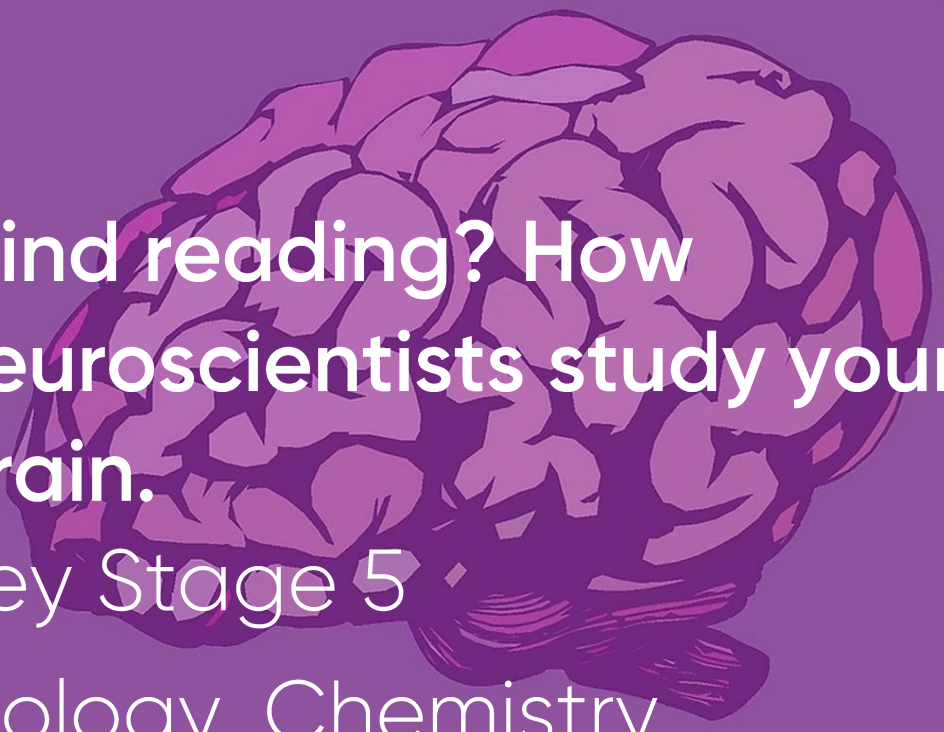
Research
Based
Curricula



Mind reading? How neuroscientists study your brain.

Key Stage 5

Biology, Chemistry, Mathematics, Physics, and Psychology.

2020

BROUGHT TO YOU BY RBC ACCESS ED

Contents

Part 1: Introduction

Part 2: Resources

Each resource is a chapter with activities to complete to demonstrate learning

Part 3: Tips and Guidance

For Students
Getting Started

RBC means Research-Based Curriculum,. Each RBC coursebook is written by a PhD student at a university about their cutting edge research.

Why complete an independent 'RBC' study pack?

RBC courses are challenge courses to sharpen your skills and resilience: finishing a RBC course is a major accomplishment to add to your academic CV. To get into the university, you must demonstrate that you are intellectually curious, and will make the most of the academic opportunities available to you. Completing a pack will allow you to gain invaluable experience to write about in your university application..

It allows you to:

- ✓ Build your subject experience to mention in your UCAS Personal Statement
- ✓ Sharpen your academic skills
- ✓ Experience what it's like to study beyond school and at university
- ✓ Better understand what you enjoy and don't
- ✓ Improve your overall subject understanding ahead of final exams

For Students
Getting Started

What's in this booklet?

Your RBC booklet is a pack of resources containing:

- ✓ More about how and why study this subject
- ✓ Six 'resources' each as a lesson with activities
- ✓ A final assignment to gauge learning
- ✓ Extra guidance throughout about the university skills you are building
- ✓ End notes on extra resources and where to find more information

Who should complete this pack?

Anyone interested in improving their academic skills or understanding what they should do at university. *This pack is especially great for anyone interested in studying* ***Sciences,*** *particularly* **Psychology, Biology, Chemistry, Physics or Maths,** *and want to understand how they link.*

Even if you are unsure of where your interest in these subjects can take you, by completing this pack you will have a clearer idea of the variety of subjects that link to one another.

If you have any questions while you are using the resources in this pack, you can contact your teacher or email us directly at schools@access-ed.ngo.

Good luck with your journey to higher education!

For Students
University Skills

To complete this resource, you will have to demonstrate impressive academic skills. When universities are looking for new students, they will want young people who can study independently and go above and beyond the curriculum. All of these skills that you will see here will demonstrate your abilities as a university student – while you're still at school!

Every time you have to look something up, or write up a reference you are showing that you can work independently.

Every time that you complete a challenging problem or write an answer to a difficult question, you might demonstrate your ability to think logically or build an argument.

Every time that you evaluate the sources or data that you are presented with, you are showing that you can "dive deep" into an unfamiliar topic and learn from it!

Skills you will build for university:

independent research	your ability to work on your own and find answers online or in other books
creativity	your ability to create something original and express your ideas
problem solving	your ability to apply what you know to new problems
building an argument	your ability to logically express yourself
providing evidence	your ability to refer to sources that back up your opinions/ ideas
academic referencing	your ability to refer to what others have said in your answer, and credit them for their ideas
Deep dive	your ability to go above and beyond the school curriculum to new areas of knowledge
source analysis	your ability to evaluate sources (e.g. for bias, origin, purpose)
Data interpretation	your ability to discuss the implications of what the numbers show
Active reading	your ability to engage with what you are reading by highlighting and annotating

Where can this subject take me?

Pathways

Studying Biology or Psychology can open the doors to many degrees and careers. It intersects with microbiology, chemistry, physiology, and sociology. Whatever interests you is likely to relate to biology in some way. See a snapshot of where studying Biology and Psychology can take you.

'Transferrable skills' from Biology to a career:

- research and data analysis
- problem-solving and creative thinking
- delivering successful projects
- communication, through report writing and presentations
- teamworking and collaboration
- the ability to work independently
- numeracy and maths
- IT and computer literacy

'Transferrable skills' from Psychology to a career:

- Empathy and interest in people
- analytical research
- problem solving
- the ability to work in teams.
- written and verbal communication; report writing and presenting
- information technology
- handling of data and statistics

What are some are the 'interdisciplinary' subjects in this course?

Interdisciplinary is a term you will hear used by higher education institutions. It's also how many professionals and academics in the real-world operate: they use multiple subjects, or disciplines, to achieve their work.

By thinking about which subjects you like, alongside maths, it can help you choose a career pathway later.

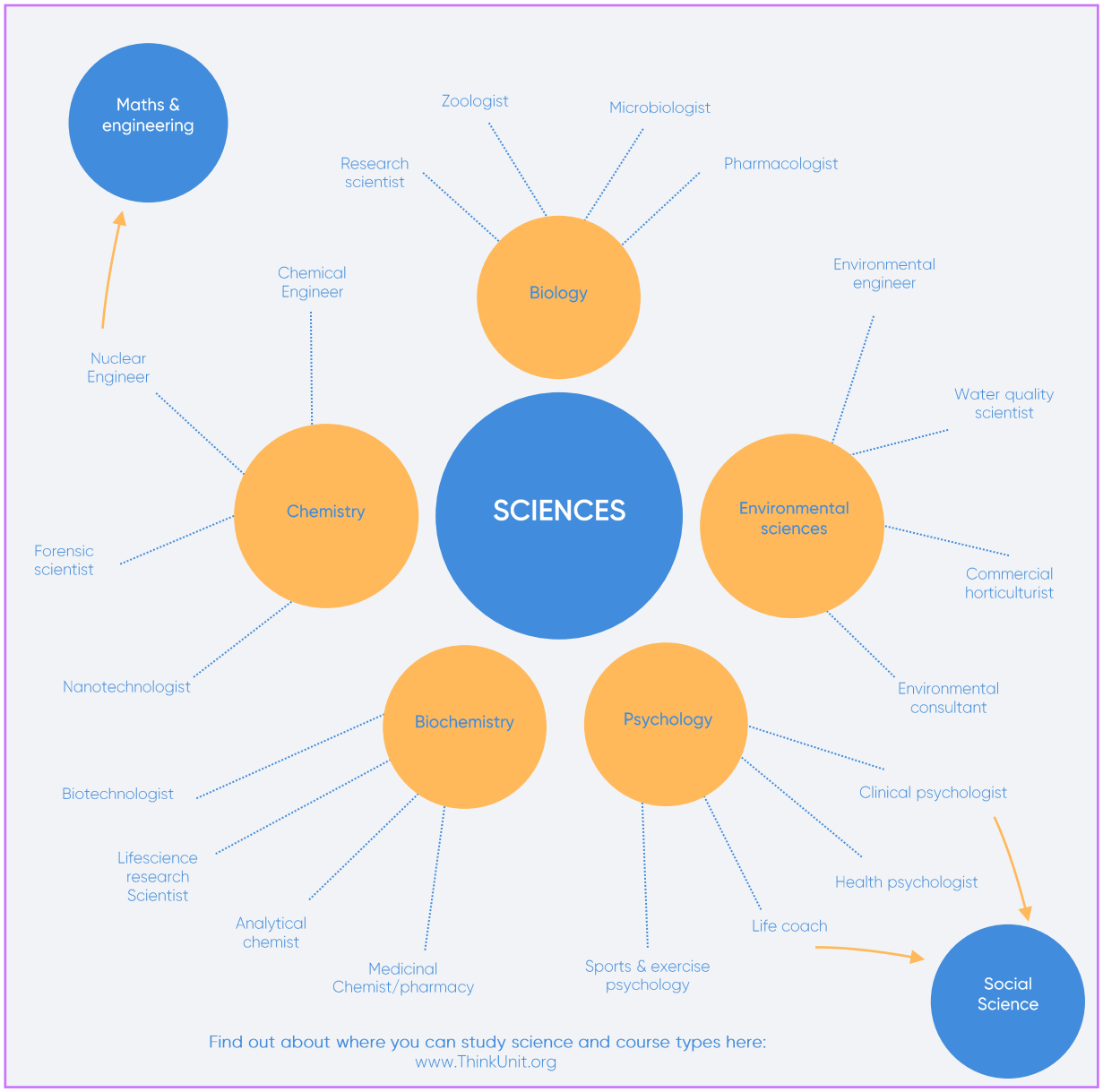
Read more about subject selection and careers pathways:

https://targetjobs.co.uk
https://www.prospects.ac.uk
https://thinkuni.org/

Subject map: Sciences

A degree in Sciences gives Students access to a large number of career choices. Many students who study sciences go on to pursue their Master's degree in Science. However, a significant portion of them also start looking out for jobs in the field of Cancer research, Stem Cell technology and other positions in this space.

Did you know? Being a scientist of any kind can open up may doors within any industries, from managing projects to labs to health policy teams with governments!



Find our about Science-related careers here:
PROSPECTS: https://www.prospects.ac.uk
TARGET JOBS: https://targetjobs.co.uk

For Teachers RBC Guide

Learner aims

The Research-Based Curriculum aims to support student attainment and university progression by providing classroom resources about cutting-edge research at local universities. The resources are designed to:

- ✓ promote intellectual curiosity through exposure to academic research
- ✓ stretch and challenge students to think deeply about content that may be beyond the confines of the curriculum
- ✓ develop core academic skills, including critical thinking, metacognition, and written and verbal communication
- ✓ inform students about how subjects are studied at university, and provide information, advice and guidance on pursuing subjects at undergraduate level

Content

The programme represents a unique collaboration between universities and schools. Trained by AccessEd, PhD Researchers use their subject expertise to create rich resources that help bring new discoveries and debates to students.

The Research-Based Curriculum offers ten modules suitable for either KS4 or KS5 study. The modules span a range of disciplines, including EBacc and A-level subjects, as well as degree subjects like biochemistry. Each module includes six hours of teaching content, supported by student packs, teacher notes and slides. All modules are available online and free of charge for teachers at select schools.

Using the RBC pack

These resources are designed to be used flexibly by teachers. The resources can be completed by students individually or in groups, in or out of the classroom.

For Teachers
Using the RBC packs

Extra-Curricular Subject Enrichment Clubs

Here are five examples of delivery options:

The resources can be completed in small groups (4-8 pupils) across a series of weekly lunch clubs or after-school clubs. Groups can reflect on their learning by presenting a talk or poster on the subject matter at the end of the course.

University Access Workshops

The resources can be used by students to explore subjects that they are interested in studying at university. This can inform their decision making with regards to university degree courses, and allow students to write more effective personal statements by including reflections on the Research-Based Curriculum.

Research Challenge

The resources can be used to ignite curiosity in new topics and encourage independent research. Schools could hold a research challenge across a class or year group to submit a piece of work based on the resources. Pupils could submit individually or in small groups, with a final celebration event.

Summer Project

Resource packs can function as 'transition' projects over the summer, serving as an introduction to the next level of study between KS3 and KS4, or KS4 and KS5. Students could present their reflections on the experience in a journal.

Why offer these?

The Research-Based Curricula programme builds on the University Learning in Schools programme (ULiS), which was successfully delivered and evaluated through the London Schools Excellence Fund in 2015. The project was designed in a collaboration between Achievement for All and The Brilliant Club, the latter of which is the sister organisation of AccessEd. ULiS resulted in the design and dissemination of 15 schemes of work based on PhD research for teachers and pupils at Key Stage 3. The project was evaluated by LKMCo. Overall, pupils made higher than expected progress and felt more engaged with the subject content. The full evaluation can be found here: ULiS Evaluation.

Questions

For more information contact hello@access-ed.ngo

Introduction to Topic Neuroscience

The topics within this pack will include:

How does magnetic resonance imaging work?

How can magnetic resonance imaging be used to measure brain activity?

How do neuroscientists measure the concentration of brain metabolite in vivo?

Experimental design and hypothesis testing.

What approaches are used to analyse brain activity?

What is open science and why is it important?

The human brain is one of the most complex things in the known universe and is certainly the most complex organ in the human body. The brain contains around 100 billion neurons, each of which can be individually connected to thousands of other neurons. Meanwhile, the activity of these neurons is supported by the activity of glial cells, whose prevalence mean glial cells can outnumber neurons by more than ten to one. Therefore, any attempt to begin to understand how the brain works requires the effort of multidisciplinary teams that cover the full spectrum of STEM to begin to make even a dent in our understanding of how the brain works.

Magnetic resonance imaging is a type of medical imaging scan that can be used to produce images of the body using magnetic fields and radio waves. In this coursebook you will learn how magnetic resonance imaging can be applied to study the activity of the human brain. This coursebook will highlight the interdisciplinary nature of neuroscience, and will provide an introduction of how the fields of biology, chemistry, mathematics, physics and psychology are all essential for neuroscientific research.

In this coursebook you will first cover how the basic principles of nuclear magnetic resonance are used to create images of biological tissue with magnetic resonance imaging. Next you will learn how magnetic resonance imaging can be used to detect activity dependent functional changes in brain activity, and the concentrations of different metabolites in the brain. After this you will then cover methodological considerations for brain imaging studies such as how studies are designed and how data are analysed. Lastly, this coursebook will introduce the topic of open science, and will provide a good starting point for discussions around how the veracity and robustness in research can be improved, and what best practice should look like in scientific research.

Introduction to Neuroscience at University

Neuroscience is a broad, interdisciplinary field that is home to people from a vast array of backgrounds with different yet overlapping areas of expertise. Many of those working in neuroscience do not necessarily have a background in biology, however those who do are not at a disadvantage relative to their peers.

Those choosing to study neuroscience at university would study a broad range of topics related to how the nervous system works, and how it generates behaviour, movement, perception, and cognition among other topics. The modules you could study will range from neuroanatomy, physiology, biochemistry and pharmacology, to developmental neuroscience, medical imaging physics, computational and systems neuroscience, neurodegenerative and mental health disorders, and cognitive neuroscience.

Alternatively, there are also opportunities to get involved in neuroscience at undergraduate or postgraduate level whilst studying for a a degree in an allied field. These include (but are not limited to) biology, chemistry, computer science engineering, mathematics, physics and psychology. For instance, a biologist could study the importance of gene expression in neurological disorder, an engineer could study how neuroscience is important for developing better prosthetics, whilst a mathematician could develop new data analysis methods and a computer scientist could use neuroscience principles to build better machine learning and artificial intelligence algorithms.

The possibilities within the field of neuroscience are endless for those from all corners of the STEM spectrum, and I hope this coursebook gives you an insight into of some of the opportunities available within the field, and how this will fit in with your interests.

Meet the PhD Researcher Brendan Williams

My path to human neuroscience research is one of the more common routes taken by researchers, although there are many ways of getting into neuroscience due to the interdisciplinary nature of the subject. I was first introduced to the field of psychology while studying for my A-levels. I initially thought that medicine was what I had wanted to do, but after undertaking voluntary work experience I knew that clinical work was not for me. I was broadly interested in biology, and how biology can influence our behavior. Therefore, I decided to go and study for a joint honors degree in Biology and Psychology at the University of Reading.

Whilst I found the modules I took in the first year of my degree enjoyable, I was somewhat disappointed in the lack of direct integration available between the two subjects of my degree. Therefore I decided to switch my focus solely to Psychology, where I was able to elect to complete modules focusing on biological psychology. I particularly enjoyed the research methods elements of my course and had several opportunities to get involved in research as an undergraduate. For example, I undertook a research internship in the summer between my second and third year investigating the impact of intolerance of uncertainty on attentional bias; and completed a dissertation project testing the effectiveness of a mindfulness intervention on healthy eating choices under acute stress.

After my undergraduate studies I was keen to develop my understanding of neurobiology further, so decided to study for a masters degree in neuroscience at King's College London. My masters was a fantastic opportunity for me to contrast and coalesce the functioning of nervous system as a homologous unit spanning from receptor and single cell activity to higher order cognition and mental health conditions. Additionally, I was able to build upon the wet lab skills from my undergraduate studies working on a research project developing methods for identifying dopamine receptors in the striatum of mice.

Meet the PhD Researcher Brendan Williams

During my masters I was in contact with a professor who had led an elective module in the final year of my undergraduate degree about options for completing my doctoral work within her lab. I was fortunate enough to acquire funding to support my doctoral research, and I am now in the third year of my PhD where I use magnetic resonance imaging to study the brain mechanisms of adaptive decision making.

Although my path into neuroscience has followed a fairly linear progression, one of the greatest strengths of the field of neuroscience is it interdisciplinarity and accessibility to individuals from all backgrounds. Regardless of your background within STEM if you have a curiosity about the inner workings of the brain then there will a niche within neuroscience that should pique your interest. I wish that I had greater exposure and understanding of the scope of neuroscience whilst studying for my A-levels, and it is my hope that this course book will give you an insight into some of the inner workings of my field in human neuroscience. Good luck!

A-Level Subjects	Biology, Mathematics, Psychology
Undergraduate	Psychology
Postgraduate	Neuroscience

Glossary

Term	Definition
Block design	Type of experimental design used in neuroimaging studies where stimuli for each condition are presented in separate blocks with rest periods in between.
BOLD imaging	Blood oxygen level dependent imaging is a neuroimaging approach where activity dependent changes in regional blood flow are used to measure activity in the brain.
Central nervous system	The part of the nervous system that includes the brain and spinal cord.
Chemical shift (δ)	The difference in the location of peaks on a magnetic resonance spectroscopy spectrum, expressed in parts per million (ppm).
Dependent variable	A variable that is measured in a scientific study and whose value is depends on other factors, such as the independent variables implemented by the experimenter.
Diamagnetic shielding	The shielding provided to protons by local electrons that alter the amount of energy required to shift a proton from the α to the β spin state.
Event-related design	Type of experimental design used in neuroimaging studies where the presentation of stimuli for each condition are intermixed with each other.
FAIR principles	A set of guiding principles for sharing scientific data. Shared data should be Findable, Accessible, Interoperable and Reusable.
Falsifiable	Something can that be proved to be false, for example a hypothesis.
Gradient coil	Component of a magnetic resonance imaging scanner required for imaging different spatial locations.
Grey matter	Tissue in the brain containing neuronal cell bodies, unmyelinated sections of neuronal axons and their dendrites, glial cells, synapses, and blood capillaries.
Haemodynamic response	Term describing the relative change in the BOLD contrast .
Haemoglobin	Protein found in the blood that is involved in the transportation of oxygen around the body.

Glossary

Term	Definition
Independent variable	A variable that is a scientific study whose value cannot be changed by other variables in the study.
Magnetic resonance imaging	An imaging technique used to create images of the body by measuring the response of protons in tissue to radiofrequency pulses when in a magnetic field.
Magnetic resonance spectroscopy	A technique associated with magnetic resonance imaging that can be used to measure the concentration of metabolites in the brain.
Metabolite	Small molecules found in the brain whose concentrations can be measured using magnetic resonance spectroscopy.
Metascience	The scientific field of study concerned with the study of science itself.
Multiple comparisons	An occurrence when multiple statistical tests are run on the same dataset that increases the probability of a type 1 error.
Neuron	Cell type responsible for the transmission of signals within the nervous system.
Open science	A movement within the scientific community that aims to improve the robustness of academic research, the credibility of findings, and the accessibility to research for all.
Peripheral nervous system	Part of the nervous system containing nerves and ganglia outside of the brain and spinal cord.
Preregistration	An open science approach where researchers describe their research plans prior to the acquisition of data. These are timestamped to improve the credibility of scientific research.
Procession	The spin of a proton around the axis of a magnetic field. Protons that process together are known as being 'in phase' while those that do not are 'out of phase'.
Radiofrequency coil	Component of a magnetic resonance imaging scanner required for emitting radiofrequency pulses and receiving signals back from the body.
Registered report	Similar to preregistration (see definition), however registered reports are peer reviewed, while preregistrations are not.

Glossary

Term	Definition
Repetition time	The amount of time required for a magnetic resonance imaging scanner to acquire a single volume of brain data.
Replicability	The ability to find results that confirm the finding of another study by using a similar analysis for different data.
Reproducibility	The ability to recreate an aspect of the study. This could be in relation to the methodology of the study, or of the results by using the same data and analysis to get the same results.
TR	See repetition time.
Type 1 error	The rejection of a true null hypothesis, that is, finding a statistically significant difference when there is no true difference.
Type 2 error	The non-rejection of a false null hypothesis, that is, finding a no statistically significant difference when there is a true difference.
White matter	Tissue in the brain containing the myelinated axons of neurons that facilitate fast, long range connectivity across the brain.
α spin state	The lower energy state for a proton where a proton is parallel to the magnetic field.
β spin state	The higher energy state for a proton where a proton is antiparallel to the magnetic field.

Resource One Overview

Topic	Spins in your brain. How MRI physics is used to measure brain activity.
A-level Modules	A-level Physics Medical physics, magnetic resonance imaging scanners.
Objectives	By the end of this resource, you will be able to: ✓ Understand the basic principles of how magnetic resonance imaging scanners work. ✓ Explain how the excitation of protons produce signals that can be measured. ✓ Describe how the structure of oxyhaemoglobin and deoxyhaemoglobin alter the signal received by an MRI scanner, and how their relative concentrations are important for imaging.
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

Resource One
Data Source

Section A

MRI.

Magnetic resonance imaging (MRI) is a radiology technique used to generate images of biological tissues. MRI images are acquired using strong magnets that are between 25,000 to 100,000+ times stronger than the magnetic field of the earth and radio waves. MRI was first used to image biological tissue in the 1970s. Since the early 1990s MRI has been used by neuroscientists to peer inside the human brain and measure the brain's response in a multitude of scenarios; from language to learning, memory to movement, and development to dreaming; MRI has an extensive reach throughout human neuroscience research. However, MRI is not the only technique for investigating brain activity in human neuroscience. For example, electroencephalography (EEG), magnetoencephalography (MEG) (Figure 1) measure brain activity using sensors that are placed on the scalp to measure electrical activity.

Data interpretation

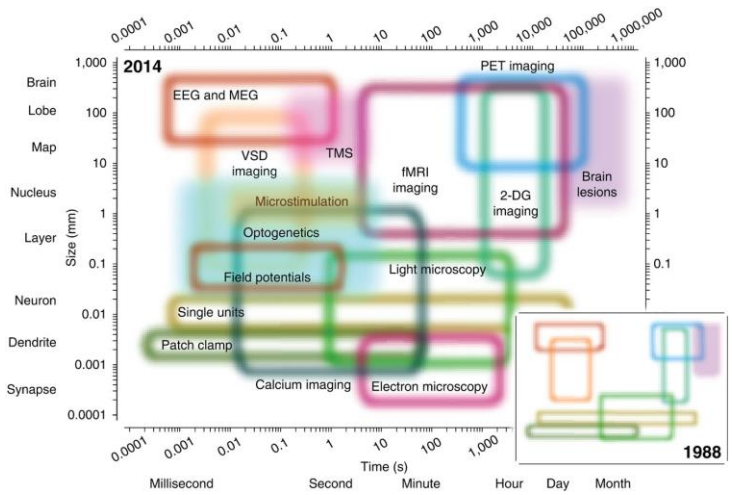
There are strengths and weaknesses associated with different neuroimaging techniques, and different techniques have different spatial and temporal resolutions. The spatial resolution is like a measure of detail, for example a digital camera with 5 megapixels would have a higher spatial resolution than a camera with 3 megapixels because the 5 megapixel camera uses more pixels to capture the same image. Meanwhile, the temporal resolution describes the amount of time taken to acquire a measurement. A camera that takes 100 milliseconds to take a picture would have a higher temporal resolution than a camera that takes 200 milliseconds as less time is needed to take a photo.

Resource One
Data Source

Ferree, T., Clay, M. and Tucker, D., 2001. The spatial resolution of scalp EEG. Neurocomputing, 38-40, pp.1209-1216.

EEG and MEG have a high temporal resolution, meaning they can measure brain activity with millisecond precision, but have low spatial resolution of between 6cm to 40cm, depending on the number of electrodes. Additionally, EEG and MEG can directly measure electrical activity in the brain, however activity can only be measured for the most superficial cells that are either perpendicular (EEG) or parallel (MEG) to the sensor. Meanwhile, MRI can measure activity from the whole brain with a high spatial resolution (<1mm to 3mm+), but with a relatively low temporal resolution. The temporal resolution of MRI is typically around 2 seconds, however this is dependent on the amount of time the scanner takes to acquire one whole brain volume of data, this is known as the repetition time or TR. Furthermore, brain activity is not directly measured using MRI. Instead relative changes in the concentration of oxygenated and deoxygenated blood are used as a proxy for neuronal activity (see chapter 2 for further information).

- Figure 1:



Spatial and temporal resolutions for neuroimaging techniques from both animal and human neuroscience research available as of 2014. Inset is an overview of the techniques available in 1988, prior to the first use of MRI to study the brain. Image reproduced from Sejnowski, Churchland and Movshon, (2014)

Resource One
Data Source

Hendrix, A., 2003. Magnets, Spins, And Resonances. Erlangen: Siemens AG.

Sejnowski, T., Churchland, P. and Movshon, J., 2014. Putting big data to good use in neuroscience. Nature Neuroscience, 17(11), pp.1440-1441

An MRI scanner requires three main components to create images of the brain. These components are the magnet, the gradient coils, and the radiofrequency coils (Figure 2). The magnet in an MRI scanner is an electromagnet that creates the primary magnetic field that is used by the scanner. Gradient coils produce a secondary magnetic field over the primary magnetic field that alters the strength of the primary magnetic field. These secondary magnetic fields allow the MRI scanner to image different spatial locations as gradient coils are arranged along three axes, the x, y, and z axis (left/right, up/down, in/out). Radiofrequency coils emit radiofrequency pulses and receive signals back from the body.

Resource One
Data Source

Section B:

MRI physics.

The human body is formed of around 70% water (H2O) and MRI relies on the magnetic properties of hydrogen to produce images. The nucleus of a hydrogen proton is formed of a single proton and no neutrons, and therefore it can behave like a magnet as its spin produces what is known as a magnetic moment. When these protons are placed in the magnetic field they align parallel (a low energy state) or anti-parallel (a high energy state) to the magnetic field. When in a magnetic field a

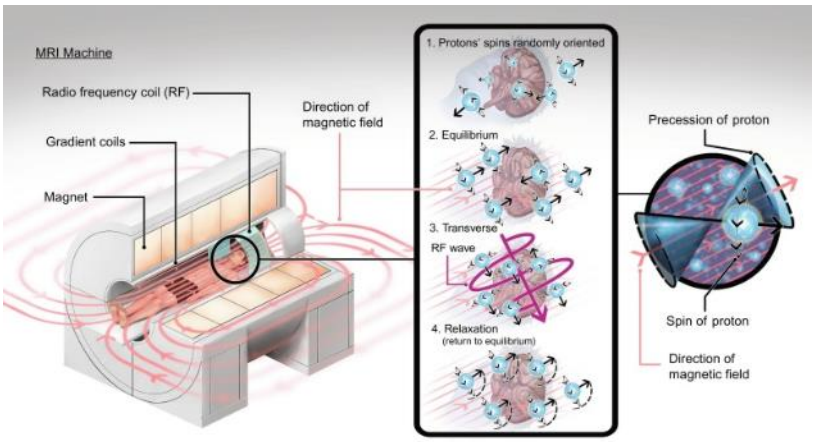


Figure 2:

The magnet, gradient coils are the key components of a magnetic resonance scanner that acquire signal from tissue by taking advantage of the properties of hydrogen atoms in water. Figure reproduced from Kodaverdian, (2019)

proton will spin around the long axis of the magnetic field, and this is known as procession. Protons that process together are 'in phase', while those that process separately are 'out of phase'. Radiofrequency pulses are used to disturb the alignments of protons in the magnetic field, flipping them from the low to higher energy state, and causing the protons to process in phase. After the radiofrequency pulse protons that were flipped to the high energy state return to the lower energy state and release energy. This is known as T1 relaxation. Also, protons that were processing in phase begin to dephase, this is known as T2 relaxation.

Kodaverdian, N., 2019. fMRI in Economics: What Functional Imaging of the Brain Can Add to Behavioral Economics Experiments. Biophysical Measurement in Experimental Social Science Research, pp.47-83.

Resource One
Data Source

Wansapura, J., Holland, S., Dunn, R. and Ball, W., 1999. NMR relaxation times in the human brain at 3.0 tesla. Journal of Magnetic Resonance Imaging, 9(4), pp.531-538.

During T2 relaxation, the rate that spins dephase is dependent on the T2 relaxation time of tissue and the presence of inhomogeneities (irregular disturbances) in the magnetic field; therefore, the actual T2 relaxation time of a substance is known as T2*. Grey matter and white matter (components of the central nervous system, explained in more detail in Chapter 2) have different T2 relaxation times which are approximately 80ms for grey matter, and 100ms for white matter. T2* for grey and white matter are influenced by the magnetic susceptibility (a measure of the how magnetised a material may be when placed in a magnetic field) of their composite molecules. One molecule, whose magnetic susceptibility is extremely important for human neuroscientists, is haemoglobin.

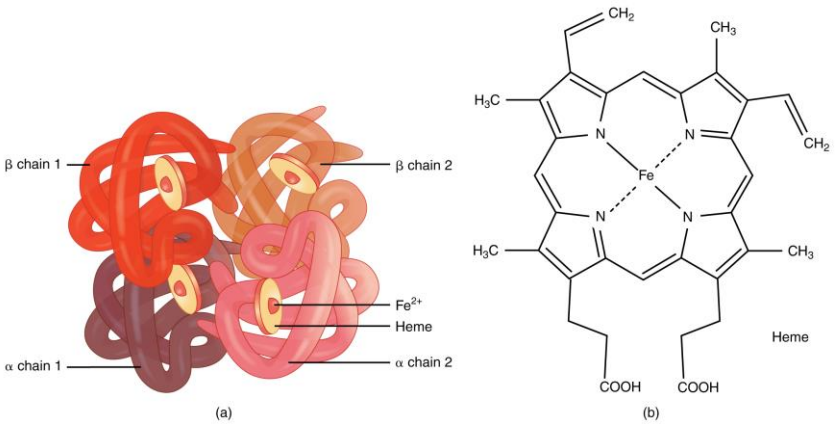


Figure 3:

Openstax.org. 2020. 18.3 Erythrocytes - Anatomy And Physiology | Openstax. [online] Available at: <https://openstax.org/books/anatomy-and-physiology/pages/18-3-erythrocytes>.

A: composition of the quaternary protein haemoglobin. Haemoglobin contains two α chains and two β chains. Each chain has an associated heme group. B: Molecular structure of a heme group. The iron (Fe) molecule in the centre of the porphyrin ring of each heme group can bind to a single O2 molecule to convert deoxyhaemoglobin into oxyhaemoglobin. Figure reproduced from 18.3 Erythrocytes - Anatomy and Physiology | OpenStax, (2020)

Resource One
Data Source

Section C:

Magnetic properties of haemoglobin.

Haemoglobin is a protein found in red blood cells that is essential for oxygen transport around the body. Haemoglobin is a quaternary protein, meaning it is a protein that is composed of four smaller proteins. These smaller proteins are called sub-units (two α chains, two β chains, Figure 3A), and each sub-unit is associated with a heme group meaning each haemoglobin molecule contains a total of four heme groups (Figure 3B). Each heme group contains one iron atom, that can bind to a molecule of oxygen (O_2) by pairing their electrons. When oxygen is released by the heme group it then has two unpaired electrons.

Active reading

Oxygenated haemoglobin, known as oxyhaemoglobin, is a diamagnetic molecule with no net spin, and is repelled by a magnetic field because it does not contain unpaired electrons. Deoxygenated haemoglobin, known as deoxyhaemoglobin, is paramagnetic due to its unpaired electrons, has net spin, and is attracted to the magnetic field. The diamagnetic and paramagnetic properties of oxyhaemoglobin and deoxyhaemoglobin give them different magnetic susceptibilities, meaning they influence T2* relaxation times differently. More specifically, the paramagnetic properties of deoxyhaemoglobin create field inhomogeneities that increases the rate of spin dephasing. This increased rate causes the signal detected by the MRI scanner from deoxygenated blood to be weaker, relative to the signal detected from oxygenated blood. This is the basis of the blood-oxygen level dependent (BOLD) contrast that will be described in more detail in Chapter 2 and is the basis of functional imaging in human neuroscience, also known as fMRI.

Elster, A., 2020. BOLD Contrast Mechanism. [online] Questions and Answers in MRI. Available at: <http://mriquestions.com/bold-contrast.html>.

Resource One Activities

Activities

1. Name two strengths and weakness of electroencephalography and magnetoencephalography?
2. Name two strengths and weakness of magnetic resonance imaging?
3. Why is there a difference in T2 and T2* relaxation times?
4. What neuroimaging approach would you use to measure the activity of small (approximately 1000mm^3) brain region located deep in the brain and why?
5. Consider two brain regions that contain equal proportions of grey matter and white matter. One of these regions contains haemoglobin molecules where oxygen molecules are bound to only two of the heme groups. In the other region there are oxygen molecules bound to three of the heme groups. Which region will have a greater difference between T2 and T2* and which will have a lower contrast when detected by an MRI scanner? Explain your reasoning.

Resource One
Further Reading

Explore

- Introduction to MRI Physics
  https://www.youtube.com/watch?v=Ok9lLIYzmaY
- Questions and Answers in MRI
  http://mriquestions.com/index.html

Resource Two Overview

Topic

The haemodynamic response. Why is measuring blood flow important for neuroimaging?

A-level Modules

A-level Biology:

Nervous coordination, principles of homeostasis & negative feedback.

Objectives

By the end of this resource, you will be able to:

- ✓ Describe the basic structure of the nervous system and the main cell types that it contains.
- ✓ Describe the shape of the haemodynamic response.
- ✓ Explain the relationship between neuronal activity and the haemodynamic response.

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading

Resource Two
Data Source

Section A

Structure of the nervous system.

The nervous system of animals is made of two cell types, neuronal cells and glial cells. Neuronal cells communicate with other parts of the nervous system and body by transferring information using nerve impulses. The information transfer network of neuronal cells is maintained by glial cells, which support neurons by ensuring they function properly. For example, oligodendrocytes are glial cells that insulate neurons with a fatty membrane called a myelin sheath, and microglia are glial cells that coordinate immune responses within the nervous system. The two main tissue types in the human brain are known as grey matter and white matter. Grey matter regions of the brain contain neuronal cell bodies, unmyelinated sections of neuronal axons and their dendrites, glial cells, synapses, and blood capillaries. By contrast, white matter is formed primarily of myelinated axons of neurons that facilitate fast, long range connectivity across the brain.

Data interpretation

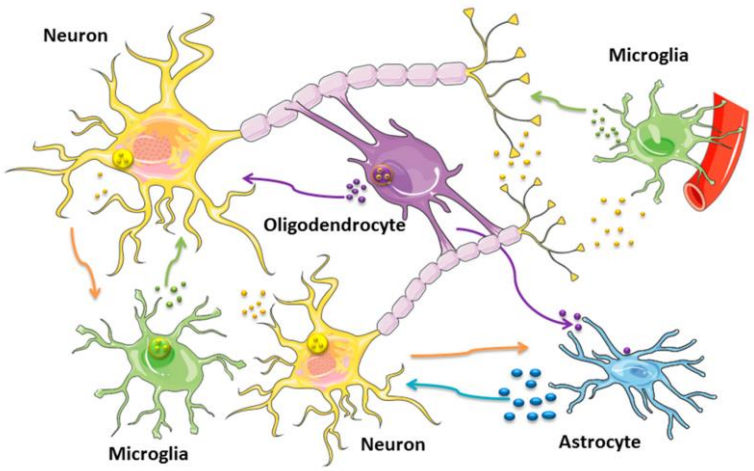


Figure 4:

Riva, P., Battaglia, C. and Venturin, M., 2019. Emerging Role of Genetic Alterations Affecting Exosome Biology in Neurodegenerative Diseases. International Journal of Molecular Sciences, 20(17), p.4113.

Primary cell types in the central nervous system. Figure reproduced from Riva, Battaglia, and Venturin, (2019).

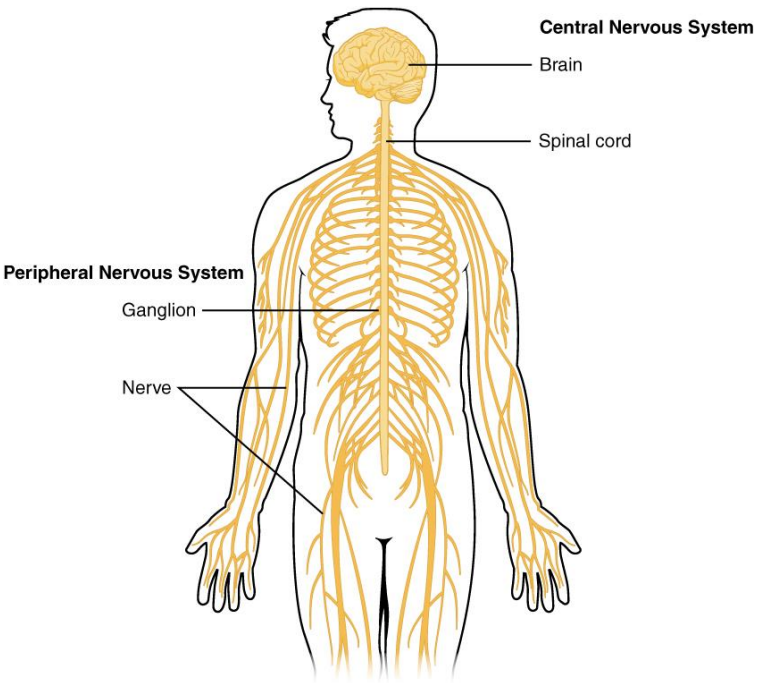
The nervous system can be subdivided into the central and peripheral nervous system. The brain and the spinal cord are part of the central nervous system (CNS). The CNS receives signals from the peripheral nervous system (PNS) that it processes and integrates with other inputs and returns output that may sent to other parts of the central or peripheral nervous system. The PNS connects the rest of the body to the CNS. The PNS sends information to the brain, such as sensory

Resource Two
Data Source

Figure 5:

Openstax.org. 2020. 12.1 Basic Structure And Function Of The Nervous System - Anatomy And Physiology | Openstax. [online] Available at: <https://openstax.org/books/anatomy-and-physiology/pages/12-1-basic-structure-and-function-of-the-nervous-system>.

information from your eyes and ears, and receives output from the CNS, for example, how to contract and relax the muscles in your legs to run away from the predator you have seen.



Schematic of the central and peripheral nervous system within the human body. Figure reproduced from 12.1 Basic Structure and Function of the Nervous System - Anatomy and Physiology | OpenStax, (2020)

Transferring information across the nervous system using neuronal cells is a resource intensive process and requires a vast amount of energy; the energy demand of the human brain equates to 20% of the total energy demand of the human body, though the human brain only makes up 2% of total body volume. Yet, despite this high energy demand, the brain does not have an abundant store of energy. Neurovascular coupling describes the process through which the activity of the nervous system is linked with its vasculature, and is an important process for ensuring energy demands are met sufficiently.

Resource Two
Data Source

Section B

The haemodynamic response.

When activity increases in a region of the brain there is increased blood flow to that region of the brain. This increase in blood flow results in a change in its relative concentration of oxygenated and deoxygenated haemoglobin. Oxyhaemoglobin is a diamagnetic (repelled by a magnetic field) molecule as it has no unpaired electrons, meanwhile deoxyhaemoglobin is paramagnetic (weakly attracted to a magnetic field) because it has unpaired electrons (see Chapter 1). As the ratio of oxyhaemoglobin to deoxyhaemoglobin changes, so does the signal detected by an MRI scanner. An increase in the concentration of oxyhaemoglobin, relative to deoxyhaemoglobin increases the signal detected by an MRI scanner, while a relative decrease in the concentration of oxyhaemoglobin results in a decrease in signal. Therefore, as activity in a brain region increases the signal detected by an MRI scanner also increases. These changes are the basis of the blood-oxygen-level-dependent (BOLD) response, and BOLD imaging is the primary method for assessing functionally driven changes in brain activity using MRI (fMRI).

Active reading

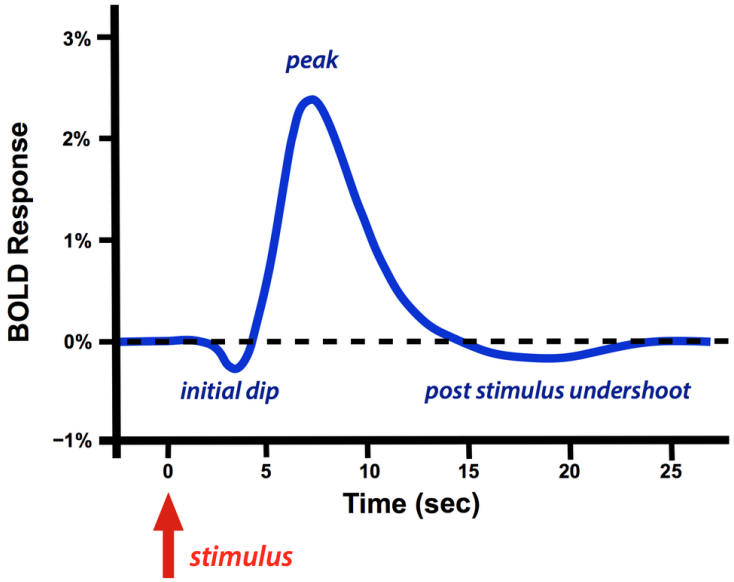
The change in signal detected by an MRI scanner when a region of the brain is activated by the presentation of a stimulus is known as the haemodynamic response, and this can be modelled using the haemodynamic response function (see Figure 6). The initial dip is the first feature of the haemodynamic response function. The initial dip is characterised by a decrease in BOLD signal relative to the onset of the stimuli. The next feature of the haemodynamic response function following on from the initial dip is the dominant peak which is characterised by a sharp increase followed by a sharp decrease in the BOLD signal over approximately 10 seconds. The BOLD signal peaks around 8 seconds after stimulus onset (although this is difference across different brain regions) and returns to its initial level approximately 15 seconds after the onset of the stimulus. The final feature of the haemodynamic response function is the post stimulus undershoot which lasts for approximately 5 seconds after the end of the dominant peak. During the post stimulus undershoot, the BOLD signal dips below then returns to its initial level prior to the onset of the stimulus. However, the shape of the haemodynamic response is not the same across all regions of the brain and is dependent on the architecture of each brain region.

Elster, A., 2020. BOLD Contrast Mechanism. [online] Questions and Answers in MRI. Available at: <http://mriquestions.com/bold-contrast.html>.

Elster, A., 2020. BOLD And Brain Activity. [online] Questions and Answers in MRI. Available at: <http://mriquestions.com/does-boldbrain-activity.html>.

Resource Two
Data Source

Figure 6:



The haemodynamic response function. Figure reproduced from Elster, A (2020) BOLD And Brain Activity.

Resource Two Activities

Activities

1. What is the difference between neuronal and glial cells?
2. Which portion of the nervous system is primarily involved in the production of sensory impulses, and which nervous system processes and integrates inputs?
3. Split the following into two lists depending on whether they are primarily found in grey matter or white matter.
    - Neuronal cell bodies
    - Myelinated axons
    - Unmyelinated axons
    - Glial cells
    - Capillaries
    - Oligodendrocyte processes
4. How much more energy does the brain require, relative to its proportion of body volume?
5. Do you think the haemodynamic response function is representative of neuronal activity? Explain your reasoning.
6. Why might the shape of the haemodynamic response be affected by the architecture of different brain regions?
7. Draw what you think the haemodynamic response would look like when a stimuli is repeatedly presented multiple times within a short space of time?

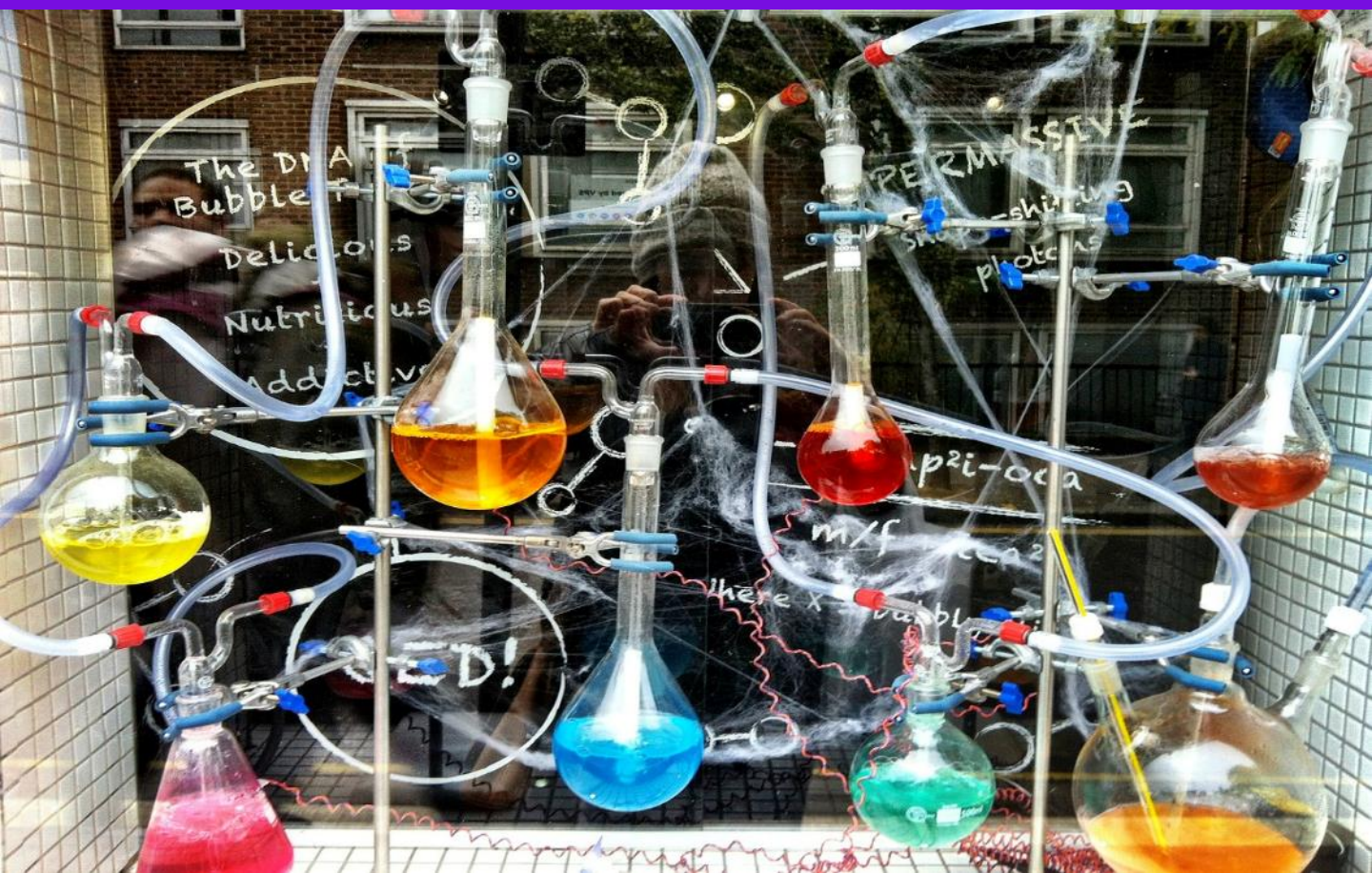
Resource Two
Further Reading

Explore

- 12.1 Basic Structure and Function of the Nervous System https://openstax.org/books/anatomy-and-physiology/pages/12-1-basic-structure-and-function-of-the-nervous-system
- BOLD Contrast Mechanism http://mriquestions.com/bold-contrast.html
- BOLD and Brain Activity http://mriquestions.com/does-boldbrain-activity.html
- Principles of fMRI Part 1, Module 8: fMRI Signal & BOLD Physiology https://www.youtube.com/watch?v=jG2WQpgpnMs&t=339s

Resource Three Overview

Topic	Magnetic resonance spectroscopy. How are the molecules of your brain measured?
A-level Modules	A-level Chemistry: Nuclear magnetic resonance spectroscopy.
Objectives	By the end of this resource, you will be able to: ✓ Understand how the principles of MRS can be applied to human neuroimaging. ✓ Describe the main metabolites found on an MRS spectra and how these relate to brain function.
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading



Resource Three
Data Source

Section A

MRS.

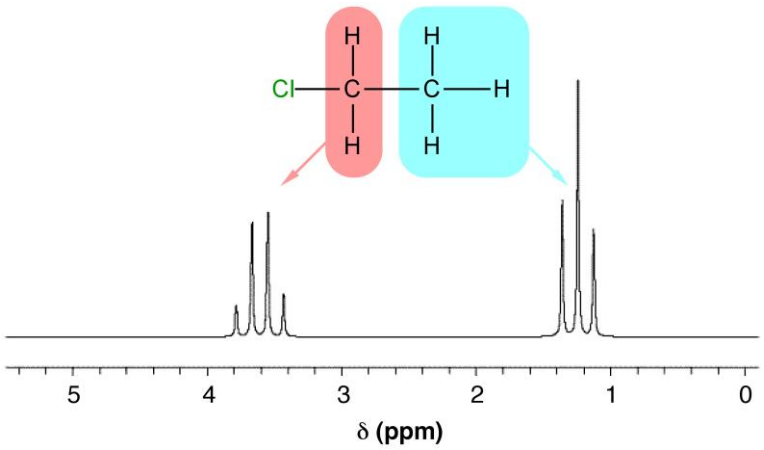
In Chapters 1 and 2 we covered how magnetic resonance imaging (MRI) can be used to study the human brain, focusing on the detection changes in blood flow in the brain. These changes produce the blood-oxygen-level-dependent (BOLD) contrast, and is used as a proxy for neuronal activity. Another way magnetic resonance can be used to study human brain is magnetic resonance spectroscopy (MRS). MRS allows neuroscientists to measure the concentrations of different metabolites in the human brain. The most common form of MRS in human neuroscience is proton MRS, also known as ^{1}H MRS.

Boyd, J. and Barron, A. (2019). 5.7.3 NMR Spin Coupling. [online] cnx.org. Available at: <https://cnx.org/contents/uieDnVBC@25.2:k7IV3aaj@1/NMR-Spin-Coupling>.

As described in Chapter 1, the charge of the nucleus of a hydrogen molecule allows it to behave like a magnet. When hydrogen nuclei (protons) are in a magnetic field, they either align with or against the magnetic field; these two alignments are known as the α (alpha) and β (beta) spin state respectively. Protons prefer to be in the α spin state as less energy is required to be in the α spin state than a β spin state, thus the majority of protons will align with a magnetic field in the α spin state. In MRS radiofrequency pulses are used to knock protons from the α to the β spin state. The amount of energy (ΔE) required to knock a proton from the α to the β spin state is dependent on what is known as diamagnetic shielding. Diamagnetic shielding is provided by local electrons, which partially shield protons from the magnetic field. The more shielding a proton has, then less energy is required to flip it into the β spin state (causing the proton to resonate) than a proton with less shielding or a proton that is deshielded.

Resource Three
Data Source

Figure 7:



Magnetic resonance spectroscopy spectra for chloroethane. Figure reproduced from Boyd and Barron (2019)

Data interpretation

Resource Three
Data Source

Section B

In vivo MRS.

For example, the spectra for chloroeathane in Figure 7 has two sets of peaks that are between 1-1.6ppm and 3.4-4ppm. There are two different sets of peaks because the red (less shielding than blue due to chlorine) and blue sets of protons are shielded differently, and therefore appear at different points on the spectra. This difference is known as chemical shift (δ). The red group of protons resonate at a higher frequency and appear further to the left (downfield) than the blue group of protons that are more shielded, resonate at lower frequencies, and appear to the right (upfield) on a spectrum.

Yüksel, C. and Öngür, D. (2010). Magnetic Resonance Spectroscopy Studies of Glutamate-Related Abnormalities in Mood Disorders. Biological Psychiatry, 68(9), pp.785–794.

Kolasinski, J. et al. (2017) 'A Mechanistic Link from GABA to Cortical Architecture and Perception', Current Biology, 27(11), pp. 1685-1691.e3.

Chemical shifts are expressed in parts per million (ppm) rather than hertz (Hz) because this standardises the unit of measurement when analysing molecules. This is useful because the same proton will resonate at a different Hz if the magnetic field strength is different. However, when the resonance frequency is converted from Hz to ppm the resonance frequency is consistent across different magnetic field strengths.

Because the molecular structure is a known property of a molecule, the shape of the spectra for a molecule can be simulated to generate a hypothetical spectrum for that molecule. These simulated spectra can be combined to create a basis set. A basis set can then be used to quantify the concentrations of different metabolites present in the brain using in vivo MRS.

Different metabolites are found at different concentrations in the brain and are involved in numerous processes. Some of these metabolites can be quantified using MRS and can therefore be investigated by researchers. For example:

- Glutamate is the major excitatory neurotransmitter in the brain that is used to send signals to other cells and increase their activity. Previous research using MRS to investigate levels of glutamate in the brain have found that concentrations appear to be decreased in the brains of individuals with major depressive disorder, and increased in those with bi-polar disorder, relative to healthy controls.

Resource Three
Data Source

Edden, R.A.E., Crocetti, D., Zhu, H., Gilbert, D.L., Mostofsky, S.H., 2012. Reduced GABA Concentration in Attention-Deficit/Hyperactivity Disorder. Arch Gen Psychiatry 69.

Bell, T., Lindner, M., Langdon, A., Mullins, P.G. and Christakou, A. (2019). Regional Striatal Cholinergic Involvement in Human Behavioral Flexibility. The Journal of Neuroscience, 39(29), pp.5740–5749.

Bjartmar, C., Kidd, G., Mörk, S., Rudick, R. and Trapp, B.D. (2000). Neurological disability correlates with spinal cord axonal loss and reducedN-acetyl aspartate in chronic multiple sclerosis patients. Annals of Neurology, 48(6), pp.893–901.

- gamma-Aminobutyric acid (GABA) is another neurotransmitter that is quantifiable using MRS and is the primary inhibitory neurotransmitter in the brain. GABA levels in the somatosensory cortex of the brain have previously been associated with levels of perception, with higher GABA concentrations enhancing perception. Additionally, concentrations of GABA have been found to be lower in children with ADHD compared to typically developing children.
- Acetylcholine is a neurotransmitter and neuromodulator in the brain. Although acetylcholine cannot be measured directly using MRS, choline (a precursor for acetylcholine) can be measured using MRS to indirectly measure acetylcholine concentrations. Choline levels have previously been found to be associated with the ability to adaptively change behaviour in response to environmental changes.
- N-Acetylaspartic acid (NAA) is a molecule found in the human brain and is most prominently found in neuronal cells. NAA can be used as a marker of neuronal density and viability, and a decrease in NAA concentrations are seen in disorders that result in the degeneration of neurons. For instance, in multiple sclerosis decreased concentrations of NAA have been found in lesioned regions and is correlated with the amount of neuronal loss.

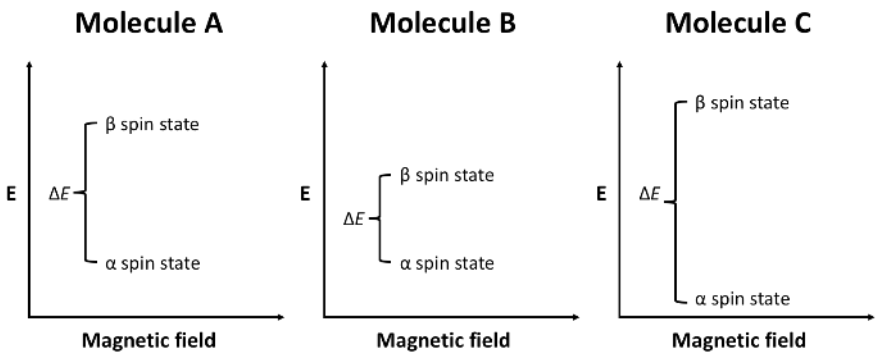
Other metabolites that can be quantified using MRS include alanine, acetate, creatine, glucose, myo-inositol and taurine (more information available here http://mri-q.com/normal-brain-spectra.html). In addition to quantifying resting levels of metabolites in the brain, MRS can also be used to measure functional changes in metabolite concentrations due to task dependent manipulations like in BOLD imaging. However, the ability to detect functional changes in these metabolites is restricted by the speed of acquisition of an MRS spectra. The number of samples required to acquire a single spectra can be >100. Therefore, functional changes in metabolite concentrations can only be reliably measured across a scale of minutes, since the acquisition of a single sample for a spectra is dependent on the repetition time of the MRI scanner which is typically around two seconds per sample.

Resource Three Activities

Activities

1. What is the difference between functional magnetic resonance imaging and magnetic resonance spectroscopy?
2. Order these hypothetical molecules from having the most diamagnetic shielding to having the least. Explain your reasoning (note, you can refer to content from chapter 1).

Problem solving



3. Why should a proton's resonance frequency be expressed in parts per million, rather than in hertz?
4. How is the measurement of functional changes in metabolite concentrations restricted by the acquisition of magnetic resonance spectroscopy data?

Resource Three
Further Reading

Explore

- MR Spectroscopy http://mri-q.com/hellipmr-spectroscopy.html
- NMR Spectroscopy https://chem.libretexts.org/Bookshelves/Organic_Chemistry/Map%3A_Organic_Chemistry_(Bruice)/14%3A_NMR_Spectroscopy
- Introducing MRI: MR Spectroscopy (48 of 56) https://www.youtube.com/watch?v=-P8oclyhnMk

Resource Four Overview

Topic

Task design. What would a neuroimaging experiment look like?

A-level Modules

A-level psychology:

Research methods.

A-level maths:

Statistical hypothesis testing.

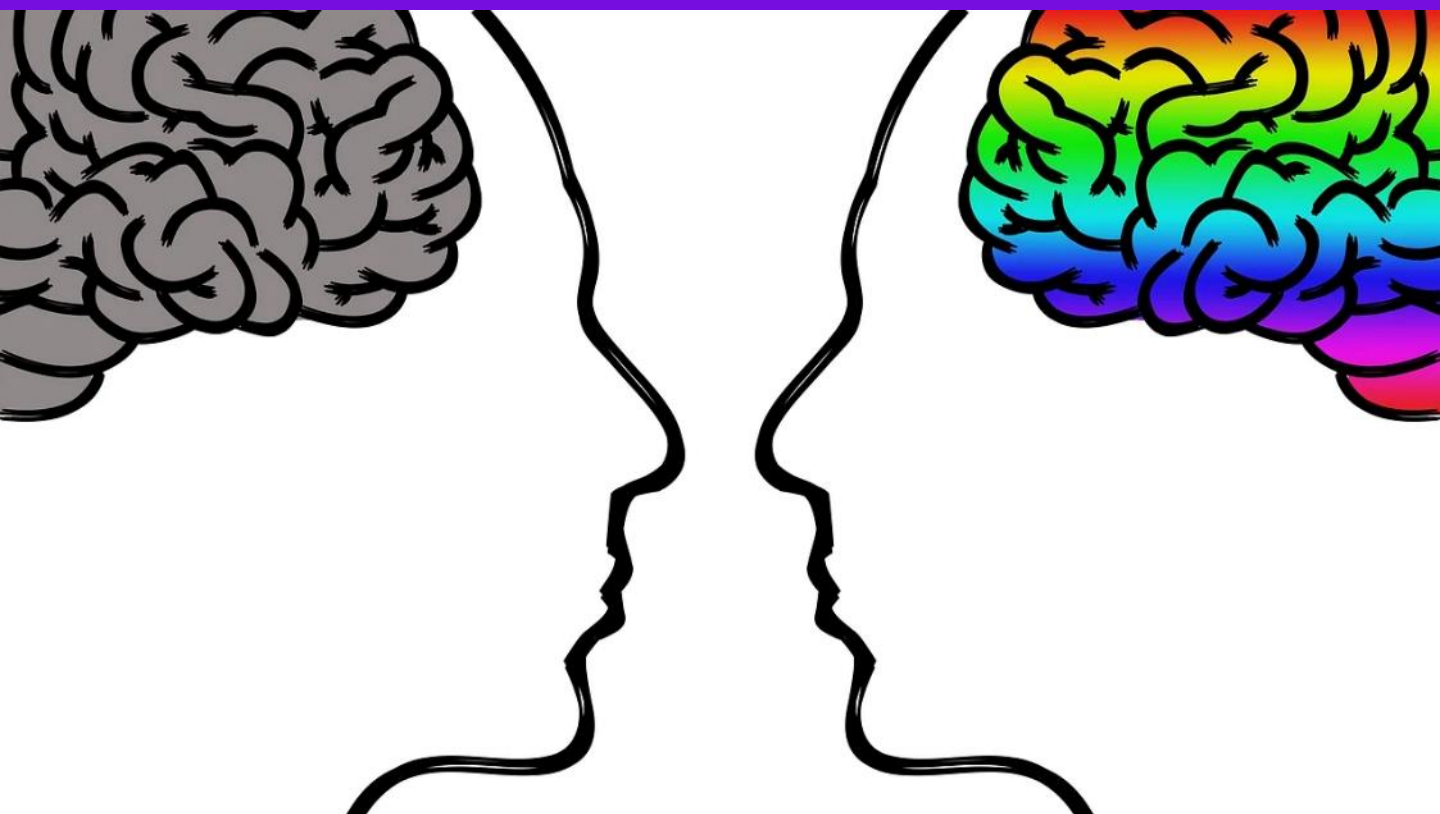
Objectives

By the end of this resource, you will be able to:

- ✓ Understand the process of hypothesis generation, and how to generate testable hypotheses.
- ✓ Explain the difference between an independent and a dependent variable.
- ✓ Describe the difference between event-related and block designs, and explain the pros and cons of each approach for a neuroimaging study.

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading



Resource Four
Data Source

Section A

Hypothesis generation.

In the previous chapters we have covered how magnetic resonance works and have learned about the underlying physics, and how it can be applied to study activity in the brain using blood-oxygen-level-dependent (BOLD) imaging and magnetic resonance spectroscopy (MRS). This section will cover core concepts relating to the design of neuroimaging studies.

Before data collection can begin for any experiment, it is first essential to consider the research questions study aims to answer. Research questions could aim to address an unresolved question in the scientific literature or replicate the findings of a previously completed study.

Once the research questions have been defined, they then need to be formalised as hypotheses. Hypotheses should be formulated based on previous scientific findings, and (most importantly) should be falsifiable. For a hypothesis to be falsifiable it should be written in a way such that it could be disproved on the basis of evidence collected in a study. Once hypotheses for an experimental study have been defined, a researcher can define their independent and dependent variables. Independent variables are variables that the experimenter has control over and should not be depend on any other variables in the experiment. Independent variables can also be thought of as the experimental manipulations. Meanwhile, dependent variables are variables that cannot be controlled by the experimenter, and their value can change on the basis of the experimental design.

Data interpretation

For example, a researcher's research question could be "how will the temperature in London change across each month in a calendar year?". Hypotheses to test this question could include "Are temperatures higher in summer months (June/July/August) than in winter months (December/January/February)?", or "Are temperatures significantly different in Autumn (September/October/November) compared to spring (March/April/May)?". In order to test these hypotheses, an experimenter would need to measure the temperatures in London each month in a year. The experimenter's independent variable would be the months of the year, while the dependent variable would be the temperatures that are measured.

Resource Four
Data Source

Section B

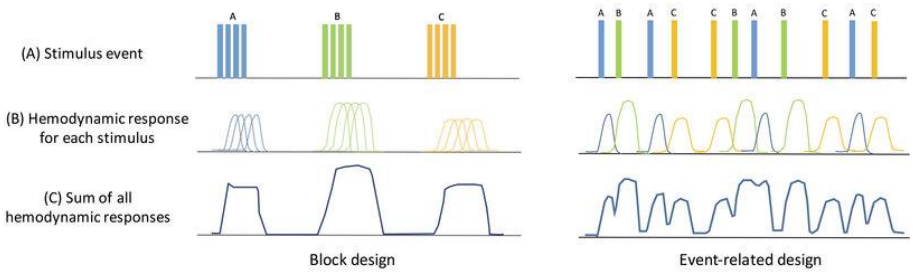
MRI study design.

Arco, J.E., González-García, C., Díaz-Gutiérrez, P., Ramírez, J. and Ruz, M. (2018). Influence of activation pattern estimates and statistical significance tests in fMRI decoding analysis. Journal of Neuroscience Methods, 308, pp.248–260.

When the research questions, hypotheses and variables have been defined for a study, the next thing to consider is the design of the experiment. There are two main experimental designs used in BOLD imaging studies which are called block designs and event related designs. In a block design, experimental stimuli for each condition are presented in blocks lasting between 15-30 seconds. Then in the subsequent blocks, stimuli are presented for the other conditions (Figure 8A). For example, if an experimenter was interested in how the brain responds to happy, sad, or angry faces, they would show happy faces, then sad faces, then angry faces in separate blocks with a gap in between.

A block design means that stimulus evoked haemodynamic responses (see chapter 2) for each condition will be positioned closely to other evoked responses in the same condition, but not to evoked responses from other conditions (Figure 8B). This makes the estimation of the sum haemodynamic response for each block relatively easy for each condition (Figure 8C). However, the shape of the sum of haemodynamic responses in a block design means that you cannot estimate the time course of the BOLD response to a single stimulus presentation. Additionally, because similar stimuli are presented within each block, stimuli can become predictable, and participants may habituate to the presentation of stimuli.

Figure 8:



A: Stimulus presentation designs; B: individual haemodynamic response functions, and C: sum of haemodynamic response functions for block design and event-related functional magnetic resonance imaging studies. Figure reproduced from Arco et al., (2018)

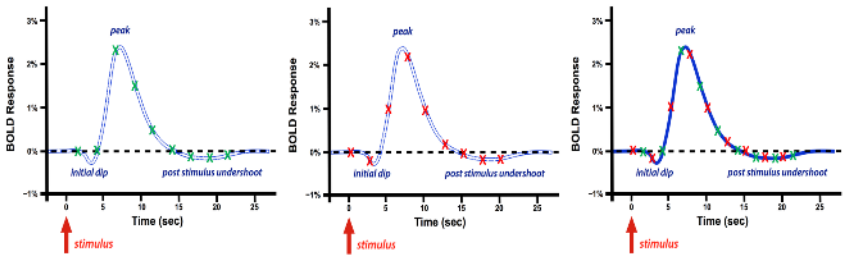
Resource Four
Data Source

In an event related design, the stimuli for each condition are intermixed with each other over the course of the experiment. Therefore, this means that the stimulus evoked haemodynamic responses for each condition are also intermixed across the experiment. This means the shape of the BOLD response for each stimulus can be estimated by using a mathematical technique called convolution (see Chapter 5). However, one limitation of event related designs is the frequency that we can sample from the BOLD response.

Active reading

The sampling frequency is restricted by the repetition time of the magnetic resonance imaging (MRI) scanner (see Chapter 1), which is how long it takes to acquire a single snapshot of the brain. In a functional MRI (fMRI) study, the repetition time, is typically around 2 seconds. Therefore, because we can only sample the BOLD response at 2 second intervals, event related design studies typically require stimulus presentations to be repeated to accurately estimate the shape of the BOLD response. For example, in Figure 9, the crosses on the leftmost graph show estimates of the BOLD response when the samples are offset by 1 second from the onset of the stimulus, while the centre graph shows estimates that coincide with the onset of the stimulus. The rightmost image shows the sampling points from the leftmost and centre graphs overlaying the actual haemodynamic response to a stimulus. By combing the sampling points of the leftmost and centre graphs, features of the BOLD response function such as the initial dip, the peak of the response, and the width of the peak, can be estimated much more accurately than when either sample is used in isolation.

Figure 9:

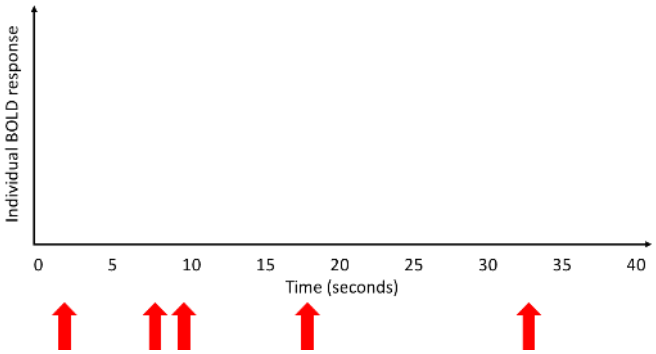


Sampling points along the haemodynamic response function with different onsets (left and centre) relative to the stimulus presentation improves the estimation of the shape of the haemodynamic response function (right). Figure adapted from Elster, A (2020) BOLD And Brain Activity.

Resource Four Activities

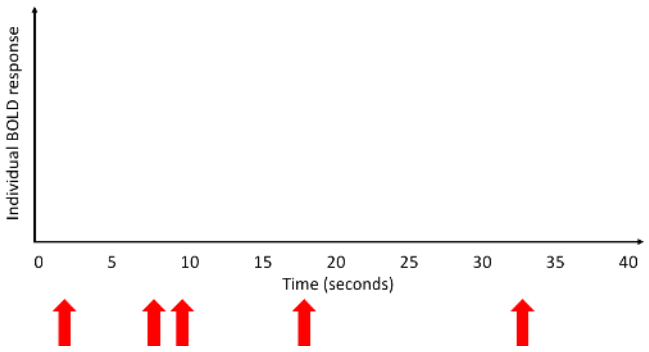
Activities

1. What is the difference between an independent and a dependent variable?
2. How do you know if a hypothesis is falsifiable or not? Write down one example of a falsifiable and non falsifiable hypothesis.
3. Name the two main design types for BOLD imaging studies and explain the pros and cons of each method.
4. Copy the graph below onto paper then draw individual haemodynamic responses for each stimulus presentation (red arrow) on the graph.



5. Copy the graph below onto paper then draw the sum of haemodynamic responses for stimuli presentations (red arrows) on the graph.

Problem solving



6. Explain the benefit of changing the onset of BOLD sampling relative to stimulus presentation for event-related designs.

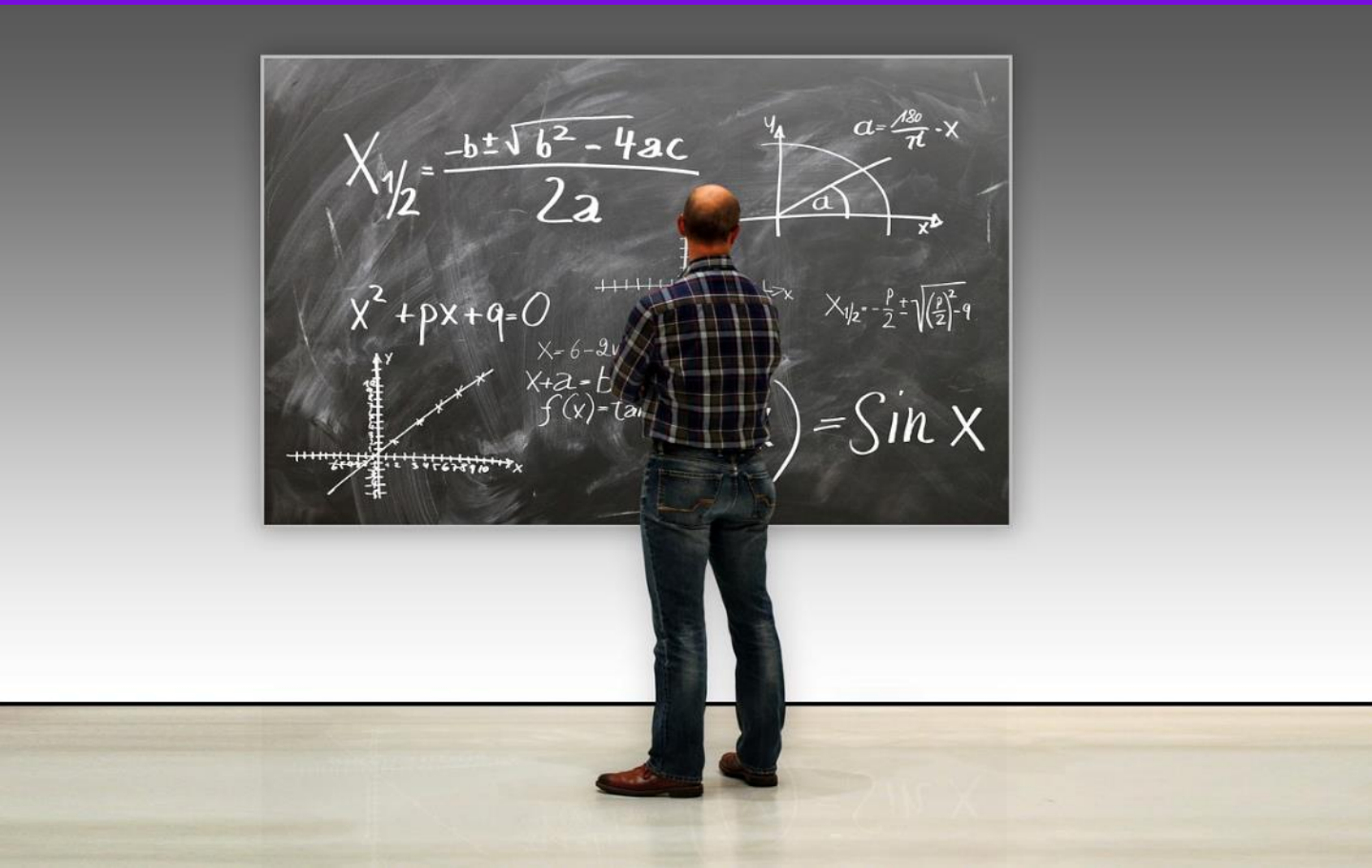
Resource Four
Further Reading

Explore

- Intro to Hypothesis Testing in Statistics - Hypothesis Testing Statistics Problems & Examples
  https://www.youtube.com/watch?v=VK-rnA3-41c
- Principles of fMRI Part 1, Module 11: Experimental Design I – Psychological principles
  https://www.youtube.com/watch?v=lwy2k8YQ-cM

Resource Five Overview

Topic	Data analysis. How should the data be analysed?
A-level Modules	A-level maths: Data presentation and interpretation, statistical hypothesis testing.
Objectives	By the end of this resource, you will be able to: ✓ Describe different methods of analyzing neuroimaging data. ✓ Appreciate why analysis methods do not necessarily report absolute measures of brain activity. ✓ Understand the necessity of correcting for multiple comparisons.
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading



Resource Five
Data Source

Section A

Data analysis techniques.

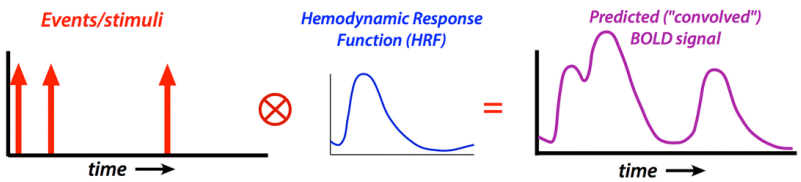
Once functional magnetic resonance imaging (fMRI) data has been collected, the next step is to analyse the collected data. There are many different techniques used to analyse fMRI data and the appropriate technique to analyse data is dependent on the research questions you would like to answer. Different analytic approaches include:

A. Statistical parametric mapping (SPM) is one of the most commonly used techniques in the analysis of fMRI. In SPM the time of onset for stimuli and the duration they are displayed for is combined with a model of the haemodynamic response function. This process is known as convolution, and is used to predict what the BOLD response to stimulus presentation would look like. This prediction is then fitted to the data and brain activity maps for conditions are contrasted against each other to identify regions with significant activation. SPM has previously been used to show how activation in the brains of mothers is different when viewing pictures of their own children's faces when they are happy and when they are sad.

Klucznik, D., Hindi Attar, C., Stein, J., Poppinga, S., Fydrich, T., Jaite, C., Kappel, V., Brunner, R., Herpertz, S.C., Boedeker, K. and Bermpohl, F. (2017). Dissociating maternal responses to sad and happy facial expressions of their own child: An fMRI study. PLOS ONE, 12(8), p.e0182476.

Elster, A. (2020). General Linear Model (GLM). [online] Questions and Answers in MRI. Available at: <http://mri-q.com/general-linear-model.html>.

Figure 10:



Convolution of the presentation of stimuli with a haemodynamic response function to generated a predicted BOLD signal that can be fit to data. Figure reproduced from Elster (2020) General Linear Model (GLM).

Kim, S., Hwang, S. and Lee, M. (2018). The benefits of negative yet informative feedback. PLOS ONE, 13(10), p.e0205183.

A. Psychophysiological interaction analysis (PPI) is an analysis approach that aims to identify brain regions that are functionally connected with a region of interest. This region of interest is known as the seed. The PPI approach allows researchers to identify other regions in the brain whose timeseries aligns with the seed region during the presentation of certain stimuli, but not at other time periods; that is to say, they are functionally connected because they both have the same activation to the presentation of stimuli. One example of how PPI analysis has been

Resource Five
Data Source

Haxby, J.V., Gobbini, M., Furey, M., Ishai, A., Schouten, J. and Pietrini, P. (2001). Distributed and Overlapping Representations of Faces and Objects in Ventral Temporal Cortex. Science, [online] 293(5539), pp.2425–2430.

B. used is to identify brain regions that are functionally connected with regions that have been identified as processing informative negative feedback.

C. Multivoxel pattern analysis (MVPA) differs from analytic approaches like SPM where a model of the task is created and fitted to the data to identify active brain regions. Instead, in MVPA the data is fed into a pattern classification algorithm to identify how different patterns of brain activity and stimuli are related. These patterns can then be used to decode the brain's response to different stimuli. MVPA has been used to identify the different patterns of responses in the brain to faces, cats, objects, and nonsense pictures.

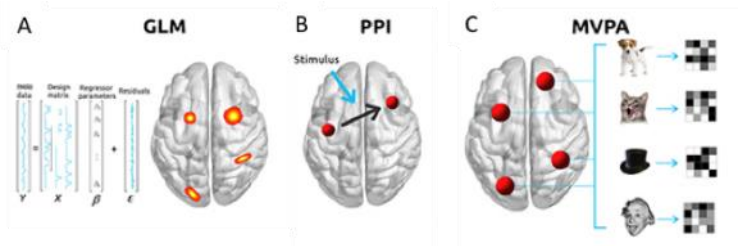


Figure 11:

Section B

Methodological considerations.

Different types of analysis for task-based fMRI studies. A: General linear modelling; B: Psychophysiological interaction analysis; C: Multivoxel pattern analysis. Figure adapted from https://doi.org/10.3389/fnins.2016.00515.

One of the most important caveats of SPM is that when brain activity is contrasted, this is ways with respect to a baseline instead of absolute activation. This baseline can be an implicit baseline, where task relevant activation is contrasted against activation when no task is being performed, or the baseline can be the amount of activation in a different condition, such that the contrast would show regions of the brain that show more or less activation in condition A, relative to condition B.

For example, in the study where SPM was used to investigate mothers responses to their children's happy and sad faces, the following contrast was used, (own child sad face > own child neutral face) > (unknown child sad face > unknown child neutral face). In this instance the researchers were interested in identifying brain regions in mothers

Resource Five
Data Source

that were significantly more activated when viewing sad faces than neural faces for their own children compared to children they do not know.

Another necessary consideration for an fMRI analysis design is correcting for multiple comparisons, which is important because uncorrected analyses are likely to have spurious results that are unrepresentative of underlying neuronal activity. The reason that corrections are necessary is to maintain the threshold of significance for statistical tests. Typically, statistical tests have the significance threshold for the p-value at 0.05, and the threshold for statistical significance is equal to the type 1 error rate. The type 1 error rate describes how many statistical tests will have a significant p-value (e.g. $p<0.05$) when there is no true difference, or in other words, in the long run what proportion of statistical tests will say there is a significant difference when in reality there is no real difference. When multiple statistical tests are run, the probability of a type 1 error increases incrementally with each additional statistical test that is run on the same data. For instance, if two statistical tests are run on the same data, then the probability of a type 1 error is two times the type 1 error rate unless the type 1 error rate is corrected for the multiple comparisons. One way to correct for multiple comparisons is called the Bonferroni correction, where the p-value for each statistical test is equal to the type 1 error rate, divided by the number of individual tests. However, Bonferroni correction is a fairly conservative test for multiple comparisons and can result in type 2 errors, which are when a real difference exists, yet it is not identified by the test. This would be particularly problematic for fMRI data analysis, where the number of voxels in a 3d volume can be up towards one million in number. Therefore, alternative methods of correction for multiple comparison are used and these include clusterwise thresholding, and false discovery rate correction, which are less conservative than the Bonferroni correction.

Active reading

Resource Five Activities

Activities

1. What is convolution?
2. Why can absolute brain activity not be determined using the SPM approach?
3. Name two appropriate methods of correcting for multiple comparisons in fMRI analysis. Why is correcting for multiple comparisons important?
4. Why would the Bonferroni correction be an inappropriate method to correct for multiple comparisons?
5. Imagine a researcher has found a region of the brain that is active when listening to rock music but not when listening to pop music. Which analytic approach (A-C) would be most appropriate to identify other brain regions that show the same response when listening to rock music but not to pop music? Explain your answer.
6. Imagine a researcher wants to identify different patterns of neuronal activity in a network when viewing pictures of different musical instruments. What analytic approach (A-C) would be best to identify these patterns? Explain your answer.

Problem solving

Resource Five
Further Reading

Explore

- General Linear Model (GLM) http://mri-q.com/general-linear-model.html
- The Multiple Comparisons Problem https://www.youtube.com/watch?v=dzi1CSvzCoU
- Type I error vs Type II error https://www.youtube.com/watch?v=a_I991xUAOU

Resource Six Overview

Topic

Open and reproducible science. How do I know if I'm doing good science?

A-level Modules

This is more of a philosophical debate on how science should, or should not be done.

Objectives

By the end of this resource, you will be able to:

- ✓ Describe the importance of having robust, reproducible scientific methods.
- ✓ Explain some of the key arguments in favour of open and reproducible science.
- ✓ Understand how issues relating to the efficacy of science have a wider societal impact.

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading

Resource Six
Data Source

Section A

Introduction to open science.

Open science is a movement within the academic community that is based on the philosophy that science should be open and available to all members of humanity. The principles of open science span a broad spectrum of ideas that range from how scientists should report their findings and share their data, to how this information is disseminated to the general public and how the public can get involved in scientific research. The aim of the open science movement is to improve the reliability, transparency, and credibility of scientific research, and to improve the scientific literacy of the general public.

The field of psychology was one of the earliest proponents of open science, due in part to what has been coined the reproducibility crisis. This crisis is based upon the inability of scientists to replicate the results of other scientists or even to reproduce the same findings using the original scientist's own data! The field of scientific study that investigates and aims to better understand the best use of open research practices is called metascience. Metascience is the scientific study of science itself, and may be better described as research about research. For instance, a metascientist may be interested in understanding why so many research findings in the field of psychology are not reproducible. To answer this question, they may investigate how the original researchers described the methods they used to collect their data and whether this was described in sufficient detail so that someone could reproduce their study, or they could look at the sample used in their data collection to determine whether the participants they used for their study were appropriate to answer the question they were asking. For example, did they recruit enough participants for their study so their study was sufficiently powered?

Open science collaboration (2015). Estimating the reproducibility of psychological science. Science, 349(6251), pp.aac4716–aac4716.

Koshland, D. (1991). Credibility in science and the press. Science, 254(5032), pp.629–629.

Resource Six
Data Source

Open science collaboration (2015). Estimating the reproducibility of psychological science. Science, 349(6251), pp.aac4716–aac4716.

Koshland, D. (1991). Credibility in science and the press. Science, 254(5032), pp.629–629.

Another metascientist could be interested in how scientists can engage better with the general public to increase their awareness of what is going on at research institutions near them, and to improve their understanding of how science works. However, there are many more aspects to open research, and a few of these domains will be introduced in the following sections.

Awareness and understanding of reproducibility crisis has been catalysed by a number of recent publications such as 'Estimating the reproducibility of psychological science' in 2015, where researchers attempted to replicate findings of 100 psychology studies and found that while 97% of the original studies found statistically significant results only 36% of replications also had statistically significant results, with many of the replications have effect sizes that were smaller or even opposite to the originally reported effect. However, although the reproducibility crisis may be something that is prominent in the minds of many of today's scientists, the credibility of scientific research is something that has been scrutinised by some academics for much longer. Indeed, in a 1991 issue of 'Science' there was an editorial piece calling upon scientists to hold themselves and others more accountable to improve the creditability and the public's perception of science. Curiously, this same issue of Science also published findings from one of the first experiments using magnetic resonance imaging (MRI) to map brain functioning during a task.

Table 1:.

		Data	
		Same	**Different**
Analysis	**Same**	Reproducible	Replicable
	Different	Robust	Generalisable

The differences between whether findings are reproducible, replicable, robust, or generalisable are dependent on whether researchers are use the same or different data and analysis methods.

Resource Six
Data Source

Section B

Preregistration & registered reports.

Preregistrations, and registered reports aim to improve the quality of findings in published research by getting researchers to commit to study aims, hypotheses, methods, and analysis plans before data is collected. They are two of the most well-known open science approaches in the scientific community, and make exploratory findings distinguishable from confirmatory findings. Separating confirmatory findings from exploratory findings is important, since many studies publish findings as if hypotheses have been planned in advance when in truth this may not be the case. This results in what is known as HARKing (hypothesising after results are known), where the results of a study may be questionable since researchers have not clearly stated their hypotheses and analytic plans in advance of data collection or analysis. Therefore, preregistration and registered reports aim to minimise what are known as 'questionable research practices' by getting researchers to define their aims, hypotheses, methods, and analysis plans in advance of collecting or analysing data. Doing so reduces the likelihood that the results of the study are influenced by experimenter bias, and improves the credibility of research findings. These plans are then time stamped and archived in an un-editable form that can be openly accessed by others.

Lindsay, D.S., Simons, D.J. and Lilienfeld, S.O. (2016). Research Preregistration 101. APS Observer, [online] 29(10). Available at: <https://www.psychologicalscience.org/observer/research-preregistration-101#.WR3GyFPyvOT>.

Resource Six
Data Source

Section C

Open data

Another aspect of open research that is particularly important is open data. Open data improves the credibility of published findings as other researchers can reproduce analyses to verify findings. Open data gives researchers the opportunity to run novel analyses on existing datasets which is beneficial as it saves the time, money, and resources associated with data acquisition. If a researcher can test their hypotheses using open data, then this is also ethically the correct thing to do. Although data collection may pose minimal risks to potential participants, these risks are still infinitely more likely than if data collection is not carried out in the first place.

The FAIR principles have been developed as a way to improve the quality of data that are shared by researchers and are based on the following principles that data should be: Findable, Accessible, Interoperable, and Reusable. Firstly, data needs to be findable. Findable data should have associated metadata that allows other researchers to find it. An analogous example of how metadata works would be googling something. In order to find a webpage on a certain topic, for example the band Pink Floyd, Google, the search engine, would use metadata from other websites to find those which match with the description put in the search box. In the same way, if a researcher has collected data on x then they should ensure this dataset is associated with metadata that describes it as containing x. Once a researcher has found an appropriate dataset, the data they do find should be accessible. Accessible data should be openly and freely available for those who would like to use the dataset, and the metadata for the dataset should be perpetually accessible, even if the data itself become unavailable.

Resource Six
Data Source

Wilkinson, M.D. et al.. (2016). The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data, 3(1).

For a publicly available dataset to be useful to other researchers, the data should be formatted in such a way that other researchers could use it. Therefore, the last two principles of the FAIR principles describe how to make a dataset useful. For data to be interoperable, it should be stored in a format that is useable, and integrable with other datasets, software and hardware. This data should also be described and structured in a way that is consistent with other datasets from the same field. Having data stored in this way makes it reusable, and thus useful to other researchers within the field. For example, in human neuroimaging the Brain Imaging Data Structure (BIDS) is a widely accepted standard for structuring and describing data, while the NIFTI file type is a commonly used filetype for storing functional magnetic resonance imaging (fMRI) data. Thus, any publicly available fMRI datasets in BIDS format with NIFTI file types are intuitively understandable to other neuroscientists who would want to use them, and should be analysable using existing analysis software/hardware.

Resource Six Activities

Activities

1. What is the core principle of the open science movement?
2. What percentage of original studies that were reproduced in the paper 'Estimating the reproducibility of psychological science' had significant results and what percentage of the reproduced studies had significant results? Why do you think there is such a difference in these percentages?
3. How are reproducible and replicable results different?
4. Explain two ways that open science aims to improve the credibility of scientific research. Do you think these are sufficient to improve their credibility?
5. What would make you more or less sceptical about the findings of scientific research? Explain your reasoning.
6. Why is it problematic that journals selectively publish significant findings, and what impact is this likely to have on the scientific literature?

Resource Six
Further Reading

Explore

- False-Positive Psychology: Undisclosed Flexibility in Data Collection and Analysis Allows Presenting Anything as Significant https://doi.org/10.1177/0956797611417632
- Estimating the reproducibility of psychological science https://science.sciencemag.org/content/349/6251/aac4716
- Why Most Published Research Findings Are False https://doi.org/10.1371/journal.pmed.0020124
- Research Preregistration 101 https://www.psychologicalscience.org/observer/research-preregistration-101#.WR3GyFPyvOT

Final Reflection Activity

Deep Dive

BROUGHT TO YOU BY RBC ACCESS ED

Imagine you have been asked to conduct an neuroimaging study investigating how adolescents with autism spectrum disorder (ASD) process emotional faces differently to adolescents without ASD. Read the following extract from Wikipedia (https://en.wikipedia.org/wiki/Face_perception#In_individuals_with_autism_spectrum_disorder), then based on your knowledge write a short report that answers the covers the following:

- What does previous literature suggest about face processing in ASD?
- What are your experimental hypotheses? •
    - Are you going to use fMRI or MRS for your study?
    - If you choose MRS, which metabolite are your interested in and why?
    - If you choose fMRI, which analysis method is most appropriate to test your hypotheses?
- Would you use open science practices in your work? How do you think this will impact the perception of your research?

Part 3 – Study Skills, Tips & Guidance

This section includes helpful tips to help you complete this pack, as well as improve your study skills for any courses you take next year.

It also includes a few fantastic easy-to-use resources to know what to do next if you are hoping to go to university in the next few years, like UCAS advice and web links to more academic opportunities.

In this section:

University Study Skills:

- ✓ Cornell Notes
- ✓ Key Instruction Words
- ✓ Academic Writing
- ✓ Referencing
- ✓ Evaluating Your Sources

University Guidance:

- ✓ What next?

Subject Guidance:

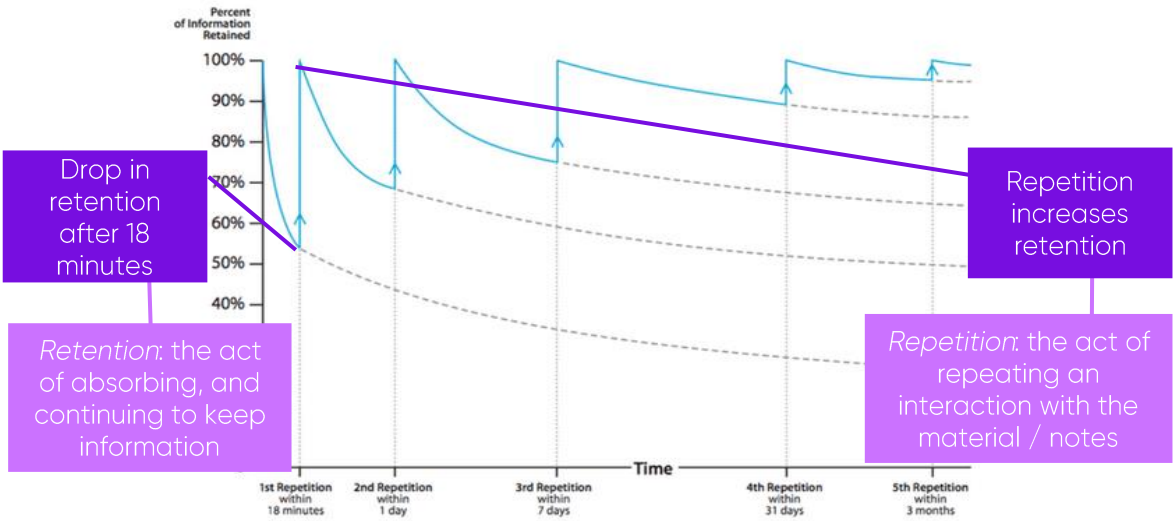
- ✓ More on studying your subject

University Study Skills
Cornell Notes

Why is good note taking important?

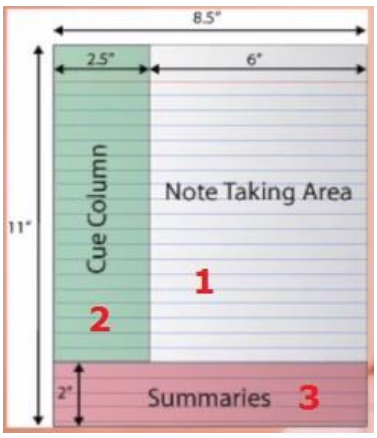
If it feels like you forget new information almost as quickly as you hear it, even if you write it down, that's because we tend to lose almost 40% of new information within the first 24 hours of first reading or hearing it.

If we take notes effectively, however, we can retain and retrieve almost 100% of the information we receive. Consider this graph on the rate of forgetting with study/repetition:



Learning a new system

The Cornell Note System was developed in the 1950s at the University of Cornell in the USA. The system includes interacting with your notes and is suitable for all subjects. There are three steps to the Cornell Note System.



Step 1: Note-Taking

1. Create Format: Notes are set up in the Cornell Way. This means creating 3 boxes like the ones on the left. You should put your name, date, and topic at the top of the page.

2. Write and Organise: You then take your notes in the 'note taking' area on the right side of the page. You should organise these notes by keeping a line or a space between 'chunks' /main ideas of information. You can also use bullet points for lists of information to help organise your notes.

University Study Skills
Cornell Notes

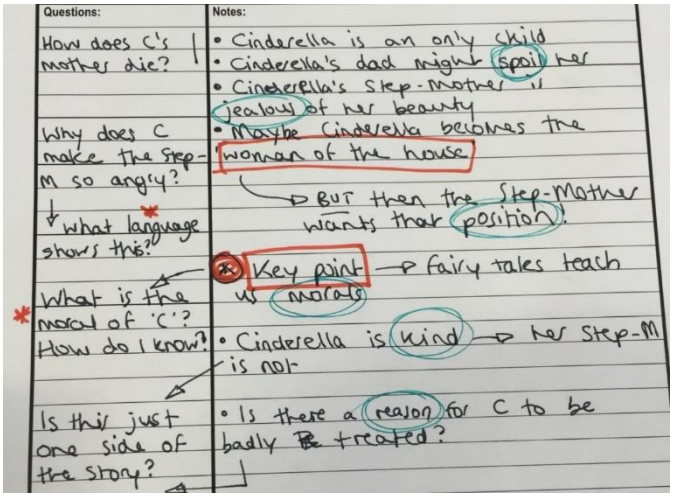
Step 2 Note-Making

1. Revise and Edit Notes: Go back to box 1, the note taking area and spend some time revising and editing. You can do this by: highlighting 'chunks' of information with a number or a colour; circling all key words in a different colour; highlighting main ideas; adding new information in another colour

2. Note Key Idea: Go to box 2 on the left hand side of the page and develop some questions about the main ideas in your notes. The questions should be 'high level'. This means they should encourage you to think deeper about the ideas. Example 'high level' questions would be:

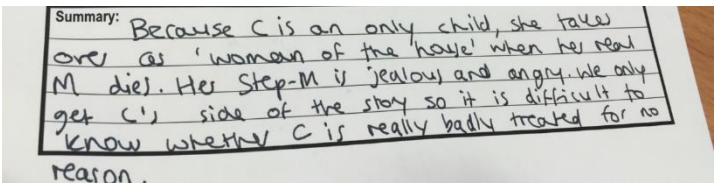
- Which is most important / significant reason for...
- To what extent...
- How does the (data / text / ideas) support the viewpoint?
- How do we know that...

Here is an example of step 1 and step 2 for notes on the story of Cinderella:



Step 3 Note-Interacting

1. Summary: Go to box 3 at the bottom of the page and summarise the main ideas in box 1 and answer the essential questions in box 2.



Give the Cornell Note Taking System a try and see if it works for you!

University Study Skills
Key Instruction Words

These words will often be used when university tutors set you essay questions- it is a good idea to carefully read instruction words before attempting to answer the question.

Analyse – When you analyse something you consider it carefully and in detail in order to understand and explain it. To analyse, identify the main parts or ideas of a subject and examine or interpret the connections between them.

Comment on – When you comment on a subject or the ideas in a subject, you say something that gives your opinion about it or an explanation for it.

Compare – To compare things means to point out the differences or similarities between them. A comparison essay would involve examining qualities/characteristics of a subject and emphasising the similarities and differences.

Contrast – When you contrast two subjects you show how they differ when compared with each other. A contrast essay should emphasise striking differences between two elements.

Compare and contrast – To write a compare and contrast essay you would examine the similarities and differences of two subjects.

Criticise – When you criticise you make judgments about a subject after thinking about it carefully and deeply. Express your judgement with respect to the correctness or merit of the factors under consideration. Give the results of your own analysis and discuss the limitations and contributions of the factors in question. Support your judgement with evidence.

Define – When you define something you show, describe, or state clearly what it is and what it is like, you can also say what its limits are. Do not include details but do include what distinguishes it from the other related things, sometimes by giving examples.

Describe – To describe in an essay requires you to give a detailed account of characteristics, properties or qualities of a subject.

Discuss – To discuss in an essay consider your subject from different points of view. Examine, analyse and present considerations for and against the problem or statement.

University Study Skills
Key Instruction Words

Con't

Evaluate – When you evaluate in an essay, decide on your subject's significance, value, or quality after carefully studying its good and bad features. Use authoritative (e.g. from established authors or theorists in the field) and, to some extent, personal appraisal of both contributions and limitations of the subject. Similar to **assess**.

Illustrate – If asked to illustrate in an essay, explain the points that you are making clearly by using examples, diagrams, statistics etc.

Interpret – In an essay that requires you to interpret, you should translate, solve, give examples, or comment upon the subject and evaluate it in terms of your judgement or reaction. Basically, give an explanation of what your subject means. Similar to **explain**.

Justify – When asked to justify a statement in an essay you should provide the reasons and grounds for the conclusions you draw from the statement. Present your evidence in a form that will convince your reader.

Outline – Outlining requires that you explain ideas, plans, or theories in a general way, without giving all the details. Organise and systematically describe the main points or general principles. Use essential supplementary material, but omit minor details.

Prove – When proving a statement, experiment or theory in an essay, you must confirm or verify it. You are expected to evaluate the material and present experimental evidence and/or logical argument.

Relate – To relate two things, you should state or claim the connection or link between them. Show the relationship by emphasising these connections and associations.

Review – When you review, critically examine, analyse and comment on the major points of a subject in an organised manner

University Study Skills
Academic Writing

What is academic writing?
'Academic writing' is a specific way of writing when communicating research or discussing an argument/point of view. It has a logical structure, and it uses formal language. There is a particular tone, 'voice' and style to the language. Unlike creative or narrative writing, academic writing will also use different sources of information to support what is being said.

The language of academic writing: do's and don'ts

- Do use words you know the meaning of and are confident using, it doesn't have to be complicated to be clear!
- Do not use contractions; don't, can't, doesn't, it'd. Do write out fully; do not, cannot, does not, it would.
- Do not use colloquialisms- this is 'writing as you speak'. Examples include misuse of the words 'literally' or 'basically', common phrases, such 'like chalk and cheese'.
- Do not use slang or jargon. For example, 'awks', 'lit', 'woke'.

Expressing your opinion in academic writing
In academic writing, it is best practice to express an opinion without writing in the first person, which can often be challenging. Always bear in mind that your work should read like a voice that is guided by the evidence and not basic personal intuition.

Therefore, rather than saying 'In my opinion, this proves that', you can express the outcome of your reasoning in other ways:

- 'This indicates that…';
- 'The aforementioned problems in Smith's argument reveal that…';
- 'Such weaknesses ultimately mean that…', and so on.

Signposting
Signposting guides your reader through different sections of your writing. It lets those who read your writing know what is being discussed and why, and when your piece is shifting from one part to another. This is crucial to for clear communication with your audience.

Signposting stems for a paragraph which expands upon a previous idea	Signposting stems for a paragraph which offers a contrasting view
Building on from the idea that … (mention previous idea), this section illustrates that … (introduce your new idea).	However, another angle on this debate suggests that … (introduce your contrasting idea)
To further understand the role of …(your topic or your previous idea) this section explores the idea that … (introduce your new idea)	In contrast to evidence which presents the view that … (mention your previous idea) an alternative perspective illustrates that …
Another line of thought on … (your topic or your previous idea) demonstrates that …	However, not all research shows that … (mention your previous idea). Some evidence agrees that …

University Study Skills
Referencing

What is a reference or referencing?

A reference is just a note in your assignment that tells your reader where particular ideas, information or opinions that you have used from another source has come from. It can be done through 'citations' or a 'bibliography'.

When you get to university, you will need to include references in the assignments that you write. As well as being academic good practice, referencing is very important, because it will help you to avoid plagiarism.

Plagiarism is when you take someone else's work or ideas and pass them off as your own. **Whether plagiarism is deliberate or accidental, the consequences can be severe.** You must be careful to reference your sources correctly.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

University Study Skills
Referencing

Is it a source worth citing?

Question your sources before referencing using these tips:

Currency: the timelines of the information

- When was it published or posted? Has it been revised or updated? Does your topic require current information, or will older sources work as well?

Relevancy: the importance of the information for your needs

- Does the information relate to your topic or answer your question? Who is the intended audience? Have you looked at a variety of sources?

Authority: the source of the information

- Who is the author/publisher/source/sponsor? What are the author's credentials? Is the author qualified to write on the topic?

Accuracy: the reliability and correctness of the source

- Is the information supported by evidence? Has the information been reviewed or refereed? Can you verify whether it is a personal or professional source? Are there errors?

Purpose: the reason the information exists

- Does the author make the intensions/ purpose clear? Is the information fact opinion or propaganda? Are there are biases? Does the viewpoint appear objective?

University Study Skills
Referencing

How do I reference?

- There are a number of different ways of referencing, but most universities use what is called the Harvard Referencing Style. Speak with your tutor about which style they want you to use, because the most important thing is you remain consistent!

- The two main aspects of referencing you need to be aware of are:

1. In-text citations

- These are used when directly quoting a source. They are located in the body of the work, after you have referred to your source in your writing. They contain the surname of the author of the source and the year it was published in brackets.
    - E.g. *Daisy describes her hopes for her infant daughter, stating "I hope she'll be a fool—that's the best thing a girl can be in this world, a beautiful little fool."* ***(Fitzgerald, 2004)***.

2. Bibliography

- This is a list of all the sources you have referenced in your assignment. In the bibliography, you list your references by the numbers you have used and include as much information as you have about the reference. The list below gives what should be included for different sources.

- Websites – Author (if possible), *title of the web page*, 'Available at:' website address, [Accessed: date you accessed it].
    - E.g. *'How did so many soldiers survive the trenches?'*, Available at: http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [Accessed: 11 July 2019].

- Books – Author surname, author first initial, (year published), *title of book*, publisher
    - E.g. Dubner S. and Levitt, S., (2007) *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything,* Penguin Books

- Articles – Author, *'title of the article'*, where the article comes from (newspaper, journal etc.), date of the article.
    - E.g. Maev Kennedy, *'The lights to go out across the UK to mark First World War's centenary'*, The Guardian Newspaper, 10 July 2014.

University Study Skills
Evaluating your sources

Knowing about the different types of sources and what makes them worth using is important for academic work.

When doing research you will come across a lot of information from different types of sources. How do you decide which source to use? From newspaper articles to books to tweets, this provides a brief description of each type of source, and breaks down the factors to consider when selecting a source.

A platform for millions of very short messages on a variety of topics.

Blogs (e.g. Tumbler) are an avenue for sharing both developed and unpublished ideas and interests with a niche community.

A collection of millions of educational, inspirational, eye-opening and entertaining videos.

A reporting and recording of cultural and political happenings that keeps the general public informed. Opinions and public commentaries can also be included.

A collection of analytics reports that outline the objectives, background, methods, results and limitations of new research written for and by scholars in a niche field.

The information presented is supported by clearly identified sources. Sometimes each chapter has a different author.

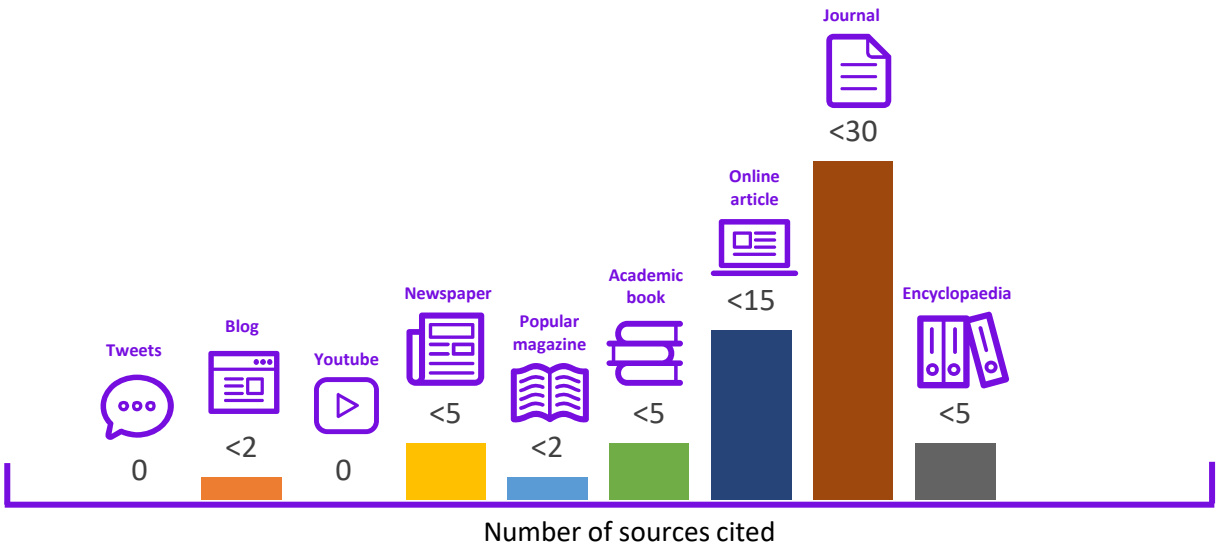
Books or online – giving information on many different subjects. Some are intended as an entry point into research, some provide detailed information and onwards references.

A glossy compilation of stories with unique themes intended for specific interests.

University Study Skills
Evaluating your sources

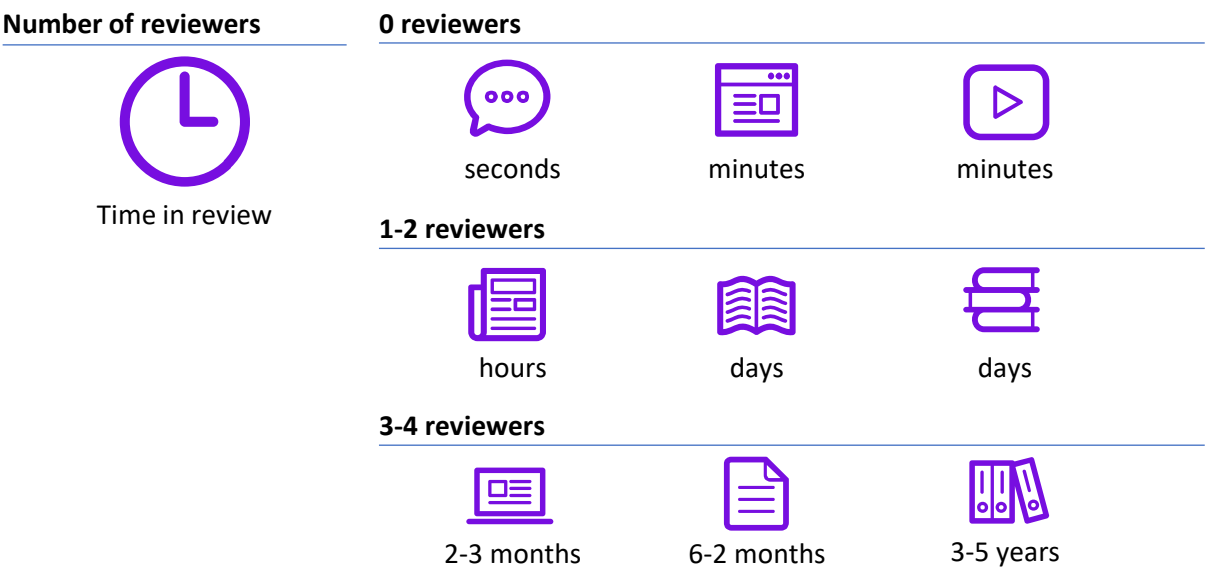
Number of outside sources

When an author used many outside sources into their writing, they demonstrate familiarity with ideas beyond their own. As more unique viewpoints are pulled into a source, it becomes more comprehensive and reliable. This shows the typical number of outside sources used in each publication.



Degree of review before a source is published

Two factors contribute to the amount of inspection that a source receives before it might be published: the number of reviewers fact-checking the written ideas, and the total time spent by reviewers as they fact-check. The more people involved in the review process and the longer the review process takes, the more credible the source is likely to be.



University Guidance
What next?

University Guidance

Different people go to university for different reasons. You might have a particular job in mind or just want to study a subject you are passionate about. Whatever your motivations, going to university can help improve your career prospects, as well as develop your confidence, independence and academic skills.

Choosing a course and university

Choosing the right course to study is an important decision so make sure you take time to research the different options available to you. Here are some top tips:

- ✓ You don't have to choose a course which you have already studied, there are lots of courses which don't require prior knowledge of the subject. You can apply skills gained from school studies to a new field.
- ✓ The same subject can be taught very differently depending on the course and university you choose. Take a look at university websites to find out more about the course content, teaching styles and assessment types.
- ✓ When choosing a university, think about what other factors are important to you. Do you want to study at a campus university or be based in a city centre? What accommodation options are there? Does the university have facilities for any extracurricular activities you're involved in?
- ✓ To research your options, have a look at university prospectuses and websites, as well as seeing if there are opportunities to speak to current students who can give you a real insight in to what life is like there.

Insight into: University of Reading

The author of this coursebook attends the University of Reading.

The University of Reading runs a large number of sessions to help find out more about the process of applying to university as well as taster sessions and Open Online Courses in a number of different subjects. To find out more, visit: www.reading.ac.uk/virtual-events.

Chat to current University of Reading students via Unibuddy and get their views on what university life is like!

University Guidance
What next?

Exploring Careers and Subject Options

- ✓ Find job descriptions, salaries and hours, routes into different careers, and more at https://www.startprofile.com/
- ✓ Research career and study choices, and see videos of those who have pursued various routes at http://www.careerpilot.org.uk/
- ✓ See videos about what it's like to work in different jobs and for different organisations at https://www.careersbox.co.uk/
- ✓ Find out what different degrees could lead to, how to choose the right course for you, and how to apply for courses and student finance at https://www.prospects.ac.uk/
- ✓ Explore job descriptions and career options, and contact careers advisers at https://nationalcareersservice.direct.gov.uk/
- ✓ Discover which subjects and qualifications (not just A levels) lead to different degrees, and what careers these degrees can lead to, at http://www.russellgroup.ac.uk/media/5457/informed-choices-2016.pdf

Comparing Universities

Use our platform ThinkUni.org to take a short quiz about your preferences and interests to find out which universities might be a great fit for you.

Other popular resources:

- ✓ https://www.ucas.com/
- ✓ https://www.whatuni.com/
- ✓ http://unistats.direct.gov.uk/
- ✓ https://www.thecompleteuniversityguide.co.uk/
- ✓ https://www.opendays.com/

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UCAS and the university application process

All applications for UK degree programmes are made through UCAS. There is lots of information on the UCAS website to guide you through the process and what you need to do at each stage.

Apply

- Applications **open in September** the year before you plan to start university.
- You can apply for up to **five courses.**
- The deadline for most courses is **15 January**, though there is an earlier deadline of **15 October** for Oxford and Cambridge, medicine, veterinary medicine/science and dentistry.

Decisions

- Some courses may require an interview, portfolio or admissions test in addition to UCAS application. Check individual university websites details.
- Check UCAS Track which will be updated with decisions from the universities you have applied for and to see your deadline for replying to any offers.
- You should choose a firm (or first) choice university and an insurance choice. If you already have your exam results or a university thinks your application is particularly strong, you might receive an **unconditional offer**.

Results

- If you're holding a conditional offer then you will need to wait until you receive your exam results to have your place confirmed.
- Clearing & Adjustment allows you to apply to courses which still have vacancies if you didn't meet the conditions of your offer, have changed your mind about what or where you want to study, or have met and exceeded the conditions of your offer and would like to look at alternate options.

Personal statements

A really important part of your application is the personal statement. The personal statement gives you the opportunity to tell universities why they should offer you a place.

Here a few top tips for making your personal statement stand out:

- You can only submit one personal statement so it's important that you are consistent in your course choices. Make sure you have done your research to show your understanding of the subject area and passion for it.
- Start by brainstorming all your skills, experience and attributes. Once you have everything written down, you can begin to be selective – you only have 47 lines so won't be able to include everything.
- The ABC method: action, benefit and course can be a useful way to help demonstrate your relevant experience and how it applies to the course you're applying for.

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Personal Statement do's and don'ts

Read the tips below from real life professors and admissions staff in university Biology and Psychology departments, on the 'do's' and 'don'ts' of what to include in your personal statement:

Biology

- Tell us why you want to study Biology
- What area of Biology fascinates you? I.e. ecosystems
- Demonstrate your interest by telling us what you have recently read, watched or listened to and how they helped your understanding of Biology
- What activities or practical work have you completed which helped to develop your lab-based skills?
- Describe how your school or individual work has equipped you with the necessary knowledge and ability to be a successful Biology student.

Psychology

- Try to avoid **clichés** such as 'I want to help people' or I want to 'find out what makes them tick'.
- Show your passion for the subject through wider reading, academic studies, work experience or volunteering.
- You don't have to have direct work experience, but you should show the skills that relate to this subject.
- Highlight the areas of Psychology that most interest you.
- Demonstrate your understanding of what studying the specific university course will entail. Can you show that you have these skills?

Further useful resources

Be sure you know what you'll need to do to apply to university in the UK:

- ✓ Key dates and deadlines: www.access-ed.ngo/timelines-for-applying-to-university
- ✓ Get tutor advice on writing a UCAS personal statement at www.access-ed.ngo/writing-your-ucas-personal-statement
- ✓ An easy template to start practising your personal statement: https://www.ucas.com/sites/default/files/ucas-personal-statement-worksheet.pdf
- ✓ Untangle UCAS terminology at https://www.ucas.com/corporate/about-us/who-we-are/ucas-terms-explained
- ✓ Discover more about the application process including when to apply and how to fill in your application on the UCAS website.
- ✓ Read more useful advice about what to include in your personal statement on UCAS, the Complete University Guide and The Student Room.
- ✓ Attend one of our virtual sessions to find out more about applying and personal statements.

More on studying this subject

A Deeper Look Into Neuroscience

- ✓ **Watch:** The Mind Explained https://www.netflix.com/gb/title/81098586
- ✓ **Read:** A Hitchhiker's Guide to Functional Magnetic Resonance Imaging https://doi.org/10.3389/fnins.2016.00515
- ✓ **Listen:** Naked Neuroscience Podcast https://www.thenakedscientists.com/podcasts/naked-neuroscience
- ✓ **Do:** Visit The Brain Collection at The Grant Museum of Zoology, UCL, London https://www.ucl.ac.uk/culture/grant-museum-zoology/brain-collection

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