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Delve Deeper into 'Your Amazing Brain' – A Guide for the Curious-minded

Within the exhibition 'Your Amazing Brain: A User's Guide' we deliberately tried to keep the amount of information short and relatively easy to read. However, you may enjoy finding out more. This guide allows you to delve deeper into some of the topics highlighted in the exhibition and into the research, addressing the question 'but how do they know that?'

'Your Amazing Brain' was a partnership between the University of Oxford's Wellcome Centre for Integrative Neuroimaging (WIN) and Banbury Museum & Gallery and was originally shown in Banbury from February to June 2022. There was a brain-related exhibition and a programme of events for a range of audiences in the Banbury community.

Key contextual information

Who are the University of Oxford scientists who worked on the exhibition?
A research institute within the University of Oxford, called the Wellcome Centre for Integrative Neuroimaging, or WIN for short, carries out brain research. They study how the healthy brain works, and what happens to the brain in disease and mental illness. They are also committed to engaging the public in their research and receive funding from a medical research charity, called the Wellcome Trust, to help do this. Scientists from WIN partnered with Banbury Museum and Gallery to create the exhibition. One of the main tools that WIN scientists use is *MRI*.

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What is MRI?

One of the key technologies we use at WIN is MRI.

'MRI' stands for 'Magnetic Resonance Imaging'. An MRI scanner is a big tube that takes pictures inside the body.

To have an MRI scan, you lie inside the tube. The scanner uses a very strong magnet and radio waves to create images of the inside of the body. An MRI scan can examine different parts of the body: not just brains, but also organs and blood vessels. The results of the scan can help diagnose that someone is sick, help decide the best course of treatment, or see whether previous treatment has been effective.

The same MRI scanner can be used to take pictures of what the brain looks like, how blood is flowing, how different brain areas are connected, and the levels of different brain chemicals that are present.

The strength of a magnetic field is measured in a unit called a 'Tesla.' Typical MRI scanners are '1.5T' – 1.5 Tesla, which is 30,000 times stronger than the Earth's magnetic field! The University of Oxford even has a '7T' scanner, which uses a magnet so strong it could move a double-decker bus.

MRI scans are very different from x-rays because they use magnets, not radiation. MRI technology was developed in the 1970s. Like most scientific technology, it is constantly improving as researchers make new discoveries.

MRI scanner at the Wellcome Centre for Integrative Neuroimaging (WIN),
University of Oxford. Photo by John Cairns.

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Research at WIN

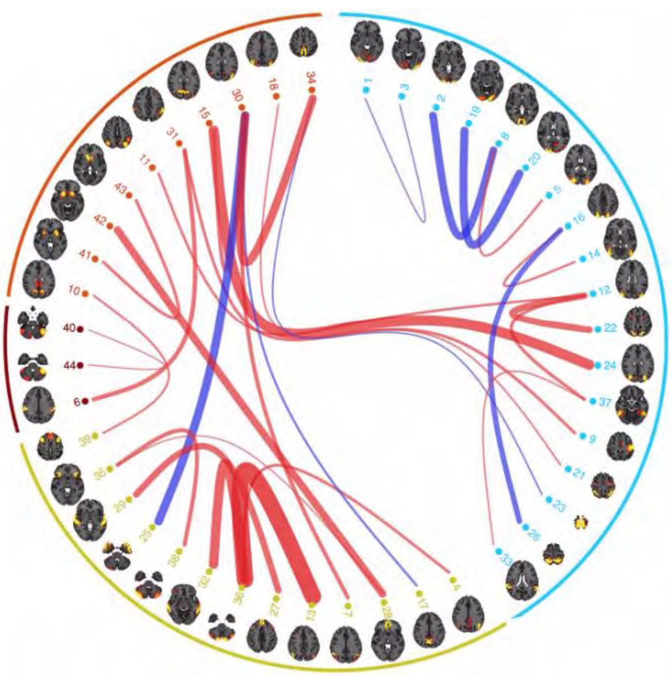
There are over 300 researchers at WIN, each looking at different aspects of how the brain works, what happens in brain disease, how to take better quality pictures or how to analyse the data. Here are two examples of research that is done in WIN.

UK Biobank

Professor Stephen Smith, Biomedical Engineering, University of Oxford

UK Biobank is a large-scale biomedical database and research resource. 500,000 people in the UK have given permission for UK Biobank to access their medical information. One in five people are also having brain scans, to add further value to the medical information. The participants' medical information is saved in a database that researchers from around the world can apply to access. Giving researchers access to the brain scans of so many people helps them make new discoveries about life-threatening diseases. 75% of the researchers who use UK Biobank data are from outside the UK – from 90 different countries!

Along with colleagues in Oxford, we lead the brain imaging component of UK Biobank. Most recently, WIN has worked on UK Biobank brain scans from participants before and after COVID-19. We found that some brain areas related to the sense of smell were affected. This should help researchers understand the disease more deeply.



Large sets of brain scans like those collected by UK Biobank allow us to explore how brain regions are linked and change over time. Image by Stephen Smith.

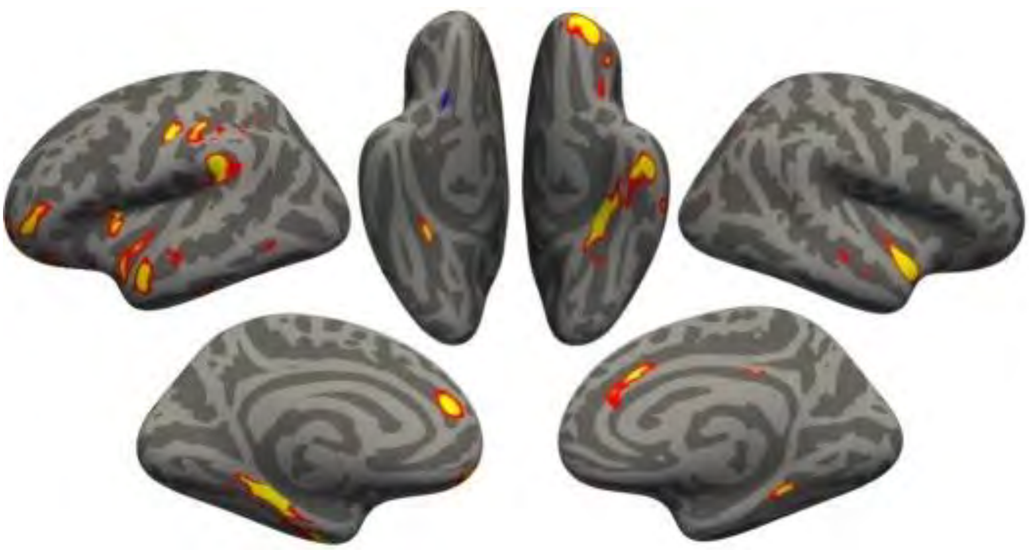
COVID and the brain

Professor Gwenaëlle Douaud, Associate Professor in Clinical Neurosciences, University of Oxford

Scientists are still working to understand how COVID-19 affects our brains. Along with my colleagues in Oxford, we showed in research published in the scientific journal 'Nature' in March 2022 that even mild cases of SARS-CoV-2 infection can damage brain tissue and affect mental capabilities. However, there is still a lot that we don't know yet about how COVID impacts our central nervous systems, and how reversible the effects are.

To be more specific, the study identified several effects, on average 4.5 months following infection, including a greater reduction in grey matter thickness, mainly in the regions of the brain associated with smell (such as the orbitofrontal cortex and parahippocampal gyrus). UK Biobank participants who had been infected with SARS-CoV-2 also displayed evidence of greater tissue damage in regions connected with the primary olfactory cortex, an area dedicated to smell, and a greater reduction in whole brain size. Depending on the regions of the brain, the infected participants showed an additional 0.2% to 2% loss or tissue damage compared with the non-infected participants. To make sense of how big or small these effects are, it is worth putting them in the context of what happens in healthy ageing: it has been shown previously that people lose each year about 0.2% to 0.3% of grey matter in regions related to memory.

On average, the participants who were infected with SARS-CoV-2 also showed greater cognitive decline between their two scans, specifically in their ability to perform a complex task. This greater cognitive decline was, in turn, associated with the greater atrophy (deterioration) of a specific part of the cerebellum (a brain structure) linked to cognition.



Areas in yellow showed the strongest reduction in grey-matter thickness
in people who had tested positive for Covid-19. Image by Gwenaëlle Douaud.

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A walk through the exhibition

Beuchet Chair Illusion

The Beuchet Chair is a classic optical illusion – and you can see one right here in the 'Your Amazing Brain' exhibition. It was invented by Jean Beuchet, a French psychologist, in 1963. The illusion consists of an oversized chair seat and back, that is further away than the four legs. When viewed from the correct point, with one person sitting or standing on the chair and another standing by the leg, you see the illusion of one person appearing to be much smaller than the other. The illusion works best if you close one eye, so that you no longer have the perception of depth – or take a photo on your phone. Because we expect the chair to be a single object, our brain's perception is fooled and we see one person as smaller than the other, rather than the broken-up chair.

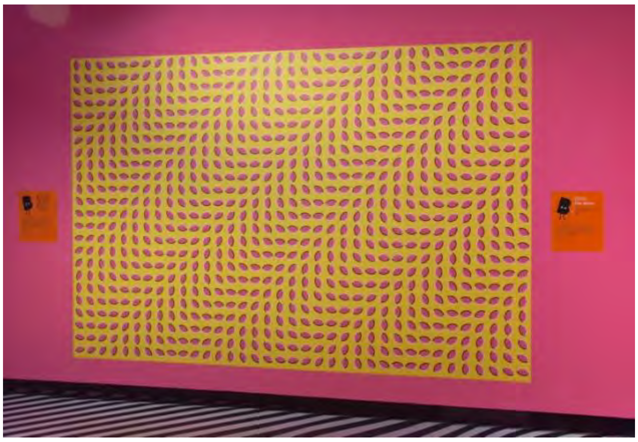
The Beuchet Chair Illusion. Photo by Hanna Smyth.

Brains and vision

Professor Holly Bridge, Vision Group, University of Oxford

The first section of the exhibition deals with vision. WIN professor Holly Bridge specialises in vision and explains more about this section of the exhibition below.

Holly Bridge



'Vision' section of exhibition

Like the rest of the brain, the visual system is not fully developed at birth. Understanding the patterns of light that arrive at the eye takes experience and requires assumptions about the physical world. The Beuchet Chair Illusion relies on us making assumptions about 3D structure. Since the retina at the back of the eye is 2-dimensional, seeing in 3D requires comparing information from our 2 eyes (which have different viewpoints) but also using information such as perspective which gives us a sensation of 3D in pictures and on TV. This illusion works when we view it with just one eye. In the absence of complete information (that the chair is split in two parts), we assume that the chair is a standard shape as this is what experience has taught us.

The disappearing dots illusion illustrates the differences in the resolution of the visual system. At the centre of our vision, that we use to read and recognise people's faces, we have very high resolution to see very fine detail. We also use a large amount of our brain to process this information. However, as we move further away from the centre of vision, there is a large drop in resolution. This can be illustrated by trying to read words that you are not looking at directly. The brain accounts for this low-resolution information by 'making up' the missing information so we are not aware that it is missing unless the brain 'gets it wrong.'

Faces are extremely important to humans (and other animals), reflected in multiple brain regions specialised for processing them. These are linked to other important brain structures that help us interpret the emotional information contained within the faces that can drive our behaviour. Since many neurons respond to the characteristic two eyes, nose, mouth pattern of faces, other non-face items with this type of pattern are often perceived as 'face-like' (although never confused with real faces).

How unique am I? Your brain is similar to animal brains

Dr Kamila Szulc-Lerch, Senior Research Associate in Preclinical Imaging, University of Oxford

The next section of the exhibition deals with animal brains. WIN researcher Kamila Szulc-Lerch specialises in animal brain research and explains more about this section of the exhibition below.

Kamila Szulc-Lerch

'Animal brains' section of the exhibition

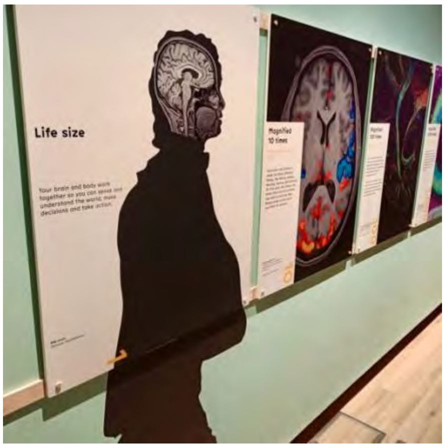
I use magnetic resonance imaging (MRI) in combination with image analysis tools and tissue staining to study animal brains in health and disease. This allows me to identify new treatments that could help the human brain heal following brain injury. What makes this type of research possible is the fact that our own brain is similar to animal brains, including brains of other primates and even brains of rodents and fish.

Tissue staining, as shown in the brain scan images within the exhibition, shows us that human and animal brains are made from the same types of cells. These look alike under a microscope and display almost identical functional characteristics. Brain MRI reveals that these cells are organised into a variety of sub-regions that display varying degrees of homology (similar/corresponding features) with brains of animals of different species. Overall, by using the types of techniques like the ones I use in my own studies we can clearly see that, even though our own brain is unique and there is no other brain exactly like ours, it is also impossible not to notice the similarities between our 'unique brain' and the brains of other animals."

Zoom into your brain - **MRI images**

Professor Stuart Clare, WIN Director of Operations, University of Oxford

Stuart Clare



MRI images in 'Zoom into your brain'

The human brain is incredibly complex and is packed with huge numbers of tiny structures. Whilst an adult human brain is about 15 cm long and weighs roughly 1.3kg, in that space there are billions of nerve cells and each one of those cells can form thousands (or more) connections with other cells. You can pick up a 3D model of my brain, based on my brain scans, in the exhibition. It is a realistic size and weight!

The first three images of the brain, progressing from normal scale to magnified by a hundred, were all taken with the brain scanner based at WIN at the University of Oxford.

At x1 scale you see an MRI scan of the brain structure. This is the kind of scan that a doctor would use to look for damage to the brain caused by conditions like multiple sclerosis or a stroke. The brightest parts are the 'white matter' connections between the slightly darker 'grey matter.' In this scan the fluid that surrounds the brain appears dark.

At x10 scale you see a functional MRI scan, which shows the areas of the brain where the blood flows when the person watches patterns on a screen and listens to sounds. Scientists use this kind of scan to find out which parts of the brain are active when the person does all kind of different tasks, like identifying faces or remembering events.

At x100 scale you see a diffusion MRI scan, which highlights the connections between different parts of the brain. The MRI scanner measures which direction the tiny water molecules in the brain are moving. They move a little faster ALONG the direction of the connections than they do ACROSS them, and we pick that up with the MRI scanner.

As a researcher at WIN, I develop ways to improve the quality, speed, and amount of information that we can get from our range of brain scanners. I studied physics at university, and everything I know about the brain has been learnt by working alongside neurologists and psychologists who use our scanners to find out more about the healthy and diseased brain.

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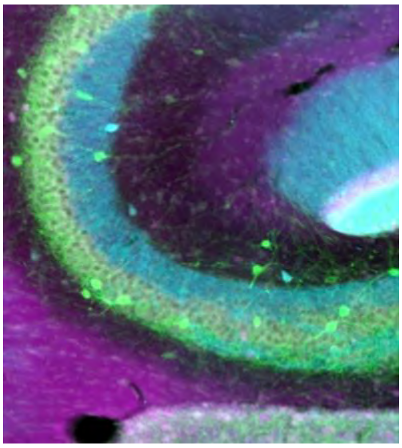
Zoom into your brain – Microscope images

Dr Natalie Doig, Postdoctoral Neuroscientist, University of Oxford

Natalie Doig



Microscope image at x1000 scale.
Image by Kouichi Nakamura.

At x1000 scale we are looking at an area of the brain called the hippocampus, which is from the Greek meaning 'seahorse' as it looks like a seahorse from some perspectives. You, and all other mammals, have two hippocampi, one on each side of your brain. This area is most well-known for its role in memory. If the hippocampus is damaged, it can cause memory problems like amnesia; it is also one of the first brain areas affected in Alzheimer's disease. This area is made up of different layers (which appear as different colours in this image), and if you look closely, you may be able to spot a few nerve cells or neurons (look for green and blue circular objects). Different types of cells in the different layers work together in large networks to do the very complex task of making and storing memories. In these networks, you have thousands of neurons working in coordination. Research has shown that these networks are very active during sleep working to file away the memories of the day.

At x10,000 scale, we are zooming to look at an individual neuron in detail. In the centre you have the cell body of a neuron. The cell body houses DNA and machinery for making proteins. Neurons are specialised cells, and you will notice a lot of long branching structures coming out the cell body. Neurons have two different types of branching structures; the first are called ***dendrites*** from the Latin for tree because of all the branching that you see. The dendrites are the 'antennae' of the cell, sticking out and receiving information from other cells in their network. The other type of structure is called an ***axon***, these are the transmitters of electrical and chemical messages, sending information out to other neurons. Axons can travel long distances; if you move your toes now the impulse has travelled - in a fraction of a second - from your brain all the way to your foot to excite muscles!

This neuron you are looking at is involved in the link between memory and reward. If you have a dog, you may know that the fastest way to get them to learn and remember to do something (like sit) is to reward them with a treat. In this study we looked at how the hippocampus is linked to another brain area called the nucleus accumbens. The cell you are looking at is an important part of this link.

At x100,000 scale we can look more closely at the axons. Because there are so many neurons in the brain, there are a lot of axons, and you can see the axons (green string like bits) forming a mesh in this image. The axons are not randomly intertwined, and there are very specific signals in the brain that control the growth of the axons during brain development. Axons can then form synapses with other neurons. The synapse is the point where an axon and a dendrite communicate with each other. In this image you can see the synapses in pink. Just look how many there are in a small space!

At x1,000,000 scale we have to use an electron microscope and that is because we are looking at something too small to see with visible light. You will notice that this image looks quite different than the three images before, which were taken with a light microscope. In this picture the axons are in pink, and the dendrites are in blue. If you look at the top axon, you will see that there are more structures within it. The two big round things at the top are mitochondria. Mitochondria are like batteries and make energy in cells. Then, below the mitochondria, are lots of little round things; these are called synaptic vesicles and are where the chemical messengers or 'neurotransmitters' are stored. Dopamine and serotonin are two types of neurotransmitter. The synapse itself is the small gap between the axon and dendrite and this is where the neurotransmitter is released."

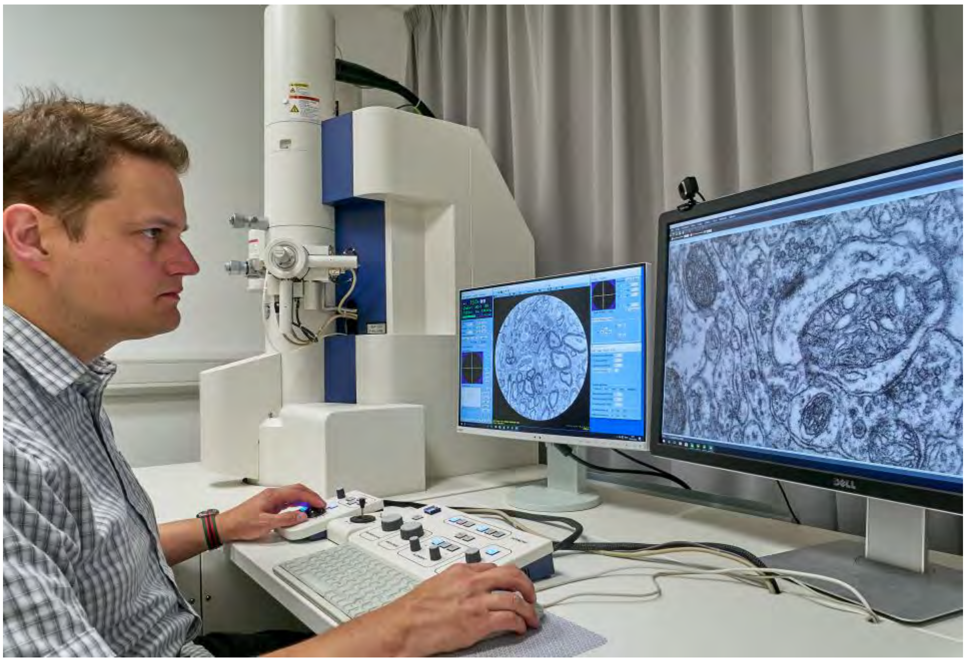


Photo of one of the microscopes at the MRC Brain Network Dynamics Unit (BNDU), University of Oxford. Photo by Ben Micklem.

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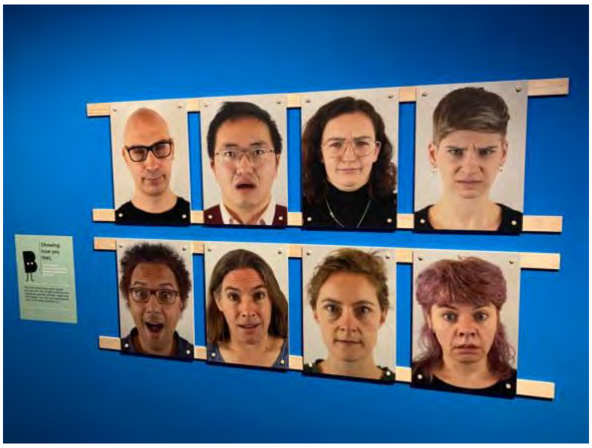
Brains and emotion

Professor Catherine Harmer, Director of the Psychopharmacology and Emotional Research Lab, University of Oxford

The next section of the exhibition deals with emotions. WIN professor Catherine Harmer specialises in researching emotions and explains more about this section of the exhibition below.

Catherine Harmer



‘Emotions’ section of the exhibition

Our lab looks at how our emotional responses are affected when we are depressed or anxious and how this is affected by current and new treatments. We know for example that we can see things in a more negative light when we are feeling low and this can make us feel even worse, setting up a vicious cycle.

This negative processing can be changed quite quickly with drug and psychological treatment, even before we start to feel better in ourselves. We are using these measures to see if we can predict who will benefit from different treatments and to test out new treatments which might work more quickly for the treatment of depression.

Photo of a research study volunteer having an MRI scan.
University of Oxford. Photo by John Cairns.

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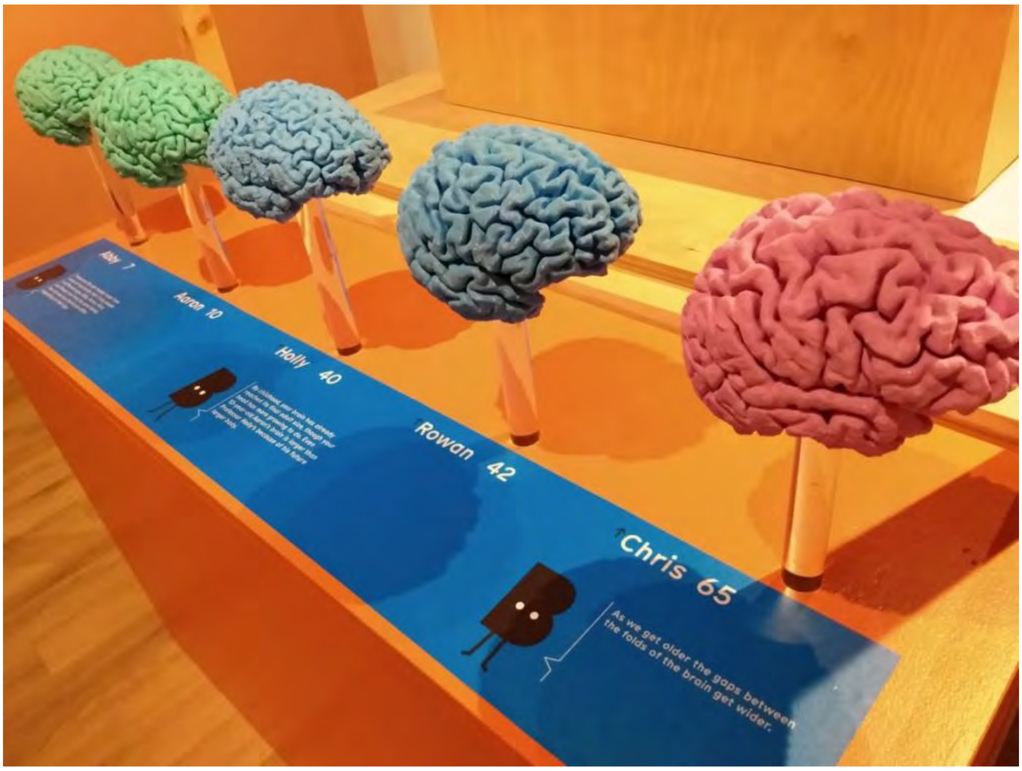
Brain size vs intelligence

Professor Holly Bridge, University of Oxford

The 3D printed brains in the exhibition are from WIN researcher Holly's family.



A family of brains in 'Your Amazing Brain'

These life size models of the brains of people in my family (and one of one of my colleagues) show us that a bigger brain does not always mean a more intelligent brain! Some animals' brains are small because those species of animals are small, but they are still very intelligent. Some people's brains are smaller than other people's, but that does not mean they are less intelligent. Albert Einstein, a famous physicist who died in 1955, is widely considered to be one of the most intelligent people ever – and he had an average-sized brain!

Brains and Ageing

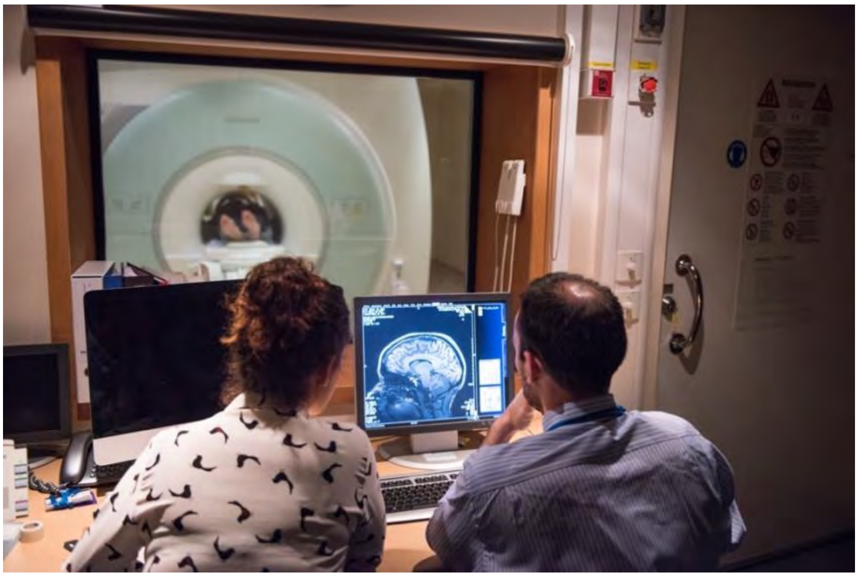
Dr Sana Suri, Principal Investigator of the Heart and Brain Research Group, University of Oxford

The final section of the exhibition deals with ageing. Dr Sana Suri specialises in researching ageing and explains more about her research below.

Sana Suri

'Ageing' section of the exhibition

My group's research combines multi-modal neuroimaging to study risk and resilience for cognitive decline in ageing. We use structural, diffusion, perfusion, and functional magnetic resonance imaging (MRI) to investigate how the brain's vascular health varies with age, with a specific focus on how it may be affected by genetic and cardiovascular risk for dementia.

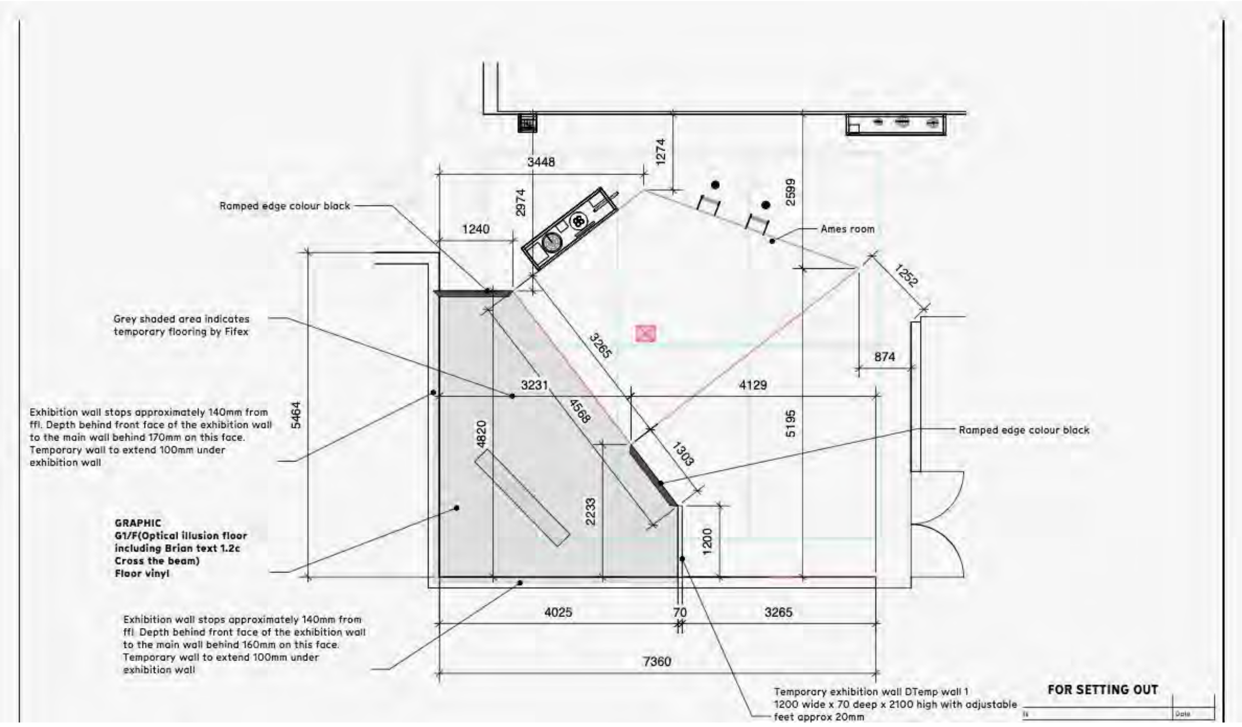


Researchers looking at the brain scan of a research study volunteer.
University of Oxford. Photo by John Cairns.

How this exhibition was created

This exhibition was created through a close partnership between the Wellcome Centre for Integrative Neuroimaging (WIN) at the University of Oxford and Banbury Museum & Gallery. We worked together for five years to develop the exhibition and associated events programme.

The words and the activities in the exhibition are all based on the research conducted by WIN scientists. Many people worked on the production of this exhibition combining skills in exhibition and graphic design, research, education, public engagement, communications, and hands-on exhibition design & production.



Before an exhibition is built, the team works together to make an exact plan of where everything in it will go and what it will look like. Floorplan by exhibition designer Polly Lewis.

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The exhibition being installed – Banbury, February 2022.
Photo by Dale Johnston.

The exhibition being installed – Banbury, February 2022.
Photo by Dale Johnston.

Want to find out more? See WIN's website for more information about our researchers and the work they do: https://www.win.ox.ac.uk/