgical procedure where the corpus callosum, which connects the two hemispheres, is cut.
Plasticity	Brain plasticity refers to the brain's ability to change and adapt because of experience.
Functional Recovery	Functional recovery is the transfer of functions from a damaged area of the brain after trauma to other undamaged areas.

Introduction – Localisation of Brain Function

Localisation of function is the idea that certain functions (e.g. language, memory, etc.) have certain locations or areas within the brain. This idea has been supported by recent neuroimaging studies, but was also examined much earlier, typically using case studies.

One such case study is that of **Phineas Gage**, who in 1848 while working on a rail line, experienced a drastic accident in which a piece of iron went through his skull. Although Gage survived this ordeal, he did experience a change in personality, such as loss of inhibition and anger. This change provided evidence to support the theory of localisation of brain function, as it was believed that the area the iron stake damaged was responsible for personality.

There are four key areas that you need to be aware of: **motor, somatosensory, visual and auditory areas.**



1a. Motor Area

The **motor area** is located in the **frontal lobe** and is responsible for voluntary movements by sending signals to the muscles in the body. Hitzig and Fritsch (1870) first discovered that different muscles are coordinated by different areas of the motor cortex by electrically stimulating the motor area of dogs. This resulted in muscular contractions in different areas of the body depending on where the probe was inserted. The regions of the motor area are arranged in a logical order, for example, the region that controls finger movement is located next to the region that controls the hand and arm and so on.

1b. Somatosensory Area

The **somatosensory area** is located in the **parietal lobe** and receives incoming sensory information from the skin to produce sensations related to pressure, pain, temperature, etc. Different parts of the somatosensory area receive messages from different locations of the body. Robertson (1995) found that this area of the brain is highly adaptable, with Braille readers having larger areas in the somatosensory area for their fingertips compared to normal sighted participants.

1c. Visual Area

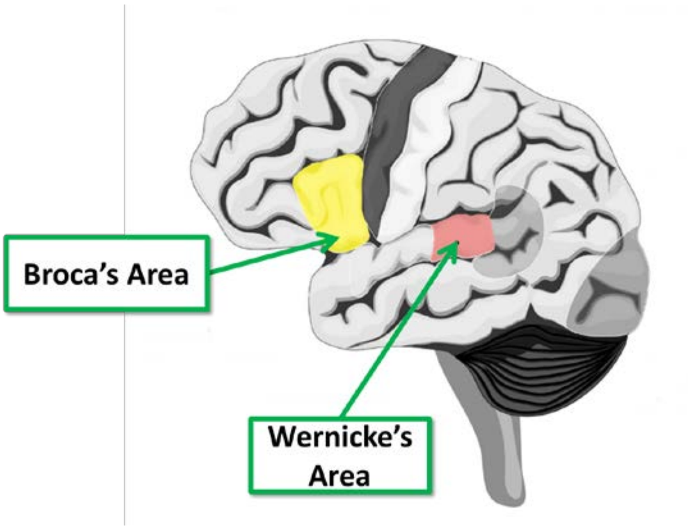
At the back of the brain, in the **occipital lobe** is the **visual area**, which receives and processes visual information. Information from the right-hand side visual field is processed in the left hemisphere, and information from the left-hand side visual field is processed in the right hemisphere. The visual area contains different parts that process different types of information including colour, shape or movement.

1d. Auditory Area

The auditory area is located in the **temporal lobe** and is responsible for analysing and processing acoustic information. Information from the left ear goes *primarily* to the right hemisphere and information from the right ear goes *primarily* to the left hemisphere. The auditory area contains different parts, and the primary auditory area is involved in processing simple features of sound, including volume, tempo and pitch.

2a. Language Centres: Broca's Area

The **Broca's area** is named after Paul Broca, who discovered this region while treating a patient named Leborgne, who was more commonly referred to as 'Tan'. Tan could understand spoken language but was unable to produce any coherent words, and could only say 'Tan'.



After Tan's death, Broca conducted a post-mortem examination on Tan's brain and discovered that he had a lesion in the **left frontal lobe**. This led Broca to conclude that this area was responsible for speech production. People with damage to this area experience **Broca's aphasia**, which results in slow and inarticulate speech.

Extension: *Due to the significance of this finding, Dronkers et al. (2007) decided to conduct an MRI scan on Tan's brain, to try to confirm Broca's original work. Although there was a lesion found in Broca's area, they also found evidence to suggest that other areas may have also contributed to the failure in speech production. Therefore it is likely that the Broca's area is not solely responsible for speech production, as other areas may also play a role.*

2b. Language Centres: Wernicke's Area

At a similar time, Carl Wernicke discovered another area of the brain that was involved in understanding language. Wernicke found that patients with lesions to Wernicke's area were still able to speak, but were unable to comprehend language.

Wernicke's area is found in the **left temporal lobe,** and it is thought to be involved in language processing/comprehension. People with damage to this area struggle to comprehend language, often producing sentences that are fluent, but meaningless **(Wernicke's aphasia)**.

Wernicke concluded that language involves a separate motor and sensory region. The motor region is located in Broca's area, and the sensory region is located in Wernicke's area.

Extension: *However, research by Saygin et al. (2003) found that some patients displayed symptoms of Wernicke's aphasia without any damage to this area. This suggests that language comprehension is much more complex than originally thought. Further evidence has also been found which suggests some left-handed people process language in the right hemisphere.*

	LOCATION	FUNCTION	LEFT, RIGHT OR BOTH HEMISPHERES
MOTOR AREA	Frontal Lobe	The motor area is responsible for voluntary movements by sending signals to the muscles in the body.	**Both** The motor area on one side of the brain controls the muscles on the opposite side.
SOMATO-SENSORY AREA	Parietal Lobe	The somatosensory area receives incoming sensory information from the skin to produce sensations related to pressure, pain, temperature, etc.	**Both** The somatosensory area on one side of the brain receives sensory information from the opposite side of the body.
VISUAL AREA	Occipital Lobe	The visual area receives and processes visual information. The visual area contains different parts that process different types of information including colour, shape or movement.	**Both** Information from the right-hand side visual field is processed in the left hemisphere, and information from the left-hand side visual field is processed in the right hemisphere.
AUDITORY AREA	Temporal Lobe	The auditory area is responsible for analysing and processing acoustic information.	**Both** Information from the left ear goes *primarily* to the right hemisphere and information from the right ear goes *primarily* to the left hemisphere.
BROCA'S AREA	Left Frontal Lobe	The Broca's area is found in the left frontal lobe and is thought to be involved in language production.	**Left**
WERNICKE'S AREA	Left Temporal Lobe	The Wernicke's area is found in the left temporal lobe and is thought to be involved in language comprehension.	**Left**

Evaluating Localisation of Function

- The claim that functions are localised to certain areas of the brain has been criticised. Lashley proposed the **equipotentiality theory**, which suggests that the basic motor and sensory functions are localised, but that higher mental functions are not. He claimed that intact areas of the cortex could take over responsibility for specific cognitive functions following brain injury. This therefore casts doubt on theories about the localisation of functions, suggesting that functions are not localised to just one region, as other regions can take over specific functions following brain injury.

- There is a wealth of case studies on patients with damage to Broca's and Wernicke's areas that have demonstrated their functions. For example, Broca's aphasia is an impaired ability to produce language; in most cases, this is caused by brain damage in Broca's area. Wernicke's aphasia is an impairment of language perception, demonstrating the important role played by this brain region in the comprehension of language.
  - However, although there is evidence from case studies to support the function of the Broca's area and Wernicke's area, more recent research has provided contradictory evidence. **Dronkers et al. (2007)** conducted an MRI scan on Tan's brain, to try to confirm Broca's findings. Although there was a lesion found in Broca's area, they also found evidence to suggest other areas may have contributed to the failure in speech production. These results suggest that the Broca's area may not be the only region responsible for speech production and the deficits found in patients with Broca's aphasia could be the result of damage to other neighbouring regions.

- Furthermore, psychologists suggest that it is more important to investigate *how* the brain areas communicate with each other, rather than focusing on specific brain regions. Wernicke claimed that although the different areas of the brain are independent, they must interact with each other in order to function. An example to demonstrate this is a man who lost his ability to read, following damage to the connection between the visual cortex and the Wernicke's area, which was reported by **Dejerine**. This suggests that interactions between different areas produce complex behaviours such as language. Therefore, damage to the connection between any two points can result in impairments that resemble damage to the localised brain region associated with that specific function. This reduces the credibility of the localisation theory.
  - Also, critics argue that theories of localisation are **biologically reductionist** in nature and try to reduce very complex human behaviours and cognitive processes to one specific brain region. Such critics suggest that a more thorough understanding of the brain is required to truly understand complex cognitive processes like language.

- Finally, some psychologists argue that the idea of localisation fails to take into account individual differences. **Herasty (1997)** found that women have proportionally larger Broca's and Wernicke's areas than men, which can perhaps explain the greater ease of language use amongst women. This, however, suggests a level of **beta bias** in the theory: the differences between men and woman are ignored, and variations in the pattern of activation and the size of areas observed during various language activities are not considered.

3. Hemispheric Lateralisation

Lateralisation is the idea that the two halves of the brain are functionally different and that each hemisphere has functional specialisations, e.g. the left is dominant for language, and the right excels at visual motor tasks. The two hemispheres are connected through nerve fibres called the **corpus callosum,** which facilitate interhemispheric communication: allowing the left and right hemispheres to 'talk to' one another.

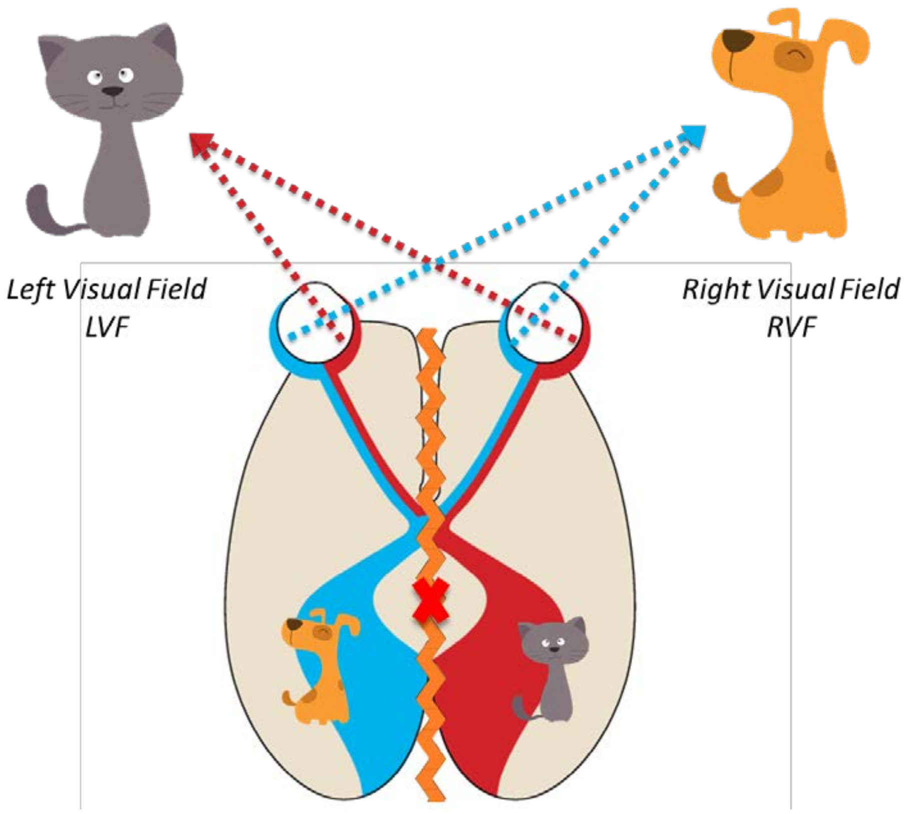
Split-Brain Research

Sperry and Gazzaniga (1967) were the first to investigate hemispheric lateralisation with the use of split-brain patients.

Background: Split-brain patients are individuals who have undergone a surgical procedure where the corpus callosum, which connects the two hemispheres, is cut. This procedure, which separates the two hemispheres, was used as a treatment for severe epilepsy.

Aim: The aim of their research was to examine the extent to which the two hemispheres are specialised for certain functions.

Method: An image/word is projected to the patient's left visual field (which is processed by the right hemisphere) or the right visual field (which is processed by the left hemisphere). When information is presented to one hemisphere in a split-brain patient, the information is not transferred to the other hemisphere (as the corpus callosum is cut).



Sperry and Gazzaniga conducted many different experiments, including describe what you see tasks, tactile tests, and drawing tasks.

- In the **describe what you see** task, a picture was presented to either the left or right visual field and the participant had to simply describe what they saw.
- In the **tactile test**, an object was placed in the patient's left or right hand and they had to either describe what they felt, or select a similar object from a series of alternate objects.
- Finally, in the **drawing task**, participants were presented with a picture in either their left or right visual field, and they had to simply draw what they saw.

Findings:

DESCRIBE WHAT YOU SEE	
Pictured presented to the right visual field (processed by left hemisphere)	**Picture presented to the left visual field (processed by right hemisphere)**
The patient could describe what they saw, demonstrating the superiority of the left hemisphere when it comes to language production.	The patient could not describe what was shown and often reported that there was nothing present.

TACTILE TESTS	
Objects placed in the right hand (processed by the left hemisphere)	**Objects placed in the left hand (processed by the right hemisphere)**
The patient could describe verbally what they felt. Or they could identify the test object presented in the right hand (left hemisphere), by selecting a similar appropriate object, from a series of alternate objects.	The patient could not describe what they felt and could only make wild guesses. However, the left hand could identify a test object presented in the left hand (right hemisphere), by selecting a similar appropriate object, from a series of alternate objects.

DRAWING TASKS	
Pictured presented to the right visual field (processed by left hemisphere)	**Picture presented to the left visual field (processed by right hemisphere)**
While the right-hand would attempt to draw a picture, the picture was never as clear as the left hand, again demonstrating the superiority of the right hemisphere for visual motor tasks.	The left-hand (controlled by the right hemisphere) would consistently draw clearer and better pictures than the right-hand (even though all the participants were right-handed). **This demonstrates the superiority of the right hemisphere when it comes to visual motor tasks.**

Conclusion: The findings of Sperry and Gazzaniga's research highlights a number of key differences between the two hemispheres. Firstly, the left hemisphere is dominant in terms of speech and language. Secondly, the right hemisphere is dominant in terms of visual-motor tasks.

Evaluating Split-Brain Research

- It is assumed that the main advantage of brain lateralisation is that it increases neural processing capacity (the ability to perform multiple tasks simultaneously). **Rogers et al. (2004)** found that in a domestic chicken, brain lateralisation is associated with an enhanced ability to perform two tasks simultaneously (finding food and being vigilant for predators). Using only one hemisphere to engage in a task leaves the other hemisphere free to engage in other functions. This provides evidence for the advantages of brain lateralisation and demonstrates how it can enhance brain efficiency in cognitive tasks.
    - However, because this research was carried out on animals, it is impossible to conclude the same of humans. Unfortunately, much of the research into lateralisation is flawed because the split-brain procedure is rarely carried out now, meaning patients are difficult to come by. Such studies often include very few participants, and often the research takes an **idiographic** approach. Therefore, any conclusions drawn are representative only of those individuals who had a confounding physical disorder that made the procedure necessary. This is problematic as such results cannot be generalised to the wider population.

- Furthermore, research has suggested that lateralisation changes with age. **Szaflarki et al. (2006)** found that language became more lateralised to the left hemisphere with increasing age in children and adolescents, but after the age of 25, lateralisation decreased with each decade of life. This raises questions about lateralisation, such as whether everyone has one hemisphere that is dominant over the other and whether this dominance changes with age.

- Finally, it could be argued that language may not be restricted to the left hemisphere. **Turk et al. (2002)** discovered a patient who suffered damage to the left hemisphere but developed the capacity to speak in the right hemisphere, eventually leading to the ability to speak about the information presented to either side of the brain. This suggests that perhaps lateralisation is not fixed and that the brain can adapt following damage to certain areas.

4. Plasticity and Functional Recovery

The brain is not a static organ, and the functions and processes of the brain can change as a result of experience and injury. **Brain plasticity** refers to the brain's ability to change and adapt because of experience. Research has demonstrated that the brain continues to create new neural pathways and alter existing ones in response to changing experiences (see evidence below).

The brain also appears to show evidence of **functional recovery**: the transfer of functions from a damaged area of the brain after trauma to other undamaged areas. It can do this through a process termed **neuronal unmasking** where 'dormant' synapses (which have not received enough input to be active) open connections to compensate for a nearby damaged area of the brain. This allows new connections in the brain to be activated, thus recovering any damage occurring in specific regions.

Evidence/Evaluation for Plasticity and Functional Recovery

- **Kuhn et al.** found a significant increase in grey matter in various regions of the brain after participants played video games for 30 minutes a day over a two-month period. Similarly, **Davidson et al.** demonstrated the permanent change in the brain generated by prolonged meditation: Buddhist monks who meditated frequently had a much greater activation of gamma waves (which coordinate neural activity) than did students with no experience of meditation. These two studies highlight the idea of plasticity and the brain's ability to adapt as a result of new experience, whether it's video games or mediation.

- There is further research to support the notion of brain plasticity. **Maguire et al.** found that the posterior hippocampal volume of London taxi drivers' brains was positively correlated with their time as a taxi driver and that there were significant differences between the taxi drivers' brains and those of controls. This shows that the brain can permanently change in response to frequent exposure to a particular task.
    - However, some psychologists suggest that research investigating the plasticity of the brain is limited. For example, Maguire's research is biologically reductionist and only examines a single biological factor (the size of the hippocampus) in relation to spatial memory. This approach is limited and fails to take into account all of the different biological/cognitive processes involved in spatial navigation which may limit our understanding. Other psychologists suggest that a holistic approach to understanding complex human behaviour may be more appropriate.

- There is research to support the claim for functional recovery. **Taijiri et al. (2013)** found that stem cells provided to rats after brain trauma showed a clear development of neuron-like cells in the area of injury. This demonstrates the ability of the brain to create new connections using neurons manufactured by stem cells.

- While there is evidence for functional recovery, it is possible that this ability can deteriorate with age. **Elbert et al.** concluded that the capacity for neural reorganisation is much greater in children than in adults, meaning that neural regeneration is less effective in older brains. This may explain why adults find change more demanding than do young people. Therefore, we must consider individual differences when assessing the likelihood of functional recovery in the brain after trauma.

- A final strength of research examining plasticity and functional recovery is the application of the findings to the field of **neurorehabilitation.** Understanding the processes of plasticity and functional recovery led to the development of neurorehabilitation which uses motor therapy and electrical stimulation of the brain to counter the negative effects and deficits in motor and cognitive functions following accidents, injuries and/or strokes. This demonstrates the positive application of research in this area to help improve the cognitive functions of people suffering from injuries.

Possible Exam Questions

1. Explain what is meant by the term plasticity. (2 marks)

2. Briefly explain how split-brain patients could be examined in an experiment. (4 marks)

3. Briefly explain what split-brain research has shown. (4 marks)

4. Outline evidence in relation to brain plasticity. (4 marks)

5. Outline evidence in relation to functional recovery. (4 marks)

6. Evaluate research using split-brain patients to investigate hemispheric lateralisation of function. (4 marks)

7. David is fourteen years old. Last year, he was hit by a bus when walking to school and suffered from serious head injuries. While David made a full physical recovery, he has problems with his speech and comprehension of language. However, after one year, David had recovered nearly all of his language abilities. Use your knowledge of functional recovery and plasticity to explain David's recovery. (4 marks)

8. Joseph suffered a stroke when he was 45-years-old. He could move his left arm and leg but was paralysed down his right side. While Joseph could understand what was said to him, he was unable to speak. Referring to Joseph, discuss hemispheric lateralisation of language centres in the brain. (16 marks).

9. Describe and evaluate what research has shown about localisation of function in the brain. (16 marks)

10. Describe and evaluate research into lateralisation and/or the split brain (16 marks).

11. Discuss evidence for plasticity and/or functional recovery after trauma. (16 marks)