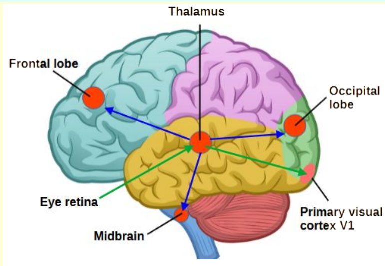
Consciousness

– Rex M Heyworth PhD



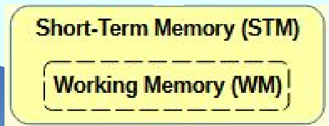
As regular visitors to my website will know, I have written projects on a variety of topics. One topic I have long wanted to write on is that of 'consciousness.' I did start about two years ago but found it extremely difficult so I gave up. One of the major problems was that many of the articles on the Internet that I often rely on for ideas were just too difficult or even downright impossible to understand. Further, as the topic is rather new, there are many disagreements among the writers of these articles! If the reader does not believe me, look at some of the files in the website references in the appendix to this project. As a result of this difficulty, I almost gave up. But I tried again. And sometimes I resorted to giving my own interpretations of what the 'experts' cannot agree on.

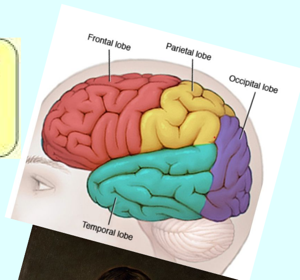
AI Chat: One thing I was able to use now that was not around previously are the AI chatbots that now inhabit the Internet. The one I use is called 'AI Chat.' It is not an alternative to having to wade through difficult articles, but it allows me to get reasonably good answers (though not always perfect!) to specific questions I have relating to consciousness. In fact, by the time I finished the project, I had collected over 100 pages of notes from AI Chat!

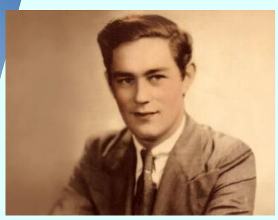
Dear reader, I suggest that as you read through this project, if there is something that you don't understand, you might like to ask AI Chat – you can find it at the website: https://deepai.org/chat

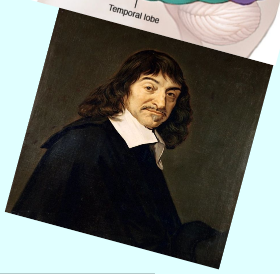
Further, as you read, from time to time you will come across some unusual things. This includes a gorilla (see picture above, left) and even intelligent tortoises.

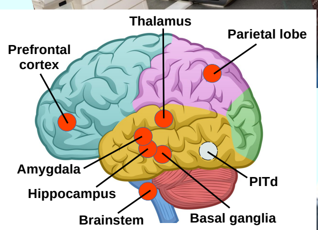
Also note: E&OE!!! So then, let us begin.

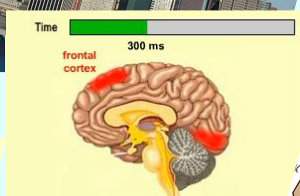


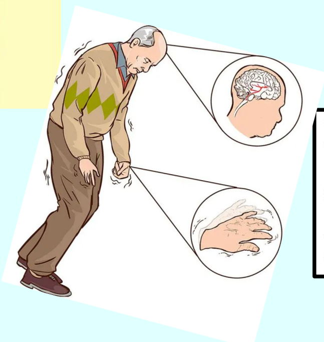


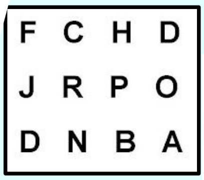


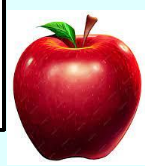












Contents

Consciousness

Introduction: What is consciousness?

We all know the word. But what is its meaning? This is not so easy to answer; even the experts in the field cannot agree. Consciousness is considered one of science's most perplexing and persistent mysteries. We know more about distant galaxies and the deepest ocean regions than we do about our consciousness.

Although there is no other phenomenon with which we are so intimately familiar, scholars have spent centuries trying to understand exactly what it is and how it operates, and have yet to arrive to an agreed explanation.

Definition of consciousness: So, what is consciousness? Here are three definitions:

- *Consciousness is being aware of one's surroundings, our thoughts, our feelings, and sensations.* [Merriam-Webster dictionary]
- *The state of being aware of and responsive to one's surroundings.* [Oxford dictionary]
- *The state of understanding and realising something*. [Cambridge dictionary]

For example, when we look at the scene outside the window, we are aware of what we see. Also, if we feel some *pain*, we are probably aware/conscious of it.

Notes:
1 Many definitions, such as the above, include the idea of *awareness*.
2 We will see later that we probably *not* actually aware of *everything* in a scene we are looking at!
3 I chose the example of 'pain' as it is one that *several* experts refer to in their articles when discussing consciousness. It will also be discussed at various points in this project.

Despite the relative simplicity of *these* definitions, consciousness is still one of the greatest unsolved mystery of out times!

Living without consciousness?

Also, do we all have consciousness? Later in this project, we will look at *Alzheimer's disease* and its effects on human memory. (Pages 68, 71 and 76.) Many characteristics of what we call consciousness are gradually lost by people suffering from Alzheimer's disease. As the disease progresses, they become detached from everything going on around them and are no longer even sure of their own identity. But individuals with Alzheimer's disease often still have moments of lucidity and maintain a sense of self-awareness, especially during the initial stages of the disease. So they still have some degree of consciousness.

However, there is something even more disturbing about seeing someone in a *coma* after a traumatic brain injury, because there is a body, obviously alive, yet displaying *no* manifestations of consciousness. The person is unresponsive and unaware of his/her surroundings. The person is unable to recognise or interact with the environment or communicate in any way; they are living *without* consciousness.

Who studies consciousness?

Consciousness is studied by three groups of people:

1 Philosophers

This covers people from ancient times up to and including modern times. In a broad sense, philosophy is the study of and search for wisdom. (The original meaning of the word *philosophy* comes from the Greek roots *philo*- meaning 'love' and -*sophos* meaning 'wisdom.')

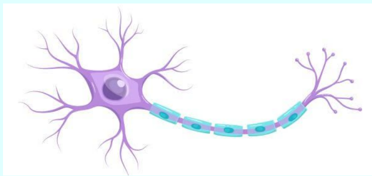
2 Cognitive psychologists

Psychology is the scientific study of the mind and behaviour. Psychologists are actively involved in studying and understanding mental processes, brain functions and behaviour. Cognitive psychology is the branch of psychology that studies mental processes such as perception, thought, attention, memory, language and problem-solving – and consciousness. Cognitive psychologists use experimental methods to investigate these mental processes and develop models and theories to explain them.

3 Neuroscientists

(*Neuro*- = relating to nerves or the nervous system) Neuroscience is the sciences that deal with the structure or function of the nervous system and brain. The ultimate explanation of consciousness is neurological – maybe!! (See note below.)

A nerve cell is called called a **neuron**. The image here shows a typical neuron. (For more information on neurons, refer to my earlier project '*Transmission of Nerve Impulses,*' pages 1 – 3). Neuroscientists try to provide explanations in terms of the *neural activity* in the brain.



Further reading: Refer to Website #B2 for the link to this earlier project.

Websites

As you read through the text, you will come across references to websites. These websites are listed on the last few pages of the project. Material from some of these has been used in this text. In addition, some websites in the list are not referred to in the text. These are background or 'extension' websites to allow readers to obtain more information about topics that interest them.

Long before scientists began to talk about consciousness, philosophers had tried to explain how consciousness fits into the objective world. However, for a long time, universities and scientists acted as if it were in bad taste to treat consciousness as a subject for serious scientific research. But gradually, in the 1980s, and then especially in the 1990s, as brain-imaging technologies became increasingly accessible, consciousness came to be recognised as a subject for serious multi-disciplinary research.

Will we ever be able to achieve a satisfactory explanation of consciousness? Some authorities doubt it, and say that the origin of consciousness is so complex that the human brain would have no more chance of comprehending it than an earthworm would have of understanding an ape.

A combined study?

It is still unclear whether neuroscience will provide the ultimate explanation of consciousness. While neuroscience *is* now providing significant insights into the brain mechanisms underlying various aspects of consciousness, it is still unable to fully explain how our experiences and self-awareness arise from physical processes in the brain (i.e. in terms of the action of neurons). Therefore, it is possible that a comprehensive understanding of consciousness may require a multi-disciplinary approach that includes philosophy, psychology as well as neuroscience.

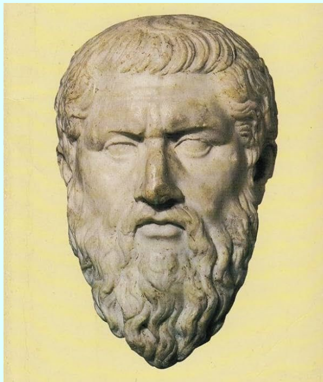
The Thoughts of Philosophers: Some History

Questions about the nature of conscious awareness have likely been asked for as long as there have been humans. Many have argued that consciousness as we know it today is a *relatively* recent historical development that arose sometime in the ancient Greek era (even though there was no word in ancient Greek that corresponds to 'consciousness').

We will mention here just one Greek – the philosopher Plato. (This actually overlaps with the project I did entitled '*The Republic of Plato*'. Readers may like to refer to this.) 'Plato' seems to have started as a nickname (for *platos* meaning 'broad') given to him by his wrestling coach – allegedly a reference to his physical girth.

Further reading: Refer to Website #B3 for the link to this earlier project.

Plato (427 – 347 BC): Dualism – Plato's two worlds



Plato's philosophy is *dualistic* in nature (*dual* = two). Dualism means the division of something into two opposed ideas. For example, mind-matter, heaven-hell, body-soul and spiritual-secular.

Plato's dualism separates the cosmos/universe into two *worlds*:

1 The *visible* world, the world of matter/objects, that is, the everyday physical world around us, and

2 An *invisible* world, which consists of ideas (which Plato called *forms*).

Dualistic view of man

Plato's dualistic view of the universe leads to a dualistic view of man which has two opposing components – a **body** and a **soul** (or *mind*). And according to Plato, the body is basically evil and a hindrance to the soul and that the soul (mind), unlike the body which can decay, is *eternal* and can continue to exist without the body after death and is immortal.

Thus Plato distinguished a mortal body from an immortal soul.

The mind-body problem

Plato's dualism seems to mean that a person has both a mind and a physical body, essentially two *independent* things connected together. But modern work on the brain suggests that the mind is *very dependent* on the brain in order to function, and in the end, to exist at all. As we shall see later, when we look at the human brain, damage to certain parts of the brain can make someone unable to think. So alterations in the body can affect the essential property of the mind; so the mind *cannot* be independent of the body – this is referred to as the mind-body problem.

The mind-body problem examines whether the mind can be explained solely by physical processes or if there is a separate non-physical aspect to the mind. It investigates how mental experiences, such as thoughts, feelings, and consciousness, relate to the physical aspects of the body, including the brain and its functions.

Plato's dualism and the development of Christianity

Greek thought in general, and Plato in particular, have influenced Christian thought. The first generations of Christians were primarily Jews, but they lived amidst a world shaped by Greek culture. As a result, Christian thought was influenced from the very beginning by Greek philosophy.

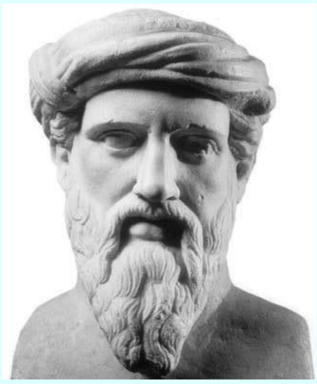
One major influence on Christianity was Greek dualism. Plato believed that the self has a dual nature, being divided into to parts, *body* and *soul*, with the soul more closely related to goodness and truth. This was incorporated into early Christianity's soul-body division.

Greek dualism has continued to plague Christianity ever since (yes, 'plague' is the word that has been used!).

The beginnings of Christianity: Christianity emerged from a two-fold ancestry: Israel and Greece. In the time of Jesus, his disciples and St Paul, Christianity was mainly based on Jewish and Old Testament thought. In the Old Testament, the Hebrews (that is, Jewish people, especially of ancient Israel) viewed God as the creator of the world, ***one world***, and that the world is good. Evil is not found in the physical world of matter, but rather in human sin, in our rebellion against God.

For the Hebrews, the body and soul were absolutely *inseparable*; they were one (so it was **monism**, not dualism – monism = oneness or singleness to an idea). Also, the focus of the Hebrews was on *this* world and making 'on earth as it is in heaven' (Lord's prayer, Matthew 6:10) which is actually the central message of Jesus and the New Testament until Greek ideas interfered.

What changed? One person who introduced Greek ideas into Christianity actually lived during the time of Jesus. This was Philo of Alexandria (a city in Egypt) (ca. 25 BC – 47 AD, depicted on the right), a Hellenised Jew, who began a Christian tradition when he attempted to explain Jewish religion in Platonist *dualism* terms, the separation of mortal body and an immortal soul. This idea served Christian theologians' ideas and they backed it with all the authority that the political power of the Church conferred on them for many centuries.



Philo of Alexandria

Note: The terms dualism and monism appear a lot in the study of consciousness. More about them later.

Further reading: We have not discussed Aristotle here. But if you would like to read about his ideas of consciousness (plus those of some other ancient philosophers), refer to Website #A1.

Consciousness: From ancient to (more) modern times

The ancient Greeks, including Plato, had no word for 'consciousness.' Though the ancients had much to say about mental matters, it is less clear whether they had any specific concepts or concerns for what we think of as consciousness today.

We now jump to the 17th Century Europe where *modern* ideas about consciousness started to appear. Two

Western philosophers of significance who struggled to comprehend the nature of consciousness were Rene Descartes (1596 – 1650) and John Locke (1632 – 1704).

Rene Descartes: Cartesian dualism

(The word *Cartes*ian derives from Descartes.)


Rene Descartes (1596 - 1650)

Descartes was a French philosopher and mathematician. Similar to Plato, he proposed a mind-body dualism in 1644, which posits that the *body* and the mind (or *soul*) are two separate *substances* that are completely independent of each other. Hence, Cartesian dualism is also called ***substance* dualism**.

Descartes' two types of substances are:
1 The physical/material world.
2 The non-physical world.

The body (and the brain) consist of physical/material substance while the mind (soul) consists of a non-physical substance. The soul includes non-physical entities such as the mind as well as thoughts, emotions, and consciousness.

This immediately raises the question of how the physical world (body/brain) and the independent non-physical world (mind/soul) interact. Descartes *did* have an answer but few later philosophers have been happy with his solution, and today his idea of substance dualism is no longer accepted.

In an attempt to retain the idea of having two separate entities, but avoid the pitfalls of *substance* dualism (e.g. the two entities cannot interact), philosophers developed several variants of dualism. These include: **property dualism**, which accepts that humans are composed *only* of one kind of matter, but that this matter has two very distinct types of properties – physical and mental. More on property dualism below.

What is a substance?

Again, do not confuse Descartes' use of 'substance' with our everyday idea of a substance as ordinary matter which are physical objects that can be observed and measured, such as the human body or a rock. Descartes expanded the meaning of 'substance' to include *immaterial* substances such as the mind. As his philosophy was *dualism*, he believed that the mind and body are *separate* kinds of substances.

John Locke: Existence dualism


John Locke (1632 - 1704)

John Locke (1632 – 1704) was an English philosopher and physician who proposed a view of consciousness that was a *modified form* of Descartes' substance dualism.

The origin of the modern concept of consciousness is often attributed to a 1690 essay by John Locke. In it, he defined consciousness as '*the perception of what passes in a man's own mind.*'

While Locke believed that human beings were physical/material substances, he also believed that consciousness or the *mind* was a non-material substance existed *separate* from the *body*. According to Locke, the mind was capable of understanding ideas and forming thoughts independent of the physical body. But in contrast with Descartes, he believed that this dualism does *not* consist in distinguishing two kinds of substances (material and spiritual), but two kinds of existence – primary and secondary for everything that exists.

The primary aspect is the object's *physical* properties, while the secondary aspect refers to the object's perception *in our minds*.

For example, a lemon has *primary/physical* qualities such as its shape, size, and weight which can be measured and which everyone can accept. These are referred to as **objective** qualities, that is *based on real facts and* not *influenced by personal beliefs or feelings*.

But the lemon also has *secondary* qualities such as taste, smell, and colour, which are dependent on the observer's perception and *will differ from the perception of another person*. So, *your* idea of a lemon's taste or smell is probably different from *mine*! These are referred to as **subjective** qualities, that is *based on personal beliefs or feelings, rather than based on facts*.

So objects have two types of existence: one that exists independently of perception (primary or objective existence) and another that exists only in our minds (secondary or subjective existence).

Overall, Locke's **existence dualism** implies that our *subjective* perception of reality is different from the objective reality itself, and that we cannot fully understand the nature of reality without taking into account both primary and secondary qualities. This is getting very close to what many philosophers accept today.

Locke's existence dualism has had a significant influence on the philosophy of mind and has been debated and further developed by subsequent philosophers.

Note: This objective-subjective difference is very important in our later discussion of consciousness so try to understand it now! It is also related to the *modern* philosophical ideas of 'Phenomenal-consciousness' and 'qualia' which are discussed later (page 14-15).

The Prince and the Cobbler

John Locke used a thought experiment of the 'Prince and the Cobbler' based on an earlier story of that name, to illustrate his concept of existence dualism, which is that a person *has* both a mind/consciousness and a body but that a person's *real identity* is separate from their bodily identity.

In this thought experiment, Locke asks us to imagine a scenario where the mind/consciousness and memories of a prince are transferred into the body of a cobbler replacing those of the cobbler, and vice versa.

According to Locke's existence dualism, the person who is the real prince but in the cobbler's body is still the prince as his *true* identity lies in his *mind/consciousness* and *not* his physical body. So even if the prince knows he is in a different body, he still remembers his own past experiences (i.e. has the same consciousness) and so is still the same prince.

By using this thought experiment, Locke argues that the mind and body are distinct entities but that the *true identity* of a person is *not* dependent on the body. This supports his theory of existence dualism, which asserts that a person's overall *identity* is made up of a physical body and conscious experiences.

However, modern thinking is that there is no way to transfer consciousness can be transferred from one person to another. So Locke's argument is *meaningless*.

Note: The story used by John Locke was entitled 'The Prince and the Cobbler.' The other title 'The Prince and the *Pauper*', shown in the picture, was the title given by Mark Twain in a story he published in 1881. However, the stories are different. Twain's story is set in Tudor England, depicting the switch between Prince Edward and a poor boy named Tom Canty. But as I could not find an appropriate picture with a cobbler, this one will have to do!

Further reading: For more on 'The Prince and the Cobbler', refer to Website #C1.

Philosophical positions on Consciousness

We introduced above the terms **dualism** and **monism**. We will now look further at various kinds of these.

Dualism vs Monism	
Substance dualism	Physicalism
Property dualism	Idealism
	Neutral monism

Dualism

As the table shows, there are two kinds of dualism – substance dualism and property dualism.

Substance dualism

Summary: Two kinds of substances → physical – body (including the brain); → non-physical (mind)

Traditional Cartesian dualism (Descartes 1644), and Locke's Existence dualism, assert the existence of *two* kinds of substances (or matter) – *physical* and *non-physical* 'substances.' The body is made of *physical* substances (matter). But the mind is made of some kind of *non-physical* 'substance/matter' that is *not* governed by the laws of physics. Though substance dualism is at present largely out of favour, it does have some contemporary proponents.

Property dualism

Summary: One kind of *substance*; two kinds of *properties* → physical properties (brain); → mental properties (mind)

Property dualism has several versions and enjoys a greater level of current support. All versions assert that there is just *one* kind of *matter/substance* (the physical kind), but that there are *two* different kinds of *properties*: physical properties and mental properties. Thus the brain is made of physical matter with physical properties just like all other matter, which can be explained and understood in terms of the laws of physics. But what we call the 'mind' is *not* made of physical *matter* and so has *non-physical/mental* *properties* (such as thinking, imagination, memory, etc.) that are *produced* by the actions of the physical brain but cannot be explained and understood in terms of the laws of physics.

Further reading: For more on 'Property Dualism', refer to Website #C2.

Monism

As the table shows, there are three kinds of monism – physicalism, idealism and neutral monism.

Physicalism (also called *material monism*)
This holds that *everything* in the world, including human consciousness and experiences, is *entirely physical*, that is, composed of matter, and can be explained by physical processes in the brain and the neurons of the nervous system (which is made of matter) involving the laws of physics.

Idealism
In contrast to physicalism, this is the philosophical view that *nothing* consists of matter. Matter is just an illusion! Everything that exists is ultimately mental/mind or spiritual and that physical objects are simply an expression of consciousness, perception or interpretation. So there is no need to study the brain as that will not give answers as to what consciousness is.

Joke: The following joke summarises the position of Idealism on the relationship between mind and matter: '*What is mind? No matter. What is matter? Never mind*.'

Neutral monism
This is the idea that there is just one fundamental substance or 'stuff' out of which *both* mind and matter are constructed, and that both mental and physical properties are two aspects or dimensions of this one substance. Neutral monism is different from both physicalism and idealism as it does not reduce the world to just one of the aspects of physical (as physicalism does) or mental (as idealism is).

Whatever this 'stuff' is (and those who favour this view are unable to say), it is *not* the kind of matter that makes up the brain. Some philosophers have suggested that this substance might even be energy. However, the exact nature of this neutral substance remains a matter of philosophical debate.

Note: There are also a large number of idiosyncratic theories that cannot cleanly be assigned to any of these to basic schools of thought and will not be discussed here.

Further reading: For more on 'Neutral monism', refer to Website #C3.

So which wins? Dualism or Physicalism?

It depends on who you ask! Some researchers are hardcore *physicalists*, but not all. Others are dualists, particularly *property dualists*, who believe there is a non-physical aspect to consciousness that cannot be explained by the physical processes in the brain. David Chalmers, for example, is a property dualist. (We will have a lot to say about David Chalmers later!)

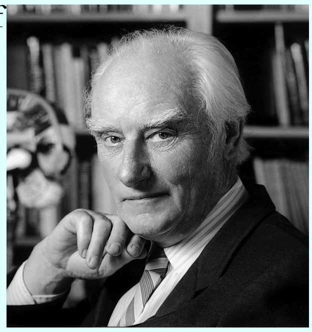
The answer to this question will require more insight into the fundamental structure of our physical world. It might turn out that a really consistent theory of physics could lead us to understand exactly what consciousness is. But it might not. Consciousness might forever remain a mystery.

What is my view?

I would probably tend to be a *property dualist* (as is David Chalmers) – one kind of substance, two kinds of properties. To me it just *seems* more ‘sensible.’ But, of course, I may be wrong and as more is learnt about consciousness, I may change my mind.

The study of consciousness becomes taboo

For a long time, science had been vigorously attempting to ignore the problem of consciousness. The source of the animosity dated right back to the 1600s, when René Descartes began the discussion that would tie scholars in knots for years to come. Might it be, for example, Cartesian (substance) dualism or physicalism?



Francis Crick (1916 - 2004)

Cartesian dualism remained the governing assumption into the 18th century and the early days of modern brain study. But it was always bound to grow unacceptable to the scientific establishment that took physicalism – the position that only physical things exist – as its most basic principle. And still, even as neuroscience gathered pace in the 20th century, no convincing alternative explanation was forthcoming. So little by little, the study of consciousness was avoided by mainstream scientists and became taboo.

It was only in 1990 when Francis Crick, the joint discoverer of the structure of the DNA molecule, used his position of eminence to break ranks. Neuroscience was far enough along by now, he declared, that consciousness could no longer be ignored. “It is remarkable,” he said, “that most of the work in both cognitive science and the neurosciences makes no reference to consciousness”– partly “because most workers in these areas cannot see any useful way of approaching the problem.”

Since that time, there has been a substantial amount of interest and research into the topic of consciousness. We will see later what caused things to change.

Francis Crick quote: "*Nature isn't conspiring against us to make important problems difficult, so given a finite life span, aim high – go after fundamental problems.*"

Animal consciousness

Are animals conscious?

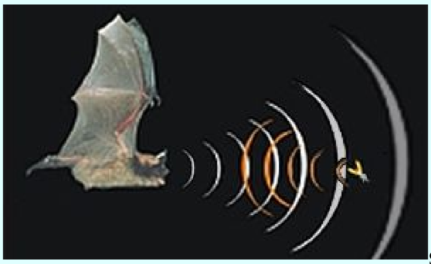
The question is occasionally raised as to whether non-human animals have consciousness. This is difficult to answer because non-human animals, lacking the ability to express human language, cannot tell humans about their experiences. Also, it is difficult to reason objectively about the question, because a denial that an animal is conscious is often taken to imply that it does not feel, its life has no value, and that harming it is not morally wrong. Descartes, for example, has sometimes been blamed for mistreatment of animals due to the fact that he believed only humans have a non-physical mind.

Most people have a strong intuition that some *animals*, such as cats and dogs, are conscious, while others, such as insects, are not; but the sources of this intuition are not obvious, and are often based on personal interactions with pets and other animals they have observed. And according to many neuroscientists, some birds too are probably conscious.

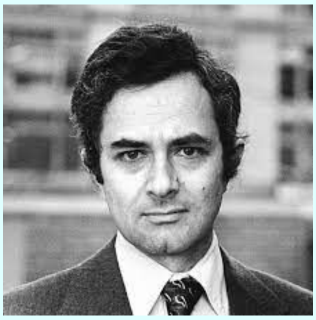
Cambridge Declaration on Consciousness: At a conference on consciousness in 2012 at the University of Cambridge, in the presence of Stephen Hawking, a statement was issued stating to everyone there, that animals have consciousness but that this is not obvious to the rest of the world.

Stephen Hawking (1942 - 2018)

What is it like to be a bat?



In a 1974 article entitled '*What is it Like to Be a Bat?*', the philosopher Thomas Nagel wondered if a bat has consciousness and how this might differ from that of humans. For example, humans see using our sense of sight. Bats 'see' using echolocation: they emit high-frequency sounds, then use the echoes returned by obstacles to 'see' their prey. So the way bats perceive the world is different from ours. As we humans have a completely different sensory system to a bat, we are incapable of echolocation, we will never be able to feel 'what it is like to be a bat.'

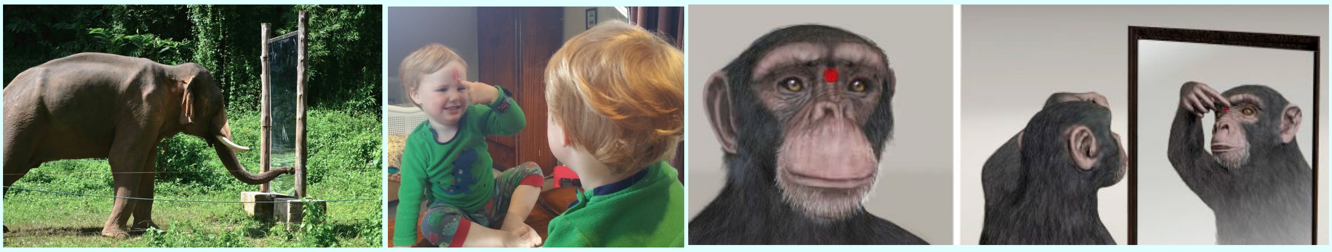


Thomas Nagel (1937 -)

Nagel's point is that there is a limit to what science can tell us about the nature of consciousness and that we need to take *subjective/personal* experience seriously if we are to fully understand the world around us.

Mirror test

One characteristic of consciousness is self-awareness, that is, the ability to distinguish oneself from others. In the 1970s a test for self-awareness, known as the mirror test, was used to test whether animals are able to differentiate between seeing themselves in a mirror versus seeing other animals. The classic example involves placing a spot of colouring on the skin or fur near an animal's forehead and seeing if it attempts to remove it or at least touch the spot, thus indicating that it recognises that the individual they are seeing in the mirror is themselves. Humans (older than 18 months), great apes, some dolphins, killer whales, pigeons and elephants have all been observed to pass this test.



Artefact consciousness

[Also known as **panpsychism**] An artefact is an object made by a person.

This is the belief that consciousness is a fundamental property of the universe and is *present in all matter* and *not* just in animals. The argument goes: If humans have it, and apes have it, and dogs and pigs probably have it, and maybe birds, too – well, where does it stop? Why not include trees and rocks? For some people, the idea even goes as far as to suggest that consciousness exists at a basic level in atoms.

The ethical implications of panpsychism are unsettling: might we owe the same care to trees, rocks, and even 'intelligent' machine that we bestow on animals? For this reason, one proponent of panpsychism, the neuroscientist Christof Koch, even tries to avoid *stepping on insects* as he walks!

Note: The idea of an artefact made conscious is an ancient theme of mythology, appearing for example in the Greek myth of *Pygmalion*, a king of Cyprus, who carved a statue that was magically brought to life. He fell in love with the statue of a woman he had sculpted. (1786 painting, right, by a French painter.)

Thought: Should we avoid killing all animals in case they too have consciousness? (Cf. Koch above). Maybe we will have to become vegans. But what if plants too exhibit consciousness?

Can blind people have consciousness?

Helen Keller and consciousness

Helen Keller (1880 - 1968)

Some people have said that if a person loses his/her senses, they lose their consciousness. However, Helen Keller was both blind and deaf and so had lost two senses. However, she was still aware of herself and the world around her, despite her physical limitations. Even without hearing or sight, she was still able to experience and learn through touch and taste. Therefore, her loss of some senses did *not* negate her ability to be conscious.

But what about people *born* without any senses? Their minds would have no information from outside. In this case such people would probably have no consciousness at all as sensory input is crucial for the development of consciousness. However, it is important to note that consciousness is complex and not fully understood, so it is difficult to definitively say what the experience of someone born without any senses would be like.

Further reading: Does consciousness depend on our five senses? Refer to Website #A2.

Consciousness after death

According to science, there is currently no scientific evidence to suggest that consciousness can exist after death. Although some people report near-death experiences that feel real to them, these experiences can be explained in terms of brain activity. However, the question of whether consciousness can exist without a physical brain is still a subject of debate and ongoing research in various disciplines.

Further reading: Can consciousness continue after death? Refer to Website #A3.

The idealist view of consciousness after death

Idealism – remember – is the philosophical view that *nothing* consists of matter. (Look back at pages 7, 8). The idealist view of consciousness after death holds that consciousness is eternal and transcends physical existence. In this view, the body and brain serve as a vessel for consciousness while a person is alive and that after death, the consciousness persists but in another kind of existence. This could be a spiritual realm or another embodied form. The idealist view is often associated with religious and spiritual beliefs in an afterlife.

When does a person first have consciousness?

The development of consciousness is a complex and still not fully understood process. There is some debate as to when a person's consciousness fully develops, with some arguing it occurs at conception. Others argue that a developing foetus may have some level of consciousness while still others argue that it occurs after birth. However, most scientists and researchers agree that *consciousness is a gradual and ongoing process that develops over time* as the brain and body continue to develop and mature.

Two Kinds of Knowledge

Objective and subjective knowledge

Objective refers to factual data that is always the same and is not influenced by personal beliefs or feelings. It exists independently what we might think; it is actual or real as are *scientific facts*.

Subjective relates to something based on personal beliefs or feelings, rather than based on facts. These will differ from person to person and cannot be clearly defined or described.

Consider several people looking at the same object, let's say a red apple. How does it differs in terms of objective and subjective knowledge.

Objective knowledge: The apple has a set of physical properties, for example size, mass, shape, volume, density, colour, acidity of its juice, that can be measured by scientists and will always be the same. These facts constitute *objective* knowledge (at least for this one red apple we are looking at).

Subjective knowledge: Now imagine you want to describe the apple *you* saw to somebody else. Here is the catch. We *don't* tend to access and report *objective* facts about the apple. Instead we tend to give our personal viewpoints about the apple, that is, a *subjective* report. And such reports of the same red apple will differ from person to person as each of us will have slightly different subjective experiences, even though the 'scientific facts' about the red apple are the same. So, as a result, each of us will tend to describe it in a slightly different way.

So how would a scientist report it to others? Well, perhaps surprisingly, even scientists will have difficulty describing it to others (which is *subjective* and personal to them), *unless* they restrict themselves to talking about the *objective* physical measurements they made with their instruments and which will be the same for everyone for that particular red apple.

So to recap, a red apple has a set of objective information/facts. But when each of us access this information to talk to others about it to others, what we report is not this factual, objective information but our own, personal subjective views about it. Exactly how or why there is a change from objective to subjective, researchers do not know.

Here are two other examples of objective vs subjective experiences.

1 Pain: When we step on a nail, we all feel some pain. And pain, like the properties of the red apple, can be explained by *scientists* in an *objective* way. For details on the objective, scientific 'facts' for what happen in our bodies during pain, refer to the earlier project '*The Brain and Body Movement Level I.'* However, if we describe the pain we feel to others, it is the *subjective* view of our experience that we describe. And no one else can fully measure or feel *our own subjective* experience of pain (even if the same physical experience of stepping on the same were to be exactly the same).

Further reading: The Brain and Body Movement Level I. Refer to Website #A22.

2 Armed bank robbery: Eyewitnesses to an armed bank robbery, all of whom were at the scene and observed the same details, often give entirely conflicting stories, even though it may also be caught on video. Their stories are *subjective*; the video is *objective*. The video shows, for example, that there were two robbers, only one bullet was fired and six people witnessed the event. These are *objective* facts. However, although the witnesses 'experienced' the identical event, they give conflicting stories. Although all had a clear view, some said there was one robber; others said two robbers. And one of these said Robber A fired the shot while another said it was Robber B. These are subjective details of the event they have in their individual minds.

Two Kinds of Consciousness

In the 1990s, the philosophers Ned Block and David Rosenthal introduced what they believed to be two possible kinds of consciousness. They called them:

***Access* consciousness** (or A-consciousness), and
***Phenomenal* consciousness** (or P-consciousness)

This is a ***very*** *controversial* topic with many details still to be worked out. The distinction between A-consciousness and P-consciousness is still a subject of philosophical debate and scientific research *as to what they actually mean*. As more research is done, some changes may be necessary to what is described below, which includes *my* interpretation of what is meant!

As we will see, these two kinds of consciousness are related to the two kinds of knowledge just discussed, that is, *objective* knowledge and *subjective* knowledge. Also, it involves various memories in the human memory system (sensory memory, short-term memory, long-term memory) which are introduced here but discussed in much greater detail (refer to pages 35ff).

An important difference: Access-consciousness refers to the action of consciously accessing information we observe in our environment. Phenomenal-conscious relates to the content of this information.

Access Consciousness

Access-consciousness, also known as A-consciousness, refers to our ability to *access* and be *consciously aware* of information from the environment around us and to be able to *report* on it. The key words here are *access*, *aware*(ness) and *report*. So:

A definition of access-consciousness: Information from the environment that enters sensory memory which we access and become consciously aware of and can report on.

Note: While Ned Block used the word ‘Access’, I think the letter ‘A’ standing for ‘Aware’ or ‘Awareness’ also seems appropriate as A-consciousness involves both **access** to information and being consciously **aware** of it.

To see what happens, take an example.

Imagine you are looking at the view outside your open window (the same one mentioned earlier!!!). It may include buildings, roads, trees, people, the noise of passing vehicles, the bright sun. Further, it may also include the smell of food cooking behind you in the kitchen. All this information enters the brain via the *sensory organs*– the eyes (sense of sight), ears (sense of hearing) and nose (sense of smell). (The other two senses – touch and taste – would not be involved in this example). This information passes from the sensory *organs* into the first of our memory systems – the *sensory memory*.

The need of attention for access-consciousness

Because the scene from a window will contain a huge amount of information, we are only likely to access a sub-set that we consciously focus our attention on. **Attention** is needed for access-consciousness

Take another example. A person shows you an apple, but only briefly for a second before removing it. An image of the apple will enter the sensory memory, but – and this is important – we cannot wait too long to access information about the apple as it *only remains in our sensory memory temporarily – maybe a few seconds at most – as it starts to fade and disappear*. However, if we are paying attention, we will have enough time to access the image of the apple.

Note: If the apple is *not* removed but remains in our sight for a much longer time, the information in sensory memory is continually refreshed giving us plenty of time to focus attention on it. (Of course, as soon as the apple is removed and is no longer in our sight, the image in our sensory memory will then begin to fade.)

In order to access information, attention is needed. If we are ‘dreaming’ or ‘half-asleep’, we will probably access very little or even nothing at all! But, as the scenery outside does not disappear (as the apple might), if we ‘wake up’ and focus attention on the scene, we *can* access what we are looking at. (But because a scene like this will contain a huge amount of information, we are only likely to access a few bits that we consciously focus our attention on.)

The content in our sensory memory that is attended to is **accessed** and passes into our *short-term memory*. It is here where P-consciousness enters the picture.

Phenomenal Consciousness

The information from our surroundings we have accessed is still ‘objective.’ It is here, in short-term memory, where this objective information, *tends to change* to form our own *personal view* of the surroundings, that is, a *subjective* view. This subjective information is referred to as our *P-consciousness*.

From short-term memory (which is still 'short' though not as short as sensory memory) it may pass into our *long-term memory* and become a part of our permanent personal history or memory. These experiences in our long-term memory can be recalled in some form, though specific details may fade from long-term memory over time (a common experience for all of us!!).

From short-term memory, it can then be stored for the long-term in our *long-term memory*. (At least, this is how I understand it!)

Subjective content and definition of P-consciousness

So, the content of things in our surroundings which we access is initially objective, but on passing from sensory memory into short-term memory seems to become subjective and so only approximates the actual objective qualities of the things observed. (At least that is how I interpret it!!) And as the content is subjective, it is personal and will differ from the subjective content of others looking at the same scene; it is a *first person* view of the world and thus is *private*.

Further, as we have probably all experienced, we may sometimes (often?) have difficulty agreeing with others about our *own subjective* experiences as *their* subjective experiences are personal to them and will differ from ours even for the same things (such as what we see when we look at an apple).

From this, we can get a definition of P-consciousness:

A definition of phenomenal consciousness: The subjective, first-person experience of of being aware of our surroundings.

Origin of the word 'phenomenal': Phenomenal is an adjective that comes form the word *phenomenon*. A phenomenon is simply an observable event. So all the things we experience, as in the earlier examples, are phenomena and are the content of phenomenal consciousness.

Advance note: Trying to explain the subjective experiences of P-consciousness is part of the so-called 'hard problem' of understanding consciousness. Refer later to pages 17ff.

Qualia

Phenomenal-consciousness refers to the purely *subjective contents* of experience. These *specific* subjective experiences are *also* known as **qualia**. For example, the *subjective* 'redness' of a flower or of an evening sky, the taste of wine, the *subjective* experience of pain, or the *subjective* smell of food cooking. And, to repeat, because these experiences are *subjective*, they are unique to each of us and cannot be fully captured or communicated or understood by others through words alone. So they will probably differ slightly from the subjective experiences of other people.

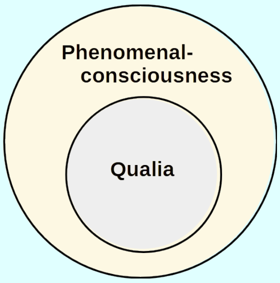
Definition of qualia: There are many definitions of qualia, which have changed over time. One of the simpler, broader definitions is: The 'what it is like' character of mental states such as the way it feels to have mental states such as pain, seeing red, smelling a rose, etc. mentioned above.

The term qualia comes from a Latin word meaning '*of what sort'* or '*of what kind'* in a specific instance, such as the redness of the sky we are looking at now, what it is like to taste an apple.

A more formal definition of qualia is: The specific subjective experiences of phenomenal consciousness.

Non-interchangeability of terms

The terms qualia and P-consciousness are often used interchangeably by some writers in discussions of consciousness and the philosophy of mind. However, the two terms are *not entirely interchangeable*. Qualia refer *specifically* to the subjective experiences of just *sense* perceptions from observing our environment (as in the example above of looking out your window), whereas phenomenal qualities can *also* include *other* aspects of consciousness, such as emotions or thoughts.



So think of phenomenal consciousness as referring to the *overall* subjective experience of being conscious, whereas qualia are the *specific sensory* experiences that contribute to phenomenal consciousness. That is, 'qualia' are a subset of 'phenomenal-consciousness.'

What do scientists access?

Scientists who focus attention on the same red apple will, like us, also get a *subjective* image with properties that are personal and will differ from those of other observers.

But scientists will not be happy just with a *subjective* view! When they observe things, they want to get *objective/scientific facts* about things in order to communicate with other scientists. To do this this, they use laboratory *instruments*. For example, a balance to measure its *mass*, a graduated measuring jar/cylinder containing water to measure its *volume* (and use both of these to calculate its *density*), a *colorimeter* or a *spectrophotometer* to determine its precise colour.

As this information is objective, it seems *unlikely* to become subjective on entering short-term memory. However, when scientists talk to *non*-scientists, they will probably not use this scientific factual/objective information but, like us, use *subjective*, personal information about the apple that they too will have.

The same applies when scientists just look out a window. As no measurements are made, the information they like us get will become subjective and personal.

At least the explanation above is what ***I*** think happens!! As mentioned above, A-consciousness and P-consciousness is a *very controversial* topic with many details still to be worked out.

Other examples of objective access-consciousness

1 The loudness of sounds: The information about loudness which we access and become aware of is *subjective* and so slightly different from the subjective information others have. *Scientists* can make physical measurements with instruments, such as a sound meter (pictured, right), which they can communicate to others and which will be *objective*. But for the rest of us, as well as scientists when *not* in their laboratory measuring things, the loudness of the sound accessed becomes *subjective* and it is this subjective information that is use to talk about with others.

2 The sensation of pain: Again, the information about this sensation which we access and become aware of (as when stepping on a nail) becomes *subjective* when we talk about it to others. Handheld pain devices with a visible dial, such as the one in the picture (right), are available to measure perceived pain. Scientists and doctors can use such devices to get an *objective* measurement of a person's pain, rather than relying on the *subjective* comment a patient would give depending on his level of pain tolerance.

Consciousness: The 'easy' versus the 'hard' problem

The job of scientists, and especially neuroscientists, is to provide a physical/scientific explanation of how things occur in the brain and body. As *objective* properties are the same for everyone, explanations in terms of what happens in the brain will be the *same* for everyone (as is the case of physical pain, mentioned above). However, *subjective* experiences differ from person to person and there will *not* be one explanation for everybody.

The easy problem: The '**easy**' problem of consciousness (Chalmers 1996) refers to explaining how *objective* experiences arise from processes in the brain, and specifically the patterns of neural activity involved.

It has been described as an *easy* problem for scientists to solve, not because it is actually 'easy' but because it is much easier than trying to explain *subjective/personal* experiences which, of course, will differ from person to person. And, as mentioned earlier (pages 12-13), my project '*Movement Level I*' provides such an objective scientific explanation for pain.

The hard problem: The '**hard**' problem of consciousness (again Chalmers, 1996) refers to the difficulty in explaining how *subjective* experiences, such as colours, sounds, tastes, emotions arise from physical processes in the brain, and specifically the specific patterns of neural activity involved.

For example, trying to explain why *my* subjective idea of the 'redness' of an apple or the loudness of a sound is different from *yours*, even though the apple and the loudness of the sound have the same objective properties is not easy!

So, phenomenal-consciousness, which consists of *subjective* phenomena poses a greater challenge for neuroscientists to explain what happens in the brain as it is *not* the same for everyone.

Substance dualism, property dualism and the 'hard' versus 'easy' problem

1 Substance dualism: Compare the philosophical idea of substance dualism discussed earlier (pages 5, 7), that is, there are two kinds of matter/substance. The body (including the brain) is made of *physical matter* governed by the laws of physics, and so might be explainable. The mind is made of some kind of *non-physical 'substance/matter'* that is *not* governed by the laws of physics and so is more difficult (or impossible!) to explain. Thus phenomenal consciousness (our subjective experiences) is an essential aspect of the mind and, according to substance dualism, is not physical matter and so *cannot* be explained solely by physical processes in the brain.

2 Property dualism: With this view, the brain is made of physical matter and has *physical properties*. just like all matter. But the mind has its own *mental (non-physical) properties*. Although consciousness *arises* from physical processes in the brain, the *mind* has its own set of unique non-physical properties that cannot be fully explained by physical processes in the *brain*.

So either way, while the physical processes in the brain may be (relatively!!) easy to explain, trying to explain what is going on in the mind may not only hard but perhaps impossible.

Is there really a 'hard' problem?

While some philosophers insist that access consciousness differs from phenomenal consciousness, Stanislas Dehaene (a neuroscientist and not a philosopher) considers the access/phenomenal distinction and the 'hard' problem as 'highly misleading' and feels it leads down a slippery slope to dualism' (as I was commenting on above!!!). But others, including scientists and psychologists, disagree with Dehaene's dismissal of the hard problem, and believe the hard problem – P-consciousness and related qualia are real.

Oh the difficulties of studying consciousness!!!

Perhaps have a look at Website #A4 for more on consciousness and the brain.

Can we have one type of consciousness without the other?

P-consciousness without A-consciousness?

This idea was also suggested by Ned Block, one of the philosophers who introduced the ideas of phenomenal-consciousness and access-consciousness (pages 13ff). Can we sometimes have a subjective (phenomenal) experience which we are unaware of because we have not *consciously* accessed it (i.e. no conscious access-consciousness)? That is, can we experience something without knowing? A major challenge to the supporters of this dissociation is the apparent inability to experimentally demonstrate that P-without-A consciousness exists; once participants report having a P-experience, surely they already have access to it.

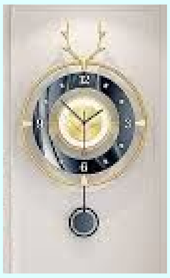
Although P-consciousness and A-consciousness typically go together, we *may* have P-consciousness without A-consciousness (P- without A-) because we did not *consciously* access it. The reason is due to attention (or lack of it).

Take an example. Are you *conscious* of the sensation of your clothes rubbing against your skin? Surely you are conscious of it *now*, but were you *before* you read the question? Of course, the clothes were all the time rubbing on your skin so the sensation still entered your sensory memory. Only when someone directed your *attention* to it did you become consciously aware of it, that is, have A-consciousness and so can verbally report on it.

However, there are some experiments which, along with our strongest intuitions, do suggest that we may have bodily sensations of much more than we direct attention to and so aren't consciously aware of. This is described as having P- without A-. It may be explained (just *may* be!) by saying that information may be accessed from sensory memory and pass into short-term memory *without a person's attention or* *awareness* and become stored there as P-consciousness.

However, there is no direct *empirical/scientific* evidence for P-without-A consciousness – it is part of the 'hard' problem after all! So the above explanation is largely speculation and how P- without A- occurs is still not known.

Other possible examples of P- without A-:



1 Ticking of a clock. You are in a room which has a clock on the wall. But you have not been consciously aware of anything about the clock. Perhaps you then suddenly become aware of the steady ticking of the clock. The ticking has been there all along and *may* have been present in your short-term memory as P-consciousness, but until that moment you were not *consciously aware* of it until someone or something drew your attention to the sound, that is, you had not consciously *accessed* the sound of the ticking clock and so did not have A-consciousness of it.

2 Inattentional blindness: This is discussed in detail later (pages 20ff) in an experiment known as '*The gorilla in the room.*' It involves not seeing – consciously accessing – things in broad daylight, right in front of our eyes (the gorilla in this example) as the participants in the experiment were focusing their attention on other things rather than on the appearance of a gorilla and so did not get access and become *consciously* aware of the gorilla (though it may have passed subconsciously into short-term memory).

Conclusion: Lack of conscious attention seems to best explain the idea of P-consciousness without A-consciousness, that is, experience something without knowing.

A-consciousness without P-consciousness

While P-consciousness without A-consciousness is accepted as being *possible*, there have been some hypothetical examples of A-consciousness without P-consciousness. Here are two examples.

1 Zombie: Ned Block refers to a zombie as physically identical to a human being but *lacks* a memory that holds *subjective* experiences (i.e. P-consciousness). This thought experiment is used to explore the nature of consciousness and its relationship to physical processes in the brain. By imagining a being that behaves exactly like a human but lacks this consciousness, philosophers and scientists can investigate the role of consciousness in shaping our actions, and experiences.

Also, a robot computationally identical to a person, but whose *silicon* brain, unlike a human brain, can not support subjective experiences would not have P-consciousness and so would be like a zombie. Thus this robot zombie would probably just give us *factual/objective* information mechanically about what it is doing as, unlike a human, it would not have *subjective* information.

Such cases may be conceptually possible, but this is *very* controversial.

2 Blindsight – a partial zombie: Blindsight is a condition in which a person who is partially blind or has impaired vision (but is *not* completely blind) can access visual information without *consciously* seeing things. These people appear to have some sort of access to visual information *in a blind region* within their brains, that is, they have some sort of A-consciousness. However, they seem to lack P-consciousness in the same way a normal person would have, that is, the *conscious subjective* experience of seeing things such as an apple on a table which would be stored in the short-term memory.

Thus the person with blindsight may say he is vaguely aware of an apple on a table, suggesting he may have *some* A-consciousness of the apple in order to be 'aware' of it. But as he is partially blind, he probably has no P-consciousness of the apple that normally occurs with visual awareness.

Note: Blindsight is discussed in more detail later (see pages 24ff).

For readers with some knowledge of how the brain works: In blindsight there has been damage to the ventral system though the dorsal system is normal. This suggests there is A-consciousness without P-consciousness.

More problems: The philosopher David Chalmers, who has been mentioned a few times already (e.g. pages 8 and 17) and who is mentioned in detail later (e.g. pages 27, 28, 29, 30, 31), believes that A-consciousness and P-consciousness always occur together!!! So there cannot be P-consciousness without A-consciousness or vice versa. I would probably agree with Chalmers!

Further reading: P-consciousness without A-consciousness and vice versa. Refer to Website #A5.

Access Consciousness and kinds of blindness

Consider again, the above example of looking at an outside scene through a window. The scene contains an incredible amount of detail which passes into our sensory memory. We access *some* of this detail which passes into our short-term memory as our subjective P-consciousness.

However, it turns out that the amount of information in our P-consciousness is much less than what we might expect. We seem to be 'blind' to a lot of this information we were looking at from the window. Why is this? Two reasons. One is due to lack of attention.

This problem of being 'blind' to many things/details we look at has been investigated experimentally. Three experiments investigated kinds of blindness are known as:

1 Inattentional blindness,
2 Change blindness, and
3 Blindsight (We also comment on a related phenomenon of 'deaf hearing').

We look at each of them.

1 Inattentional blindness

Definition: Inattentional blindness is the phenomenon where individuals fail to notice things because their attention is focused on something else.

It' is logical to think that we see things whenever our eyes are open. But the reality is that we fail to notice many things, even things right in front of us. This is because attention plays a major role in visual perception and that this failure is purely a result of this lack of attention rather than any vision defects or deficits. Hence the amount of information we consciously access is less than it could be.

Inattentional blindness (as the name 'inattention' suggests) is purely a result of a lack of attention rather than any defects in vision.

Inattentional blindness is a psychological phenomenon and a primary reason why we may fail to notice things like obvious bloopers in movies. When we focus our attention hard on one thing, such as the actions of the main character in a film, we might not notice unexpected things entering our visual field.

Invisible gorilla test

One of the best-known experiments demonstrating inattentional blindness is the 'invisible gorilla test'. In this experiment, researchers asked participants to watch a video of people passing a basketball and were asked to count the number of passes by the players in the team dressed in white while ignoring the passes of those in black.

Video: Here is a link to the video the participants viewed. Have a look at this video and see if the gorilla is really invisible.

https://www.youtube.com/watch?v=vJG698U2Mvo

Afterwards, the participants were asked if they had noticed anything unusual while watching the video. Across all the tests, approximately 50% of the participants reported seeing nothing out of the ordinary. But in reality, something odd *had* happened. In some instances, a person dressed in a gorilla suit strolled through the scene, turned to the camera, thumped her chest, and walked away. The gorilla was on the screen for nearly nine seconds, yet half of those who watched the video didn't see it. While it may seem impossible that the participants missed such a sight, the gorilla basically became invisible as their attention was focused elsewhere on other tasks.

Is the gorilla (shown in black) really invisible to viewers?

This finding is a particularly dramatic example of inattentional blindness; *the failure to see something obvious when focusing attention on something else*. Rather than focusing (or trying to) on every tiny detail in the world around us, we tend to concentrate on things that are most important to us.

The video is now so well known that many people *know* to look for a gorilla whenever they are asked to count basketball passes. The researchers decided to use its notoriety to their advantage. They created a *similar* video, again with teams of white- and black-clothed players, the same rules, and a chest-thumping gorilla.

Before reading further, have a look at the similar video at either of the following two links:

https://youtu.be/IGQmdoK_ZfY
https://www.youtube.com/watch?v=IGQmdoK_ZfY

I will not tell you the result of the revised task. Instead, after viewing the video, stand on your head and read the text in the box below to find out what happened. Alternatively, open the following website and read the second paragraph:

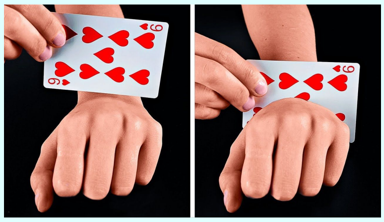
https://www.smithsonianmag.com/science-nature/but-did-you-see-the-gorilla-the-problem-with-inattentional-blindness-17339778/?no-ist

In 2010, the creator decided to make a sequel – the one you have just looked at. This time viewers were expecting the gorilla to make an appearance. And it did. But the viewers were so focused on watching for the gorilla that they overlooked other unexpected events, such as the curtain in the background changing colour.

Other examples of inattentional blindness

We all experience inattentional blindness from time to time, such as in these potential situations:

- **Driving**: Even though you think you are paying attention to the road, you fail to notice a car swerve into your lane of traffic, resulting in a traffic accident. (This is also an example of change blindness – see below).
- **Traffic light**: You decide to make a phone call while driving through busy traffic. You fail to notice that the traffic light has turned red, so you run the stop light and end up getting a traffic ticket. (This is also related to ‘Multi-tasking’; refer to pages 50f for more details.)



- **Magicians** often use the concept of inattentional blindness to create illusions and tricks. They direct the audience's attention to one thing while something else is happening that the audience is unaware of. In this way, magicians are able to create breathtaking illusions that leave their audience in awe.

For information on the brain regions involved in inattentional blindness, refer to page 78.

Website reading: For more on intentional blindness and the ‘invisible gorilla’, refer to Website #A6 in the appendix.

2 Change blindness

Definition: Change blindness is the failure to notice an obvious change in a visual scene even when it happens right in front of our eyes and is obvious and noticeable.

This phenomenon also highlights the limited capacity of human attention and the brain's ability to overlook changes in our environment. Normal people seem to have a strikingly *poor* ability to detect changes in a visual scene. This has been taken as evidence that the brain represents only a few objects at a time, namely those we are currently *attending* to (called the Focus of Attention). Change blindness illustrates the fact that we access much *less* of the information that enters our sensory memory than we *think* we do. We just access what we focus our attention on. So, we may miss significant changes that occur because our attention is focused elsewhere.

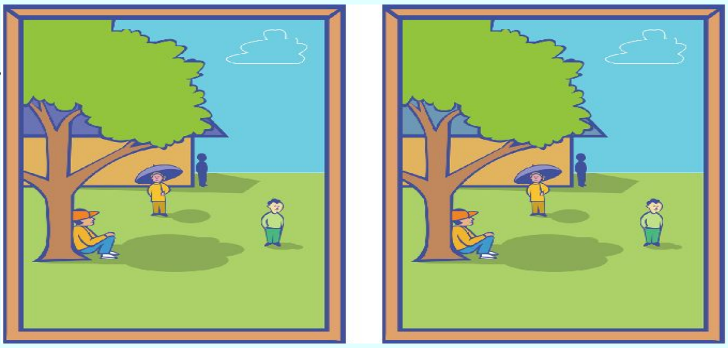
Here are examples to illustrate change blindness:

1 Talking to someone in the street

Have a look at the following video. (This was created by the same person who created the inattention blindness video above on the gorilla in the room.)

Change blindness video:
https://www.pbs.org/wgbh/nova/insidenova/2011/03/change-blindness.html

2 Colour changes



Colour plays an important role in visual perception of a scene. *Yet we often fail to notice changes in colours*. Look at the two images on the right. Can you see any colour change in the two images? (I will not tell you the answer!) Colour plays an important role in scene perception as it is linked to the gist of the scene. Nevertheless, even large changes in object colours can take more than a minute to be noticed, that is, for us become aware of it. This also illustrates the fact that we see much *less* than we think we do.

3 Driving

Quite often, the ‘blindness’ in a situation can involve *both* inattentional blindness and change blindness. Driving is one example.

While driving we may fail to notice a pedestrian stepping out onto the road which leads to an accident. Change blindness (failing to notice the change in the scene) and inattention (for whatever reason) can lead to dire, even fatal, consequences. Distractions like talking on your phone or texting while you drive is also another example of ‘multitasking’ – refer to page 50f) that can affect attention and lead to increased change and inattention blindness. (The picture shows both use of a phone and not noticing pedestrians.)

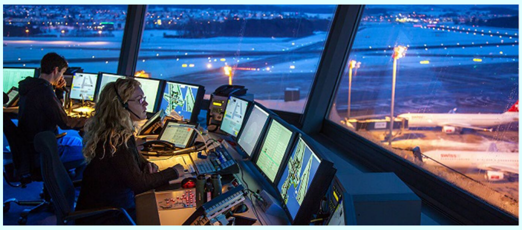
Try it yourself

The photographs, right, show an example of images that have be used in a change blindness task. Although similar, the two images have a number of differences. Can you spot them?

Further examples of change blindness in the real world: Refer to Website #A7. The above photographs are found in the Wikipedia website in #A7.

Other examples of change blindness in the real world

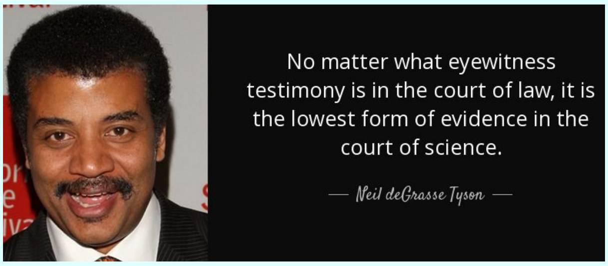
1 Driving (see above).



2 Air traffic control: A disaster could result if an air traffic controller failed to detect changes when monitoring take-offs, landings, and flight paths.

3 Social interactions. Change blindness can affect day-to-day social interactions – for example, asking the wrong waiter for the bill when you're dining out (and talking to someone on the street as mentioned above).

4 **Eyewitness testimony** (mentioned above on page 13). Change blindness can affect an eyewitness's ability to recount the details of a crime or to correctly identify the perpetrator.



Still, while we do sometimes fail to miss things in the world around us, we are generally pretty good at noticing information that is relevant to us, such as a car speeding toward us.

Cause of inattentional and change blindness

The specific causes of these two kinds of blindness are not clear and are still debated, but they are known to be linked with focus of attention, memory and consciousness. One view (which I like) ascribes them to a *lack* of A-consciousness. What this means is that our sensory receptors (eyes, ears, etc.) detect most, if not all, of the information being observed and pass this into our sensory memory but then *only* information that we focus *attention* on is *accessed* and passed into short-term memory where we become *consciously* aware of it.

If this explanation is correct, then intentional blindness and change blindness may be unavoidable as (a) we cannot focus attention on everything, and (b) limited capacity in short-term memory so we are unable to access and be aware of as much as we might want.

For information on the brain regions involved in inattentional blindness and change blindness, refer to page 78.

3 Blindsight

Definition: Look back at pages 19f.

Some people who have visual problems because of brain damage have ‘blindsight’, an extraordinary ability to react to emotions on faces and even navigate around obstacles *without knowing* they can see anything. It occurs when a part of the brain needed for vision is damaged, but the eyes and other parts of the brain that help with vision can be perfectly intact.

For example, a person with blindsight may be able to accurately point to the location of an object but may not be able to *consciously* see the object. They may also be able to navigate a cluttered room without bumping into objects, even though they cannot see the objects.

The term ‘blindsight’ was coined by Lawrence Weiskrantz, a British neuropsychologist at Oxford University, and his colleagues in a paper published in a 1974. A later famous case was when a blind patient (named TN), when visiting his doctor, reached out and grabbed the doctor’s hand! Imagine the doctor’s surprise. It was as if some kind of ‘second sight’ was guiding the patient’s behaviour, beyond his conscious awareness. Researchers had hints that TN might have blindsight. So in 2008 they carried out an experiment.

They took him to a hallway and asked him to walk along it without his white cane. TN was not aware at the time, but the researchers had placed various obstacles in the hallway to test if he could avoid them without conscious use of his sight or white cane. To the researchers' delight, he moved around every obstacle with ease, at one point even pressing himself up against the wall to squeeze past a trash can placed in his way. After navigating through the hallway, TN reported that he was just walking the way he wanted to and not because he knew anything was there. Despite him saying he wasn't able to see any objects, he was seen shooting by on his very first attempt. Amazing! He was not aware of the objects, but he could still avoid them.

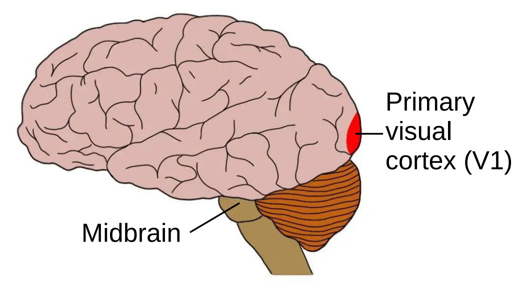
The picture above shows TN walking down the corridor with Dr Weiskrantz behind him.

So, to repeat TN had '*blindsight*' – the remarkable ability to respond to what his eyes *can* detect without knowing he can see anything at all.

Video: Watch for yourself a video of the experiment with TN. (Both links show the same video.)
https://www.youtube.com/watch?v=GwGmWqX0MnM
https://www.youtube.com/watch?v=nFJvXNGJsws

Cause of blindsight

Blindsight is caused, *not* due to problems with the eyes, which may be perfectly healthy (as in the case of TN), but to damage of a region in the back of the brain called the primary visual cortex (V1) that processes visual information received from the eyes. Patient TN had perfectly normal eyes; his blindsight was due to a damaged primary visual cortex. The small red area in the diagram of the brain is the primary visual cortex, V1.



Conscious visual experience is based on the flow of information from (healthy) eyes to the primary visual cortex which is the location of visual sensory memory. If the primary visual cortex is damaged, then the person will not 'see' the objects and events that we normally associate with vision.

However, besides the pathway from the eyes to the primary visual cortex, there are pathways in the brain that feed visual information from the eyes to *other* areas of the brain where it is processed *unconsciously*. One of these secondary brain areas is located in the midbrain (see diagram above). It is unconscious information in this area that allows blindsight patients to 'see' though they are unaware of this. Because of his unconscious processing, Patient TN was able to avoid objects in his path.

For more on the brain regions involved in blindsight, see later: the primary visual cortex (V1) and brain regions (pages 78f).

This project is about *consciousness*. It is common to *assume* that everything we know about the world around us and about our own thoughts and internal experiences must go through the doorway of our *conscious* mind. Evidence from blindsight is just one of several lines of research that shows that we process more information than we are aware of. Learning just how much this unconscious information can influence our thoughts and actions, our preferences and beliefs, is an important challenge for the rising generation of scientists.

Blindsight: A-consciousness without P-consciousness

As discussed earlier (page 19), blindsight seems to involve A-consciousness without P-consciousness.

In normal people, the brain region for visual sensory memory is the primary visual cortex (V1) from which they access the visual information it contains *and are aware* of it. But for people with blindsight, V1 is damaged leading to a partial (but not complete) loss of vision. Instead, they have access to visual information that enters *secondary* areas of the brain, such as the *midbrain*, that allow visual information to bypass the damaged primary visual cortex and reach these other visual processing areas.

People with blindsight appear to focus attention on information in these secondary areas and thus have some form of access-consciousness though this is done *unconsciously*. So while they seem to demonstrate *access* consciousness in these *secondary* brain regions they do not have have full P-consciousness which would involve their short-term memory.

It is important to remember that *you* also have these same 'unconscious' secondary areas in your brain. That means your conscious experience of the visual world may not only derive from the visual information in your primary visual cortex (V1) but in these secondary areas as well. In other words, you may 'know' more than you 'see'.

Note: Blindsight does *not* seem to apply to people who are 'sleep walkers' as they, unlike people with blindsight, often bump into things or knock objects over as they navigate through their surroundings such as when they wander around their house.

Further reading: For more on blindsight, refer to Website #A8 which contains many interesting and informative links.

Deaf hearing

Definition: The ability in individuals who are deaf or hard of hearing to sense sound vibrations through parts of their body, such as the skin or bones, and perceive sound in a way that is not conscious.

This can be seen in studies where deaf individuals are able to accurately recognise tunes or rhythms despite not hearing the actual sound.

The lady in the picture is using a hearing aid attached to her spectacles. It works by converting sound into vibrations picked up by the bones in her ear which passes them on to the brain. Bone conduction is not a new discovery. Ludwig Van Beethoven overcame deafness by biting a metal rod attached to his piano to hear his work.

The Hard and Easy problems of Consciousness

Having already mentioned David Chalmers a few times, we now look in greater detail about the man and his work. The terms 'hard problem' and 'easy problem' were coined by the Australian philosopher David Chalmers in a 1994 talk given at *The Science of Consciousness* conference held in Tucson, Arizona. The scholars attending the talk knew they were doing something edgy: in many quarters, consciousness was still taboo, having not been seriously discussed since way back in the 1600s (as mentioned earlier page 9). However, the conference later went down as a landmark conference on the subject of consciousness as Chalmers actually got the participants talking, *not* about 'consciousness' per se but about the *hard and easy problems*.

The Hard Problem

David Chalmers, not in Arizona, but at an event in Manila in 2012

David Chalmers introduced the idea of the *hard problem* as a 'catchy name' but it stuck. It is the challenge of *explaining* how our *subjective* experiences, such as colours and tastes, arise from physical processes involving the neurons in the brain.

The hard problem of consciousness refers to the qualia of phenomenal-consciousness. Qualia – remember – are the specific subjective personal experiences such as *our* personal *sensations* of pain, the taste of chocolate, or the colour red that differ from the subjective experiences others have. The hard problem of consciousness is the challenge of understanding how these subjective experiences arise from the physical processes of the brain. Also, why should the firings of the neurons in the brain lead to the sensation of the taste of chocolate rather than some other feeling (such as, for example, the red colour of a flower or the feeling of thirst)?

Reminder: I write above 'phenomenal consciousness/qualia.' This is because some folks talk as if they are interchangeable. But I, and others, think they are *not* quite the same thing (look back at page 16.]

Qualia are central to the hard problem. The very nature of qualia – their subjectivity and their intimate connection to our experience of the world – makes them difficult to explain in purely physical terms. The hard problem is often framed as the challenge of explaining how a physical system (the brain) can give rise to non-physical mental qualities (qualia). Many philosophers and scientists argue that this challenge is insurmountable, and that the existence of qualia represents a fundamental mystery about the nature of consciousness.

Access-consciousness is *not* part of the hard problem. David Chalmers has argued that A-consciousness can in principle be understood in mechanistic terms (i.e. in terms of the *physical matter of the brain* and what processes happen in the brain). But understanding qualia/P-consciousness in terms of what happens in the brain is much more challenging if not impossible. (See pages 17f, 30 for a discussion of this issue.)

Note: David Chalmers is a property dualist (look back at page 8). That is, there just *one* kind of matter (physical kind), but that there are two different kinds of *properties*: physical properties and mental properties. The brain is made of physical matter with physical properties just like all other matter. But what we call the 'mind' though not made of physical matter has non-physical/mental properties (such as thinking, imagination, memory, etc.) that are produced by the actions of the physical brain but are not explainable in terms of neurons as are actions in the brain. Qualia and P-consciousness come into this category.

The hard problem is still *very* controversial. Not everybody agrees there is a hard problem. But from the results of a 2020 survey, it seems that the majority of philosophers (62.42%) agree that the hard problem is real, with a substantial minority that disagrees (29.76%). Some even claim that the hard problem is just a collection of easy problems and will eventually be solved through further investigation of the brain.

Related idea: The Explanatory Gap

Definition: The difficulty that *physicalist* philosophies have in explaining how *physical properties* of the brain give rise to the way things feel *subjectively* when they are experienced.

In 1983, the philosopher Joseph Levine proposed that there is an *explanatory gap* between our understanding of the physical world and our understanding of consciousness. Levine accepts the hard problem and disputes that conscious states are reducible to a physical explanation in terms of brain neurons. This is almost the same as what Chalmers called the hard problem of consciousness.

Earlier, when discussing philosophical positions on consciousness, physicalism was mentioned. (Look back at this on page 8.) The explanatory gap is a **big** problem for physicalism which claims that everything in the world, including human consciousness and experiences is *entirely physical*, that is, composed of matter, and can be explained by physical processes in the brain and nervous system (which are made of matter).

In other words, it is the gap between (a) the physical and neural processes of the brain and (b) the subjective experience of consciousness. This gap has been a major challenge for scientists and philosophers trying to understand and explain consciousness.

The hard-problem question is not new

Until Chalmers delivered his speech in Tucson in 1994, science had been vigorously attempting to ignore the problem of consciousness for a long time, right back to the 17th century (and possible earlier). Some examples:

1 *John Locke* (1632 – 1704): He found it impossible to conceive how matter (thinking of the substance making up a brain) is able to produce sense, thought and knowledge and that these must be properties completely separable from matter. (This perhaps explains why he proposed a view of consciousness that was a modified form of Descartes substance dualism.)

2 *Gottfried Leibniz* (1646 – 1716), the German mathematician, philosopher, scientist imagined a machine that could think, feel, and have perception. If so, we should, on examining its interior, find only parts which work one upon another, and never anything by which to explain a perception.

3 *Isaac Newton* (1643 – 1727) wondered about the sense of colour in our minds and said that it is not so easy to explain in *physical* terms.

Gottfried Leibniz

Isaac Newton

Further reading: As of 2022, there was still there is no adequate theory that explains what consciousness is and how to solve this hard problem. But new research is being done to solve the mystery of consciousness. If interested, look at Website #C4: A New Theory in Physics Claims to Solve the Mystery of Consciousness.

The Easy Problem(s)

The easy problems relevant to consciousness concern *mechanistic* analysis of the *neural processes* that accompany behaviour. Examples of these include how sensory systems work, how sensory data (i.e. the information our senses – eyes, ears, etc.) is processed in the brain.

'Easy' is only relative. David Chalmers calls them 'easy' only in the sense that it may be possible to investigate them by current scientific methods.

How the hard and easy problems are related

For example, suppose someone steps on a nail and yelps. In this scenario, the *easy* problem is the physical/scientific explanation that involves the activity of the brain and nervous system such as the propagation/transmission of nerve signals from the foot to the brain. These are 'easy' to explain (perhaps!). Refer to the earlier project 'Transmission of Nerve Impulses' in Website #B2 for details on how this occurs (and perhaps also to the project 'The Brain and Body Movement Level I' in Website #A22).

But if two people step on the same nail, although their *physical/neuron* processes in their bodies are the same (*objective*), their *feeling* of pain could be quite different (*subjective*). This is *not* easy to explain why. The *hard* problem is why these mechanisms are accompanied by the *subjective feeling* of pain. Chalmers argues that the physical/scientific explanations do *not* lead to facts about such subjective experience. Facts about subjective experience are *not* derivable from facts about the neurons in the brain.

So: Easy problem, think *objective* → physical/neural explanation may be possible.
Hard problem, think *subjective* → physical/neural explanation not possible.

Related idea: Mary' room

A thought experiment, known as 'Mary's Room', proposed by philosopher Frank Jackson in 1982, tries to distinguish between the hard vs easy argument. It argues that even an extremely accurate knowledge of the brain and of a neural explanation of subjective consciousness does not give access to the *actual* subjective experience itself a person experiences.

Jackson proposed a hypothetical neuroscientist named Mary who has lived her whole life in a black-and-white room and has never seen colour before. She also happens to know *everything* there is to know about the brain and colour perception. When Mary sees the colour red for the first time (such as a red apple), she gains *new* knowledge – the knowledge of 'what red looks like' — which is quite different from her prior *physical knowledge* of the brain or visual system. By looking at a real apple, she gained *non-physical phenomenal-consciousness* (or qualia), the purely *subjective* content of this experience, the subjective experiences of 'what it is like'. (Look back at page 15.)

Philosophical zombies and the impossible problem

It was around 1996 when David Chalmers, having introduced the 'hard' problem idea in 1994, started talking about 'people' zombies (not robot zombies mentioned earlier, page 19).

The zombie scenario goes like this: Imagine that you have a doppelgänger. This person physically resembles you in every respect, and behaves identically to you; he or she holds conversations, walks, eats and sleeps, looks happy or anxious precisely as you do. The sole difference is that the doppelgänger has *no* subjective experiences or awareness/consciousness that real people have, that is, no P-consciousness. It cannot feel the subjective experiences of pleasure, pain, joy, or sorrow. It is merely a complex machine that reacts to external stimuli without any internal mental processes. Its mind would be a blank.

This is what *philosophers* mean by a 'zombie' (as opposed to a groaning, blood-spattered walking corpse from a movie!)

By imagining a scenario in which someone could exist without the P-consciousness of subjective experiences (i.e. a philosophical zombie), Chalmers wanted to highlight the mystery of the 'hard' problem of how physical processes in the brain give rise to subjective experience and to get people to address the problem. However, others argue that it is impossible (and *not* just a 'hard' problem) to prove that other beings even have conscious experience. Still others argue that consciousness is an essential aspect of life – anyone's life – and so zombies do not exist.

My comment: To me, fashion models on a runway give the appearance of zombies! Although they can give the appearance of a zombie-like demeanour, this is simply a part of the performance aspect of modelling.

Zombies?

How would a normal person and a philosophical zombie differ in their verbal reports of a red apple?

A normal person and a philosophical zombie would likely differ in their verbal reports of a red apple in terms of their *subjective experiences* and consciousness.

A *normal* person, possessing subjective consciousness, would have an actual experience of perceiving the apple's colour. When asked about the red apple, they would be able to describe their *sensory, subjective* and personal qualities of seeing the colour red, the brightness, and perhaps even associate it with past experiences or emotions. Their verbal report would likely contain rich details about their personal perception of the red apple and their conscious experience of it.

On the other hand, a philosophical *zombie*, although physically indistinguishable from a normal person (perhaps!), would *lack* subjective consciousness or any actual experience. They would merely *mimic* the behaviour of a normal person, purely through mechanical responses, without having an internal subjective and personal conscious experience of the red apple. Therefore, when asked about the red apple, a philosophical zombie would struggle to provide any meaningful or accurate description of its colour or sensory qualities. Their verbal report would likely be limited to *repeating learned responses* or using generic descriptions without any genuine understanding or subjective. personal experience.

In summary, while a normal person would be able to provide a genuine and detailed verbal report based on their conscious experience of perceiving the red apple, a philosophical zombie would lack subjective consciousness and thus provide empty or *incoherent verbal reports that do not reflect any genuine understanding or conscious experience of the object*.

The zombie blues: David Chalmers sings 'The zombie blues' (about having no consciousness). Refer to the YouTube link in Website #C27. He sang this song at the close of the conference he participated in at the University of Arizona.

Blindsight patients – real zombies?

Blindsight was discussed earlier. Could it be that people with blindsight are like zombies? One of the attractions of blindsight to philosophers is that it appears to offer a real, albeit partial, example of a favourite of the philosophical thought experiment – the zombie.

The philosophical zombie is a being whose behaviour is indistinguishable from that of a human in every way, but who is supposed to have *no* inner *subjective* experience at all of the world in which it is behaving. These inner subjective experiences are what we have referred to as `qualia.' (That is, while their brains may take in sensory information of the world – the P-consciousness which contains the qualia is *absent*.)

The only difference between ourselves and zombies is the *presence* or *absence* of qualia (P-consciousness). Zombies probably could *not* have access-consciousness (A-consciousness) as there is nothing for them to access (as normal people can). So any 'awareness' would just be a blank.

For example, when a zombie sees a red apple, it does not have the personal experience of the qualia 'redness.' But because it is a zombie and not a real human, it has to pretend as if seeing red. So, while it might be able to react to the presence or absence of a red apple, it will likely have no conscious perception of its colour.

People with blindsight (such as Patient TN above) come to know that they respond appropriately to visual stimuli (e.g. avoiding objects when they walk) even though they have no conscious awareness of seeing the objects because they cannot visually see them. This may be – just may be – how a zombie might react.

So it is not surprising that *some* people have suggested that Patient TN might be a zombie.

Cloning

A clone is an organism that is *genetically identical* to another organism.

In the study of consciousness, the idea of the cloning of animals sometimes arises. Would a clone of an animal or a person have the same consciousness as the being from which it was derived?

Dolly: Born July 1996. Died February 2003 (aged 6)

In 1996, Dolly the sheep became the world's first mammal to be cloned successfully from an adult cell. Since then, scientists have successfully cloned various animals such as cats, dogs, cows, pigs, horses, and even monkeys. According to scientific records, no human beings have been cloned as it is considered unethical and is illegal in most countries.

Would the clone be a different animal or person?

According to the current understanding of consciousness, a clone of a person *would not have the same consciousness as the original person*. Although they would have the same genetic material, their experiences and environment would shape their individual consciousness.

While a clone would have the same biological makeup as the original person, it would not have the exact same experiences throughout its life. Small differences in their environment or how it responds to those situations could lead to distinct personality and way of thinking. Additionally, *consciousness is not solely determined by biology*; it also stems from experiences, memories, and emotions.

Further reading: For a little more the biological difference between identical twins and clones, have a look at Website #A9.

Identical twins - Fifi and Coco

Are identical twins clones?

No! A clone is created *artificially* in a laboratory and so has *exactly the same DNA* as that *single* parent.

Identical twins come from *two* parents – a single egg from the mother and a single sperm from the father – followed by the splitting of the resulting single embryo into two genetically identical individuals of the same sex. So the identical twins share the same DNA as *each other* but still have their own individual consciousness.

Consciousness: We are living in the past

Vision seems so effortless: We open our eyes and let the world stream in. We feel that we live in the present. But what we are seeing right now is actually in the past! Only a very small fraction of time in the past, but still the past. Let us explain.

We don't actually 'see' with our eyes – we actually 'see' with our brains, and it takes time for the world to arrive there. The brain seems to 'know' this and can make slight adjustments to *predict* the present.

Light from an object reaches the eye and takes *about* 50 ms (milliseconds) to reach the retina at the back of the eye. But then things slow down a lot. It can take another 120 ms or so for the signal to be processed as it passes through the brain until we become conscious of the object. Therefore what we see actually happened about 170 ms (i.e. 50 + 120) earlier. Due to this delay, the information available to our conscious experience of the object is always *outdated*; it occurred in the past!

The exact time can vary depending on factors such as the complexity of the visual information and the processing speed in the brain.

Further reading: How fast can the human brain process images? Have a look at Website #A10 (though the times given there differ from those above. Perhaps we do not know exactly what the times are.)

Perception of *moving* objects

For stationary objects, this is not a problem. A building, for example, is in the same place now as it was a few milliseconds ago. But it is different for *moving* objects.

Consider a moving ball at some position X in front of us and moving towards us. After about 170 ms (using the same time as above) our brain sees the ball at position X. But during this time, the ball has continued to move, so in reality it is now closer to us. So the brain's information about where the moving ball is will always lag behind where the ball actually is. This delay is known as the 'perception-reaction time'.

Professional cricketers have been known to hit a ball at speeds exceeding 150 kilometres per hour. Take a cricket ball leaving the batsman's bat at 150 km/h. Only after about 170 ms will our brain see the ball leaving the bat. But in this time the ball has actually moved about 7 metres (ignoring air resistance). So the ball is actually about 7 metres closer to us than what the brain tells us. So, for a player to catch the ball (as in the picture), his/her brain has to compensate for the delay.

Clearly, if we 'see' the ball's position on the basis of the most recent information available to the brain, we would never be able to catch it with any accuracy at all as we are acting on its *past* position. That is often too late for a despairing player! But cricket (and baseball players) somehow seem to catch moving balls quite well.

In tennis, the fastest speed recorded for a serve was 263 km/h made by Sam Groth in May 2012 (pictured). In 170 ms, the ball would move 12.4 m which is about half the 23.77 m length of a tennis court. So the receiver has very little time to return the serve as the ball is closer than the player's brain tells him/her where it is.

How is this possible?

Remarkably, this is because scientists believe the brain makes *predictions*. In the case of a moving object, the brain predicts the object's real position as it moves forward. So the brain 'sees' the ball based on where it *expects* the ball to be, rather than based on the actual information from the eyes. So when a cricket player wants to catch an approaching ball, the brain 'tells' the player to move his/her body and hands to the actual location of the ball. And if the ball is moving in a curve, the brain also seems to predict the actual path.

Of course, the player is *unaware* of the time delays and the 'instructions' the brain is giving his/her hands and probably thinks (s)he is reacting 'normally.' Similarly, a tennis player's brain is unconsciously planning actions in order to hit a rapidly approaching ball and (s)he may have actually hit the ball before having seen it. Hard to believe!

Note: In all the above examples, we can ignore the time that *light* from the moving objects reaches the eye. This is because light travels at 300 000 kilometres per second (i.e. 3 000 km per millisecond). This is way faster than than the movement of the signals inside the brain.

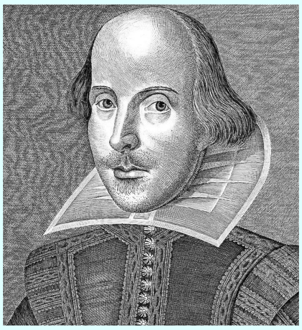
Further reading: Refer to the following for more on this topic:
Website #A11 for (a) seeing fast-moving objects and (b) seeing into the future.

Website #A12 for how our brains predict to perfect the catch.
Website #A13 for living in the past and our brain makes up for it.

Consciousness: Why am I me?

Each of us develops a unique consciousness. And the question "Why am I me?" often arises. Is there an answer to this question? This is a question that has ‘bugged’ me for a long time. Why am I me and not you, or my brother, or even Shakespeare?

Scientifically, consciousness arises from the interaction of neurons in the brain. It is the result of complex biochemical and electrical processes that enable us to perceive, feel, think, and experience the world around us. However, the exact mechanism of how an individual consciousness emerges from the brain activity is still a mystery to neuroscientists.



William Shakespeare (1564 - 1616)

Philosophically, there are several theories that attempt to explain the nature of consciousness and why we experience reality in a certain way. Some philosophers argue that consciousness is an inherent property of the universe, similar to space and time, and that it emerges from fundamental physical laws. Others propose that consciousness arises from a non-physical entity, such as a soul, that transcends the material world.

However, the question “Why am I me?” still does not have an answer. Frustrating to me as I often ask this question!

Cognitive Psychology and Consciousness

We discussed earlier the part played by some *philosophers* in explaining (or trying to explain) consciousness. We now take a look at the part *psychologists* play in our understanding of consciousness. A lot of psychology known as *cognitive* psychology deals with an understanding of human memory and the processes that take place in memory.

Notes:

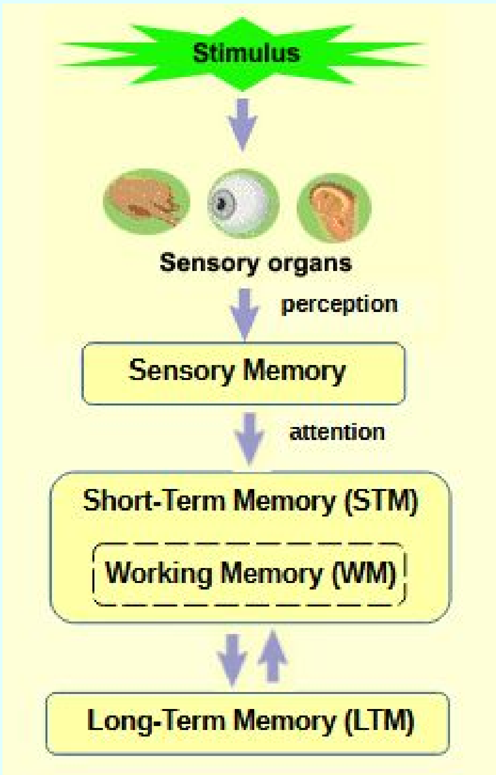
1 The material here overlaps with the content in an earlier project '**The Psychology of Learning and Teaching**' and the part in it dealing with '*The Cognitive Approach to Learning and Teaching'* (especially pages 16 to 25). Some of this is included below but I suggest the reader looks at these pages so that all of it does not need to be repeated here. (Website #A14 gives a link to this project.)

2 Another kind of psychology is *behavioural* psychology (or behaviourism). Unlike cognitive psychology, it emphasises observable behaviour and *not* mental processes, which is the realm of cognitive psychology. The mind, and what happens in it, are of *no* interest to behavioural psychologists. The early 20th Century rise of behaviourism eclipsed the study of consciousness for several decades. For more on behavioural psychology, the reader may like to refer to the same earlier project, pages 5-6 and 9-15 for more on this. (Page 5 in that project also comments on neurophysiology.)

3 Ideas related to consciousness discussed earlier (such as P-consciousness and A-consciousness) will be added in the discussion of human memory.

Model of Human Memory

***Memory** is simply the ability to remember past experiences.*



The diagram (right) shows a model of human memory. This model is a psychological model, not a physical model. The model hypothesises the existence of different kinds of memories and how we process information in each. The model has proved useful and resilient in applied *psychology* and *neuroscience* over the decades. The model consists of sensory memory and three other kinds of memories.

Note: The model shown does *not* indicate any *physical* parts of the brain. As we continue to discuss the parts of this model, references are made to parts of the brain involved. Also, note that there are slight differences between *this* diagram and the diagram on page 16 in my earlier article on The Psychology of Learning and Teaching.

The **parts** of this model of human memory include:

- **Sensory *organs***.
- Different kinds of memories: **Sensory Memory**, **Short-Term memory (STM), Working Memory (WM),** and **Long-Term Memory (LTM)**.

Various models of human memory have been proposed and there is no universal agreement as to which model is best (let alone correct!). I have chosen the model that makes most sense to me. In this model, working memory is a part of short-term memory (as the diagram above shows). In another similar model, the parts are reversed, that is, short-term memory is a part of working memory.

Further reading: For more on hypothetical models of the relation between short-term memory and working memory, refer to Figure 1 in the link in Website #A15. The model I am using is Model D.

Role of attention: When using many parts of human memory (except long-term memory), attention is needed. This is usually described as an overall level of alertness or ability to engage with our surroundings. And the specific things we concentrate on when attending to things are often referred to as our 'Focus of Attention' (FoA).

Approximate times memories hold information: Sensory Memory: 500 milliseconds to 1 ~ 3 seconds. Short-term memory and working memory: < 1 minute. Long-term memory: days, months, years, lifetime.

We now look at each kind of memory shown in the diagram above.

Sensory Memory

Sensory memory can also be called **sensory register**.

Sensory memory is the first stage in the model of human memory. It uses our sensory organs to obtain information from the world around us using our senses, that is, with our eyes (sight), ears (sound), tongue (taste), nose (smell) and skin (touch). For example, looking at a flower with our eyes or the taste of chocolate using our tongue. All this information passes automatically from the sensory organs into the sensory memory. It provides a 'snapshot' of *some* of the information in our surroundings.

Note: Sensory memory does *not* require any *conscious* attention. As information from the environment is perceived, it is stored in sensory memory *automatically* (but for only a very, very brief time).

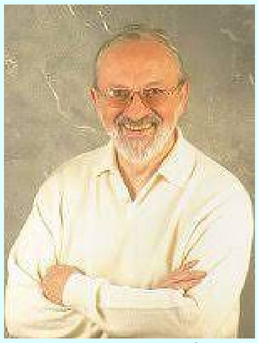
The sensory memory can hold a huge amount of information but only for a very brief moment, lasting from perhaps half a second (500 ms) to no more than perhaps 3 seconds. It is also processed at high speed, ensuring that there is enough time for the most relevant information to be accessed and passed on to the next stage of memory, which is short-term memory, for further processing. Note however, that if we are *continually* looking at a scene, the first bit of information may fade after 500 ms – 3 s, but further bits of of the same information keep entering the sensory system and refreshing it.

Role of attention: But, and this is a very big but, if information that has entered the sensory memory is not attended to, it fades and disappears, which happens a lot of the time as it impossible to be focus attention on everything in the world around us. Thus, when looking out a window, there is so much visual information that enters the sensory memory but we cannot possibly attend to all of it and such information, while it does enter sensory memory, will fade and disappear.

Sperling's experiment on the duration of sensory memory

The duration of sensory memory was first investigated in the 1960s by psychologist George Sperling. In a classic experiment, participants stared at a screen on which a 3 x 4 array of 12 letters (such as the 12 shown in the diagram below, left) were flashed very briefly – for just 1/20th of a second. Then, the screen went blank.

The participants then immediately had to repeat as many of the letters as they could remember seeing. Most of the participants were only able to report about four or five letters (for example, as shown in the second diagram), but some insisted that they had seen *all* the letters but that the information *faded* too quickly for them to report them. So 1/120th of a second gave then enough time to focus attention and recall a few letters but was too short a time for *all* the information to be attended to and so most of the letters in their sensory memories before they faded and were lost.



George Sperling (born 1934)

F	C	H	D
J	R	P	O
D	N	B	A

F			
J		P	O
		B	

Note: In Sperling's experiment, the letters were only visible for a fraction of a second. Of course, *if* they were shown for a longer time, the participants would have had time to focus attention on many letters before the screen went blank and they faded and so would be able to recall more than four or five letters, just as you would if you looked at the 3 x 4 diagram above. (But, of course, that was not the point of the experiment!)

Further reading: Website #A16 gives more information on sensory memory including Sperling's experiment.

Iconic memory

Sperling interpreted his finding by suggesting the existence of a very short-lived sensory memory store for visual information which he termed **iconic memory**. Accordingly, he explained his findings by saying that subjects *can* see all the letters at the moment of presentation, but *only a few of them can be attended to then accessed and transferred to short-term memory* from where they can be reported. The remainder fade and disappear. (From short-term memory they may be transferred to long-term memory.)

So, iconic memory is a type of very short-term *sensory* memory in which one gets a brief memory of a visual image that lasts from about 500 ms to 3 seconds (max) as mentioned above, *after the physical image has disappeared*. Iconic memory receives visual signals from the outside world and if attended to, are transferred to short-term memory.

As well as Sperling's letter display, an everyday example of iconic memory might be when you see a car passing by at high speed on the highway which, like the letters in his letter display, would enter your sensory memory but only be present for a fraction of a second. And like the letters in Sperling's letter display, the image of the car is passed on to your short-term memory so you can recall it.

Note: Short-term memory holds information for a few seconds to a minute or two (which is why it is called '*short' term* memory) though this is much longer than sensory memory holds information unless you keep thinking about it, which is probably not a wise idea if you are driving on a highway!

Further reading: Website #A17 gives more information on iconic memory.

Other kinds of sensory memories

To repeat, sensory memory refers to the immediate, *temporary* input of a *large amount* of sensory information from the environment. It is an extremely brief memory system that helps in processing incoming sensory information. As well as iconic memory (the *visual* sensory memory), there are other types of sensory memory:

1 Echoic Memory: This refers to the auditory sensory memory and involves the temporary retention of *sounds*. It allows us to *briefly* store and process auditory stimuli, such as a conversation or a phone number we hear.

2 Haptic Memory: This is the sensory memory related to *touch* or tactile sensations. It involves the temporary retention of tactile information, like the feel of an object or the texture of a surface. Haptic memory helps us distinguish and remember different tactile sensations. (Photo copied from page 18.)

3 Gustatory Memory: This type of sensory memory is related to the sense of *taste*. It involves the temporary retention of taste sensations, allowing us to briefly remember and process the flavours we experience.

4 Olfactory Memory: This refers to the sensory memory related to the sense of *smell*. It involves the temporary retention of odours (smells), enabling us to briefly remember and recognise different scents.

So, while iconic memory mainly deals with visual information, echoic memory, haptic memory, gustatory memory, and olfactory memory encompass the sensory memories associated with auditory, tactile, taste and smell sensations respectively.

Sensory memory and A-consciousness

Access-consciousness is information from the environment that we access and become consciously aware of and can report on. Information from the environment enters our sensory memory. As mentioned earlier (page 14), the content in our sensory memory that is attended to is accessed and passes into our *short-term memory*, where we become consciously aware of it and can report on it.

Summary: Sensory memory is the first stage of memory processing, where information from the environment is briefly retained in its original sensory form. It is a temporary storage system that holds on to sensory information for a very brief amount of time, from perhaps 500 ms to three seconds. Sensory memory attended is accessed and passes on to the short-term memory. There are different types of sensory memory, including iconic memory (visual) and echoic memory (auditory).

Sensory memory and attention

There are two kinds of attention: (1) Attention and (2) Selective Attention. There is a slight difference in their meanings.

1 Attention: Attention is a *general* term that refers just to the state of consciousness when an individual is alert and attending to a particular stimulus or task. For example, Sperling's complete 3 x 4 array.

2 Selective attention: This is the ability to *concentrate* on a *specific* stimulus while ignoring or filtering out distracting stimuli. It involves consciously directing attention towards certain sensory inputs while disregarding others. But this takes time. For example, the four or five letters in Sperling's array that participants identified was because they had *just* had *sufficient time* to *focus* their attention on these but not the other letters.

In real life, sensory memory holds details of what we see, hear, etc. in the world around us. It holds a flood of information but only for a *brief moment* as there is usually far too much to process. So we focus **selectively** on just a few of the incoming stimuli. Different people will focus on different stimuli while ignoring, usually unconsciously, other stimuli which may be irrelevant to them. This means that no two people will perceive (see) exactly the same thing even if they are looking at the same thing, especially if the thing being observed is very detailed, such as a view of the surroundings (or even the 12 letters in Sperling's 3 x 4 array of letters above).

So selective attention refers to the ability to focus on a specific stimulus while ignoring or filtering out other irrelevant stimuli. It involves consciously directing attention towards certain sensory inputs while disregarding others. For example, listening to a person talking to you or reading a book in spite of lots of background noise that might also attract your attention.

As the model of human memory above shows, information that we have time to focus attention on in sensory memory, is *accessed* and passes from the sensory memory into the short-term memory. It is *here* where we have more time to become fully consciously/aware of that information. But even in short-term memory it is still only brief, being held for a few seconds to a minute or two before it fades and disappears (which, as mentioned earlier, is why it is called 'short-term').

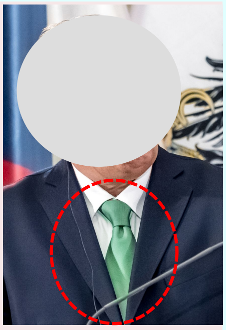
What stimuli are affecting you right now? Are you looking at something? Hearing something? Smelling something such as burning toast while watching TV? Are people with you recognising the same things? Whatever you are attending too, other stimuli are *not* completely ignored. Your attention is selective.

Examples of *selective* attention

1 A conservation at a party. There is a lot to look at, a lot of background noise, maybe also the smell of food cooking that is entering your sensory memory and which could attract your attention. But how much of this are you actually focus your attention? Very little. But it is not completely ignored. Suppose you are talking to a person. You may think you are not paying attention to other people. But if someone else suddenly says your name – even quietly – you probably hear it very easily, largely because it is meaningful to you so you focus attention on it.

2 Classroom: A teacher calls the name of an inattentive student. Again, the name is very meaningful so he/she stops doing all the other things and looks up at the teacher.

3 Inattentional blindness (from pages 20ff): The 'invisible gorilla test' is a good example of *selective attention* (on the players) which means that other information is not attended to (the gorilla). Note that on the opening picture in the video (as shown in the picture) is written '*Selective* Attention Test from Simons & Chabris (1999).'



4 The green tie [A personal experience] In February 2024 on the TV news, I was watching a meeting of European Union leaders. The leader of one country turned up unexpectedly wearing a green tie (pictured, right, but identify of the leader is hidden). I did ***not*** notice it! Why not? Although all the information from the scene must have entered my sensory memory, there was just too much to focus attention on everything and so I missed seeing his green tie.

The news commentator mentioned the leader and his green tie. So later, when I saw the same TV news item again, this time I ***did*** see the green tie as I deliberately focused my attention on it. But as a consequence, I probably did not see other things! Not unlike inattentional blindness / 'gorilla in the room' and – by focusing attention on *one* thing, I missed other things.

Advance note: As we will see later, we are also conscious of information in our *working memory* but this information enters working memory from short-term memory and *not* from sensory memory, which is why, in the diagram of the model above, working memory is shown *inside* short-term memory.

Wakefulness and attention

Wakefulness refers to the state of being awake, alert, and responsive to the surrounding environment. Wakefulness and attention are *closely related*. When we are *awake*, we rely on *attention* to prioritise and select information from the environment, maintain vigilance, and carry out tasks.

But attention is influenced by our *level* of wakefulness. When we are tired or drowsy, our ability to focus and sustain attention may be impaired, whereas increased wakefulness (even via caffeine or other stimulants) can enhances our focus of attention on information to enter sensory memory.

Short-Term Memory (STM)

Short-term memory is the capacity to store and hold a small amount of information received from sensory memory in a *conscious* but *passive* form for a short period of time, typically for a few seconds to a minute or two before it fades and disappears (which is why it is called 'short-term'). The exact duration in short-term memory can vary depending on factors such as the complexity and nature of the information. To stop it from fading, we use our working memory (discussed later, page 41ff).

Short-term memory is considered *conscious* (for the short time it is there). From short-term memory, if the information has not faded, it may *also* pass on to *long-term memory* for more permanent storage.

Two examples:

1 When we *focus attention* on some flowers and then look away (or close our eyes), we can still 'see' the *image* of the flower as it has passed from our sensory memory and is now in our short-term memory.

2 A telephone number we hear someone saying. But again it too will be lost from short-term memory in a few seconds unless we do something with it, such as repeating the number to ourselves.

The information in our short-term memory just 'sits' there; it is *not actively manipulated*; it is passive. So, the image of the flowers we look at or the phone number we hear will disappear forever unless we make a conscious effort to retain them, such as consciously *visualising* the flowers (which tends to keep repeating the image) or by *repeating* the phone number. But this conscious *active* manipulation of the flowers or the number, such as repeating it, occurs in *working memory* (see below).

So, short-term memory is the first place for the temporary but passive storage of the information it receives from sensory memory. In the course of a day, there are many times when we need to keep some piece of information in our head for just a few seconds – in our short-term memory.

Short-term-memory and access-consciousness

In terms of type of consciousness, short-term memory is associated with *access*-consciousness as it receives information *accessed* from sensory memory for *passive* storage. This information in short-term memory is then further accessed by working memory for *active* manipulation/processing.

Capacity of short-term memory

Unlike sensory memory, which is believed to be able to hold huge amounts of information, the *capacity* of short-term memory, that is, the amount of information it can hold is very limited. See pages 47ff below for more on the capacity of short-term memory as well as working memory and long-term memory.

Short-term-memory and attention

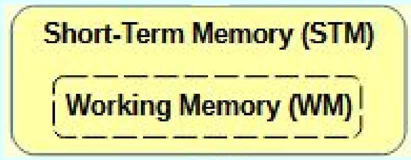
As the capacity of short-term memory is limited, it makes sense to focus attention just on what we want to enter it from sensory memory. For example, a teacher *verbally* gives a class a list of words to memorise. If the list is not too long, students should be able to focus on all the words and pass them into short-term memory before they fade from sensory memory (just as in Sperling's array of letters). However, if a student is engaging in a secondary task that demands attention, less attention will be available for the list of words. Consequently this student's ability to later recall the words given by the teacher will probably be impaired.

This idea is discussed again later in the topic of 'Multi-tasking' (pages 50f).

Advance note
Neuroscientists have found that short-term memory is distributed throughout multiple brain regions, primarily associated with the prefrontal cortex, which is located at the front part of the brain. However, other brain regions also play a role in short-term memory processing. These include the *hippocampus*, which helps with the encoding and consolidation (see definition on page 45) of new information from short-term memory into long-term memory. For more details, refer to pages 46, 73f, 77f.

Working Memory (WM)

Relation with short-term memory: Working memory, as well as short-term memory, are both 'short-term' memories, with working memory being a subset of short-term memory. Both are *conscious*. Both hold information for limited time intervals. The only difference is that short-term memory stores/holds information passively whereas working memory selects some of this short-term information and actively *manipulates/processes* it. When the manipulating/processing is finished, the modified information just becomes part of short-term memory again though, of course, slightly different as some of it has been changed during manipulation in working memory.



So working memory is *temporary* and *only comes into existence* when some of the information in short-term memory is selected to be manipulated. That is why the diagram for the model of human memory shows short-term memory as a solid line/box and working memory as a *dotted* (temporary) line/box. So when we consciously imagine the vase of flowers with fewer flowers or consciously *repeat* the phone number, we are doing this in our working memory.

Of course, we cannot keep on doing this forever, so we need somewhere more permanent to hold the image or the phone number. This 'more permanent' place is our long-term memory, which we look at below (page 44ff).

The diagram of the model of human memory may also suggest that the *location* of this working memory box is fixed. However, different tasks will use information held in different parts of short-term memory, so the 'location' of working memory for different tasks will differ (i.e. the dotted box will move to different parts of the short-term memory that has the content to be manipulated in working memory).

Note further that unless *all* the information in short-term memory is selected for manipulation in working memory, the information *not* selected may still fade and disappear as short-term memory only holds information for few seconds to a minute or two.

Also, once the modified information is returned from working memory to short-term memory, this modified information can now be held for *another* few seconds to a minute or so. So the to-and-fro from short-term memory to working memory and back again could, I suppose, prevent information from ever disappearing! But very boring!! Hopefully, the modified information will pass into *long-term memory* for more permanent storage.

A workspace: Describing this in another way, working memory can be thought of as a mental 'workspace' where conscious thinking/processing – our mental work – of information from short-term memory actually takes place, for example. reading a book, doing an arithmetic problem. It's the 'mental workspace' where we hold information temporarily and do actively something with it.

Note: Some writers claim that short-term memory and working memory are the same thing. But this is *incorrect*. Short-term memory is a place for *conscious* but *passive* storage of information for a short time. Working memory is a broader concept. It is a temporary part of short-term memory (as the model above shows) but involves the *active* manipulation/processing of the information in this part of short-term memory. Therefore, while the terms are related, they are not synonymous.

Capacity of working memory

Working memory, like short-term memory, has limited capacity for information it can process/manipulate. See later (pages 47ff) for more on the *actual* capacities of working memory, short-term memory and long-term memory.

Working memory and attention

Like short-term memory, the capacity of working memory is also very limited. So more attention on one item means less is available for other items. So, in the above example to memorise a list of words, students will access words from short-term memory and actively manipulate them (in this case by repeating the words to themselves). Again, the student doing a secondary task will probably access some of this material thus affecting his ability to practice the words given by the teacher.

Working memory and access-consciousness

As mentioned above, information in working memory is considered to be conscious as it is part of the active thought processes that are currently being attended to. For example, if someone is trying to solve a mathematics problem in their head, the numbers and operations they are currently working with are held in their working memory. They are consciously holding onto this information as they manipulate it and solve the problem.

In terms of type of consciousness, working memory, like short-term memory, is associated with access-consciousness (A-consciousness), as it is accessing information from short-term memory. The difference is that in working memory, the accessed information is being *actively* manipulated. An example of this is when we access numbers and hold them in our working memory in order to do an arithmetic calculation or try to remember the list of words by repeating them.

When we are *asleep* and not conscious, we do not have to actively manipulate information and there is no need of working memory.

Can working memory be unconscious?

The relationship between *unconscious* processing and working memory is being studied and debated in the field of consciousness research. While there is evidence to suggest that they are related, the precise nature of this relationship is still unclear. Here are two examples:

1 **Driving**: If you are driving along a familiar route, you may not consciously be aware of every turn and movement you make, but your brain is still processing the visual and sensory information needed to navigate the road. This type of automatic processing is thought to be mediated by *unconscious* aspects of working memory.

2 **Blindsight**: People with blindsight, that is – remember – having a partial, but not complete, loss of vision because of brain damage (even though their eyes may be perfectly healthy (pages 19f, 24ff, 31 again. They can be *aware* of seeing things without being *consciously* aware of seeing them. In other words, they can process visual information and perform certain tasks related to vision despite having no conscious experience of seeing.

Individuals with blindsight may need to use their working memory to process the *subconscious* visual information they receive, and to make sense of it in a way that allows them to navigate their environment effectively – remember patient TN walked down a corridor and avoided all the obstacles in his path just as a normal person would. This suggests that an *unconscious* working memory *may* play a role in their ability to process and respond to visual information even though, like TN, they report no conscious awareness of obstacles.

However, the exact extent to which working memory is involved in blindsight abilities may vary depending on the individual and the specific circumstances. More research is needed to fully understand the relationship between blindsight and working memory.

Kinds of material manipulated in working memory

Working memory can manipulate any kind of material (I think!), including *verbal* material (words), *visual* material (images) and mathematical symbols (e.g. numbers). Here are some examples:

1 **Numbers**: Repeating a set of numbers mentally to ourselves when working on an arithmetic problem in order to remember the numbers for longer takes place in working-memory. Otherwise, the memory of these numbers will disappear very quickly, in less than a minute. (Unless, of course, the numbers are written down in which case we can just glance at these if we forget them.) (See the example on the next page for calculating '7 x 6'.)

2 **Words**: These are manipulated, for example, when we alter the spelling of words, when we join words into sentences, when we repeat words or a poem and repeating a list of words that has just been read to you.

3 **Simultaneous interpretation**: Another good example is where an interpreter must store information in one language in memory (which will be working memory) while orally translating it into another.

4 **Images**. Ways of manipulating images includes: rotating them to view from a different angle, zooming in/out to focus on details, changing colour or shape (though I admit this does not seem an easy thing to do)!

Other examples of working memory in action include holding a phone number in mind while dialling it, remembering directions while driving, keeping a mental list of items to purchase at the grocery store, or performing mental calculations while solving a complex problem.

Other kinds of materials that can be manipulated include:

(i) sounds, such as manipulating and remembering sequences of sounds or melodies.

(ii) spatial information, allowing us to mentally manipulate and remember the arrangement or positions of objects in space.

(iii) concepts/ideas, such as understanding and manipulating mathematical or logical concepts.

Working memory and ageing

In humans, the ability to do tasks involving working memory is believed to increase gradually over childhood and decline gradually in old age. This may be due to slower processing speeds as we grow older which allows more time for content in working memory to *decay*. Another possibility, for which there is some empirical support, is that we are less able to inhibit irrelevant or distracting information. This leads to working memory being cluttered with irrelevant content that reduces its effectiveness.

Working memory should be quite good for these children

Advance note: One neurobiological explanation is that the prefrontal cortex (an area at the front of the brain which is involved in working memory) shows the highest degree of age-related atrophy (wasting away) due to the degeneration of brain cells in that brain region. Refer to pages 66ff for more on the neurobiological explanation of ageing in working memory and also some conditions and disorders that affect working memory.

Further reading: For information on how to help primary school age improve working memory, refer to Website #A18.

Example involving sensory memory + short-term memory + working memory

1 A teacher *tells* the class to do the arithmetic calculation '7 x 6'.(Note: In this example, the teacher does *not* write the '7 x 6' on the blackboard.)
2 If the students are paying *attention*, they *hear* this (via sensory/echoic memory – ears) and the numbers 7, 6 and the word 'multiply' enter their short-term memory.
3 The numbers 7 and 6 and the word 'multiply' are then activated and enter their working memory.
4 The students then consciously manipulate the two numbers by multiplying them in working memory to get '42.'
5 The answer '7 x 6 = 42' is returned from working memory to short-term memory as it needs no more manipulation. It *may/probably* then becomes part of their long-term memory for long-term storage.

If students have done this specific calculation before, they won't need to do the calculation again; they can just recall it from their long-term memory. But if they have forgotten the answer as it is no longer in their long-term memory, they *will* have to do it all over again!!

Note: This example undoubtedly is an over-simplification of what actually happens, but you should get an idea of the main steps involved.

Long-Term Memory (LTM)

Long-term memory refers to the storage and retrieval of information over an extended period of time, ranging from minutes to years or even a lifetime. It is part of the three-stage model of memory, shown in the diagram of human memory, along with sensory memory and short-term memory (with working memory as a sub-set). And as the double arrow in the diagram also shows, movement of information is in two directions: from short-term memory to storage in long-term memory and back again from long-term memory to short-term memory when it is recalled.

Consolidation – definition: The transfer of information from short-term memory to long-term memory to make it more *enduring* or even *permanent* is known as **consolidation**.

Long-term memory involves the formation and storage of memories that can be recalled and utilised at a later time. It has a *much larger capacity* than short-term memory and can retain information about personal experiences, facts, concepts, and skills learned in the past. Long-term memory is believed to be organised into different categories, such as **episodic** memory (for specific events), **semantic** memory (for general knowledge), and **procedural memory** (for skills and procedures).

The *capacity of long-term memory seems unlimited,* and can last days, months, years, or even an entire *lifetime* – unless it is forgotten! But it is far from infallible. It sometimes distorts facts, and it tends to become less reliable as we age.

The information in long-term memory is *subconscious*, that is, we are not aware of it until we consciously recall it or when it 'pops into our mind' (i.e. pops into our short-term memory).

Episodic memory: Memory that involves the recollection of specific events, situations, and experiences that have occurred at a particular time and place in a person's life.

Semantic memory: A type of long-term memory that involves the storage and retrieval of general knowledge about the world, including concepts, facts, and language.

Neuroscientists have found that long-term memory is also distributed throughout multiple brain regions and that the *hippocampus* is one of the key brain regions responsible for the formation and consolidation of new memories. It plays a critical role in converting short-term memories into long-term memories. (Refer to pages 70, 74).

Effective consolidation in long-term memory

As mentioned above, the transfer of information from short-term memory to long-term memory making the memory for the information more enduring or even permanent is called ***consolidation***.

For *effective* consolidation of new information *permanently* in our brain, it must be transferred from short-term memory and *integrated with previous knowledge already in our long-term memory* to give large networks of knowledge.

This linking of information to other information and to prior knowledge to form a large network of related ideas is called **elaboration**. This is an important classroom strategy teachers should use.

Further reading: For more details on the strategy of elaboration, refer to my earlier project '*Psychology of Learning and Teaching*' pages 35ff, Website #B1, where this idea in discussed together with examples.

If consolidation is not effective, for example, if we just try to memorise *isolated* facts rather than linking the facts to other information, it will quickly fade and disappear. (A common experience for most of us, I guess!)

Failure of consolidation: But there is no guarantee that information will be consolidated in long-term memory. Here are some examples:

1 Lack of attention: If an individual is not paying attention to information, it is *less* likely to be transferred from short-term memory to long-term memory. For example, if someone is listening to a lecture while texting on his phone, he may not process or retain much of the information permanently in long-term memory. (Refer also to 'multi-tasking' on pages 50f).

2 Stress: High levels of stress can interfere with the transfer of information from short-term memory to long-term memory. This is because stress hormones can disrupt the functioning of the brain areas involved in memory consolidation. For example, a person who is worried about an upcoming exam may struggle to remember what he/she has been studying.

3 Overload: If the individual is overloaded with too much information, it can be difficult for the brain to process and transfer it into long-term memory. This can happen when studying for multiple exams or trying to learn new skills in a short amount of time.

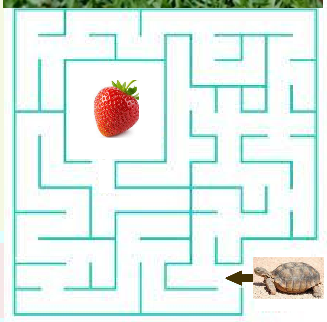
4 Lack of prior knowledge: It is easier for new information to be transferred to long-term memory *if it can be integrated with existing and related knowledge* in the brain (elaboration again!). If the individual has no prior knowledge of a topic, the new knowledge is less likely to be retained.

5 Ageing: As we saw on page 44 above, working memory declines gradually in old age. This also diminishes the ability to transfer information from short-term memory to long-term memory. This can lead to difficulties with remembering new information and forming new memories.

Tortoises and long-term memory

Despite being viewed as slow, simple creatures, tortoises have a good memory. A good long-term memory is essential for animals' survival. Tortoises *especially* have good long-term memories. It has been found that a tortoise can remember tasks it's been trained in for at least nine years, perhaps longer. Food sources in their natural habitats are often scattered across the land in patches, so tortoises need to recall information to navigate their environment.

Complex tasks are recalled in detail for weeks, while simple tasks can be recalled for years. Tortoises have also learnt how to solve mazes in order to get food placed at the centre. They remember this and can repeat it without making any errors as the route is in their long-term memories!



Note: The mazes used in experiments with tortoises are simpler that the one shown which is my construction as I cannot find the original picture! (Though the original picture did have a strawberry at its centre!)

Further reading: For more on this, visit Website #A19.

Capacities of Human Memories

During the past decades, experimental psychology has shown the stark limitations of conscious processes: it seems that our memory system can only handle a limited amount of information at the same time, especially short-term memory and working memory. This is referred to as a **capacity** limit of memory.

Capacity of sensory memory

As mentioned several times already, sensory memories hold a *very large amount* of information but only for a few milliseconds (no longer than half a second, or 500 ms), unless of course, the information entering sensory memories is being continually refreshed which occurs, for example, when we look at something for a period of time.

Capacity of short-term memory and working memory

The capacity of these memories is usually described as the number of items of information that can be held in the memories. Working memory and short-term memory generally described as having a capacity of around 4 ± 1 items, that is around 3 to 5 pieces of information, though it varies from person to person. Only these few bits of information can be held simultaneously and unless we repeat them mentally to ourselves (in working memory), they will disappear. Note: The capacity also depends on age – see below.

The items held may be small (such as individual numbers or letters) or large (such as individual words, even long words). *Capacity is a function of the number of items, not their size*.

As we will see below, one way to enhance the storage capacity of short-term memory is to increase the *size* of these items through a more effective encoding strategy, such as grouping items, which is known **chunking**.

Capacity of long-term memory

Compared with the limited capacity of working memory and short-term memory, long-term memory can hold large amounts of information and, as mentioned earlier, may hold it for a lifetime. The actual capacity of long-term memory is not known but is believed to be unlimited, that is, no capacity limitations.

Capacity and a person's age

Typical example: How many numbers or words can you hold in your short-term/working memory without writing them down?

This depends on *age*.

- The number of items that a young child of about age 5 can hold in short-term memory and working memory is generally limited to around 3 ± 1 items, that is, about two to four items.
- This capacity increases as children grow older, and by the age of 10 and through adulthood, most can hold around 7 ± 2 items, that is, from about five to nine items.

However, it is important to note that there may be differences depending of the kind of item. For example, capacity for numbers/digits *may* be slightly higher than for words.

Also there can be individual differences due to inherent mental ability. Children with higher-than-average intelligence often have greater working memory capacity (e.g. 4 ± 2 rather than 3 ± 1) and so are more likely to excel in the classroom.

Chunks and chunking

The individual bits/items of information held in short-term memory and working memory are also referred to as **chunks**. A chunk is a meaningful unit of information that can be stored and processed.

A chunk can consist of individual letters, words, numbers, or even whole phrases that are remembered as a *unit*. (Remember again that capacity depends on the number of items/chunks, not the size of the chunks.)

Chunks may be small or large. Thus the *letter* 'A' may be a single chunk while the letters 'C' 'A' and 'T' may be *three single* chunks. But when they are combined to give the *single word* 'CAT', this would be a *single but larger* chunk.

Chunking then is the process of grouping or combining several individual chunks into a single but larger chunk. Chunking can enhance learning and recall.

Examples of chunks and chunking for a 5-year old

1 **Arithmetic**: Hearing '7', '6' and 'multiply' *may* be *three* chunks. Similarly, hearing the numbers 1, 6, 0, 9 could be *four* chunks. Also, a 5-year old child could cope with doing the arithmetic calculation 1 + 2 in his/her head without external aids (writing them on paper) as the '1', '2' and '+' are perhaps just three chunks.

2 **Letters**: Hearing three individual letters of the alphabet (such as X, C, M) would be three chunks. And if the child *cannot* spell, the three letters C, A, T in the word CAT might also be three chunks. But, if the child *can* spell, then, as mentioned above, the letters C, A, T would probably be just one chunk as

'CAT' is one word (an animal). Hence this child has just one chunk in her working memory and so now would be able to retain, for example, the three more 'word chunks' such as CAT, DOG and BIRD in her working memory (i.e. without having to write them down or look at the words in a book).

These example show that for two different children, one who *can* spell and one who *cannot*, the number and sizes of the chunks depends on their background knowledge.

3 Individual words vs a sentence: Imagine a five-year old trying to recall a list of six *random* words for a test, that is, six individual chunks! While they *may* be able to hold all six words in working memory, performance on the test may be poor particularly if the words have no significance or context.

However, if the student is given a list of 12 *related* words *that form a single coherent sentence*, working memory will be less taxed as there is now perhaps only *one* chunk to remember. This is what happens when young children (or anybody!) learn poems. And if the poems are rhyming poems, that may require even fewer chunks. For example, we know that young children can repeat from memory complete poems, such as 'Two Little Dicky Birds' or 'Little Jack Horner'. Hence the whole poem may be remembered as just 3 ± 1 sentences due to the chunking of words into sentences. For example the following four sentences may be remembered as four chunks, one for each line:

'Two Little Dicky Birds sat upon a wall.
One named Peter, the other named Paul.
Fly away Peter, fly away Paul.
Come back Peter! Come back Paul!!'

Of course, for some children, it may be just two chunks or maybe even just one chunk if the poem is memorised and stored in long-term memory.

Further reading: For short English poems for kids to recite and memorise visit Website #A20.

4 Mathematics: A Primary 6 child who can work *very fast* may be able to do '36 x 7' *completely* in his/her head (i.e. without seeing it written down), holding in working memory the numbers currently being processed, and in short-term memory all the numbers that need to be temporarily stored until needed again in the working memory to continue the calculation.

(Dear reader, try this yourself. Can you do the multiplication successfully, even as an adult? I can do it: My strategy is to mentally visualise '36 x 7' then close my eyes (so I can't see these numbers in print!) and repeat this visualisation from time to time so that it doesn't disappear from short-term memory, and at the same time do the mental arithmetic involved in working memory with the occasional repetition in order not to forget. However, I am not sure of the number of chunks that were involved!)

Examples of chunks and chunking for an adult

1 Telephone numbers. As an adult, have you ever tried to remember a telephone number somebody tells you (without writing it down)? If the digits of the telephone number are '123-45678' this may constitute just *one* chunk if you realise that the individual numbers are from '1 to 8'.

If the digits of a phone number are '555-12345', this *might* be *two* chunks ('555' and '1-2-3-4-5' the latter being the first four numbers from '1 to 5'; also a brief pause between the '555' and '12345' may help to make them two chunks).

However, if you are *told* '85218782049', for most adults would be difficult to recall precisely and may be 11 chunks (one for each digit), i.e. impossible to recall and especially if given quickly (I know – I have tried this number!!).

But for this telephone number:

(a) If the numbers are spoken *very slowly*, this gives the listener time to mentally practice/repeat the list of digits as they are being spoken and *may* result in fewer that 11 chunks.

(b) The first three digits '852' are a country code. So that can be one chunk or completely ignored. This is why is many countries, the country code is bracketed. So (852) 1878204 may be only 7 chunks. Or 1878 204 if splitting it into two parts may even be just two chunks.

(c) Of course, writing the numbers down on paper as they are spoken overcomes the problem of holding chunks in memory.

2 Remember the steps of a recipe: The process of chunking can be used to remember the steps of a recipe. Let's say you want to remember a recipe for a home-made pizza. Your recipe may have 14 individual steps. Instead of trying to memorise these individual steps in short-term memory (probably impossible), the first few times you prepare the food, you can follow the written instructions one-by-one. And after this, you may find that your memory has been able to chunk the individual steps into a smaller number of chunks and has been transferred to your long-term memory, so in future you just need to recall the steps one-by-one from your long-term memory.

3 Learning a new language: Chunking can be useful by first *breaking down* long sentences into smaller phrases, which are easier to remember and understand then chunking these into long sentences again.. For example, the sentence 'J*e voudrais aller au cinéma ce soir*' (meaning 'I would like to go to the cinema tonight') can be chunked into '*Je voudrais*' (I would like), '*aller au cinéma*' (go to the cinema), and '*ce soir*' (tonight), making it easier to remember and use the sentence in conversation. Note: So this may be considered as *first* creating smaller units *followed by* chunking into the larger, original sentences again – a useful teaching strategy for foreign language learning.

Multi-tasking

Working memory has capacity limitations; it can only hold a small number of items. Overloading working memory occurs with '**multi-tasking**', that is, trying to do several tasks at the same time. This is mentioned in the project '*Psychology of Learning and Teaching*' (Website #B1) page 23. Have a look at it. (The image, right, is taken from page 23 of this project.)

With many tasks, we tend to focus our attention on *one* task (e.g. looking at our mobile phone) and are 'blind' (inattentive) to others (e.g. telephone conversation) as our working-memory can only hold a small amount of information, then we switch our attention to another *single* task. If this switching happens quickly, it gives the impression that several tasks are being done simultaneously, which is *not* the case. So it is really *single*-tasking with the brain switching rapidly from one task to another rather than performing them simultaneously.

The problem is, there's *no such thing as multi-tasking*. As multiple studies have confirmed, true multi-tasking – doing more than one task at the same time – is a **myth**. People who think they can split their attention between multiple tasks at once are not actually getting more done.

Further reading: For more on this, visit Website #A21.

Multi-tasking, inattentional blindness and change blindness

Intentional blindness and *change blindness* show the *limitations* of working memory. There is just too much information in the environment for us to pay *attention* to all if it. So we focus our attention on the details that are important/relevant and ignore the rest.

Also, multi-tasking is linked to inattentional blindness and change blindness as both are related in terms of the role attention plays in each phenomenon, though they are *separate* concepts. Multi-tasking involves *dividing attention* among multiple tasks, while inattentional blindness and change blindness pertain to how *focus of attention* affects perception.

However, attempting to multi-task can increase the likelihood of both inattentional blindness and change blindness as attention is directed away from important stimuli or changes in the environment. For example:

- **Inattentional blindness**: When someone concentrates on reading or texting on their phone while walking, they might not notice a familiar person passing by (inattentional blindness)
- **Change blindness**: Look back at the picture above of the lady multi-tasking in the office. While focusing attention on both her telephone and mobile phone (or even on just one of them), she may not notice some important *changes* in information that appear on her computer screen because of her limited ability to detect changes in her visual environment when not explicitly attending to that visual environment.

Other references to inattentional blindness and change blindness:
- Earlier references: pages 20ff.
- Parts of the brain involved (page 78).

Noise and multi-tasking

The discussion above also relates to the concept of **noise**. In the context of human memory, the term ‘noise‘ refers to information that is irrelevant or distracting and so interferes with to a task, or with information being remembered. This can include environmental stimuli such as background noise, irrelevant details in a story or presentation, or competing thoughts or emotions when the focus should be on just one task.

The examples involving the several tasks the young lady above is trying to focus attention instead of one important task are examples of noise. Other examples of noise in memory include trying to remember a phone number while listening to loud music in the background, trying to read a book while a TV is on in the same room, or trying to remember a list of items while also worrying about an upcoming deadline. In these cases, the noise (both literal and metaphorical) can interfere with the ability to focus attention on the relevant information for the task in hand.

Neuroscience and Consciousness

We have mentioned that consciousness is studied by three groups of people: philosophers, cognitive psychologists and neuroscientists. We have looked at the first two. We now turn our attention to the work of neuroscientists. The work of neuroscientists is *neuroscience*, that is, the sciences that deal with the structure or function of the brain and nervous system. This work began in earnest in the 1990s.

Neuroscience

Basic definition of neuroscience: The science that deals with the structure and function of the brain and nervous system. A scientist who studies the brain and nervous system is a *neuroscientist*.

Today, the study of consciousness has neuroscience as its central discipline. Neuroscientists have learnt a great deal about the brain in recent years.

The brain is composed of billions of **neurons**. A neuron (also called a nerve cell) is a specialised cell that transmits information throughout the body via electrical and chemical signals. Neuroscientists try to find out how the action of neurons explain phenomena. For example, the action of neurons to explain *movement* is quite well understood.

Neural explanations: Refer to Website #B4 and #B5 for the projects '*The Brain and Body Movement: Level I*' and '*The Brain and Body Movement: Level II*' to see how body movements are explained in terms of the action of neurons (also referred to as the 'neural processes/mechanisms' in the brain.

Neuroscientists also want to understand how the action of neurons explain *consciousness*. In particular, how neural processes in the brain explain both the objective experiences (the actual/factual parts) and our subjective (personal) experiences such as seeing colours of things or feeling pain.

The objective experiences are the same for everyone and correspond to properties that neuroscientists can investigate and explain. But in trying to investigate subjective (personal/individual) experiences, neuroscientists have run into big, big, big difficulties. All these difficulties relate to the hard problem of consciousness, which was introduced earlier (look back at pages 17ff) and which do *not* seem to have a scientific explanation (at least at present).

Extension: 'Silent' neurons

When a neuron acts, it is said to 'fire.' A small population of brain neurons fire hundreds or thousands of times more often than others. But many *cortical* neurons are 'silent.' The term 'silent' refers to neurons that are present in the brain but are not actively firing or transmitting signals. Some silent neurons may be inhibited by other neurons or neurotransmitters, preventing them from firing. While these 'silent' neurons may not currently be active, they are still vital to overall brain function and play a role in shaping neural circuits and connections.

Neurotransmitters: A neurotransmitter is a chemical that moves across a space (called a synapse) from one neuron (nerve cell) to the next in the brain.

Note: The term 'cortical neurons', mentioned above, refers to the type of neurons found in the cerebral cortex, which is the outer layer of the brain, distinguishing them from other types of neurons found in different regions of the brain and the nervous system.

Neuroscience and the hard problem; the explanatory gap

Note: What follows is largely a repeat of points that have been made earlier.

As mentioned earlier (page 17), the ‘hard problem of consciousness‘ was coined – remember? – by philosopher David Chalmers in 1995 to highlight the challenge of understanding how neural processes in the brain give rise to *subjective* conscious experiences that *cannot* be explained or reduced to physical processes. This implies that there is a non-physical aspect to consciousness that cannot be explained solely by the brain's physical processes.

While today’s neuroscientists have gained valuable insights, they have been unable to provide a solution to the very difficult problem of subjective consciousness.

Objective vs subjective: *Objective* experiences seem to be open to a physical explanation involving neural processes; straightforward but still very, very difficult! *Subjective* experiences appear to be a fundamentally *different* aspect of consciousness, being non-physical and as such *cannot* be explained in *physical/neural* terms. (Compare movement, mentioned above, which is *completely* physical and so can be explained by the action of neurons.) This fundamental distinction poses a challenge to bridging the gap between the objective (physical) and subjective (non-physical) aspects of consciousness. As mentioned earlier, this is known as the ‘explanatory gap.‘ (Refer back to page 28.)

Neuroscience and philosophy – dualism vs physicalism

The explanatory gap also relates directly to dualism vs physicalism. When we looked at philosophy of consciousness, we discussed dualism and physicalism (a form of monism) (pages 7f). (Chalmers believes this non-physical aspect of consciousness necessitates a *dualistic* view of the mind and body.)

Dualism is the view that the mind and body are *separate* entities. Although mental processes, such as thoughts and emotions, which are *non-physical*, are *grounded* in physical processes within the brain, they cannot be entirely explained by neurological (physical) activity. So, in this view, the mind is still something *separate* from the brain, which is the idea of dualism, and so cannot be explained by neurological activity, which is brain activity involving neurons.

Physicalism is the view that *everything* that exists in the world, including human consciousness and experiences, is *entirely physical*, and is composed of matter. So our thoughts and emotions (which *dualism* says are *non*-physical) are physical processes and so should be possible of a physical/neural explanation. So, with physicalism, when we speak of consciousness at the *level of the brain* as a whole, we are taking a *physicalist* (materialist) view that everything, including consciousness, can be explained in terms of neural processes in the brain.

Many neuroscientists today *perhaps* lean towards a *physicalist* explanation but do not rule out dualism. Some neuroscientists do admit that mental states *can not* be entirely explained by physical processes, hence the possibility of a *non-physical* aspect of the mind that is, that the explanatory problem still exists!

Neural Correlates of Consciousness (NCCs)

Given the difficulties just mentioned. what should be done?

Neuroscientists have decided that instead of looking for an *explanation* of the *neural processes of consciousness*, they should just look for a *correlation* between neural processes and aspects of consciousness. (Correlation and correlates: From Medieval Latin *correlātiō*, from *com-* = together + *relātiō* = relation → how two or more things are related.)

Explanation vs correlation

Explanation (or Cause) refers to *why* something happens. An explanation aims to provide a deeper understanding of the relationship between variables by demonstrating how one variable influences or determines another.

On the other hand, correlation indicates just a pattern between two variables, even if one variable does or does not not cause the other.

Example: Suppose we are studying the relationship between hours of studying and exam scores for a group of students.

Correlation: A correlation *just* shows how the number of hours studied and the exam scores are related. For example, if there is a positive correlation, it means that as the number of hours studied increases, the exam scores also tend to increase. There is not even a hint that one is the cause of the other.

Explanation: An explanation looks for a *cause*. It could be that hours of studying is the cause of improved exam scores. The more time student spend studying, the more knowledge they acquire, leading to better performance in exams. Of course this might *not* be the actual cause. It could be that the cause is because *motivated* students study more and so perform better on exams. If this is the correct then student motivation rather than number of hours would be the explanation.

So, in neural correlates of consciousness (NCCs), neuroscientists just try to find neural processes in the brain that are *correlated/associated* highly with some aspect of consciousness that we observe.

Example: An example of NCCs can be observed when we see an object. The visual information is processed by various brain regions responsible for vision, such as the *primary visual cortex (V1)*. Of course, there *will* be an explanation in terms of what the neurons are doing, but neuroscientists instead just look for the brain regions – the NCCs (in this example the primary visual cortex) – and not the neural processes.

An explanation in terms of neural processes will (?may) *eventually* be found, but that is still quite a long way in the future!

Further reading:
For more on correlation vs causation, visit Website #A23.
For more on NCCs, visit Website #A24.

NCCs in practice

So in practice, neuroscientists often do *not* always investigate actual behaviour of *neurons*. Instead, they just look for **regions in the brain** that seem to be *correlated/linked with* particular conscious experiences. And that is what we will be doing in the remainder of this article.

Two initial examples of NCCs

Here are two examples of correlations between brain processes and brain regions, which are dealt with in more detail later in this section:

- Working memory seems to be correlated with (or located in) an area in the front of the brain called the prefrontal cortex.
- Long-term memory seems to be stored in various regions of the brain, the prefrontal cortex being just one of these.

Extension: Techniques used by neuroscientists

To observe and measure activity in brain regions involved in human consciousness, neuroscientists use a number of techniques, including the following:

1. Magnetic Resonance Imaging (MRI)
2. Functional Magnetic Resonance Imaging (fMRI),
3. Electroencephalography (EEG),
4. Positron Emission Tomography (PET), and
5. Magneto-encephalography (MEG).

1 Magnetic Resonance Imaging (MRI): MRI scanning is primarily used to visualise the internal structures of the body using strong magnetic fields and radio waves. It helps in identifying and diagnosing a wide range of medical conditions such as tumours, injuries, and diseases affecting organs, bones, and soft tissues. Information provided: MRI scans provide detailed anatomical images, showcasing the structure and composition of organs, tissues, and fluids in the body. The apparatus used looks very similar to that for fMRI (below).

2 Functional Magnetic Resonance Imaging (fMRI): This technique measures changes in blood flow and oxygen levels in the brain to understand brain activity. It uses a strong magnetic field and radio waves to create images of brain regions and detect areas of increased neural activity. The picture (right) shown an fMRI machine with a person about to be placed inside it.

fMRI machine

3 Electroencephalography (EEG): EEG measures electrical activity generated by the brain using small electrodes placed on the scalp (as shown in the picture). It records the collective activity of thousands of neurons, providing information about the brain's electrical activity in the cerebellum and regions above and forward of the cerebellum such as the hippocampus, thalamus, amygdala and basal ganglia.

EEG machine

4 Positron Emission Tomography (PET): PET involves injecting a small amount of radioactive substance into the body. This substance emits positrons (like electrons but with a positive charge), which interact with the surrounding tissues and produce gamma rays which can produce images to show activity in different brain regions. The apparatus used also looks very similar to that for fMRI.

5 Magneto-encephalography (MEG): MEG measures the magnetic fields produced by electrical activity in regions of the brain. By analysing the magnetic fields, MEG can tell us about the activity of neurons in these brain regions. Again, the apparatus used looks very similar to that for fMRI.

Regions of the Brain

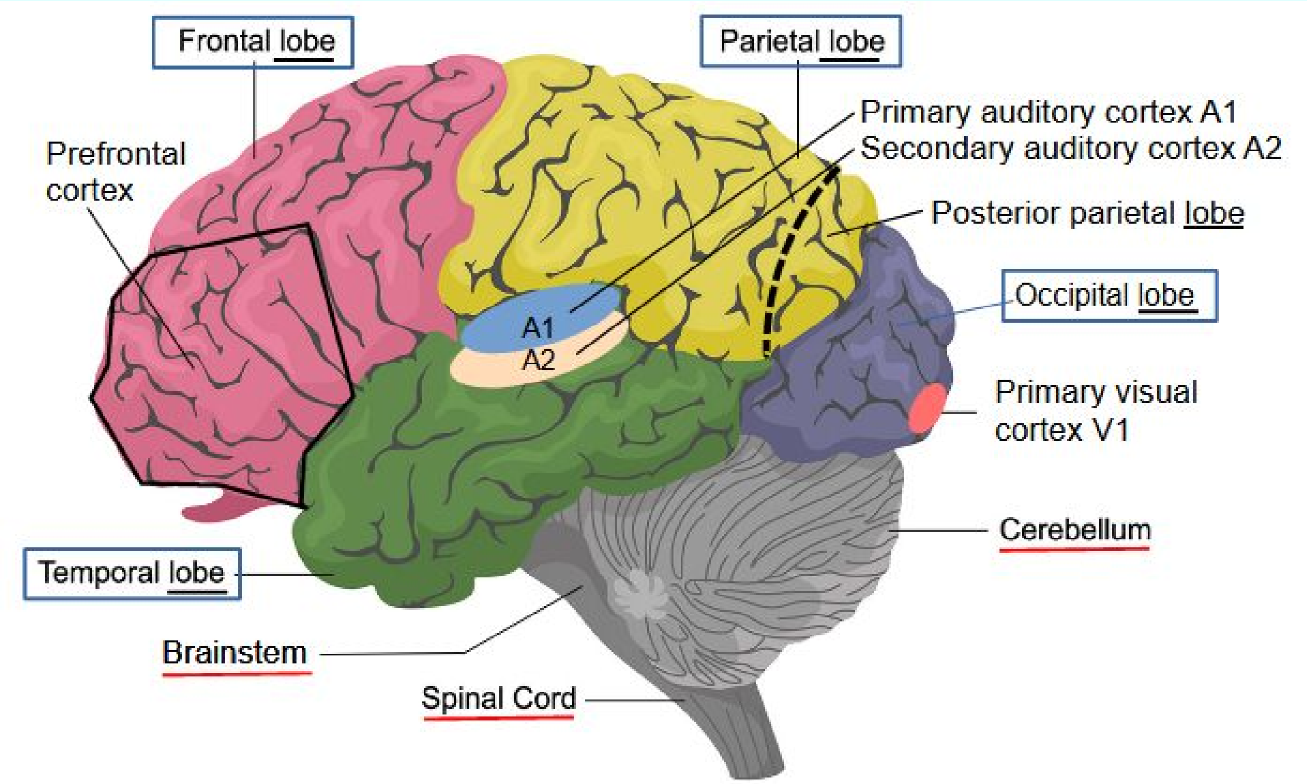
Conscious phenomena seldom emerge from a single region/location in the brain. Instead, they are the product of a system involving multiple regions of the brain. That is why, for instance, when someone's brain suffers damage in one area (termed *localised damage*), their consciousness may be modified, but rarely eliminated completely. The specific areas of the brain that produce consciousness are still under debate and are not fully understood but consciousness is thought to emerge from the interactions between various regions of the brain rather than being localised to a single area.

Note: Many scientists have found it difficult to reconcile the fact that information is distributed across multiple brain areas with the apparent unity of consciousness.

The diagram below show the major regions of the brain involved in consciousness. As you read the text from here on, keep referring to this diagram for the locations of the parts being discussed.

The *major* regions of the brain are the **cerebral cortex**, **cerebellum**, **brainstem** and **spinal cord**.

As we shall see soon, most of the brain regions shown in this diagram are involved in working memory, short-term memory and long-term memory.



Further reading: For more on the parts of the brain, visit Website #A25.

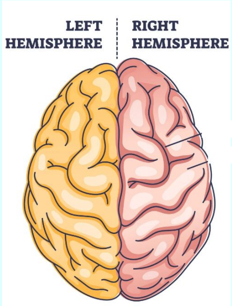
Cerebral cortex

- A **cortex** is the *outer* region (*not* the inner parts) of a body structure (from Latin: *cortex* = bark (of a tree), outer area).
- **Cerebral** = relating to the brain (from Latin *cerebrum* = a brain). Note: Don't confuse 'cerebral' with the 'cerebellum.'

So, the **cerebral cortex** is the *outermost* region of the brain and is a major part of the brain. The cerebral cortex is sometimes referred to simply as the **cortex**.

The cerebral cortex is responsible for many of the brain's functions, including consciousness, memory, language and voluntary movement. The above diagram includes the cerebral cortex (not labelled, but the entire *visible, outer layer*) plus the three *other* major regions – the **cerebellum**, the **brainstem** and the **spinal cord** – underlined in red.

Two other related terms

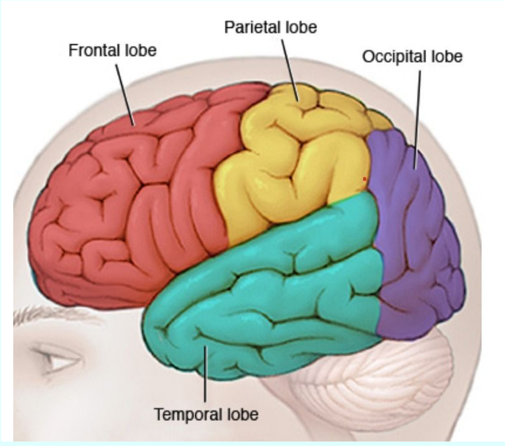


1 **Cerebrum**: This is the parts above and forward of the cerebellum. It is the largest part of the brain, of which the cerebral cortex is its *outer* layer. It is composed of two halves or hemispheres (right and left side of our head as viewed from above).

2 **Neocortex**: This is a *very thi*n layer on the *very* outermost part of most of the cerebral cortex. It evolved most recently and is highly developed in mammals (from Ancient Greek *neo-* = new, young). Note: It is too thin to be shown on the diagram above.

Lobes

The cerebral cortex has *four* regions called **lobes**: frontal, parietal, occipital and temporal. Each lobe controls various functions. Note: The cerebellum, brainstem and spinal cord are *not* part of the cerebral cortex; only the four lobes are! (Shown again, right, in a less-detailed diagram.)



Frontal lobe. The largest lobe of the brain, located at the front of the brain. It has many functions including speech production (in an area called Broca's area) and maintaining attention.

Parietal lobe. (Sometimes called the *Parietal cortex*.) The middle part of the brain. Its functions include attention, processing of sensory information and language processing.

Occipital lobe. The occipital lobe is the rear part of the brain and is involved in the processing of *visual* information and interpretation of things we see (it includes the primary visual cortex V1, shown in the previous diagram).

Note: The occipital lobe does *not* have a direct role in *memory* formation and storage. Therefore, none of the brain's memory systems (working memory, short-term memory, long-term memory) directly involve the occipital lobe.

Temporal lobe. Located at the sides and lower parts of the cerebral cortex behind the ears, the temporal lobe is the second largest lobe. It is involved in many functions, including short-term memory and language comprehension. Many of its processes involve interactions with other brain regions.

As well as the cerebral cortex, other regions that are thought to play a crucial role in consciousness include those discussed below.

Other parts shown in the diagram

Prefrontal cortex: This is a part of the frontal lobe (from Middle English *pre-*, borrowed from Latin *prae-* = before, in front of). It is located at the forefront of the frontal lobe, directly behind the eyes and forehead. It comprises nearly 30 percent of the area of the cerebral cortex (though the diagram above does not perhaps suggest this!), making the prefrontal cortex of humans proportionately larger than that of any other animal. The prefrontal cortex and *not* primary *sensory* areas (e.g. V1, A1) is one area of the brain that produces *consciousness*. (Other crucial regions that are thought to play a crucial role in consciousness include the parietal cortex, thalamus, and different parts of the limbic system.)

Further reading: For more on the prefrontal cortex, visit Website #A26.

Visual cortex: The visual cortex of the brain is the area of the cerebral cortex that processes visual information. It is located in the *occipital lobe*. The visual cortex has five different areas (V1 to V5) based on function and structure. The above diagram shows just V1, called the *primary* visual cortex. Sensory input originating from the eyes travels from the retinas of the eyes to the visual cortex.

Auditory cortex: The auditory cortex involves processes auditory/sound information. The initial processing takes place in the *primary* auditory cortex, A1. Below A1 is the *secondary* auditory cortex A2 which is involved in more complex auditory processing as well as integrating auditory information with other sensory inputs.

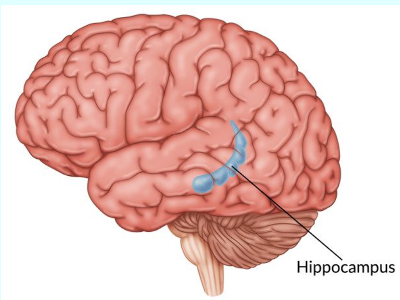
Cerebellum: Also shown in the diagram is the *cerebellum* (meaning 'little brain'). It is ***not*** part of the cerebral cortex but is a separate structure located in the lower rear of the brain and above the spinal cord. It communicates with parts of the cerebral cortex and plays a crucial role in motor (movement) coordination and balance.

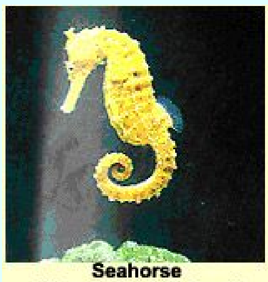
Brainstem: The brainstem controls several vital functions necessary for survival such as breathing, heart rate, and digestion. It acts as a connection between the brain and the rest of the body, transmitting messages to and from the brain to other parts of the body. It also controls sleep cycles and coordinates motor movements (along with the cerebellum).

Spinal cord: The main function of the spinal cord is to transmit signals between the brain and the rest of the body and serve as a pathway for sensory information from the body to reach the brain, allowing us to perceive sensations such as touch, pain, temperature. Similarly, motor signals from the brain travel through the spinal cord to control muscle movements throughout the body.

Parts **inside** the cerebral cortex

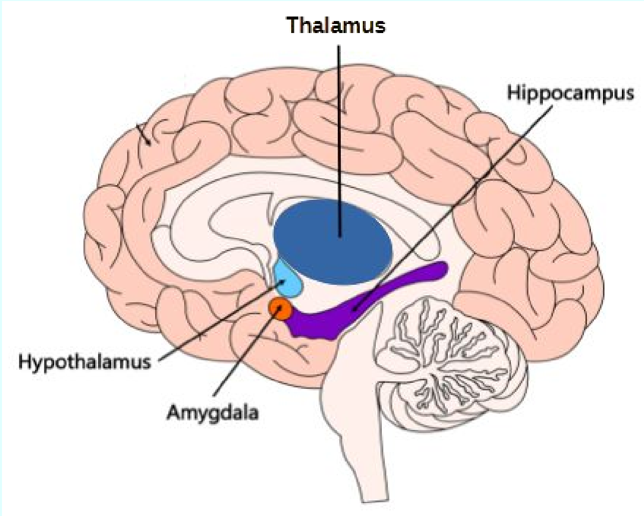
Hippocampus: This is a small, C-shaped structure embedded deep *inside* the temporal lobe (even though the diagram on the right suggests it is on the surface). The hippocampus is often compared to a *seahorse* due to its unique shape (*hippo-* = horse; -*campus* = sea monster → seahorse). It is involved in the formation and retrieval of memories and works with various parts of the *cortex*.





Seahorse
(hippokampos in Greek)

Note: There are actually two hippocampi (plural of hippocampus) in the brain, one in each hemisphere/side of the brain.

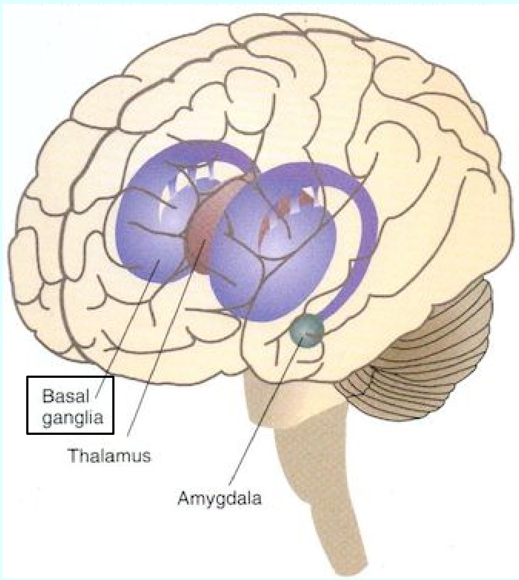


Thalamus: This is a structure located deep within the brain (and above the hippocampus) in the temporal lobe area but does not belong to any specific lobe. As we shall see, this convenient location makes the thalamus a major highway (or 'relay station') for consciousness because signals from most of the sense organs (eyes, ears, etc., but not nose) (as well as motor signals) must pass through it to reach parts of the cerebral cortex for further processing such as to the prefrontal cortex. The thalamus also helps in *consolidating* and storing information in long-term memory. In addition, the thalamus has a role in regulating consciousness, sleep, and alertness.

Hypothalamus: Below the thalamus is a small structure called the hypothalamus (*hypo*- = below, under). It is responsible for regulating many bodily functions such as hunger, thirst, body temperature, circadian rhythms, and hormone production but is *not directly* responsible for consciousness. However, it has connections with other brain regions that are involved in consciousness, such as the thalamus, cerebral cortex, and limbic system. Note: Circadian rhythms are the biological processes occurring at 24-hour intervals.

Amygdala: The amygdala is an almond-shaped structure that also lies deep in the temporal lobe and is connected to the front end of the *hippocampus*. (It gets its name from its resemblance to almonds.) Its main function is to process emotions, particularly fear and aggression. It also plays a role in forming and storing *memories* related to emotional events.

Note: Limbic system: The hippocampus, hypothalamus and amygdala (but not the thalamus) are parts of the limbic system, which is involved in processes such as emotion, motivation, memory, and basic drives such as hunger and thirst. But we will not get into it.



Basal ganglia: The basal ganglia are a group of structures located on *both* sides of the brain. They begin at an *amygdala* and loop around a thalamus. Although the basal ganglia system is *not* directly responsible for consciousness, it does have connections with other regions of the brain that *are* involved in consciousness. (Note: Ganglia is plural; its singular is ganglion.)

Note: The amygdala are also connected to the hippocampus. And these connections are stronger than the connection of the amygdala to the basal ganglia. (The diagram, right, unlike the previous one, *does* not show the hippocampus.) As we shall see, the basal ganglia have many functions including *attention* and *working memory*.

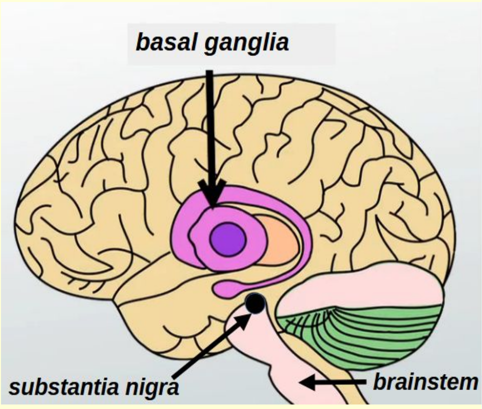
We now turn our attention to regions of the brain that may explain the various parts of consciousness. For consciousness to exist, there must be communication among various parts of the brain.

Conscious phenomena do not emerge from a *single* location in the brain. Instead, they are the product of a system involving *multiple* areas of the brain.

That is why, for instance, as mentioned earlier, when someone's brain suffers localised damage, their consciousness may be modified, but rarely eliminated completely.

Substantia nigra: This is a small part at the top of the brainstem, located immediately below the basal ganglia. Substantia nigra is Latin for '*black substance*', reflecting the fact that part of it appears darker than neighbouring areas, because it contains a blackish substance which gives it that colour, as shown by the appropriate black region in the diagram (below, right)!

Note: Many articles say that the substantia nigra is part of the basal ganglia. But this is *wrong*. It is actually a small part at the top of the *brainstem*, located immediately *below* the *basal ganglia*. The confusion arises from the fact that the substantia nigra is closely connected with the functioning of the basal ganglia. As we shall see below, dopamine, a neurotransmitter, is produced in the substantia nigra which is required for the basal ganglia to function appropriately.



Visual perception of a *word* and an *image*: Brain regions involved

Note: **Perception vs seeing/recognition**

Recognition/Seeing refers to the physical/mechanical act of using the eyes to detect light and objects, while perceiving involves more complex mental processes of *thinking about and understanding the information received through the act of seeing*.

So perceiving goes beyond just the physical act of seeing and involves the brain's *processing* and *interpretation/understanding* of visual (or other sensory) information. People *see the same* but can *perceive differently*.

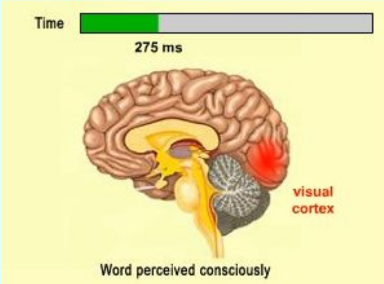
For example, imagine looking at a red apple (again!) Seeing, in this context, would refer to the basic act of visually registering the apple's colour, shape, and presence. It is a purely sensory experience that occurs through the eyes. However, perceiving goes beyond this initial observation. It involves not just recognising the apple as an object, but linking it to previous knowledge or experiences, and understanding its implications. Perceiving the apple may involve thoughts of taste, nutritional value, or maybe even memories of biting into a similar apple.

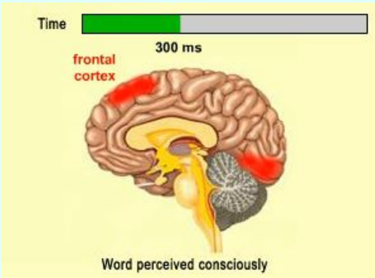
Visual perception of a word

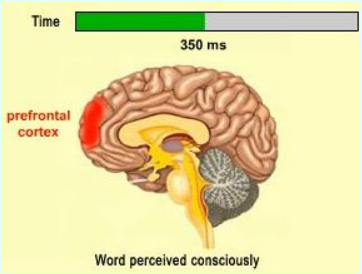
In the recognition of a word, several brain regions mentioned above are involved. They include the thalamus, the primary visual cortex (V1), the occipital lobe and the prefrontal cortex. Here we discuss *both* the recognition and the perception of a word.

This is what happens:

1 Light from the word travels through the eyes and reaches the retinas at the back of the eyes. This takes about 50 ms (ms = milliseconds. 1 millisecond = 0.001 second.)

2 

3 

4 

2 A signal travels from the retina along a nerve (called the optic nerve) to the **thalamus** (not shown in the diagram) which directs it to *the* (primary) **visual cortex** (V1) at the back of the **occipital lobe**. V1 begins to reconstitute the word from the signals received from the retina into a recognisable image of the word. From the retina to the visual cortex takes about 275 ms. Note: In V1, only a mechanical/physical basic recognition of the word occurs.

3 From the visual cortex, a signal passes to the **frontal lobe/cortex** (time to get there from the retina to get there is about 300 ms).

4 Then to the **prefrontal cortex** (time now about 350 ms) where real perception (thinking about the word) occurs.

So, the *total* time from looking at the word to perceiving the word in the prefrontal cortex is about 400 ms (i.e. 50 + 350 ms).

As the above steps and pictures shows, conscious phenomena (in this case the perception of a word) do *not* emerge from a *single* location in the brain; they are the product of a system involving multiple areas of the brain. That is why, for instance, as mentioned earlier, if someone's brain suffers some damage in one part, their consciousness may be modified, but rarely eliminated completely.

More living in the past: This is another example of living in the past as the word becomes conscious to the viewer only after about 400 ms. Look back at pages 32ff 'Consciousness: We are living in the past.'

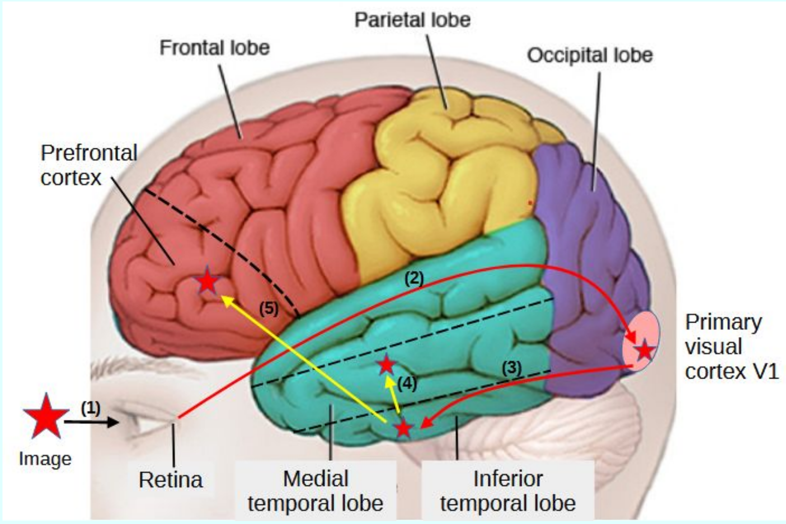
Notes

1. In this example, the process has been simplified quite a lot; it just shows *key* regions involved and does *not* fully show the complexity and interactions between different brain regions involved in word/image perception.
2. The time varies slightly from person to person. The *average* time it takes to perceive the *word* is 400-500 milliseconds (1 millisecond = 0.001 seconds). (So in the above example, the total time of 400 ms would be the average time taken.)

Visual perception of an image

The above example is for the perception of a *word*. The time for processing an *image* is significantly *shorter* than the time to process words! Object recognition can occur as quickly as 150 ms from onset of image exposure (cf. 400 ms for the recognition of a word). This is why visual information is often recognised and understood more quickly than text-based information. The perception of an *image* also follows a slightly different pathway in the brain.

The diagram (right) shows the route taken through the brain (slightly simplified):



1 Light from the *image* reaches the retinas at the back of the eyes; again this would take about 50 ms. [Same as Step 1 above for words.]

2 Retina of eye → thalamus (not shown) → primary visual cortex (V1) This takes about 13 ms. [Same as Step 2 above for words but faster.] This is where basic recognition of the image occurs (as it did for words – see above).

3 From the primary visual cortex (V1) → *inferior* temporal lobe (i.e. lower part of the temporal lobe). This is where recognition of complex visual images occurs, such as object shapes and faces.

4 Inferior temporal lobe→ via *hippocampus* to the medial (middle part) temporal lobe for consolidation (i.e. storage in memory). (The hippocampus is inside the medial temporal lobe but is not shown in the diagram.)

5 Inferior temporal lobe → prefrontal cortex and conscious awareness probably via the *thalamus*). Total time for this to occur would be about the 150 ms mentioned above. This is where perception of the image occurs (as for the *word* above).

Note: Experimental evidence identifies the Inferior Temporal Lobe as *essential* for *complex* image *recognition*, especially for complex visual images.. Damage to the inferior temporal lobe impairs the ability to *recognise* such visual images, a condition known as *visual agnosia*. (Agnosia = loss of the ability to interpret sensory stimuli, such as sounds or images.)

Further reading: For more on how fast the brain processes images and words, visit Website #A27.

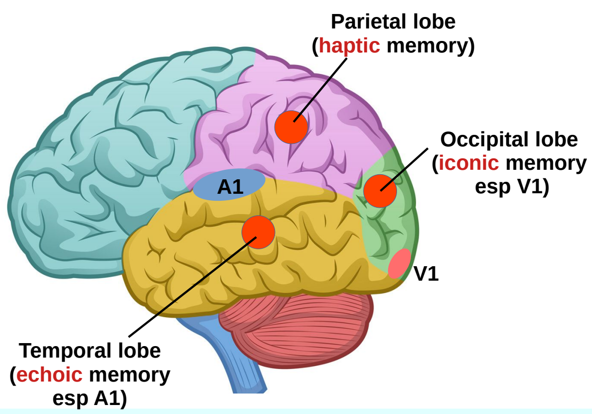
Now to processes and brain regions involved in our model of human memory – sensory memory, attention, working memory, short-term memory and long-term memory.

Sensory Memory – Brain Regions

Incoming information detected in the environment is briefly stored in our sensory memory. The sensory memory is not located in a specific part of the brain. It involves the *initial* processing of sensory information in various brain regions, such as the *visual* information processed in the visual cortex V1 (see diagram next page) or the auditory information processed in the primary auditory cortex A1 (same diagram). Below A1 is the secondary auditory cortex A2; this is involved in more complex auditory processing as well as integrating auditory information with other sensory inputs. All sensory information is then transferred briefly to other areas of the brain for further processing and storage.

Sensory memory is stored in the primary sensory areas of the cerebral cortex, which include:

- Iconic memory (visual sensory memory) is stored in the *occipital lobe*, particularly in the primary visual cortex V1.
- Echoic memory (auditory/sound sensory memory) is stored in the *temporal lobes*, particularly in the primary auditory cortex A1.
- Haptic memory (tactile/touch sensory memory) is stored in an area of the *parietal* lobe.



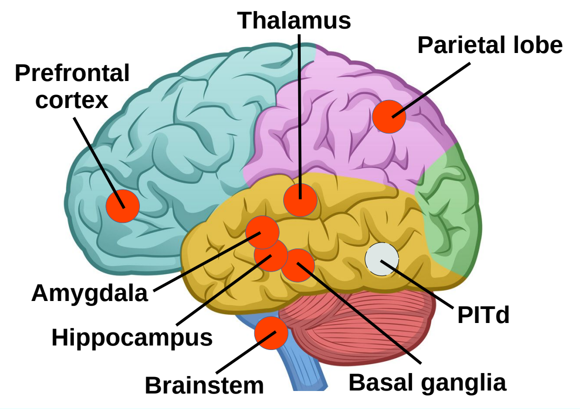
Note: The contents of sensory memories, as mentioned earlier, are temporary lasting from perhaps half a second (500 ms) to no more than perhaps 3 seconds as they quickly fade and disappear.

Note: The *visual* cortex in the occipital lobe, as well as containing area V1, actually contains a total of five main regions V1 to V5 (some say seven if subregions are considered) each responsible for different aspects of visual processing. The *auditory* cortex contains two areas A1 and A2 for different aspects of auditory processing. But we need not go into details of these areas in this project.

Attention – Brain Regions

Attention involves a complex network of brain regions working together to store, process and prioritise incoming sensory information.

Many parts are involved (diagram, right). The prefrontal cortex in the frontal lobe is a major player in attention, especially as information attended to there then passes to the short-term memory. Other regions involved include the parietal lobe, the thalamus, amygdala, hippocampus and basal ganglia. Parts of the brainstem are crucial for maintaining wakefulness and alertness, which are essential for attention.



Together, all these areas are required to filter out irrelevant information in order to focus attention on important stimuli. Very complicated!

PITd: Recently, another part of the brain was found to be important for the control of selective attention. This is the PITd area of the brain and is located in the posterior part of the lower part of the temporal lobe (see diagram). Its function is to process visual information related to object recognition, particularly the identification of complex objects such as faces, animals, and objects with specific shapes. It is also involved in categorising objects based on their features and associations with other objects. The PITd area has connections with other areas of the brain involved in memory, attention, and decision-making.

Note: PITd stands for posterior inferior temporal cortex, dorsal division; posterior = at the back / nearer the rear; inferior = low or lower in position; dorsal = upper side/back of a structure. Don't worry about all this detail; just remember that it is located towards the rear and lower part of the temporal lobe – shown by the grey circle in the above diagram.

Working Memory – Brain Regions

Short-term memory is the brain system that *first* receives information from sensory memory allowing for conscious awareness of this information. However, this information is held passively. If active processing/change is wanted, the information must pass into working memory where it can be manipulated/changed. When the active manipulation is finished, the modified information just becomes part of short-term memory again where it once more sits passively until it either fades from memory or passes to more permanent storage in long-term memory.

While short-term memory with a discussion of the brain regions involved may seem the logical place to begin a discussion, we are actually going to start with working memory!

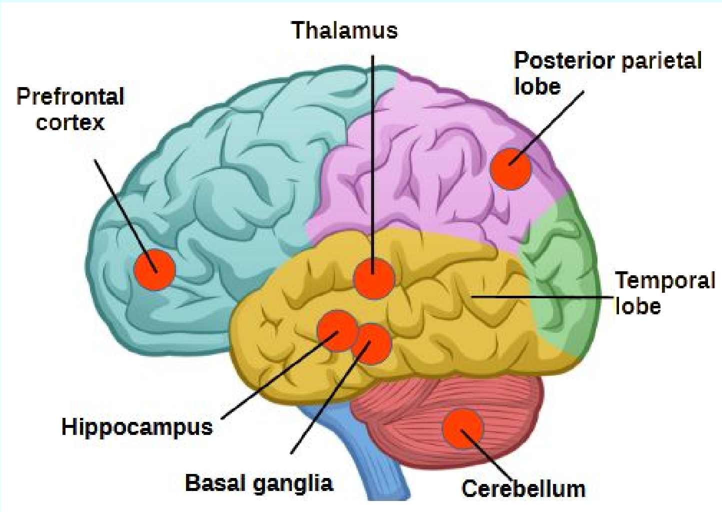
Working memory has also been associated with persistent neural activity in *several brain regions*. But which brain regions? Only one thing is certain: the **prefrontal cortex** (PFC) plays the key role in working memory. It enables people to keep information available that they need for their *current* reasoning processes. Research has found that removing the PFC results in a deficit in working memory (though *not* in the passive short-term memory). The prefrontal cortex is a part of the frontal lobe that mediates complex mental processes such as organising, planning, learning and memory.

MRI scanning: When people perform tasks requiring them to hold information in their working memory, the prefrontal cortex becomes active. This was discovered used the method of magnetic resonance imaging (MRI mentioned earlier on page 55).

Brain regions that contribute to the functioning of working memory

Note: The term 'working memory' is *not* itself *one* brain region but is a general term that involves many different areas of the brain that work together to perform the functions of what is described as working memory.

As well as the prefrontal cortex, other brain regions include the posterior parietal lobe, the thalamus, the basal ganglia, the hippocampus, and even the cerebellum (possibly). These areas are shown in the diagram. The specific involvement of different brain regions may vary depending on the type of working memory task being performed.



It is very difficult to describe exactly how each of the regions in involved in working memory. Instead, brief comments are given for each region.

1 **Prefrontal cortex**: It enables people to keep information available while they manipulate it.

2 **The hippocampus:** This is located in the temporal lobe. It plays a crucial role in working memory. It is involved in the temporary storage and manipulation of information that is needed for current tasks. Cf earlier comments about the hippocampus such as on pages 41, 46, 58).

Damage to the hippocampus and surrounding area can cause anterograde amnesia, which is a type of memory loss that occurs when new memories cannot be formed. This implies that the hippocampus is important for forming memories.

The hippocampus is also involved in memory consolidation, the slow process by which memories are converted from short-term memory to storage in long-term memory.

It has been found that it is possible to form new semantic memories but *not* episodic memories *without* the hippocampus. This means that explicit descriptions of actual events (episodic) cannot be learned, but some meaning and knowledge is gained from experiences (semantic).

3 **The posterior parietal lobe**: This is heavily involved in *spatial* processing, which is essential for *working memory* tasks that require the manipulation and organisation of *spatial* (3D) information, the ability to understand how objects in two and three-dimensions are arranged. For example, visualising the layout and arrangement of furniture and objects in a room in your mind while searching for something in the room. The posterior parietal lobe helps you maintain this spatial representation.

Another example: People also need visual processing skills to make sense of letters and numbers. For example, to look at '6' and '9' and 'W' and 'M.' They have different meanings depending on how they are rotated on the page. Visual-spatial trouble can make it harder to learn to read and do mathematics.

Further reading: For a brief but good article on visual-spatial processing, visit Website #A28.

4 **The thalamus:** This region is *not* within the temporal lobe as the diagram suggests (and has been mentioned earlier), but is deep within the brain. The thalamus acts as a *relay station*, receiving sensory information and transmitting it to other areas of the brain for further processing, such as to the prefrontal cortex. The thalamus also helps in consolidating and storing information.

5 **The basal ganglia**: The basal ganglia are also *not* in the temporal lobe (as the diagram suggests) but, like the thalamus, reside deep within the brain. They are important in **procedural learning and memory**. This includes the body's *voluntary movements* such as how to tie shoelaces, play a musical instrument, ride a bike and how to drive a car. The learning is often *unconscious* and *automatic*, as the brain produces memories to execute a set of actions without conscious effort. This takes place in the working memory and involves the basal ganglia.

Procedural learning also *resides* in the basal ganglia. Brain disorders involving movements are associated with basal ganglia damage or dysfunction, including Parkinson's disease (see pages 68, 70) and Huntington's disease (for long-term memory, page 77).

Definition of procedural memory: The acquisition of skills and habits through repetition and practice until the necessary actions can be performed without actively thinking about each step involved.

The ability to ride a bicycle: When you first learn to ride a bike, you have to consciously think about every movement, such as pedalling, balancing, and steering. But with practice, these actions become automatic, and you are able to ride without having to consciously focus on each movement. Your body has learned the procedural steps needed to balance and ride the bike, and this skill becomes ingrained into your *motor memory / muscle memory*. (Note below.)

Extension: Motor memory and muscle memory

These two terms are related but with some differences.

Motor memory is a *broader* concept that encompasses the brain's ability to learn and store patterns of movement with accuracy and efficiency without conscious thought.

Muscle memory is more of a colloquial term and is a form of *procedural memory* that refers specifically to the ability of muscles to ‘remember’ and perform those movements automatically due to repetition and practice. This type of memory is not stored in the brain, but rather in the muscles themselves, which allows for faster and more efficient movement patterns.

Examples for both motor and muscle memory include riding a bicycle, typing on a keyboard, playing a musical instrument or performing sports skills.

6 **The cerebellum**: This is mainly involved in the control of movement and balance, but recent research has suggested that it *may* also have some involvement in non-motor functions, including certain cognitive processes like working memory and also attention. It is also involved in procedural learning.

Implicit memory

The unconscious procedural learning mentioned above, such as riding a bike and playing a musical instrument, is implicit (implicit = not expressly or directly stated; implied). Implicit memory involves two key areas of the brain: the cerebellum and the basal ganglia.

Further reading: For more on implicit and explicit memory, visit Website #A29.

Further reading on working memory: Visit Website #A30 (includes brain regions and ageing)

Conditions and disorders that affect working memory

1 **Ageing**: In humans, working memory is believed to increase gradually over childhood and decline gradually in old age. One neurobiological explanation is that the *prefrontal cortex* (which is crucial for working memory) shows the highest degree of age-related atrophy (wasting away) due to the degeneration of brain cells in that brain region.

2 **Brain injury**: Events such as car accidents, concussive head injury, and sports can cause impaired working memory. Many brain regions can be affected including the temporal lobe, parietal lobe, basal ganglia and several subregions in the prefrontal cortex. That is, almost all key regions! Repeated traumatic brain injuries, such as concussions, which are relatively common in contact sports like American football, have been associated with cognitive impairments including working memory problems.

3 **Stress and depression**: Both of these reduce working memory *capacity*. In severe cases, this capacity can be reduced to zero for simple working memory tasks. Depression is heavily characterised by negative thoughts that can direct attention away from the task at hand.

Stress and depression can lead to reduced activity and impairments in the *prefrontal cortex* and the *hippocampus*, affecting the ability to focus on and manipulate information in working memory.

Chronic (prolonged) stress can lead to an increase in *cortisol* levels, which in turn affects the release of brain *neurotransmitters* such as dopamine. This can disrupt communication within brain networks involved in working memory. Another important brain neurotransmitter associated with stress is glutamate. (See box below and disorder #5 below on 'Schizophrenia'.)

Neurotransmitters: A neurotransmitter is a chemical which moves across a space (called a synapse) from one neuron (nerve cell) to the next in the brain. In so doing, it allows nerves to transmit 'messages' around the body. (For more on neurotransmitters, refer to Website #B2 for the project '*Transmission of Nerve Impulses*' pages 4 – 21ff.)

Also refer to Website #A31 on neurotransmitters.

Glutamate neurotransmitter and flashbulb memory

When humans and animals are stressed, the brain secretes *more* of the neurotransmitter glutamate, which helps them remember the stressful event. This is clearly evidenced of what is known as the flashbulb memory phenomenon. It is an exceptionally clear recollection of an important event.

The 9/11 attack on the twin towers in New York in 2001.

Where were you when you first heard about the 9/11 terrorist attacks in 2001? Most likely you can remember where you were and what you were doing. A survey found that for those Americans who were age eight or older at the time of the event, 97% can recall the moment they learned of this event, even a decade after it happened. I too can remember exactly where I was – it was in Cappadocia, Turkey, when I was on holiday there.

4 ADHD (= Attention deficit hyperactivity disorder) People with ADHD can seem restless and may have trouble concentrating and paying attention. Studies have found that the prefrontal cortex is smaller in children with ADHD resulting in these behaviours.

As connections between the prefrontal cortex and other brain regions are crucial for working memory. people with ADHD may exhibit impaired functioning between these regions, making it more challenging to sustain and control information in working memory.

The neurotransmitter dopamine is another factor affecting working memory in people with ADHD. Dopamine is responsible for transmitting signals between neurons, and abnormalities in its functioning have been linked to ADHD (as well as stress and depression, as mentioned above). In children with ADHD, some dopamine pathways are thought to be disrupted, leading to lower levels of dopamine.

ADHD and Driving: Risks and Safety Strategies: For more on this topic, refer to Website #A32.

5 Schizophrenia: [From Greek *schizo-* = to split, and *-phren* = mind] This is a mental disorder in which people interpret reality in an abnormal way. Imaging studies have found that brain activity in the *prefrontal cortex* is less active than normal in schizophrenic patients. This results in poor *attention* and deficits in *working memory* (as well as in short-term memory).

The neurological explanation for how schizophrenia affects working memory is not fully understood. But here are some factors:

(i) Prefrontal cortex: People with schizophrenia have impaired working memory, which is believed to be due to problems with the neurons in this region of the brain.

(ii) Problems with neurotransmitters in the prefrontal cortex: *Reduced* amounts of dopamine is one problem. Glutamate is another important brain *neurotransmitter*. *Reduced* glutamate levels in the prefrontal cortex of individuals with schizophrenia also seem to disrupt working memory.

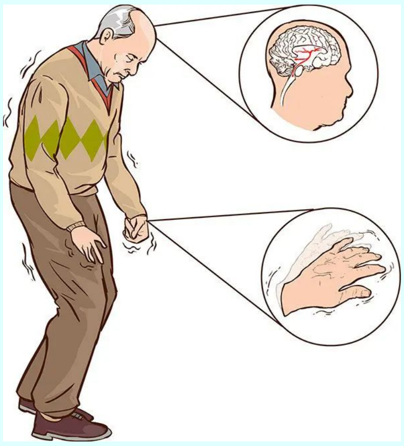
6 **Parkinson's disease (PD)**: Parkinson's disease is a progressive disorder of the nervous system. The symptoms of Parkinson's disease can vary from person to person and may develop slowly over time. The disease is named after English doctor James Parkinson (pictured, right), who published the first detailed description of the disease in 1817.

James Parkinson (1755 - 1824)

Patients with Parkinson's disease show signs of a reduced verbal function of working memory and a lower amount of memory *capacity* than normal.

Parkinson's disease results from problems in the substantia nigra and the basal ganglia. (For more on the substantia nigra, look back at page 60.) This is evident in the impaired *movements* of Parkinson's patients.

The *substantia nigra* produces the neurotransmitter dopamine which it passes to a part of the *basal ganglia*. This dopamine signalling is crucial for the proper functioning of the basal ganglia and plays a crucial role in *balance* and *movement*. Dysfunction in or loss of this dopamine pathway can lead to movement disorders like Parkinson's disease.



In Parkinson's disease, there is a gradual loss of these dopamine-producing cells. This loss leads to *movement-related symptoms* that include, but are not limited to:

1. Tremors (shaking): Typically starting in the hands or fingers,
2. Slow movement: Slowness and loss of voluntary movement, including difficulty starting or stopping movements.
3. Impaired posture and balance: This may result in frequent falls.

Some non-movement symptoms may also occur as the disease progresses, such as *sleep* problems. Many individuals with Parkinson's disease may experience sleep disturbances, including insomnia, acting out dreams and daytime sleepiness.

Parkinson's disease can also affect the basal ganglia, resulting in working memory deficits.

7 **Alzheimer's Disease:**

Alzheimer's disease is named after Dr. Alois Alzheimer (pictured left), the doctor who, in 1906, first described the affliction. And pictured on the right is the first patient he examined.

Working memory is affected by Alzheimer's and one of the reasons for its decline is the effect of Alzheimer's on semantic memory. (Semantic memory is the ability to understand and recognise *words*. Since language processing may be slower in people with

Alzheimer's disease, working memory (which manipulates our stored memories) may also be impaired.

Alzheimer’s disease results in the massive loss of neurons involved in learning and memory processes, including the hippocampus and frontal cortex which is associated with memory deficits that manifest in early stages of the disease.

Alzheimer's disease affects our memories and depends on how far the disease has progressed. Short-term memory and working memory are first to be affected. Long-term memory is usually affected later.

Alzheimer's disease is *caused* by the accumulation of two abnormal substances in the brain – beta-amyloid plaques and tau tangles. Refer to pages 71 and 72 for more details.

Alzheimer’s disease: For more on how Alzheimer’s Disease affects human memories, refer to Website #A33.

Short-term Memory – Brain Regions

How short-term memory works: Refer to Website #A34.

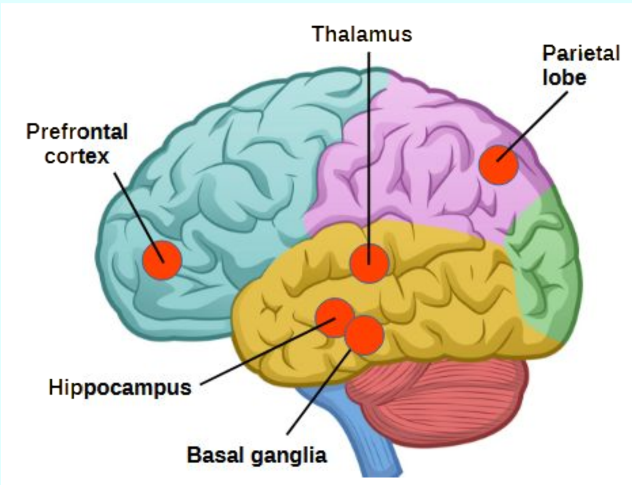
Short-term memory is the brain system that *first* receives information from sensory memory allowing for *conscious awareness*. It has the ability to hold information in the absence of sustained sensory input. But the information is only held *passively* and only briefly (from a few seconds to a minute or two) before it fades and disappears.

If we want to manipulate/change the information, it must become working memory. After manipulation in working memory, the modified information just becomes part of the passive short-term memory again. There, the information remains *again* briefly before fading and disappearing or being shuffled along and stored in long-term memory.

There is also an *overlap* of brain regions involved in short-term memory and working memory,

Brain regions that contribute to the functioning of short-term memory

Key regions of the brain involved in the formation of short-term memories are similar to those for working memory, though *without* the cerebellum. (Refer back to the diagram for working memory on page 64.) Though how all these brain regions work together still remains unclear.



1 The prefrontal cortex: Short-term memory also relies heavily on the prefrontal cortex. It is known that when people perform tasks requiring them to hold information *briefly* and *passively* in their short-term memory, the prefrontal cortex becomes active. (This temporary storage is *before* the information moves to working memory for manipulation or to the *neocortex* for long-term storage.)

2 Parietal lobe: Recent research has shown that regions of the parietal lobe play an important role in short-term memory (for both *verbal* and *visual* information).

3 **Thalamus:** The thalamus, as mentioned earlier (see pages 59,65) acts as a relay station for sensory information coming from various sensory systems.

4 **Hippocampus:** The thalamus then sends information to the *hippocampus* which is where short-term memories are formed before they are passed to the neocortex for more stable long-term storage. This transfer is needed as the hippocampus itself can only store a limited amount of information whereas the neocortex can hold huge amounts. The hippocampus is thus a crucial brain structure responsible for the *consolidation* of short-term memories into long-term memories in the neocortex.

Dysfunction of the hippocampus cause difficulty with short-term memory and thus also with long-term memory storage as the two are linked. Such dysfunction can be caused by brain injury and also by Alzheimer's disease, depression and other factors (see below).

Further reading:
1. Refer to Website #A35 for hippocampus damage and effects on memory.
2. Refer to Website #A36 for brain region linking short-term to long-term memory.

Henry Molaison: Refer to pages 75f, to see how Henry Molaison suffered short-term memory loss as a result of having his hippocampus removed.

5 **Basal ganglia**: The involvement of the basal ganglia in *short-term memory* is not as well-established as the other brain regions mentioned. However, it is known that a pathway connecting that thalamus to the basal ganglia is required for short-term memories to form.

In addition, implicit memories, such as motor (movement) memories, rely on the basal ganglia (and the cerebellum)

Hippocampus: Retrieval of information from long-term memory to short-term memory

The hippocampus *also* assists in *retrieving* information from long-term memory when needed and passing it into short-term memory. (We are always doing this! For example, recalling a poem stored in our long-term memory, a visual image of some scene, etc.) If that information needs to be acted on/manipulated, it then becomes part of working memory until the manipulation is complete when it becomes part of short-term memory again and then probably also back to long-term memory.

Conditions, diseases and drugs that affect short-term memory

1 **Brain injury**: Just as with working memory, brain injuries can cause impaired short-term injury. Susceptible brain regions include the *prefrontal cortex* in the frontal lobe. Furthermore, brain injury can affect other related brain regions, such as the *hippocampus* and the *temporal lobe*, which are crucial for memory processing (Cf. Henry Molaison again). Damage to these areas or their connections with the prefrontal cortex can further contribute to short-term memory impairments.

2 **Parkinson's Disease**: See above under working memory for symptoms of this disease. As well as affecting working memory, the disease also affects short-term memory. In studies with humans, Parkinson's disease patients show lower short-term capacity across digit span tests (how many items you can retain in your short-term memory). Look back at page 48 where it is mentioned that most adults can hold around 7 ± 2 items; Parkinson's disease patients hold fewer.

Digit span test: Open the website in #A37 and try the digit span test to see how many numbers you can retain in your short-term memory. (If you cannot follow the instruction, there are others online you might try.)

As with working memory, the problems arise in the *substantia nigra* with the dysfunction or loss of dopamine-producing neurons which leads to a depletion of dopamine, a critical neurotransmitter in the brain. Dopamine plays an important role in the formation of memories.

Parkinson's disease can also affect other brain regions involved in memory, such as the hippocampus and prefrontal cortex. The hippocampus is crucial for the formation of new memories and, as mentioned, for the consolidation of short-term memories into long-term memories.

3 Alzheimer's Disease:

Website reading: Refer to Website #A38 for hippocampus damage and effects on short-term memory.

Alzheimer's disease affects working memory (see above), short-term memory and, in its later stages, long-term memory. In Alzheimer's disease, the hippocampus undergoes massive cell loss, which is associated with memory deficits that manifest in early stages of the disease.

In its *early* stages, Alzheimer's disease typically affects short-term memory. For example, this might involve forgetting what you ate for breakfast or repeating yourself in a conversation. Other examples include repeating questions over the course of several hours or telling the same story you told five minutes ago. All of these are signs of short-term memory impairment.

Short-term memory decline is one of the earliest symptoms of Alzheimer's disease by reducing the capacity of short-term memory (the number of items it can hold).

Alzheimer's disease is *caused* by the accumulation of two abnormal substances in the brain – beta-amyloid plaques and tau tangles. These disrupt the normal functioning of brain cells, leading to their degeneration and death, consequently impairing various cognitive processes, including memory.

The accumulation of beta-amyloid plaques primarily affects the hippocampus. The hippocampus plays a crucial role in the formation of new memories and is responsible for transferring information from short-term memory to long-term memory storage.

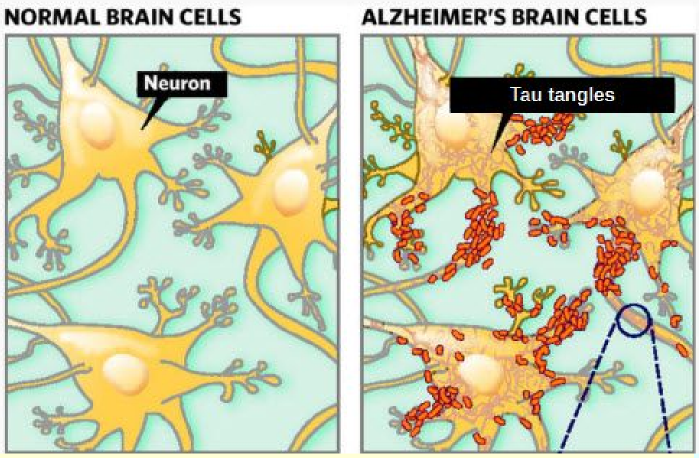
The tau tangles spread throughout the brain, affecting various brain regions involved in memory processing, including the prefrontal cortex which becomes less effective, impairing the ability to retain information in short-term memory.

Additionally, the degeneration of neurons and the loss of synapses (gaps between neurons), which are vital for communication between neurons, contribute to the decline in short-term memory function with Alzheimer's disease.

Tau tangles and Beta-amyloid plaques

Tau tangles are formed by the accumulation of a protein called tau. In healthy brains, tau is needed for the proper functioning of neurons. However, under certain conditions, tau undergoes abnormal changes and forms twisted, insoluble filaments, which are known as tau tangles. (See diagram next page.)

Beta-amyloid plaques are abnormal clumps of protein fragments known as beta-amyloid, which is a normal protein in the brain, but in Alzheimer's disease it accumulates in excessive amounts and forms plaques/clumps which accumulate between nerve cells in the brain.



Note: It's normal to be concerned if you experience occasional memory lapses, but you can be rest reassured that not all short-term memory problems are a sign of Alzheimer's. As I get older, I find it more difficult to remember things without writing them down! And I do *not* have Alzheimer's Disease!

4 **Sleep deprivation**: Sleep deprivation is associated with many negative health consequences, including disrupted cardiovascular health, immunity, and problems acquiring knowledge. Sleep deprivation also affects short-term memory due to its impact on the brain's hippocampus and prefrontal cortex.

During various stages of sleep, particularly during the REM (rapid eye movement) sleep stage, the hippocampus plays a vital role in transferring information from short-term to long-term memory storage.

Sleep deprivation impairs the functioning of the prefrontal cortex, leading to deficits in attention, concentration, and the ability to remember and manipulate information. This can result in decreased performance on tasks requiring short-term memory, such as learning new information or remembering lists.

5 **Depression**: Damage to the hippocampus can also be related to depression. Individuals who experience depression or post-traumatic stress disorder (PTSD) often show reduced hippocampal volume in their brain scans. The hippocampus can also appear smaller in size during periods of depression. However, scientists are uncertain whether this shrinking in size results directly from depression or is simply a contributing factor causing depression.

6 **Alcohol**: Alcohol affects dopamine (and other neurotransmitters). It *increases* dopamine release in the brain's *reward* pathway, leading to the pleasurable effects of drinking. However, *excessive* alcohol consumption can disrupt normal dopamine production affecting the communication between brain regions involved in memory processes. Additionally, alcohol can cause inflammation in the hippocampus. which is an area critical for memory formation. This can damage neurons and impair their ability to create and retrieve memories.

Website reading: Refer again to Website #A38 for hippocampus damage and effects on short-term memory.

Long-term Memory – Brain Regions

Why is it that we are able to recall a childhood birthday that occurred years ago but we fail to remember what we had for lunch last Tuesday? The difference lies in long-term memory and the way works.

Long term memories are those that can be recalled days, months, or even years after they were originally stored. Unlike short-term memory and working memory, which have a small capacity, long-term memory has a limitless store, but limited *accessibility*. The exact mechanisms of the transfer of information into long-term memory are still not fully understood and are an area of active research in the field of neuroscience.

Consolidation: Newly formed or acquired information in short-term memory is integrated/stored into existing networks of knowledge in long-term memory. This storage process – as has been mentioned several times – is called memory consolidation.

Two kinds of long-term memory – declarative memory and procedural memory

Long-term memory is broadly divided into declarative memory and procedural memory (also known *non-declarative* memory).

Declarative memory, also known as explicit memory, is a type of long-term memory for memories of things we can talk about. It is further broken down into semantic memory, the memory of our *factual knowledge*, and episodic memory, the memory of narratives and events or episodes in our lives.

So, it encompasses both semantic memory, which refers to general knowledge and facts acquired through learning and experience, and episodic memory, which relates to specific events and personal experiences. Declarative memory is distinct from procedural memory, which involves the unconscious recall of skills and habits.

Procedural memory is a type of long-term memory for learned skills and procedures of specific *actions* or tasks, for example. riding a bike, driving a car, typing. Procedural memory is often *unconscious* and is implicit, that is, implied rather than being directly stated as explicit learning is. (Note: Procedural memory is also often called procedural knowledge.)

Refer back to pages 45f for the definitions of episodic memory and semantic memory and page 45 for procedural memory and page 65f for the definition of procedural memory.

That is:

Long-term memory = → declarative memory (is explicit) = semantic + episodic
→ procedural memory (is implicit)

The brain stores declarative/explicit knowledge in two main places, the hippocampus and the neocortex though the temporal lobe may also be involved.

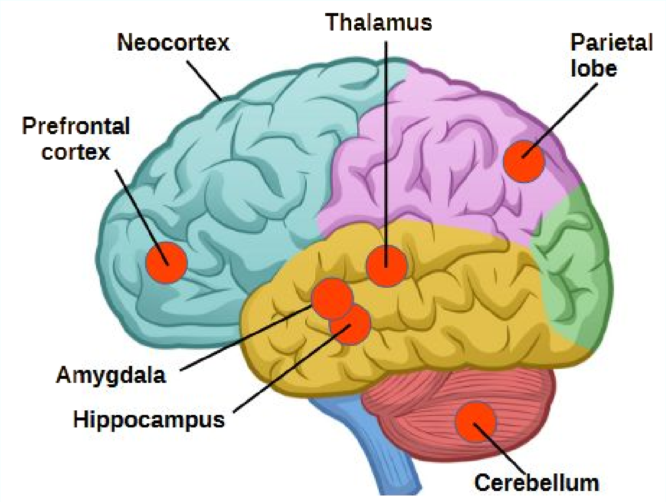
Several brain regions are thought to be involved in procedural knowledge including the basal ganglia, cerebellum, prefrontal cortex, and motor cortex (in the posterior – rear – of the frontal lobe).

Monkey business and long-term memory

Research results from work done with rhesus monkeys has provided valuable insights in understanding the neurobiological basis of long-term memory, elucidating the role of different brain regions, and highlighting key similarities between human and primate memory systems.

A rhesus monkey

Brain regions that contribute to the functioning of long-term memory



Long-term memory, along with working memory and short-term memory, is also distributed throughout multiple brain regions but here we just look at *key* regions of the brain. The brain regions seem to be the same as for working memory (cf. diagram for working memory on page 64). Note: Like working memory, but *unlike* short-term memory, the cerebellum is included!

1 **Hippocampus**: The hippocampus is one of the key brain regions responsible for the formation and *consolidation* of new memories in long-term memory from short-term memory.

The hippocampus itself is *not* the site of *permanent* long-term memory which is in the *neocortex*, but it plays the *initial* and crucial role in the consolidation process, particularly of *declarative* memories (facts and events) – see next page for the case of patient Henry Molaison.

The destruction of both hippocampi (as the result of a stroke, for example, or by consuming excess alcohol – see below) has disastrous effects on long-term memory, preventing an individual from learning anything new whatsoever.

2 **Prefrontal cortex**: The prefrontal cortex, particularly the *dorsolateral* prefrontal cortex (dorsolateral = back and sides), is also involved in the storage and retrieval of long-term memories. It helps in organising and retrieving memories based on context and cognitive control.

3 **Parietal lobe**: The neuroimaging literature indicates that the parietal lobe has an important role, especially in *episodic* memory. Parietal lobe damage impairs the ability to fully re-experience past autobiographical/episodic events. Normal parietal function is imperative for the effortless recollection of detailed episodic memories.

4 **Amygdala**: The amygdala helps in the formation and long-term storage of *emotional* memories.

5 **Thalamus**: This contributes to long-term memory storage but exactly how is not yet known though experiments (in mice) have shown that inhibiting the thalamus disrupts the formation of long-term memories in the mice and, conversely, stimulating the thalamus forms memories that would not otherwise have been stored long-term, and makes them last.

Ways to stimulate the thalamus and so promote long-term memory storage

1. Focusing attention on information being presented and engaging actively with material, such as asking questions or relating it to existing knowledge (i.e. elaboration).
2. Repetition in the use of information.
3. Sleep and Rest: The thalamus plays a role in memory consolidation during sleep. Obtaining sufficient sleep and restful periods supports the thalamic processes involved in memory formation.

6 **Cerebellum**: Although normally associated with motor (movement) coordination, the cerebellum also plays a role in certain types of long-term memories, including motor learning and (possibly) procedural memories.

Website reading: Refer to Website #A39 for cerebellum and procedural knowledge.

7 **Neocortex**: The neocortex is a very thin outer layer of the cerebral cortex and, as mentioned above, plays a crucial role in the long-term storage and retrieval of memories. Different regions of the neocortex are specialised for different types of memories, such as visual memories in the occipital lobe or language-related memories in the temporal and frontal lobes.

More on the hippocampus and the neocortex

Certain memories, especially of specific events in our lives, like the coffee we had with a friend last week (an example of *episodic* memory), are believed to be transferred from the *hippocampus* and stored in the *neocortex* as *general* knowledge. We know this because of patient H.M. (see below). But more recent research suggests that traces of episodic memories remain in the hippocampus but we are not sure why. These traces *may* store details of the memory, while the more general outlines are stored in the neocortex.

It is important to note that memory is a complex process involving interactions between these and various other brain regions. The exact roles and mechanisms of these regions in long-term memory formation and storage are still an active area of research.

Henry Molaison (1926 – 2008)

In 1953, a patient named Henry Molaison (or Patient H.M. as he was referred to then) was suffering from epilepsy. Surgeons thought that removal of his *hippocampus* surgically would treat the epilepsy. His epilepsy *was* cured and Molaison lived a further 55 healthy years. However, he suffered from severe short-term memory loss after having the hippocampus removed.

Henry Molaison in 1953 before his surgery

H.M.'s short-term memory loss was so severe that he was completely unable to create and store *new* long-term memories after the surgery. Although he could *not* remember events or people he encountered after the surgery because of his short-term memory loss, he could still recall events and memories that had been formed and stored in his long-term memory *before* the surgery. His existing *procedural* memory, which involves skills and habits, was also largely intact.

The type of amnesia (memory loss) that Molaison developed is known as severe anterograde amnesia where an individual experiences profound difficulty in forming *new* memories *after* a particular event or injury. However, the ability to recall events and memories prior to the onset of the amnesia may remain intact; it is only the ability to create *new* memories that is impaired.

Note: ‘Severe anterograde amnesia’ is more extreme than the less severe ‘anterograde amnesia.’

This amnesia is often associated with damage to the hippocampus, a brain region involved in memory formation. Individuals with severe anterograde amnesia have difficulty remembering recent events, learning new information, or remembering people they have recently met. This suggests that long-term memories (particularly memories of specific events) are *not stored* in the hippocampus, as once believed, but are stored *outside* the hippocampus. We now know that information from certain memories that are *temporarily* stored in the hippocampus are transferred to the neocortex as for permanent long-term storage (look back at pages 57, 69f).

Further research on other patients with hippocampal damage confirmed that recent memories are more impaired than distant ones providing additional evidence that the hippocampus provides temporary storage for new information whereas other areas may handle long-term memory. Events that we are later able to remember appear to be channelled to the neocortex for more permanent storage.

The study of Patient H.M. greatly contributed to our understanding of memory and the role of the hippocampus in memory formation. Here was a man who, one could argue, created the modern discipline of cognitive neuroscience, not by his brilliance or *ability* but, instead, by his mental *dis*ability!

Website readings

1. Refer to Website #A40 for articles on where memories are stored.
2. Refer to Website #A41 for long-term memory (good article).
3. Refer to Website #A42 for article on 'Henry Molaison dies'.

Diseases, conditions and drugs that affect long-term memory

Note: The material below overlaps with that above for working memory and short-term memory as all involve similar brain regions. Have a look at this previous material.

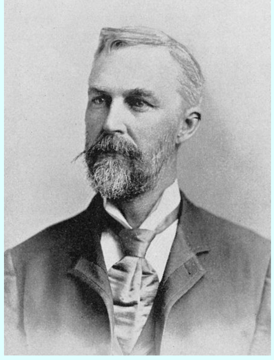
1 Alzheimer's disease: As mentioned earlier, Alzheimer's disease also affects both working-memory and short-term memory. In the early stages of the disease, individuals may experience mild forgetfulness and memory loss mainly related to recent events or new information (look back at short-term memory and Alzheimer's disease, pages 71f).

As the disease progresses, it begins to interfere with long-term memory as well. This happens in two different ways: A person can have difficulty in:
(i) *storing* the information in long-term memory, and
(ii) *retrieving* it from long-term memory.
A person can forget *important life events* (e.g. weddings), *names* of family members and friends, and other significant memories from their past. And in the late stages of Alzheimer's, your loved one might not even be able to demonstrate an awareness of your presence.

These effects are due to the degeneration of neurons in the hippocampus and surrounding areas leading to the loss of connections between neurons (synaptic connections). This loss disrupts the communication between brain regions involved in memory processing and *storage*. Consequently, the *retrieval* of previously formed long-term memories then becomes increasingly difficult, leading to the aforementioned memory deficits as the inability to remember events, facts, or people from the past.

Website reading: Refer to Website #A43 for long-term memory and Alzheimer's Disease.

2 Huntington's disease: Huntington's disease is a rare inherited but non-fatal disease, which affects long-term memory, for which there is no cure. It is caused by the progressive degeneration of neurons in certain brain structures, particularly the *basal gangli*a and parts of the cerebral cortex (cf. Alzheimer's disease which is due to degeneration of neurons in the *hippocampus*). The disease was named after George Huntington (pictured, right), an American physician who described the condition in 1872 (at the age of just 22!).



George Huntington (1850 - 1916)

Symptoms of Huntington's disease include, but are not limited to:

1. Movement problems, such as jerking or twitching in the arms, legs, face, or torso, may be one of the earliest symptoms.
2. Memory loss and difficulty in learning new things.
3. Physical decline: In advanced stages, individuals may have difficulty swallowing, speaking, and eating. They may also experience weight loss, weakness, and decreased coordination, making it challenging to perform daily activities.

Website reading: Refer to Website #A44 for the outlook for people with Huntington's Disease.

3 Sleep deprivation: Sleep deprivation, mentioned earlier, affects short-term memory. It also affects long-term memory where the effects tend to be more long-lasting and pervasive.

When we sleep, our brain *consolidates* and processes the information we have learned during the day, transferring it from short-term memory storage* to long-term memory storage in parts of the neocortex. It is believed that sleep supports the reactivation and replay of memories, facilitating their integration into existing long-term networks networks and enhancing their long-term storage. Hence the importance of sufficient and quality sleep for optimal memory consolidation.

Michael Jackson (1958 - 2009)

Sleep deprivation impairs this process by impairing the functioning of the *hippocampus* which is needed to integrate newly acquired information into long-term storage in the neocortex. Moreover, sleep deprivation can also disrupt the normal functioning of the *prefrontal cortex*.

Additionally, chronic sleep deprivation can contribute to the development of cognitive disorders such as Alzheimer's disease and dementia.

Michael Jackson was one person who suffered from severe sleep deprivation.

4 Alcohol: We saw earlier the effect of alcohol on the neurotransmitter *dopamine* and its effect on short-term memory. But alcohol also affects another neurotransmitter called GABA (*gamma-aminobutyric acid*).

GABA is an inhibitory neurotransmitter, which normally inhibits/lessens the effects of *excitatory* neurotransmitters, thereby helping to calm down brain activity! Alcohol *increases* the release of GABA, thus *increasing* its inhibitory activity, which contributes to the sedative and calming effects of alcohol.

Unfortunately, this increase of GABA also interferes with the *consolidation* of new memories into long-term memories by causing damage to areas of the brain, especially the *hippocampus*, which is crucial for storage in long-term memory.

***More on sleep and memory consolidation**

Also as mentioned earlier, short-term memory typically has a limited duration. However, if the information is deemed important, it may remain longer and can undergo consolidation during sleep to be stored in long-term memory. During sleep, the brain experiences different stages, including non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep. Both stages play a role in memory consolidation. NREM sleep is essential for consolidating *declarative* memories, which include facts and events; memories from the hippocampus, where they were initially stored, are transferred to the neocortex for long-term storage. Additionally, REM sleep is linked to the consolidation of *procedural* memories, which involve learning and remembering skills or tasks. This stage of sleep helps enhance motor learning and integrates information obtained during wakefulness.

Brain regions for Visual Deficiencies

We look at the parts of the brain associated with the visual deficiencies of: **change blindness, inattentional blindness** and **blindsight**.

1 Change blindness

The parts of the brain that affect change blindness are largely those that are involved in visual perception and attention. Specific brain areas involved can include the prefrontal cortex, parietal lobe, occipital lobe and parts of the temporal lobe. Specifically, the prefrontal and parietal areas are important in directing attention towards particular stimuli and processing the information that is received. The occipital lobe is also heavily involved in visual perception and is responsible for detecting changes in visual stimuli.

These parts of the brain function by working together to identify changes in the environment and to effectively process the information that is being received. However, these areas may be subject to limitations in attention or processing abilities, leading to an inability to detect the changes that occur. This can occur due to a variety of factors, including distractions, limitations in perceptual abilities, and other cognitive factors.

2 Inattentional blindness

Unlike change blindness, inattentional blindness primarily involves *attentional* processes rather than difficulties in comparing visual representations, because attention is focused on something else. But the brain regions implicated in inattentional blindness are *similar* to those involved in change blindness, including the prefrontal area, parietal lobe, occipital lobes, as well as the parts of the temporal lobe.

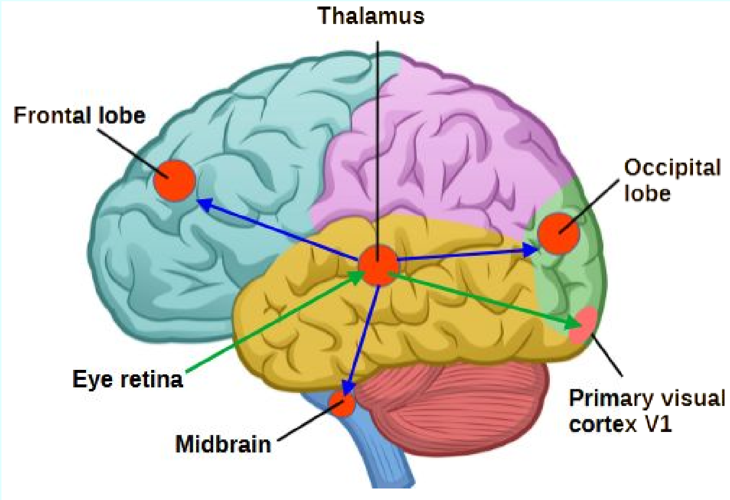
While there is overlap between the brain regions involved in change blindness and inattentional blindness, it is important to note that they do not always coincide. The specific brain mechanisms and areas activated can vary depending on the nature of the task, the stimuli involved, and differences in individuals. The study of consciousness and these related phenomena is complex, and further research is needed to fully understand the precise neural mechanisms underlying them.

3 Blindsight

Look back at pages 19f, 25f, 43, 74ff for earlier discussions on blindsight and particularly how 'secondary' regions of the brain help people with blindsight to have some unconscious visual awareness.

Brain regions involved in blindsight include areas that surround the primary visual cortex (V1), the midbrain and a part of the thalamus. The thalamus acts as a relay station between different brain regions and is believed to play a crucial role in transmitting visual information to brain regions involved in blindsight.

Blindsight occurs because the visual system has a **primary** pathway (eye retina to thalamus to primary visual cortex V1, shown in the diagram in **green**), but it also has **secondary** pathways (eye retina to thalamus to *other* brain areas, shown in **blue**). These 'other brain areas' include parts of the frontal lobe that guide eye movements, parts of the midbrain that help guide visual attention, and parts of the occipital lobe that process features of the visual perception, including shape, movement and colour.



Because of the *secondary* pathways, the other brain areas *get some direct visual information* (i.e, input that does *not* first go to the primary visual cortex V1) which means that it is possible for a person to respond accurately to questions about colour or motion or shape *without consciously 'seeing' the objects* that, for example, have colour or shape or are moving.

It is important to remember that all of us have these same 'unconscious' secondary pathways in our visual system. That means our conscious experiences of the visual world may not include all of the visual information we are processing. In other words, we may 'know' more than we 'see.'

It is also important to note that blindsight is a complex and dynamic phenomenon, and understanding its underlying mechanisms is still an active area of research. The involvement of these brain regions suggests that unconscious visual processing in blindsight occurs through *alternative* neural pathways that bypass the damaged visual cortex.

Website reading: Refer to Website #A45 for more on consciousness and blindsight.

Summary: Main Points

A summary is included as it can be difficult to recall accurately the main points when there is so much information – and that includes me too, and I wrote the article!

What is consciousness?

- Several definitions. One is: The state of being aware of and responsive to one's surroundings. [Oxford dictionary]
- Most people, including people with diseases, such as Alzheimer's disease, live with consciousness. But people in a coma are probably living *without* consciousness.
- Consciousness is studied by three groups of people: philosophers, cognitive psychologists and neuroscientists. All try to explain what it is.
- Some authorities doubt that a satisfactory explanation of consciousness will ever be achieved.
- It is possible that a comprehensive understanding of consciousness may require a multi-disciplinary approach that includes philosophy, psychology as well as neuroscience.

The thoughts of some past philosophers

- Thinking about consciousness goes back at least to the Greek philosopher Plato. His philosophy is dualistic in nature. He proposed a *dualistic* view of man which has *two* opposing components, a mortal body, which is evil, and an immortal soul (or mind).
- Old Testament Hebrews believed in *monism*; the body and soul were one and inseparable.
- Plato's *dualism* influenced the development of Christianity, initially though Philo of Alexandria (who lived during the time of Christ) who separated a mortal body and an immortal soul.
- Western philosophers of significance who struggled to comprehend the nature of consciousness were Rene Descartes (1596 – 1650) and John Locke (1632 – 1704).
- Descartes proposed *substance dualism*: a body consisting of a substance, and a mind (soul) of a non-physical substance. (A substance for Descartes differed from ordinary matter/substances.)
- Locke proposed *existence dualism*, a variation of Descartes' substance dualism. There are two kinds of existence – a *primary* (or *objective*) existence for the *physical* properties of objects, and a *secondary* (*subjective*) existence for how we mentally perceive the same objects. This view is close to what many philosophers accept today.

Philosophical positions on consciousness

- *Dualism* is either substance dualism or property dualism. *Monism* is of three kinds: physicalism, idealism or neutral monism.
- Substance dualism (i.e. *two* substances) is that of Descartes and of Locke's existence dualism. The body is a *physical* 'substance' while the mind is also a 'substance' but a *non-physical* 'substance.'
- Property dualism: Only one kind *substance/matter* exists but two kinds of *properties* exist. The brain, made of matter, has *physical* properties. The mind is *not* made of matter and has its own mental (non-physical) properties.
- Monism – physicalism: Everything in the world, including human consciousness and experiences, is entirely physical, composed of matter, and can be explained by physical processes in the brain and nervous system (which is made of matter).
- Monism – Idealism: *Nothing* consists of matter; everything that exists is mental/mind or spiritual.

- Neutral monism: *Both* mind and matter are made of some ‘stuff’ (undefined).
- I, like David Chalmers, tend to be a property dualist.
- Many neuroscientists think animals may have consciousness. Evidence comes from the mirror test.
- Some philosophers even suggest that consciousness is present in *all matter* and not just in animals.
- Those who accept the idealism type of monism hold that consciousness exists after death.

Two kinds of knowledge

- Knowledge is either objective or subjective.
- Objective knowledge is like scientific facts; it exists independently of what we might think.
- Subjective knowledge is based on personal beliefs or feelings and not on facts and so will differ from person to person.

Two kinds of consciousness

- These are access consciousness (or A-consciousness) and phenomenal consciousness (or P-consciousness).
- Access-consciousness is information from the environment that enters sensory memory which we access and become consciously aware of and can report on. This information is objective.
- Access of this information only occurs if we pay attention. The information attended to is accessed and passes into our short-term memory where we become aware/conscious of it.
- In short-term memory the objective information, tends to change to form our own personal view of the surroundings, that is, a subjective view.
- This subjective information is referred to as our phenomenal-consciousness (or P-consciousness).
- From short-term memory, this information may pass into long-term memory.
- The specific subjective experiences in our P-consciousness are termed qualia.
- When scientists do experiments and make measurements using apparatus, they get objective/scientific facts. When talking to non-scientists, they probably do not use this scientific information but, like us, use their *subjective*, personal information.

Consciousness: the ‘easy’ versus the ‘hard’ problem

- The ‘easy’ problem of consciousness refers to explaining how *objective* experiences/facts arise from processes in the brain, and specifically the patterns of neural activity involved.
- The ‘hard’ problem of consciousness refers to the difficulty in explaining how *subjective* experiences, such as colours, sounds, tastes, emotions arise from physical processes in the brain, and specifically what specific patterns of neural activity are involved.
- Phenomenal-consciousness, which consists of *subjective* phenomena, poses a greater challenge for neuroscientists to explain what happens in the brain as it is not the same for everyone.

Can we have one type of consciousness without the other?

- Can we have P-consciousness without A-consciousness? Maybe. Some information in the sensory memory may be accessed and passed into short-term memory *without* having focused *attention* on them.
- Examples of ‘P-consciousness without A-consciousness’ include things that happen around us that we are not aware of, for example, clothes rubbing on our skin and the ticking of a clock in the background.
- Lack of *conscious* attention seems to best explain the idea of P-consciousness without A-consciousness.

- A-consciousness without P-consciousness is less widely accepted than P-consciousness without A-consciousness. Examples are still hypothetical. Examples commented on in the text are those of a zombie and of blindsight.

Access consciousness and kinds of blindness

- Inattentional blindness: The phenomenon of failing to notice things because attention is focused on something else (even when eyes are open!). The 'invisible gorilla test' illustrates this.
- Other examples of inattentional blindness are inattention while driving, multi-tasking, magicians' tricks.
- Change blindness: The failure to notice an obvious change in a visual scene even when it happens right in front of our eyes and is obvious and noticeable. It occurs when we access much less mush less of the information that enters sensory memory than we think we do.
- Examples of change blindness: Failing to notice changes in surroundings when talking to someone, not noticing changes in colours of objects, driving and failing to notice the change in a scene, witnesses to an accident who cannot agree on the details of what happened.
- The cause of inattentional blindness and change blindness *may* be due to a lack of A-consciousness because of a lack of attention on information in sensory memory.
- Blindsight (see above): Some people with visual problems are able to 'see' things. It is caused, not due to problems with the eyes, but to damage of the primary visual cortex in the brain; other areas of the brain process visual information *unconsciously* allowing people with blindsight to 'see' without awareness.
- Blindsight is a case of A-consciousness without P-consciousness.
- Deaf *hearing* is related to blind-*sight*.

The hard and easy problems of consciousness

- The hard problem is the challenge of explaining how our *subjective* experiences, such as colours and tastes (the qualia of P-consciousness), arise from physical processes involving the neurons in the brain.
- The hard problem is related to *property* dualism; the mind is not made of matter and so has non-physical/mental properties *not explainable* in terms of neurons. The difficulty is trying to explain these mental/non-physical subjective properties of the mind in terms of physical neurons is called the explanatory gap.
- The explanatory problem is a big problem for the kind of monism called physicalism which holds that everything in the world is physical and explainable in the physical brain and its neurons.
- The hard problem is very controversial. Not everybody agrees there is a hard problem.
- The hard problem is not new: Locke, Leibniz and even Newton realised it, though they did not refer to it as the 'hard' problem.
- In contrast, the (so-called) easy problems of consciousness concern understanding the neural processes that accompany behaviour, for example, the *physical* explanation for pain (though not the subjective, personal feelings which can vary a lot).
- A related idea is that of a 'philosophical zombie' which, although physically indistinguishable from a normal person, would lack subjective consciousness or awareness. It is impossible (not just a hard problem) to prove it has have conscious experience. It is merely a complex machine that reacts to external stimuli without any internal mental processes.

- Some have suggested that blindsight patients are like zombies. They respond appropriately to visual stimuli (e.g. avoiding objects when they walk) even though they have no conscious awareness of seeing the objects because they cannot visually see them. This may be how a zombie might react.

Clones and identical twins

- The clone of an animal or a person would not have the same consciousness as the *single* being from which it was derived. Consciousness is not solely determined by biology; it also stems from experiences, memories, and emotions.
- Similarly, identical twins, though having the same genetic make-up, are derived from two parents and so are two different people with their own individual consciousness.

Consciousness: we are living in the past

- Light from objects takes time to reach the areas of the brain where we perceive the objects. Hence we perceive what happened (slightly) in the past.
- Perception of moving objects could be a problem in the playing of sports as a moving ball is always (slightly) closer to us that we perceive. However the brain seems to compensate for this and predicts the real position of a ball so players still catch or hit the ball correctly.

Consciousness: Why am I me?

- Each of us develops a unique consciousness. However, the exact mechanism of how an individual consciousness emerges from the brain activity is still a mystery to neuroscientists. So the question "Why am I me?" still does not have an answer.

Model of human memory

- Consciousness is studied by philosophers, cognitive psychologists and neuroscientists. The model of human memory is a psychological model.
- Memory is simply the ability to remember past experiences.
- The parts of the model include: sensory organs, sensory memory, short-term memory, working memory and long-term memory. Working memory is a sub-part of short-term memory.
- The approximate times memories hold information: sensory memory: 500 milliseconds to 1 ~ 3 seconds. short-term memory and working memory: < 1 minute. Long-term memory: days, months, years, lifetime.

Sensory memory

- Sensory memory is the first stage in the model of human memory. Its does not require conscious attention.
- Attention is *not* needed for information to enter sensory memory. But once entered, it must be attended to in order to pass it on to the short-term memory.
- If the information in sensory memory is not attended to, it fades and disappears, which happens a lot of the time as it impossible to be focus attention on everything in the world around us.
- The duration of sensory memory was investigated by George Sperling by displaying 3 x 4 letter arrays for just 1/20th of a second. This gave only enough time for four to five letters to be attended to; the other letters faded and disappeared too quickly. Conclusion: Duration in sensory memory is very brief.
- Iconic memory is the name used for storage of visual information.
- Other kinds of sensory memories are echoic memory (for sounds), haptic memory (for touch),

gustatory memory (taste) and olfactory memory (smell).

- Content in sensory memory that *is* attended to is accessed and passes into short-term memory, where we become consciously aware of it and can report on it.

Sensory memory and attention

- There are two kinds of attention: 'Attention' and 'Selective attention.' In the latter, which is common in real life, the focus is on a specific stimulus while ignoring or filtering out distracting stimuli, though other stimuli not completely ignored, for example, background conversation at a party.
- Wakefulness enhances our ability to focus selectively on information that enters sensory memory.

Short-term memory (STM)

- Short-term memory holds a small amount of information received from sensory memory in a *conscious* but *passive* form for a short period of time, typically for a few seconds to a minute or two before it fades and disappears.
- So, a phone number we hear will disappear forever from short-term memory unless we make a conscious effort to retain it, such as by deliberately repeating it to ourselves. This conscious repetition of the number occurs in the working memory, the sub-set of short-term memory and such repetition requires conscious attention.
- Short-term memory is associated with access-consciousness as it accesses information from sensory memory for *passive* storage.
- The capacity of short-term memory is much less than that of sensory memory. Hence it makes sense to focus attention just on information in sensory memory that we want to enter short-term memory.

Working memory (WM)

- Working memory is where we consciously *manipulation* information (such as a phone number).
- When active manipulation is finished, the modified information becomes part of short-term memory again. But this memory is still only 'short-term' as it will fade and disappear unless it passes into long-term memory for permanent (perhaps) storage.
- Working memory, like short-term memory, has limited capacity. So more attention on one item means less is available for other items.
- Working memory, like sort-term memory, is also associated with access-consciousness as it accesses information from short-term memory. The difference is that in working memory, the information is actively manipulated.
- Working memory *may* involve *unconscious* processing. Examples include driving without being consciously aware of everything action taken, and blindsight where people seem to be aware of seeing things without being *consciously* aware of seeing them.
- In humans, the ability to do tasks involving working memory is believed to increase gradually over childhood and decline gradually in old age.

Long-term memory (LTM)

- The transfer of information from short-term memory to long-term memory makes the memory for the information more enduring or even permanent. This is known as *consolidation*.
- Long-term memory is believed to be organised into different categories, such as episodic memory (for specific events), semantic memory (for general knowledge), and procedural memory (for skills and procedures).

- The capacity of long-term memory seems unlimited, and can last days, months, years, or even an entire lifetime – unless it is forgotten!
- Effective consolidation in long-term memory is *less* effective with: lack of attention to the task, stress, overload (too much to remember), lack of related knowledge for elaboration, ageing.

Capacities of human memories

- Sensory memory: very large amount of information but only for a few milliseconds.
- Short-term memory and working memory: 4 ± 1 items, that is around 3 to 5 pieces of information.
- Long-term memory: not known but is believed to be unlimited.
- As children grow older, capacity of short-term memory/working memory increases; by the age of 10 and through adulthood, most can hold around 7 ± 2 items.

Chunks and chunking

- Capacity of memory is a function of the number of items, *not* their size.
- The individual bits/items of information held in short-term memory and working memory are referred to as chunks.
- The chunking/grouping of smaller items into larger items can enhance learning and recall.
- Chunking can be done for most tasks. Examples: letters into words, words into sentences, grouping individual numbers into larger meaningful units, foreign language learning (breaking a long sentence into small chunks then, when are understood, combining them again into the original, longer sentences).

Multi-tasking

- Multi-tasking is trying to do several tasks at the same time. It is impossible! A myth!
- Attempting to multi-task can increase the likelihood of both inattentional blindness and change blindness because attention is directed away from important stimuli or changes in the environment.
- Noise (and human memory): Information that is irrelevant or distracting and so interferes with the task or information being remembered. This can occur in multi-tasking.

Neuroscience and consciousness

- Neuroscience is the scientific study of the brain and the nervous system. Consciousness is studied by neuroscientists.
- Neuroscientists want to understand how the action of neurons explain consciousness of both objective experiences (the actual/factual parts) and subjective (personal) experiences.
- Trying to explain subjective experiences relates to the hard problem of consciousness.
- According to the philosophy of physicalism, everything that exists including the brain, is physical and so can be explained in terms of neural processes in the brain.

Neural correlates of consciousness (NCCs)

- Neuroscientists have decided that instead of looking for an explanation of the *neural* processes of consciousness, they should just look for a correlation between neural processes and aspects of consciousness.
- In practice, this means finding regions in the brain that seem to be correlated with particular conscious experiences. For example, working memory seems to be located in the prefrontal cortex.
- Techniques used for this include Magnetic Resonance Imaging (MRI), Functional Magnetic Resonance

Imaging (fMRI), Electroencephalography (EEG), Positron Emission Tomography (PET), and Magneto-encephalography (MEG).

Key regions of the brain

- The major regions of the brain are the cerebral cortex, cerebellum, brainstem and spinal cord.
- The cerebral cortex is the outermost layer of the brain and is the largest part of the brain. A very thin layer on the very outermost part of most of the cerebral cortex is called the neocortex.
- The cerebral cortex has four regions called lobes: frontal, parietal, occipital and temporal.
- Key parts inside the cerebral cortex include the hippocampus, the thalamus, the hypothalamus, the amygdala, the basal ganglia and the substantia nigra.

Visual perception of a word and an image

- In the visual perception of a word, a signal from the retina of the eye travels via the thalamus to the primary visual cortex (V1) then to the prefrontal cortex where perception occurs. The total time for this process is about 350 ms.
- Perception of an image is faster than for a word, taking about 150 ms. The signal from the retina again passes via the thalamus to the primary visual cortex (V1) then via the inferior temporal lobe to the medial temporal lobe and the prefrontal cortex.

Sensory memory – brain regions

- Sensory memory is stored in several lobes of the cerebral cortex.
- Iconic memory (visual) in the occipital lobe, especially V1. Echoic memory (sound) in the temporal lobe, especially A2. Haptic memory (touch) in part of the parietal lobe.

Attention – brain regions

- Many parts are involved. The prefrontal cortex in the frontal lobe is a major player in attention.
- Other regions involved include the parietal lobe, the thalamus, amygdala, hippocampus, basal ganglia and brainstem.
- Parts of the brainstem are crucial for maintaining wakefulness and alertness, which are essential for attention.
- The PITd in the temporal lobe is important for *selective* attention, particularly for the identification of complex objects such as faces, animals, and objects with specific shapes.

Working memory – brain regions

- The prefrontal cortex plays *the* key role in working memory, especially for current reasoning.
- Other brain regions include the posterior parietal lobe, the thalamus, the basal ganglia, the hippocampus, and even the cerebellum (possibly).
- The hippocampus is involved in the temporary storage and manipulation of information that is needed for current tasks. It is also involved in memory consolidation, the converting of memories into long-term memory.
- Working memory is also needed for procedural (skill) learning. For example, to learn to ride a bike, the learner must consciously focus attention on the steps involved. This involves the basal ganglia.
- Conditions and disorders that affect working memory include: ageing, brain injury, stress and depression, ADHD (Attention deficit hyperactivity disorder), schizophrenia, Parkinson’s disease and Alzheimer’s disease.

Short-term memory – brain regions

- Similar to those for working memory though *without* the cerebellum. Again how all the parts work together remains unclear.
- The hippocampus is where short-term memories are formed before they are passed to the neocortex for more stable long-term storage. It also assists in retrieving information from long-term memory when needed and passing it into short-term memory.
- Conditions, diseases and drugs that affect short-term memory include brain injury, Parkinson's disease, Alzheimer's disease, sleep deprivation, depression and alcohol. Alzheimer's disease is caused by the accumulation of two abnormal substances in the brain – beta-amyloid plaques and tau tangles.

Long-term memory – brain regions

- There are two kinds of long-term memory – declarative memory and procedural memory. Declarative memory is an *explicit* memory for both semantic and episodic memory. Procedural memory is an *implicit* memory for learned skills and procedures.
- Key brain regions are also similar to those for working memory but include the amygdala though not the basal ganglia.
- The hippocampus, as mentioned above for short-term memory, is the key region for consolidation of new memories in long-term memory.
- The thalamus is also involved. Attention, repetition when learning, sleep and rest stimulate the thalamus and promote long-term memory storage.
- The key role the hippocampus plays was shown in the case of the patient Henry Molaison.
- Diseases, conditions and drugs that affect long-term memory include Alzheimer's disease, Huntington's disease, sleep deprivation and alcohol. These overlap with those for working memory and short-term memory as all involve similar brain regions.

Brain regions for three visual deficiencies

- Change blindness: Largely those that are involved in visual perception and attention such as the prefrontal cortex, parietal lobe, occipital lobe and parts of the temporal lobe.
- Inattentional blindness: prefrontal area, parietal lobe, occipital lobes, as well as the parts of the temporal lobe.
- Blindsight: Includes areas that surround the primary visual cortex (V1), the midbrain and a part of the thalamus. Two pathways are involved. Primary pathway (retina to thalamus to V1). Secondary pathway (retina to thalamus to frontal lobe, occipital lobe and midbrain).

Glossary

Here is a list of difficult or specialised words used in this project together with their definitions or meanings, in alphabetical order.

Access-consciousness: Information from the environment that we access and become consciously aware of and can report on.

Attention: The overall level of alertness or ability to engage with our surroundings.

Blindsight: Blindsight is a condition in which a person who is blind or has impaired vision still seems to exhibit limited visual processing without consciously seeing things.

Cartesian dualism: (see Substance dualism)

Cerebral cortex: The outermost layer of the brain and is a major part of the brain (sometimes referred to simply as the cortex).

Cerebrum: The part of the brain above and forward of the cerebellum; it is the largest part of the brain.

Change blindness: The failure to notice an obvious change in a visual scene even when it happens right in front of our eyes and is obvious and noticeable.

Chunk: An individual bit/item of information held in short-term memory and working memory.

Chunking: The process of grouping or combining several individual chunks into a single but larger chunk. Chunking can enhance learning and recall.

Clone: An organism that is genetically identical to another organism.

Consciousness: The state of being aware of and responsive to one's surroundings. [Oxford dictionary]

Consolidation: The transfer of information from short-term memory to long-term memory to make it more enduring or even permanent.

Cortex: The outer layer (not the inner parts) of a body structure such as the brain

Cortical neuron: The type of neurons found in the cerebral cortex of the brain.

Declarative memory: A type of long-term memory that involves the conscious recollection of facts, events, and information. It is also known as explicit memory. It is further broken down into semantic memory and episodic memory.

Deaf hearing: The ability in individuals who are deaf or hard of hearing to sense sound vibrations through parts of their body, such as the skin or bones, and perceive sound in a way that is not conscious.

Dualism: The division of something into two opposed ideas, for example, mind-matter, heaven-hell, body-soul and spiritual-secular.

Easy problem (of consciousness): Explaining how *objective* properties arise from processes in the brain, and specifically, the brain processes and patterns of neural activity involved.

Elaboration: The linking of information to other information and to prior knowledge to form a large network of related ideas.

Episodic memory: Memory that involves the recollection of specific events, situations, and experiences that have occurred at a particular time and place in a person's life.

Existence dualism (John Locke): The perception of what passes in a man's own mind (a modified form of substance dualism).

Explanatory Gap: The difficulty that *physicalist* philosophies have in explaining how *physical* properties of the brain give rise to the way things feel subjectively when they are experienced.

Hard problem (of consciousness): The difficulty in explaining how *subjective* experiences arise from physical processes in the brain, and specifically, the specific patterns of neural activity involved.

Hippocampus: A small C-shaped structure embedded deep inside the temporal lobe.

Iconic memory: The sensory memory store for *visual* information.

Idealism: Nothing is made of matter; everything that exists is either mental or physical.

Inattentional blindness: The phenomenon where individuals fail to notice things because their attention is focused on something else.

Long-term memory: The storage of information over an extended period of time, ranging from minutes to years or even a lifetime.

Memory: The ability to remember past experiences.

Multi-tasking: (of a person) Trying to do more than one task at the same time.

Monism: All things, including the mind and body, consist of a single substance.

Neocortex: The very thin layer on the very outermost part of most of the cerebral cortex.

Neuron (also called a nerve cell): A specialised cell that transmits information throughout the body via electrical and chemical signals.

Neuroscience: The science that deals with the structure and function of the brain and nervous system. A scientist who studies the brain and nervous system is a **neuroscientist**.

Neurotransmitter: A chemical that moves across a space (called a synapse) from one neuron (nerve cell) to the next in the brain.

Neutral monism: Everything is made of just one fundamental substance and both mental and physical properties are two aspects or dimensions of this one substance.

Noise (and human memory): Information that is irrelevant or distracting and so interferes with a task, or with information being remembered. This can occur in multi-tasking

Objective: Factual data that is always the same and is not influenced by personal beliefs or feelings.

Panpsychism: Consciousness is a fundamental property of the universe and is present in all matter and not just in animals.

Phenomenal consciousness: The subjective, first-person experience of of being aware of the content of our surroundings.

Physicalism: Everything in the world, including human consciousness and experiences, is physical, that is, composed of matter.

Procedural memory: The acquisition of skills and habits through repetition and practice until the necessary actions can be performed without actively thinking about each step involved.

Property dualism: The world is composed just one kind of substance – the physical kind – but there exist two distinct kinds of properties – physical properties and mental properties.

Qualia: The specific subjective experiences of phenomenal consciousness.

Schizophrenia: A mental disorder in which people interpret reality in an abnormal way.

Selective attention: This is the ability to concentrate on a specific stimulus while ignoring or filtering out distracting stimuli.

Semantic memory: A type of long-term memory that involves the storage and retrieval of general knowledge about the world, including concepts, facts, and language.

Sensory memory: The first stage of memory processing, where sensory information from the environment is briefly retained in its original sensory form.

Severe anterograde amnesia: The type of amnesia (memory loss) where an individual experiences profound difficulty in forming *new* memories after a particular event or injury. The ability to recall events and memories prior to the onset of amnesia may remain intact.

Short-term memory: The capacity to store and hold a small amount of information received from sensory memory in a conscious but passive form for a short period of time.

Subjective: Something based on personal beliefs or feelings, rather than based on facts.

Substance (as defined by Descartes): An immaterial substances such as the mind.

Substance dualism: There are two distinct kinds of substances – physical substances (such as bodies and brains) and non-physical substances (such as the mind). These substances are separate and distinct from each other.

Wakefulness: The state of being awake, alert, and responsive to the surrounding environment.

Working memory: A part of short-term memory that allows the brain to temporarily hold onto information for a brief period of time while manipulating it.

Zombie: In the context of consciousness studies, a zombie refers to a hypothetical being that is physically identical to a human being but lacks consciousness and subjective experience.

Website References

The following is a list of websites used in writing this project. The list consists of three parts:

A. Websites referred to in the text.
B. Website references for writer's other projects that are referred to in the text.
C. Other websites which I have read and got ideas from but which are sometimes difficult and most of which have not been referred to in the text. They provide background reading that readers may like to refer to.

Some of the websites are very good, others marginally so. Some of the websites are not too difficult to understand; others are more difficult. There are many other websites available on the Internet for most of the topics discussed in the project, but while some of these may be very good and have been missed, it is just too time consuming to have to search through so many.

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https://www.rockefeller.edu/news/33790-scientists-discover-brain-region-linking-short-term-to-long-term-memory/

37. Online digit span test
https://tools.timodenk.com/digit-span-test

38. Alzheimer's and short-term memory
https://www.verywellhealth.com/short-term-memory-affected-by-alzheimers-98569

39. Cerebellum and procedural knowledge
https://en.wikipedia.org/wiki/Neuroanatomy_of_memory

40. Where memories are stored
https://news.mit.edu/2017/neuroscientists-identify-brain-circuit-necessary-memory-formation-0406
https://www.scientificamerican.com/article/where-does-the-brain-store-long-ago-memories/
https://qbi.uq.edu.au/brain-basics/memory/where-are-memories-stored
https://www.scientificamerican.com/article/where-does-the-brain-store-long-ago-memories/

41. Long-term memory
https://maze.conductscience.com/long-term-memory/

42. Henry Molaison dies
https://ahp.apps01.yorku.ca/2008/12/henry-molaison-dies/

43. Long-term memory loss and Alzheimer's Disease
https://www.verywellhealth.com/long-term-memory-and-alzheimers-98562

44. Outlook for people with Huntington's Disease
https://www.healthline.com/health/huntingtons-disease-prognosis

45. Consciousness and blindsight
https://courses.lumenlearning.com/waymaker-psychology/chapter/psych-in-real-life-consciousness-and-blindsight/
https://www.scientificamerican.com/article/uncanny-sight-in-the-blind/

B. Websites for writer's projects referred to in text

1. Psychology of Learning and Teaching
http://rmheyworth.byethost11.com/Files/Psychologyoflearningandteaching.pdf

2. Transmission of Nerve Impulses
https://drive.google.com/file/d/1uS-XrmON_EA6LVc4ZgHgqK6ap2iFf1qp/view

3. The Republic of Plato
http://rmheyworth.byethost11.com/Files/TheRepublicofPlato.pdf?i=1

4. The Brain and Body Movement: Level 1
http://rmheyworth.byethost11.com/Files/MovementLevel1.pdf

5. The brain and Body Movement: Level II
https://drive.google.com/file/d/1Y11B6rxwLhuDX3oMvb5iwcJ-hMo2X1_1/view

C. Websites for additional reading

Occasional references from some of these websites are made in the text. But they are mainly for additional reading. Note: Some of these articles allow a pdf version to be downloaded; I recommend to do this as they tend to be easier to read.

1. The Prince and the Cobbler
https://rintintin.colorado.edu/~vancecd/phil1020/Locke4.pdf
https://examinedlifeeducation.com/vce-philosophy-locke-personal-identity/
https://medium.com/@michaelkingsley/locke-on-personal-identity-10d8b052c8e7

2. Property dualism
https://press.rebus.community/intro-to-phil-of-mind/chapter/property-dualism/

3. Neutral monism
https://www.wikiwand.com/en/Neutral_monism

4. A New Theory in Physics Claims to Solve the Mystery of Consciousness
https://neurosciencenews.com/physics-consciousness-21222/

5. Perceptual consciousness and cognitive access
https://royalsocietypublishing.org/doi/10.1098/rstb.2017.0340
https://royalsocietypublishing.org/doi/10.1098/rstb.2017.0343
https://royalsocietypublishing.org/doi/10.1098/rstb.2017.0353

6. Inattentional Blindness in Psychology
https://www.verywellmind.com/what-is-inattentional-blindness-2795020

7. Hard problem of consciousness
https://en.wikipedia.org/wiki/Hard_problem_of_consciousness

8. What is consciousness
https://en.wikipedia.org/wiki/Consciousness
https://www.psychologytoday.com/us/blog/the-superhuman-mind/201303/what-is-consciousness
https://www.psychologytoday.com/intl/blog/consciousness-and-beyond/202305/what-is-consciousness

9. Experiencing without knowing? Empirical evidence for phenomenal consciousness without access
https://www.sciencedirect.com/science/article/pii/S0010027723001634?via%3Dihub

10. Phenomenal consciousness and cognitive access
https://royalsocietypublishing.org/doi/10.1098/rstb.2017.0353

11. Why and how access consciousness can account for phenomenal consciousness
https://royalsocietypublishing.org/doi/10.1098/rstb.2017.0357

12. Perceptual consciousness and cognitive access from the perspective of capacity-unlimited working memory
https://royalsocietypublishing.org/doi/10.1098/rstb.2017.0343
13. Facing up to the hard question of consciousness
https://royalsocietypublishing.org/doi/10.1098/rstb.2017.0342
14. Consciousness (Stanford article)
https://plato.stanford.edu/entries/consciousness/
15. Consciousness: The last 50years (and the next)
https://journals.sagepub.com/doi/10.1177/2398212818816019
16. A New Theory in Physics Claims to Solve the Mystery of Consciousness
https://neurosciencenews.com/physics-consciousness-21222/
17. Consciousness after death
https://philarchive.org/archive/KASTIV
https://www.interaliamag.org/articles/philip-nova-can-consciousness-continue-after-death-a-neuroscientific-perspective/
18. What if consciousness is not an emergent property of the brain? Observational and empirical challenges to materialistic models
https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2022.955594/full
19. Qualia
https://encyclopedia.thefreedictionary.com/Qualia
20. Colour change blindness
https://www.mdpi.com/2411-5150/3/4/61
21. What is Consciousness?
https://www.scientificamerican.com/article/what-is-consciousness/
22. Hard problem of consciousness
https://en.wikipedia.org/wiki/Hard_problem_of_consciousness
https://encyclopedia.thefreedictionary.com/Hard+problem+of+consciousness
23. Blindsight: the strangest form of consciousness
https://www.bbc.com/future/article/20150925-blindsight-the-strangest-form-of-consciousness
24. Neural correlates of consciousness
https://en.wikipedia.org/wiki/Neural_correlates_of_consciousness
25. Dualism, Reductionism, and Reflexive Monism
https://www.researchgate.net/publication/315427597
26. Unconscious Vision
https://www.rsb.org.uk/biologist-features/double-vision
27. Chalmers and the zombie plus the zombie blues
https://www.theguardian.com/science/2015/jan/21/-sp-why-cant-worlds-greatest-minds-solve-

mystery-consciousness
https://www.youtube.com/watch?v=jyS4VFh3xOU

28. Consciousness and awareness
https://www.psychologytoday.com/us/blog/consciousness-and-beyond/202305/the-many-dimensions-of-consciousness

29. Neural basis of consciousness yields first results
https://www.science.org/content/article/search-neural-basis-consciousness-yields-first-results

30. Unlocking the 'Mystery' of Consciousness
https://blogs.scientificamerican.com/observations/unlocking-the-mystery-of-consciousness/

31. Integrated information theory of consciousness (and Christof Koch, the person who tries to avoid stepping on insects as he walks!)
https://www.researchgate.net/publication/303551101

32. Cerebral cortex
https://my.clevelandclinic.org/health/articles/23073-cerebral-cortex

33. Why Am I Me and Not Someone Else?
https://philarchive.org/archive/KLAWAI-2

34. Working Memory and Consciousness: The Current State of Play
https://www.frontiersin.org/articles/10.3389/fnhum.2018.00078/full

35. A new source of attention in the brain
https://medicalxpress.com/news/2019-12-source-attention-brain.html

36. The Neural Correlates of consciousness and attention
https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2019.01169/full

37. Attention in psychology, neuroscience, and machine learning
https://www.frontiersin.org/articles/10.3389/fncom.2020.00029/full

38. Changing concepts of working memory
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4159388/

39. Multiple neural states of representation in short-term memory? It's a matter of attention
https://www.frontiersin.org/articles/10.3389/fnhum.2014.00005/full

40. The cognitive neuroscience of working memory
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4374359/

41. Locke on Personal Identity
https://plato.stanford.edu/entries/locke-personal-identity/
https://plato.stanford.edu/entries/locke-personal-identity/notes.html

42. Introduction to personal identity
https://www.slideshare.net/jcbrignell/introduction-to-personal-identity-2012

43. A framework for conscious information processing
https://philpapers.org/archive/DASAFF.pdf

44. Large capacity storage of integrated objects before change blindness
https://www.sciencedirect.com/science/article/pii/S0042698902004029?via%3Dihub

45. Attention
https://www.quantamagazine.org/to-pay-attention-the-brain-uses-filters-not-a-spotlight-20190924/

46. About the distinction between working memory and short-term memory
https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2012.00301/full

47. Free Will, the Libet Experiments and the War on Terror
https://areomagazine.com/2019/10/08/free-will-the-libet-experiments-and-the-war-on-terror/

48. What you're seeing right now is the past, so your brain is predicting the present (repeat)
https://theconversation.com/what-youre-seeing-right-now-is-the-past-so-your-brain-is-predicting-the-present-131913

49. An introduction to consciousness
https://www.psychologytoday.com/intl/blog/the-mind/202010/introduction-consciousness

50. Uncanny Sight in the Blind
https://www.scientificamerican.com/article/uncanny-sight-in-the-blind/

51. Does Phenomenal Consciousness Overflow Attention? An Argument from Feature-Integration
https://cah.ucf.edu/fpr/wp-content/uploads/sites/3/2019/11/Myers-1.pdf

52. The neural correlates of access consciousness and phenomenal consciousness ...
https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2021.749610/full

53. Iconic Memory and Visual Stimuli
https://www.verywellmind.com/what-is-iconic-memory-2795272

54. Iconic Memory: Definition & Examples
https://www.simplypsychology.org/iconic-memory.html

55. Is free will an illusion?
https://www.world-of-lucid-dreaming.com/is-free-will-an-illusion.html

56. The man rethinking the definition of reality (David Chalmers and the hard problem)
https://www.bbc.com/future/article/20220216-the-man-rethinking-the-definition-of-reality

57. Neuroanatomy of memory
https://en.wikipedia.org/wiki/Neuroanatomy_of_memory

58. Parts of the brain
https://www.verywellmind.com/the-anatomy-of-the-brain-2794895

59. High-Level Visual Processing: Cognitive Influences
https://www.krigolsonteaching.com/uploads/4/3/8/4/43848243/chapter_28-_high-level_visual_processing-_cognitive_influences.pdf