DP IB Psychology: SL

Neuroplasticity

Contents

Neuroplasticity

What is neuroplasticity?

- **Neuroplasticity** refers to the brain's ability to adapt to change, be that from injury, damage done due to illness or changes brought about due to learning and experience
- **Structural plasticity** refers to changes within brain structures (e.g. the hippocampus) due to learning experienced over time i.e. this does not happen immediately
- **Functional plasticity** (also known as **functional recovery**) refers to the brain's ability to replace lost or damaged functions by using existing brain regions in their place
- Plasticity simply means that the brain is not a static, concrete mass: it is a flexible organ that responds and adapts to **environmental stressors**

What are some examples of neuroplasticity?

- A child who has had half of her brain removed (**hemispherectomy**) to control her **epilepsy** is able to function almost completely normally as her remaining hemisphere takes over the tasks of the hemisphere which has been removed
- London black cab taxi drivers spend years navigating and learning routes through central London: their brains adapt by increasing **grey matter** in the region of the brain linked to spatial navigation (see **Maguire, 2000**)
- A person in their 60s who has been practising meditation for decades will have increased grey matter in their prefrontal cortex as a result of their practice

Which research studies support neuroplasticity?

- **Maguire (2000)** showed that years spent as a black cab driver in London may result in increased grey matter in the **posterior hippocampus**
- **Luby et al. (2013)** showed that poverty in childhood was associated with reduced grey matter in the hippocampus and **amygdala** but this was mediated by the type of care given i.e. loving or hostile
- **Rauscher et al.'s (1993)** 'Mozart effect' research linked listening to a specific Mozart sonata with functional recovery

Maguire and Luby's studies are available as separate Key Studies – just navigate the Brain and Behaviour section of this topic to find them.

Evaluation of neuroplasticity research:

- **Maguire (2000)**
  - Strength: The use of a **blind** (unbiased) researcher to count the pixels on the MRI scans increase the study's **validity**
  - Limitation: A sample size of 16 is too small to generate **robust** results
- **Luby et al. (2013)**
  - Strength: The findings have a useful **application** as they can be used to inform interventions and strategies for families living in poverty
  - Limitation: Some of the children in the study had pre-existing **depression** which could **confound** the results as this could have influenced brain development outside of the **variable** of poverty
- **Rauscher et al.'s (1993)**
  - Strength: Replications of the original study have shown that it is very successful in functional recovery when applied to the field of visual art
  - Limitation: The improvement in **spatial reasoning** in the original study only lasted for about 15 minutes with no long-term effects reported

Worked Example

Describe one study of neuroplasticity. [9]

Here is part of a response to the above question. The focus of this paragraph is on description of the procedure. Note the level of detail in the response, the use of terminology and the fact that this paragraph focuses only on procedure:

Luby et al. (2013) investigated the effect of childhood poverty on brain development and its implications once the child reached school age. The study also took into account the behaviour of the main caregiver: the mediating effect of their care on the child and, by inference, the child's developing brain. The participants underwent social and cognitive assessments every year for 3 to 6 years before having two MRI scans, one of the whole brain and one of the amygdala and hippocampal areas. The support or hostility of their caregivers was also recorded during this pre-MRI period. The MRI scans measured the brain volumes of white matter and cortical grey matter, as well as volumes of the hippocampus and the amygdala.

Two Key Studies of Neuroplasticity: Maguire (2000) & Luby (2013)

Key Study 1: Maguire (2000)

Aim: To investigate a **neuroplasticity** in London black cab taxi drivers as a result of experience in **spatial navigation**

Participants: 16 healthy, right-handed male London black cab taxi drivers who had passed 'The Knowledge', a test of spatial navigation, aged 32–62 years with a mean age of 44 years. They had all been taxi drivers for at least 18 months, with the highest number of years as a taxi driver at 42 years

Procedure: The participants were placed in an MRI scanner and their brains were scanned. The MRI measured the volume of **grey matter** in the **hippocampus** of each participant, and this was then compared to pre-existing scans of 50 healthy, right-handed males (the **control group**). Grey matter was measured using **voxel-based morphemetry** (VBM) which focuses on the density of grey matter and **pixel counting**

Results: The **posterior hippocampi** of the taxi drivers showed a greater volume of grey matter than that of the controls, who had increased grey matter in their **anterior hippocampi** compared to the taxi drivers. Maguire also carried out a **correlational analysis** which showed a positive correlation between volume of posterior hippocampal grey matter and length of time spent as a taxi driver

Conclusion: The posterior hippocampus may be linked to spatial navigation skills

Evaluation of Maguire (2000)

Strengths

- The study used a highly controlled clinical method of obtaining **objective** data which could then be easily compared and analysed
- Understanding neuroplasticity can help aid the recovery of people who have suffered **brain damage**

Limitations

- A correlation cannot show cause-and-effect so it is impossible to know whether the taxi drivers already had naturally high levels of hippocampal grey matter
- The results are only **generalisable** to male, right-handed London taxi drivers so the nature of neuroplasticity in women is not known

Key terms:

- **Spatial navigation**
- **Posterior hippocampus**
- **Voxel-based morphometry**

Key Study 2: Luby et al. (2013)

Aim: To investigate whether poverty experienced in childhood is shown in delayed brain development and the extent to which **mediating factors** may influence early deprivation.

Participants: Children who were already enrolled on a 10-year **longitudinal** study of Preschool Depression: 145 right-handed children from the USA. The children were categorised as living in poverty.

Procedure: The children had undergone regular testing: once a year (over 3-6 years) which consisted of a series of tests aimed to measure their cognitive, emotional and social skills. The researchers also collected data on how close the children were to their caregivers as well as incidences of any negative and stressful events in their lives. Each child then had two MRI scans in which the whole brain was scanned (session 1) or just the **hippocampus** and the **amygdala** (session 2).

Results: Both the hippocampus and the amygdala showed less **white** and **grey matter** in the MRI scans. However, if the child had experienced positive care from adults there was a less negative effect on the hippocampus. Difficult and stressful life events only affected the left hippocampus.

Conclusion: Poverty does appear to have a negative effect on brain development in childhood, but this can be reduced by the quality of caregiving the child experiences.

Evaluation of Luby et al. (2013)

Strengths

- The researchers were able to check the behavioural, cognitive, and social measures against the MRI results which increases the **internal validity** of the study
- The study's **longitudinal** design means that real changes and comparisons across time could be made

Limitations

- Attempting to measure complex variables (e.g. nature of caregiving, social skills) is difficult as these **variables** are not exact and may be prone to researchers interpreting them in **subjective** ways
- The sample is difficult to **generalise** from as it only represents pre-school children living in poverty who exhibit symptoms of depression so it cannot explain how poverty may affect non-depressed children

Key terms:

- **Hippocampus**
- **Amygdala**
- **Mediating factors**

Neural Networks & Neural Pruning

Neural Networks and Neural Pruning

What are neural networks?

- **Neural networks** are a group (a network) of neurons that are interlinked and connected which combine to produce a specific **neurological** function or process e.g. learning a new language; spatial navigation
- **Neural pathways** form when a new behaviour is learned, and these pathways become stronger and more embedded over time and with practice e.g. perfecting an figure-skating move; becoming more fluent in a language
- Neural pathways and networks that are not frequently used may eventually cease functioning altogether e.g. forgetting how to speak French once a person leaves school; not being able to hit a hole-in-one without sufficient golf practice

What is neural pruning?

- **Neural pruning** refers to the process carried out by the brain in order to increase its efficiency
- **Synapses** and **neurons** that are no longer used or needed are eliminated by the brain
- **Neural pruning is a key function of neuroplasticity as it is involved in the pruning of neural networks and neurons that may once have been learned (increased grey matter) but are now no longer used (decreased grey matter)**

Which research studies support neural networks and neural pruning?

- **Maguire (2000)** showed that years spent as a black cab driver in London may result in increased grey matter in the **posterior hippocampus** – evidence of **neuroplasticity** and by extension the neural networks involved in spatial navigation
- **Draganski et al. (2004)** found that learning to juggle led to neuroplasticity (increased grey matter in the mid-temporal cortex) but that this then decreased significantly when the participants stopped juggling (evidence of neural pruning)
- **Gotgay et al. (2004)** found that neural pruning occurs frequently and rapidly in children from birth, as their more spontaneous, impulsive behaviours are replaced by increasingly sophisticated **cognitions**

Maguire and Draganski's studies are available as separate Key Studies – just navigate the Brain and Behaviour section of this topic to find them.

Evaluation of neural networks and neural pruning research:

Maguire (2000)

- Strength: The choice of **sample** is suitable in terms of their experience of spatial navigation
- Limitation: There may be other explanations for the increased grey matter in the taxi drivers' posterior hippocampi

Draganski et al. (2004)

- Strength: The findings have a useful **application** as they can be used to inform possible interventions and therapies to offset degenerative brain conditions such as **Alzheimer's**
- Limitation: This was a **self-selecting** sample which means that it is not **representative** of a wider population as self-selecting samples often share characteristics e.g. helpful, interested, extrovert

Gotgay et al. (2004)

- Strength: The use of a **longitudinal** design means that the researchers could measure changes in grey matter over time
- Limitation: The findings do not explain why neural pruning occurs, only that brain development appears to follow the same pattern across the sample

Two Key Studies of Neural Networks & Neural Pruning: Maguire (2000) & Draganski et al. (2004)

Key Study 1: Maguire (2000)

Aim: To investigate how **neural networks** form as a result of **spatial navigation** in London black cab taxi drivers

Participants: 16 healthy, right-handed male London black cab taxi drivers who had passed 'The Knowledge', a test of spatial navigation, aged 32–62 years with a mean age of 44 years. They had all been taxi drivers for at least 18 months, with the highest number of years as a taxi driver at 42 years

Procedure: The participants were placed in an MRI scanner and their brains were scanned. The MRI measured the volume of **grey matter** in the **hippocampus** of each participant, and this was then compared to pre-existing scans of 50 healthy, right-handed males (the **control group**). The grey matter was measured using **voxel-based morphemetry** (VBM) which focuses on the density of grey matter and **pixel counting**

Results: The **posterior hippocampi** of the taxi drivers showed a greater volume of grey matter than that of the controls, who had increased grey matter in their **anterior hippocampi** compared to the taxi drivers. Maguire also carried out a **correlational analysis** which showed a positive correlation between the volume of posterior hippocampal grey matter and the length of time spent as a taxi driver

Conclusion: The posterior hippocampus may be linked to spatial navigation skills due to a specific **neural network** of cells within the posterior hippocampus

Evaluation of Maguire (2000)

Strengths

- The study used a highly controlled clinical method of obtaining **objective** data which could then be easily compared and analysed
- The **correlational** analysis of time spent as a taxi driver linked to increased volume of hippocampal grey matter lends **validity** to the idea that neural networks form as a result of learning and experience

Limitations

- A correlation cannot show cause-and-effect so it is impossible to know whether the taxi drivers already had naturally high levels of hippocampal grey matter
- Neural networks may have formed in the participants' brain due to other, unknown factors

Key terms:

- **Spatial navigation**
- **Posterior hippocampus**
- **Neural networks**

Key Study 2: Draganski et al. (2004)

Aim: To investigate whether **structural changes** in the brain would occur in response to learning and then ceasing juggling.

Participants: A **self-selected** sample of 24 adults aged 20–24 years old (21 female; 3 male) with no prior experience of juggling.

Procedure: The participants were **randomly allocated** to 2 conditions: jugglers or non-jugglers. Each participant underwent an MRI scan. Those in the juggling condition were taught a 3-ball cascade juggling routine. They were asked to practice this routine and to notify the researchers when they had mastered it. At that point the jugglers had a second MRI scan. After this second scan they were told not to juggle anymore and then a third and final scan was carried out 3 months later. The non-jugglers also underwent 3 separate MRI scans at pre-determined intervals.

Results: The MRI scans showed that there was no difference in grey matter in the brains of jugglers and non-jugglers at the time of the first scan (before the juggling practice began). At the end of the first part of the study, when the jugglers had been practising juggling, they had a significantly larger volume of grey matter in their **mid-temporal cortex** in both **hemispheres** (an area of the brain associated with **visual memory**, co-ordination, and movement).

Three months after the jugglers had stopped juggling the amount of grey matter in this region had decreased. However, the jugglers still had more grey matter after the study than at their first scan. The non-jugglers' brains showed no changes at all from first to final scan.

Conclusion: Grey matter appears to increase in specific brain regions (**neuroplasticity**) in response to environmental demands (learning to juggle) and shrinks in the absence of that learning (stopping juggling). Thus, this study provides evidence for both neuroplasticity and **neural pruning** (and **neural networks** as it is via these that the learning takes place).

Evaluation of Draganksi et al. (2004)

Strengths

- This study has good **internal validity** as it took **baseline measurements** of the participants before the process began so as to ensure that real changes could be observed for comparison
- The findings have a useful **application** as they can be used to inform possible interventions and therapies to offset degenerative brain conditions such as **Alzheimer's**

Limitations

- This was a **self-selecting** sample which means that it is not **representative** of a wider population as self-selecting samples often share characteristics e.g. helpful, interested, extrovert
- The participants were not in **controlled conditions** when they were learning to juggle so some of them may have over-practised, under-practised or not practised at all which would mean that the neural growth and pruning was due to other factors

Key terms:

- **Mid-temporal cortex**
- **Visual memory**
- **Structural changes**