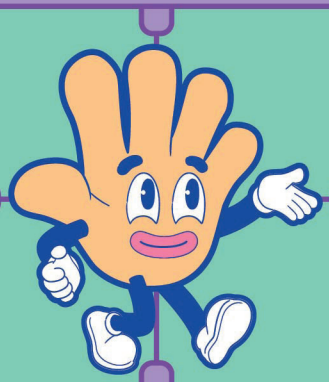
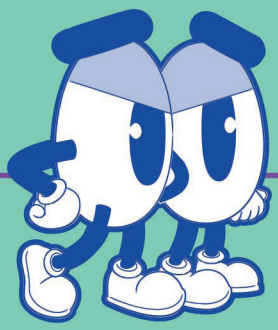
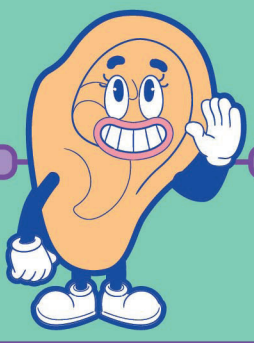
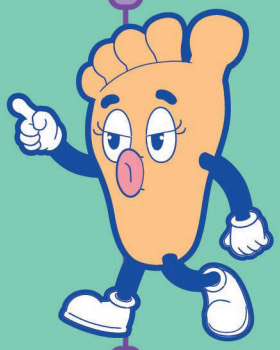
THE UNOFFICIAL GUIDE TO BEING HUMAN

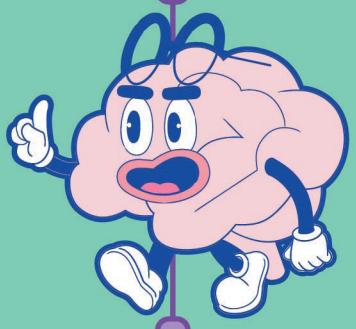
Guide for Visitors











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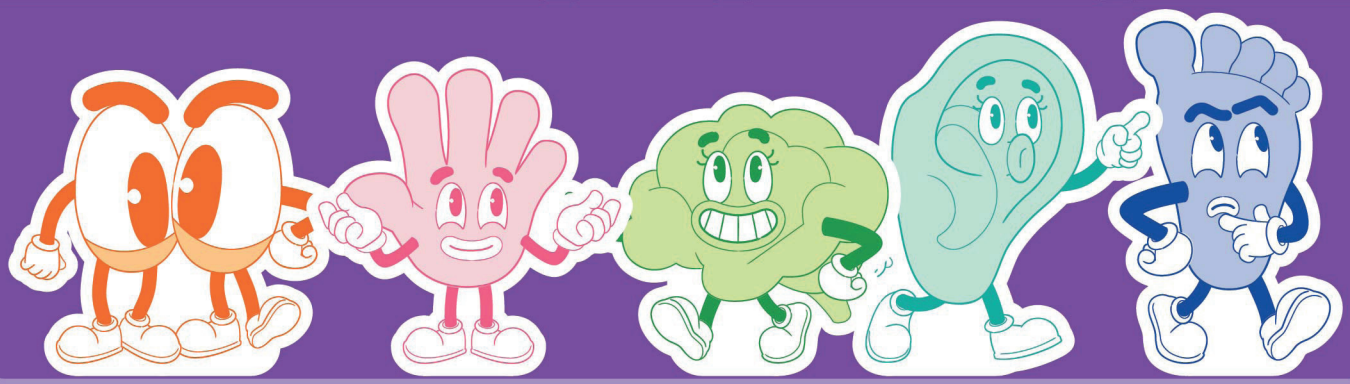


CONTENTS

WHAT TO EXPECT AT THIS EXHIBITION?

This travelling exhibition is curated for guests (like you!) to discover and experience the norms and peculiarities of the human body by exploring its exhibits, just like how one learns to operate an appliance by going through its instruction manual.

The objectives of the exhibition are as follows:

- Spark curiosity about and increase appreciation of how our body works;
- Shed light on how the body helps us interpret and navigate the world around us;
- Encourage self-directed, inquiry-based learning through guided exploration, interaction with the exhibits and links to real-life experiences.

This exhibition features a total of 17 interactive exhibits. They are grouped according to 4 main themes, easily distinguishable by the colour of their panels.

Theme	Exhibit number	Colour of exhibit panels	What this theme covers
Getting to know the parts	1 - 6	Yellow	An introduction to the parameters of the human body, as well as its sensory and motor systems.
Software optimisation	7 - 9	Pink	More on sensory processing, human perception and memory.
Hardware optimisation	10 - 12	Orange	More on the human motor system, including reaction speed, balance and how sensory feedback influences it.
Version bugs and other models	13 - 17	Turquoise	Quirks of human perception and movement, including the science behind various sensory illusions and coordination difficulties.

However, do note that the following 3 exhibits are exceptions to this general colour scheme and instead have **light green** panels.

- Exhibit 1: The Body Blueprint;
- Exhibit 12: Improvements to Sense of Balance;
- Exhibit 13: Coordination Conflict.

WHAT TO EXPECT IN THIS GUIDE?

This guide is meant as an accompanying resource for guests (like you!) planning a visit to the travelling exhibition. Each section focuses on a single exhibit and contains the following details.

- Exploratory questions: Pre-exhibit inquiry questions to stimulate thinking and discussion.
- On the exhibit: A photograph of the exhibit and the write-up on its content panel.
- Exhibit interaction: A series of suggested steps to make the best use of the exhibit for learning.
- Knowledge expansion: The science behind the exhibit.
- Extended thinking: Post-exhibit questions to provide food for thought and showcase real-world applications.

PLAN YOUR VISIT!

Overview

The senses and perception, motor control and coordination, as well as various aspects of memory – these are things we take for granted about our bodies, but which are integral in helping us to interpret and navigate the world around us. As such, this travelling exhibition hopes to draw attention to and foster appreciation for these unsung heroes, because they contribute to such a large part of our experience and what it means to be human.

If you notice the Ⓟ and Ⓢ symbols while looking through this guide, the scientific concepts behind some of the exhibits may be more suitable for children in primary and/or secondary school (ages 7-12 and 13-17 respectively). However, this is only a suggestion and should not limit guests' curiosity or exploration. Guests of all ages and/or backgrounds are welcome to interact with any of the exhibits. The following plans offer ideas on how you can maximise your visit to this travelling exhibition.

For Families

- Freely roam and interact with the exhibits.
- At each exhibit, take turns to interact with it and share your experience. Encourage each member of the family to ask questions on what they are curious about.
- Use this as a springboard to discuss the science behind the exhibit, as well as how it relates to our bodies and lived experience as humans. These can be found in the main section of the guide (Pages 5-30).
- At the same time, fill up the crossword puzzle as each clue and its answer are linked to a particular exhibit.

For Independent Learners

- Pick an exhibit of your choice and refer to the relevant section in this guide.
- Before interacting with the exhibit, have a think about the Exploratory Questions.
- Go ahead and try out the exhibit! Or give the Exhibit Interaction sub-section a read to familiarise yourself with what to do first.
- After interacting with the exhibit, reflect on your experience and try explaining the science behind it. Information on this can be found in the Knowledge Expansion sub-section.
- Finally, try the Extended Thinking exercise to further challenge yourself and apply the concepts you have learnt in the exhibit.

GETTING TO KNOW THE PARTS

1 The Body Blueprint (P)(S)

Exploratory questions

- Do you think there are predictable ratios between the sizes of your body parts?
- If yes, are these special relationships unique to you, or are they common to all humans?

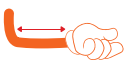
On the exhibit

Measure your body parts and compare the ratios with your friends.

Hint: For starters, try calculating your own ape index!

Height

Length of foot



Length of forearm

Arm span (finger-to-finger)

Length of femur (thigh bone)

Is there any significance behind these values?
Nature vs Nurture: Are you really limited by these proportions?
Can you challenge these boundaries?

CHECK OUT THESE RATIOS:

$$\text{Ape Index: } \frac{\text{Arm Span}}{\text{Height}} \approx 1$$

$$\frac{\text{Length of Forearm}}{\text{Length of Foot}} \approx 1 \qquad \frac{\text{Height}}{\text{Length of Femur}} \approx 4$$

Exhibit interaction

1. Stand against the measuring board.
2. Measure your height, arm span and the sizes of your other body parts.
3. Calculate the following ratios:
    a. Arm span (m) / Height (m)
    b. Length of forearm (m) / Length of foot (m)
    c. Length of femur (thigh bone) (m) / Height (m)
4. Compare your own measurements and ratios with those of your friends. Are they similar or different?

Knowledge expansion

The measurements of various body parts may differ from human to human, but the ratios are more or less similar!

- $\frac{\text{Arm Span}}{\text{Height}} \approx 1$
- $\frac{\text{Length of Forearm}}{\text{Length of Foot}} \approx 1$
- $\frac{\text{Height}}{\text{Length of Femur (thigh bone)}} \approx 4$
- $\frac{\text{Neck circumference}}{\text{Wrist circumference}} \approx 2$
- $\frac{\text{Waist circumference}}{\text{Neck circumference}} \approx 2$

But what is the significance of these ratios? They are used by artists to make the humans in their works appear more proportional and life-like. Scientists have also found that some of these ratios may relate to performance in sports!

Let's look at one such ratio: Ape index = $\frac{\text{Arm span (m)}}{\text{Height (m)}}$.

On average, the ape index is close to 1. However, some people may have an ape index slightly above 1 (arm span greater than height) while others may have an ape index slightly below 1 (arm span less than height).

Of course, many other factors from lung capacity to muscle make-up to training regimen affect athletes' performance in sports. However, if someone's ape index is higher than 1, this means that they have a longer reach. This can be advantageous in sports like combat sports, ball sports and swimming. On the other hand, if their ape index is lower than 1, a load in their arms has to be carried a shorter distance away from the centre of their body to be successfully lifted[1]. This is advantageous in weightlifting!

1| For the same normal force required to overcome the gravitational pull on the load, there is a shorter perpendicular distance from the pivot (shoulder joint) and thus a smaller moment.

Extended thinking

Calculate your ape index. Is it higher or lower than 1? How might you use this knowledge to your advantage during Physical Education lessons?

Another matter to consider is the debate on Nature vs Nurture! Is each of us really limited by our body proportions? By how much? Are we able to challenge these boundaries?

Possible answer: Our body proportions can give us certain physical advantages. For example, our ape index can give us an advantage in certain types of sports. However, many other factors like lung capacity, muscle make-up and even our training regimen can affect our performance in sports.

References

- https://www.bioedonline.org/lessons-and-more/lessons-by-topic/human-organism/fitness-and-physical-activity/human-body-ratios/
- https://sportsgratitude.com/athlete-ape-index/
- https://www.sciencedirect.com/science/article/pii/S2405844022003115
- https://www.scientificamerican.com/article/human-body-ratios/

2 Topsy Turvy ⓅⓈ

Exploratory questions

- What happens to the path of light rays after they enter your eyes?
- Do you think they continue in the same direction, or bend in a different direction?
- How does this affect the image formed on the retina at the back of your eye?

On the exhibit

Light rays cross as they pass through your eye's lens, forming an image on the retina that is upside-down and left-right reversed. Why then do you see things in the upright, non-reversed form? How would you navigate the world without this "autocorrect" function?

Exhibit interaction

1. Look at the content panel once without the topsy-turvy goggles. Then, put on the topsy-turvy goggles and look at the content panel again. What has changed about the cartoons and their labels?
2. Compare the two cartoons: The cartoon on the left is what you would normally "see", while the cartoon on the right is how the image formed on your retina actually looks. How are they different?
3. What does this tell you about how our brain helps us process visual information (i.e. information from our eyes)?

Knowledge expansion

When light is reflected off an object and enters our eyes, the image formed on our retina is actually upside down and left-right reversed!

Light rays cross each other as they pass through the convex lens in our eyes. As a result, light rays from the top half of the object fall onto the lower part of our retina, while light rays from the bottom half of the object fall onto the upper part of our retina. This forms an upside-down image on our retina. [Figure 2(a)]

In addition, light rays from the right side of the object fall onto the left half of our retina in each eye, and vice-versa. This causes the image on the retina to be reversed left to right. [Figure 2(b)]

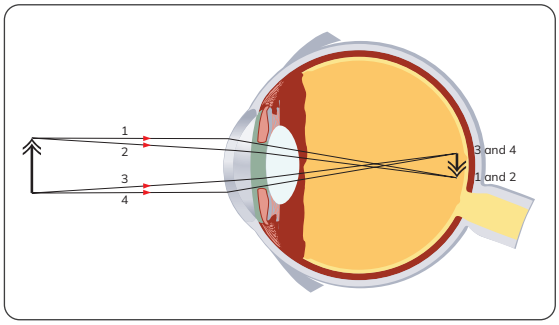


Figure 2(a): The path of light rays from an object after they enter the eye. Light rays from the top half of the object fall onto the lower part of our retina, while light rays from the bottom half of the object fall onto the upper part of our retina.
Adapted from: https://engineering.utulsa.edu/optics-of-the-human-eye/

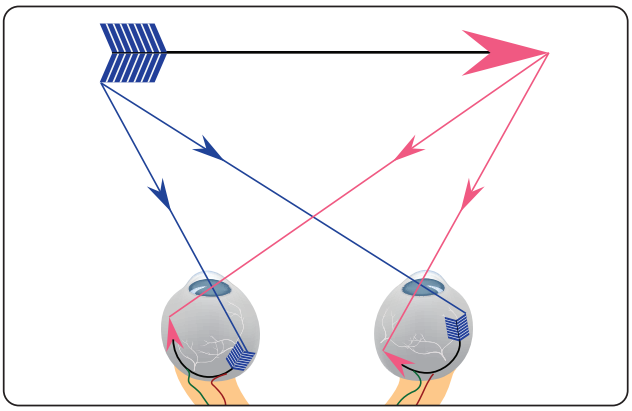


Figure 2(b): The path of light rays from an object after they enter the eye. Light rays from the right side of the object fall onto the left half of our retina in each eye, and vice-versa.
Adapted from: https://nba.uth.tmc.edu/neuroscience/m/s2/chapter14.html

Signals from our retina are sent to a part of the brain called the occipital cortex which processes visual information. The occipital cortex then decodes these signals such that we are able to perceive or "see" the object in its original upright, non-reversed form.

In this exhibit, the topsy-turvy goggles inverts the cartoons and their labels (i.e. flips them vertically such that they are upside down). In contrast, our occipital cortex "flips" the image formed on our retina both vertically and horizontally. So, comparing the two cartoons, the one on the right (i.e. the image formed on our retina) is upside down and left-right reversed compared to the one on the left (i.e. what we normally "see").

Extended thinking

Imagine that this time, you are wearing a different pair of goggles that simulates the image formed on your retina! If you are trying to hit a target, how do you think you should change your aim to have a better chance of scoring? For example, if you see the target on your top-left, where should you aim?

Hint: This pair of goggles mimics how the image formed on our retina is upside down and left-right reversed.

Answer for the example: You should aim towards the bottom-right.

Check this career out: Our vision relies not only on how our brain processes information from our eyes, but also on our eye movement and coordination. Orthoptists are like eye detectives, using science to solve mysteries and help people see better! Find out more about this cool job here: https://go.gov.sg/wow-orthoptists

3 Persistence of Vision (P)(S)

Exploratory questions

- Do you know how cartoons are made?
- How do you turn a series of still images into a moving animation?

On the exhibit

The retina at the back of your eye is made up of many light detecting cells. Once stimulated by a flash of light (in this case, the light reflected off the surface of each picture), they fire off an electrical signal to the brain.
Your brain holds on to each image long enough for it to combine the series of images into a continuous motion. This is the animation that you see.
Have you seen this happening in your everyday life?

Exhibit interaction

1. Use your hands to spin the zoetrope.
2. Look through the slits along the sides of the zoetrope. What do you see?

Knowledge expansion

The light-detecting cells that make up the retina at the back of our eye are called rods and cones. Once stimulated by a pulse of light, they fire off an electrical signal to our brain that is then interpreted as an image.

A zoetrope is a circular drum with slits along its sides. Pictures are pasted along the inner sides of the drum. As the drum is spun, these pictures are visible to the outside observer through the slits - each for a fraction of a second.

The firing of our rods and cones lasts for a longer time than the flash of light from each picture as the slit rotates past it. So, we continue to perceive or “see” each picture for a longer time than it is exposed through the slit.

Our brain holds onto each image for around 1/30th of a second, which allows it to link the sequence of pictures together to form a continuously-moving animation.

Extended thinking

Create your own animation! Use only materials found around your home or school (e.g. paper cups, an old notebook, etc.). Apps and digital software are not allowed. You can base your design on the zoetrope in the exhibit or the principles of vision you have learnt.

Check this career out: An animator brings life and movement to still images! Take a peek into the journey of one as she shares about how her passion grew from a dream into a career, and the challenges and rewards she encountered along the way. https://go.gov.sg/wow-animator

4 Audio System ⓅⓈ

Exploratory questions

- What are the parts of a human ear?
- How does its structure help it to perform its function of allowing us to hear?
- What is the normal hearing range of a human?
- How does the human ear recognize the pitch of a sound?

On the exhibit

Human ears typically detect sounds of frequencies from 20 to 20,000 Hertz. Sound waves vibrate the eardrum, and are passed along tiny bones in the middle ear to the cochlea in the inner ear. There, tiny hair cells send electrical signals to the brain, which are interpreted as sounds. Different sound frequencies activate different hair cells.

Loud noises can wear out these hair cells. Age can cause parts of the cochlea to stiffen too. Both these factors can contribute to hearing loss over time. How can we protect our hearing?

Exhibit interaction

1. Put the handset to your ear and press the button to start.
2. A tone with a gradually increasing pitch will be played.
3. Press the button again when you stop hearing the tone.
4. The highest frequency of sound you were able to hear will be shown on the display, together with an estimate of your hearing age.

Knowledge expansion

This exhibit compares the upper limit of your hearing range with that of participants in a study by Lee et al. (2012) to give you an estimate of your hearing age[2]. The normal hearing range of the human ear is frequencies from 20 Hz to 20 000 Hz. Hertz (Hz) represents the number of sound waves that pass a particular point in one second.

Sounds of different frequencies are interpreted as having different pitches by our ears. But how exactly do our ears do this?

Sound waves are funnelled by our outer ear into our middle ear. At the boundary between our outer and middle ear, these sound waves strike the tympanic membrane (i.e. eardrum), making it vibrate. This causes the three tiny bones in the middle ear - the malleus, incus and stapes - to vibrate in turn. These vibrations are passed along to a seashell-like organ in our inner ear called the cochlea. [Figure 4(a)]

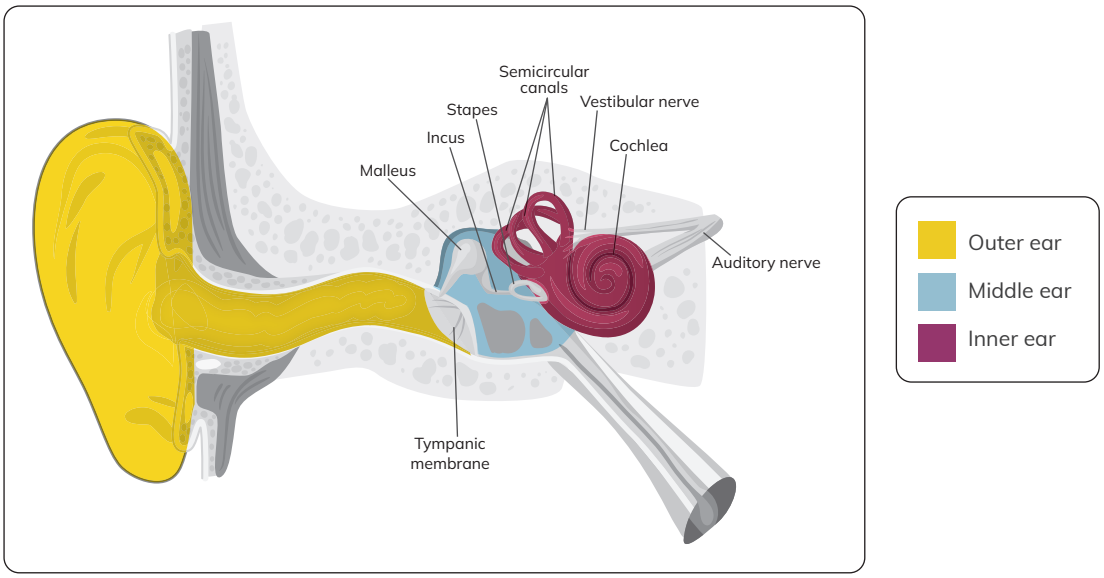


Figure 4(a): The parts of the ear. This includes: The tympanic membrane (i.e. eardrum) at the boundary between the outer and middle ear, the malleus, incus and stapes in our middle ear, as well as the cochlea in our inner ear.
Adapted from: Costanzo's Physiology (6th Edition)

Within the cochlea, there is a sheet-like layer called the basilar membrane that vibrates with the sound waves reaching it. Along the length of the basilar membrane, there are many tiny hair cells that are activated by these vibrations. They send signals to the brain which are then interpreted as sound.

Different sound frequencies activate different hair cells depending on their positions along the basilar membrane. The base of the basilar membrane (nearest the stapes) is narrow and stiff, vibrating best at high sound frequencies. So, the hair cells here are activated at high sound frequencies. The apex (or tip) of the basilar membrane (furthest from the stapes) is broad and more flexible, vibrating best at low sound frequencies. So, the hair cells here are activated at low sound frequencies. [Figure 4(b)]

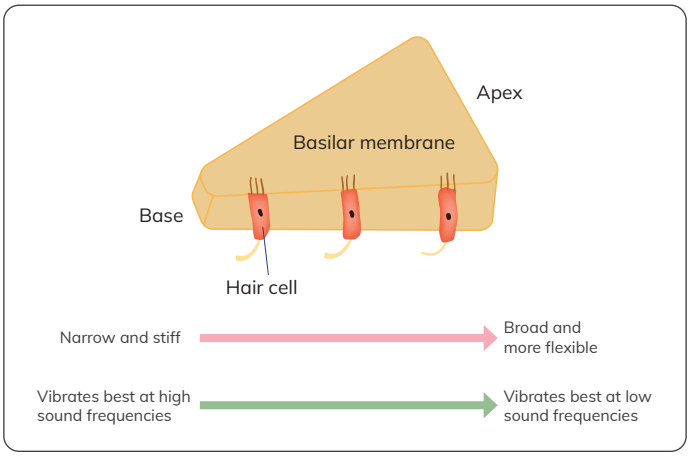


Figure 4(b): Different sound frequencies activate hair cells at different positions along the basilar membrane due to a gradation of stiffness along its length.
Adapted from: Costanzo's Physiology (6th Edition)

This creates a "position-based map" of different sound frequencies, where the brain interprets the pitch of the sound heard based on the position of hair cells along the basilar membrane that are most stimulated.

2| A link to the aforementioned study has been included in the references. Its participants were individuals between 10 and 65 years old with clinically normal hearing, and they were tested on frequencies between 125 Hz and 20 000 Hz. Do also note that this exhibit is not intended to replace a professional hearing test. Please seek advice from a qualified hearing specialist if you suspect you have hearing issues.

Extended thinking

There are various types of hearing loss, which each affect a person's hearing range in a different way. What is the science behind them?

- Presbycusis (age-related hearing loss): With ageing, there is degenerative thickening and stiffening towards the base of the basilar membrane. This leads to hearing loss that affects the higher frequencies most (i.e. impaired hearing of higher-pitched sounds).
- Noise-induced hearing loss: With prolonged and repeated exposure to loud sounds, excessive vibration damages the hair cells along the basilar membrane over time. The basilar membrane is more flexible towards its apex. So, vibration and thus vibrational damage tends to be the worst here, especially with loud sounds of lower frequencies (e.g. the rumbling of machinery or an airplane engine). As such, this type of hearing loss often affects the lower frequencies (i.e. impaired hearing of lower-pitched sounds).

Check this career out: Hearing difficulties can have a huge impact on our daily lives. Audiologists are important healthcare professionals who use science to solve mysteries of the ear and help people hear better! Uncover the secrets of this job here: https://go.gov.sg/wow-audiologists

References

- Guyton and Hall (11th Edition): The Sense of Hearing (Chapter 52)
- https://researchers.mq.edu.au/en/publications/behavioral-hearing-thresholds-between-0125-and-20-khz-using-depth

5 Delayed Speech (P)(S)

Exploratory questions

- What does the term "prosody" mean? How is it related to our speech patterns?
- How do we adjust the tone, volume, rhythm and pace of our speech?

On the exhibit

You rely on near-instant feedback from your mouth to ears to adjust your speech. Even a small delay can cause speech problems. We humans can get very creative though! Doctors have found ways to use such delays to help patients. How do you think this is done?

Exhibit interaction

1. Put on the headphones.
2. Try reading the words on the content panel aloud. Can you do so smoothly, or do you get confused along the way?

Knowledge expansion

Normally, when we speak, we compare what we say and how we say it (the tone, volume, pace and the stress we place on each syllable) to what we intend, and make the necessary adjustments to our speech along the way. This process of using the sounds we hear from ourselves to fine-tune our speech is called the auditory feedback loop, and is vital for us to be able to speak coherently (i.e. in an understandable way).

In this exhibit, you are still able to hear yourself while speaking into the microphone. However, each word in the voice playback is delayed by approximately 0.3-0.4 seconds. For a normal person, this delayed auditory feedback interferes with the ability of our brain[3] to coordinate our speech patterns, leading to incoherent speech (i.e. speaking gibberish).

3| In particular the supplementary motor area in our frontal cortex, as well as our cerebellum.

Extended thinking

In what situations might delayed auditory feedback be helpful?

Answer: For people who suffer from speech disorders like stuttering, delayed auditory feedback is used as a form of therapy to help reduce stuttering and improve the fluency of their speech!

Check this career out: Speech therapists help people with language, communication and swallowing disorders. Find out more about what they do and who they support! https://go.gov.sg/wow-speech-therapists

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- https://arxiv.org/ftp/arxiv/papers/1202/1202.6106.pdf
- https://speecheasy.com/what-is-delayed-auditory-feedback-and-how-does-it-work/
- https://pubmed.ncbi.nlm.nih.gov/27343998/

6 Grip Strength (P)(S)

Exploratory questions

- What are the functions of the human hand? How does its structure help it to perform these functions?
- You have 5 digits on each hand: The thumb, index finger, middle finger, ring finger and little finger. Which of these do you think contributes the most to grip strength?

On the exhibit

The human hand is a complex system of bones, muscles, ligaments and tendons that work together. Grip strength can serve as a marker of various aspects of your health, from overall muscle strength to even brain health!

Do you think your dominant hand is stronger? What happens to grip strength when each finger is not used? Find out which finger plays the biggest role in your overall grip strength!

Exhibit interaction

1. Squeeze the handle. Your grip strength will be shown on the LED bar next to it.
2. Using the same hand, test your grip strength with different combinations of the 5 digits around the handle. Which finger or combination of fingers gives you the greatest grip strength?

Knowledge expansion

The human hand is made up of an intricate system of bones and muscles, as well as the ligaments and tendons that "string" them together. [Figure 6]

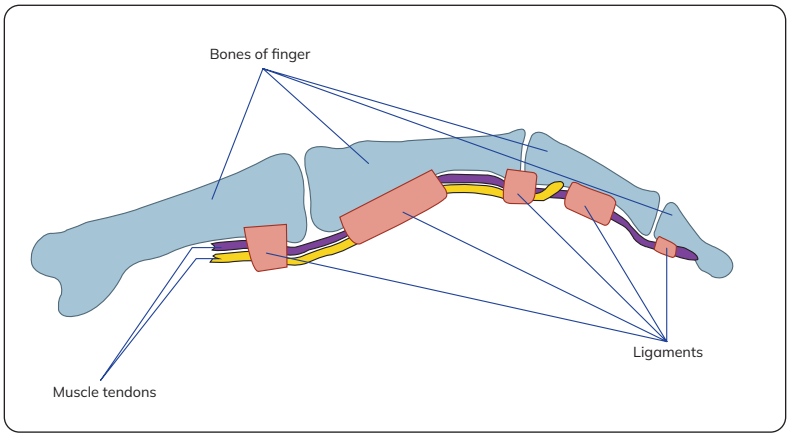


Figure 6: The system of bones, muscles, ligaments and tendons that make up our hand.
Adapted from: https://www.orchardhealthclinic.com/pulley-injuries/

Contraction of the flexor muscles of our hand causes our digits to bend towards the palm of our hand. This allows us to grip objects, like a cup, a ball or a doorknob, and perform gross motor tasks, like bringing a cup to our mouth, picking up a ball or turning a doorknob.

According to research, the middle finger is the most important contributor to grip strength (31%), with the combined effort of the ring and little fingers not falling far behind (29%). The thumb (17%) and index finger (22%) contribute the least to grip strength.

Extended thinking

The thumb and index finger do not contribute as much to grip strength as the other 3 digits. What then is their main function?

Answer: These two digits are important for another function of the human hand - pincer grasp which is key for fine motor tasks like writing!

Check these careers out: Physiotherapists and occupational therapists help patients with rehabilitation after surgery, injury or illness. This includes those with movement disorders from stroke or other conditions that affect the nervous system. Find out the difference between these two occupations here!

- Physiotherapists: https://go.gov.sg/wow-physiotherapists
- Occupational therapists: https://go.gov.sg/wow-occupation-therapists

References

- https://pubmed.ncbi.nlm.nih.gov/25085045/

SOFTWARE OPTIMIZATION

7 Audio Processing Improvements Ⓢ

Exploratory questions

- Can you play a song you have heard before by ear? Can any of your friends do it? How is this possible?
- Have you ever come across the terms “perfect pitch” and “relative pitch”? What is the difference between them?

On the exhibit

Pitch refers to how we hear a sound as either “high” or “low”. This is important in music and speech perception.

You can tell musical notes apart based on:

1. How well you can process and classify sounds (called frequency following response), and
2. How well you remember, give meaning to and recall them (called auditory working memory).

Do you know the difference between having relative pitch and perfect pitch? Can you improve your abilities with training?

Exhibit interaction

1. Pick up the handset and press any of the 4 buttons.
2. A speaker will play a pair of sound clips one after the other. Press the button corresponding to the tone that differs between them.
3. Do this for 4 more pairs of sound clips.
4. At the end, your total score will be shown on the display.

Knowledge expansion

Perfect pitch is the ability to identify a musical note without seeing how it was played on an instrument and without reference to other notes. Relative pitch is the ability to identify a musical note without seeing how it was played on an instrument, but only in reference to other notes.

If you have perfect or relative pitch, you will likely get a higher score in this exhibit than those without either of these abilities. You should also be able to reproduce a song by ear. However, people with perfect pitch can tell if the key of the song has been changed from its original version, while people with relative pitch may not always be able to do so.

Two factors that affect one's ability to identify musical notes and differentiate them from each other are: Frequency following response and auditory working memory. But what exactly do these two terms refer to?

Frequency following response refers to how well a person is able to process and classify sounds. This is related to the location-based mapping of pitch in the inner ear (see Exhibit 4). It is also related to processing mechanisms[4] that "sharpen" the identification of a sound's frequency as the signals encoding it are sent along nerve cells from the inner ear to the auditory cortex of our brain, the part in charge of processing sounds.

As a result, most of the nerve cells in our brain's auditory cortex respond only to a narrow range of sound frequencies (rather than a broad range). Those most sensitive to low-pitch sounds are located towards the front, while those most sensitive to high-pitch sounds are located towards the back. So, according to which area of our auditory cortex is activated, we are able to recognize the sound as having a certain frequency or pitch.

Auditory working memory is someone's ability to remember sounds, assign meaning to them, and keep this information readily in mind for use in current activities. In the case of music, this would mean remembering the pitch of a note, assigning it a name, and being able to readily recall this information to identify the same note when it is next heard. This involves links between the auditory cortex, the part of our brain in charge of processing sounds, and the hippocampus, a part of our brain involved in memory.

Scientists have found both frequency following response and auditory working memory can be improved with practice. This is because repeated use "strengthens" links between the nerve cells along these pathways. This means that contrary to popular belief, perfect and relative pitch can be trained up!

4| These processing mechanisms involve lateral inhibition, where if nerve cells in the pathway sensitive to one frequency are stimulated, nerve cells in pathways on either side of this main/primary frequency are inhibited.

Extended thinking

Research about the term "neuroplasticity". How do you think this relates to the saying "practice makes perfect"?

Possible answer: Neuroplasticity is our brain's ability to form, reorganise and prune the links between its nerve cells in response to stimuli like learning, experience, injury, etc. Repeated use of a pathway through practice "strengthens" the links between nerve cells along the pathway, such that they tend to fire together once one of them is activated. We thus become more efficient at performing the task associated with that pathway.

References

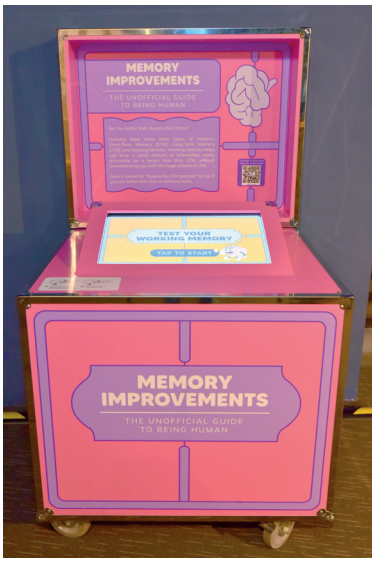
- https://news.uchicago.edu/explainer/what-is-perfect-pitch

8 Memory Improvements (P)(S)

Exploratory questions

- What do you understand by the term “memory”?
- How many types of memory do you know of? What are the differences between them?
- What are some ways to improve your memory?

On the exhibit



Are You better than Ayumu the Chimp?
Humans have three main types of memory: Short-Term Memory (STM), Long-Term Memory (LTM), and Working Memory. Working Memory helps you keep a small amount of information easily accessible for a longer time than STM, without overwhelming you with the huge volume of LTM.

Search online for “Ayumu the Chimpanzee” to see if you are better than him at memory tasks.

Exhibit interaction

1. Press “Start”. The numbers 1 to X will be shown on the screen.
2. Try to remember the positions of the numbers and press them in ascending order. Once you press the number 1, the rest of the numbers will fade from the screen.
3. There are 4 levels of increasing difficulty. If you press the numbers in the correct order, you will advance to the next level.
4. The game will end once you make an incorrect press or if you successfully complete all 4 levels. Your score will be shown on the screen.

Knowledge expansion

The game in this exhibit is a test of your working memory.

Recall this term? It was mentioned in an earlier section (see Exhibit 7)! Let’s learn a bit more about it and how it is different from the other types of memory.

There are three main types of memory: Short-term memory, long-term memory and working memory.

Short-term memory is our ability to remember information presented to us for a brief period of time, usually a few seconds. This is long enough for us to document it, but our brain often does not hold on to the information beyond that (unless we convert it to one of the other two types of memory). Long-term memory is the entire store of knowledge we have accumulated throughout our lifetime.

Working memory refers to our ability to keep a small amount of information in mind, readily available for use in our current activities - from pattern recognition, decision-making, and problem-solving to performing calculations and skill-based tasks. It helps us keep the information we need easily accessible, for a longer time than our short-term memory can hold onto it, yet without overwhelming us with the sheer volume of long-term memory.

Information can be retrieved from long-term memory and placed in working memory for moment-to-moment use. Alternatively, information in working memory can become stored in long-term memory if associated with an emotion or assigned some special significance.

In this exhibit, working memory lets us keep the order of the numbers and their positions on the screen in mind, so that we can press the next number in the sequence.

Extended thinking

Did you know that a chimpanzee has tried a test similar to the one you just did? Chimpanzees are humans' closest relatives in the animal kingdom (along with bonobos), but how does their working memory differ from ours? Watch this video to find out more: https://youtu.be/zsXP8qeFF6A

Surprised by the results? The science behind working memory and the factors that affect it is still under active research. However, scientists have found a couple of ways to improve working memory: One is a memory tool called chunking, where a long string of information is separated into smaller, more manageable groups. Another is to reduce cognitive overload (i.e. having too many pieces of information "competing" for attention and/or space in our working memory). This can happen when we are multitasking, trying to hold multiple important events in our mind, worrying about tasks we are not currently engaged in, and/or are in an emotionally-charged state. Memory aids like planners and mindfulness techniques can help to address these issues.

How might you apply this knowledge to help you in your studies?

Possible answers:

- Chunking when trying to memorise large amounts of information for an exam.
- Focussing on a single task at a time instead of multitasking.
- Practising mindfulness techniques like deep breathing exercises before a study session.

References

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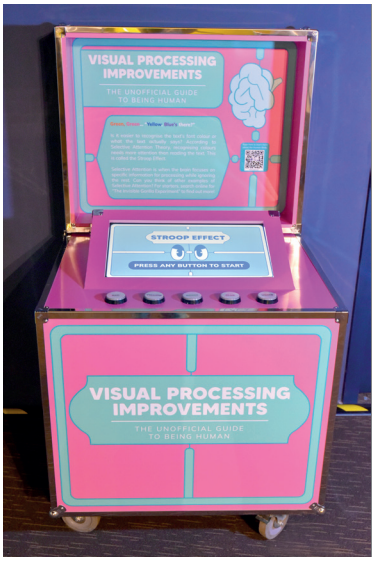
- https://www.psychologytoday.com/sg/blog/the-superhuman-mind/202009/can-you-improve-your-working-memory
- https://www.psy-ed.com/wpblog/working-memory-attention/

9 Visual Processing Improvements ⓅⓈ

Exploratory questions

- There is so much information in the world around us. How does our brain process all this information?
- How does our brain cope with conflicting sets of information? Do you think it places equal emphasis on both sets of information, or prioritises one set of information over the other?

On the exhibit



Green, Green... "Yellow, Blue's there?"

Is it easier to recognise the text's font colour or what the text actually says? According to Selective Attention Theory, recognising colours needs more attention than reading the text. This is called the Stroop Effect.

Selective Attention is when the brain focuses on specific information for processing while ignoring the rest. Can you think of other examples of Selective Attention? For starters, search online for "The Invisible Gorilla Experiment" to find out more!

Exhibit interaction

1. Press any of the buttons to start. The screen will show text in a certain colour.
2. Press the button that matches the colour of the text (not the colour spelt by the text). You will then proceed to the next round automatically.
3. There are 5 rounds altogether. The game will end once you have completed all 5 rounds. Your final score will be shown on the screen.

Knowledge expansion

The concept at play here is the Stroop effect. In the context of this exhibit, it refers to our difficulty in identifying a colour when it is used to spell the name of a different colour.

This phenomenon was first described by the psychologist, John Ridley Stroop, in the 1930s. In his experiments, Stroop found that participants took longer to name the colours of ink used to spell out the names of colours than to simply read the name of a colour printed in black ink.

Scientists think that this has to do with selective attention - in other words, our brain's tendency to choose which information is further processed and enters the awareness while ignoring the rest. It helps our brain cope with the constant influx of sensory details from the environment and prevent information overload.

In the exhibit, identifying the colour of the text requires more attention than reading the text itself. So, our brain tends to prioritise processing of the written information over its colour. As a result, we find ourselves pressing the button that corresponds to the colour spelt by the text instead of the colour it is lit up in.

Extended thinking

Can you think of other examples of selective attention? How might this impact our daily lives? To get you started, watch this video featuring the famous Invisible Gorilla: https://youtu.be/UtKt8YF7dgQ

Possible answers:

- The cocktail party effect: Our ability to focus on a single speaker or conversation in a noisy environment and ignore other sounds. This allows for communication in crowded spaces.
- Inattentional blindness:
    - Like in the Invisible Gorilla experiment! We are so focussed on a certain stimulus (i.e. the number of times the ball is passed) that we overlook other stimuli in the environment (i.e. the person in the gorilla suit walking across the court).
    - If we extend this to driving, inattentional blindness may lead to traffic accidents if drivers fail to notice road hazards which ***unexpectedly*** appear in their immediate environment because they are focussed on something else.
- Change blindness: Failing to notice an ***obvious*** change in our environment because we are so focussed on what else is happening in the same scene. Magicians often make use of this when performing tricks. For example, they may direct us to focus on one of their hands by performing dramatic gestures, whilst switching out items like cards in their other hand.

References

- https://lesley.edu/article/what-the-stroop-effect-reveals-about-our-minds
- https://www.mdpi.com/2076-3425/12/6/794

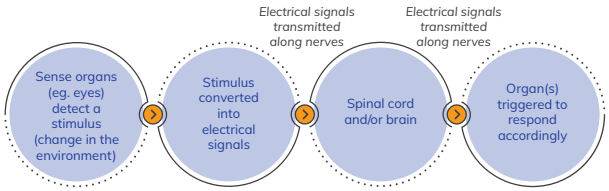
HARDWARE OPTIMIZATION

10 Improvements to Reaction Speed Ⓢ

Exploratory questions

- How do signals travel from our sense organs to the brain and from the brain to effector organs like our muscles?
- Do you think there is a time difference between detection of a stimulus by our sense organs and the response by effector organs like our muscles? Why or why not?

On the exhibit



Reaction time is how long it takes for your body to detect something, process the information, and then do something about it. Test how fast your reaction is! Is it possible to improve this?

Exhibit interaction

Solo mode

1. Press any button on Set A.
2. Wait till the display shows “Press the button when it lights up.”.
3. Press the button which lights up.
4. The game will end after 3 rounds. Your average reaction time will be shown on the display.

Duo mode

1. Player 1 to press any button on Set A.
2. Player 2 to press any button on Set B within the countdown period. The display will then show “Press the button when it lights up.”
3. Each player to press the button which lights up on their own set. Try to press the button before your friend does!
4. There are 3 rounds. The winner will be shown on the display after each round.
5. The game will end after 3 rounds. Each player’s average reaction time, as well as the overall winner, will be shown on the display.

Knowledge expansion

Our nervous system is made up of...

- The central nervous system: Our brain and spinal cord;
- The peripheral nervous system: The nerves throughout our body which send signals to and from our brain and spinal cord.

Reaction time is the amount of time required for our nervous system to detect a stimulus, process it and trigger a response by our body.

There are multiple steps involved. First, one of our sense organs like the eye, ear, nose, tongue or skin detects the stimulus and converts it into an electrical signal. Next, the electrical signal is transmitted along our nerves from the sense organ to the spinal cord. The electrical signal may either travel up the spinal cord to our brain, where it is further processed and interpreted, or is processed at the level of the spinal cord itself. An electrical signal is then sent from our brain or spinal cord back along the nerves to the effector organ(s) which is/are triggered to perform the response.

In the case of this exhibit, light-sensitive cells in the retina of our eyes detect a button lighting up. They send signals along the optic nerve to our brain, which processes this information. A signal is then sent from our brain, down our spinal cord, along nerves to the muscles in our hand. These muscles contract, making our hand press the button.

At each step in this "chain of relay", there is a slight delay in signal transmission[5]. These delays add up to produce a measurable difference in time between the stimulus and our response - our reaction time!

5| An electrical signal reaching the end of one nerve cell triggers the release of chemical signals into the "gap" between itself and the next nerve cell. These chemical signals then travel across the "gap" and trigger an electrical signal in the next nerve cell. These processes take time, and happen at every junction between nerve cells, as well as at the junction between nerve cells and effector organs, thus the delay. The chemical signals being referred to here are known as neurotransmitters.

Extended thinking

What was your average reaction time in the exhibit? Do you think it can be improved? Why or why not?

Answer: Up to a certain extent, reaction time can be improved with practice over time. This is due to a phenomenon called potentiation, where repeatedly performing an action improves signal transmission along nerve cells in the associated pathway. However, reaction time can never be zero due to the delay at each junction between nerve cells in the pathway (see [5] above).

11 Improvements to Motor Control ⓅⓈ

Exploratory questions

- How many senses do we have? Name as many as you know, and the sense organs in charge of them.
- How are we able to keep track of where our body parts are at any point in time?

On the exhibit

Proprioception is like our body's hidden GPS, allowing us to sense the position of our different body parts in space even without looking.

Can you touch your hands together with your eyes closed? That's proprioception at work! What about tasks that need both the senses of sight and proprioception?

Challenge your brain to handle unexpected visual feedback and master a new motor skill! How fast can you navigate a mirrored world and overcome the illusion?

Exhibit interaction

1. Look in the mirror.
2. Referring only to the reflection in the mirror, use your finger to trace the different shapes on the board. How challenging do you find this? Are you able to trace each shape accurately?

Knowledge expansion

Did you know that we have a sixth sense? No, not for supernatural things! Our sixth sense is called proprioception which helps us to sense the position of our different body parts in space.

In a task like tracing, proprioception helps us sense the position of our fingers in relation to one another and the board. It also helps us sense the position of our hand as it moves our finger across the surface of the board. In addition, we rely on visual feedback from our eyes to compare the path of our finger to the outline of each shape.

Tracing these shapes while looking at the reflection in the mirror adds another layer of challenge! The image in the mirror is reversed left to right. So, the visual feedback that we receive is not what our brain has been trained to interpret, and does not line up with the proprioceptive feedback from our hand and fingers. As a result, our brain is temporarily "confused" by these conflicting signals, and our tracing is initially inaccurate.

Extended thinking

What happens if you trace each shape more slowly and deliberately?

And, what if you trace each shape multiple times? Does your tracing become more accurate with each try?

With conscious effort, our brain is able process the reversed image, reconcile it with the proprioceptive feedback from our hand and fingers, and make use of this to adjust the movement of our hand. As such, our tracing can improve with concentration and practice!

References

- https://www.rigb.org/sites/default/files/attachments/proprioception_infosheet_v2_0.pdf

12 Improvements to Sense of Balance ⓅⓈ

Exploratory questions

- How do we keep our balance?
- Which of our senses do we rely on to do this?
- What happens if we remove information from one of these senses?

On the exhibit

Balance relies on information from our eyes, inner ear (vestibular system), and nerve endings in our muscles and joints (proprioceptive system). What happens if one system is affected?

Test your "inner ninja"! Maintain balance with limited sensory information and discover how your body adapts. See if you can improve with practice!

Exhibit interaction

1. Lift up one leg, with your knee bent at 90° and your shin parallel to the ground. Try to balance on your other leg for at least 5 seconds without any support. Do you feel unsteady?
2. Still standing on one leg, close both eyes. Do you find it easier or harder to stay balanced now?

Knowledge expansion

Balance relies on sensory information from our visual, vestibular and proprioceptive systems. In other words, we constantly receive feedback from our eyes, the balance canals in our inner ear, as well as the nerve endings in our muscles and joints. Our brain[6] combines and processes this information, then sends signals to the muscles in the rest of our body to make adjustments in our head position, limbs and posture. This keeps us steady from moment to moment, preventing us from swaying uncontrollably to either side while sitting, standing or walking, and reducing our risk of falls on uneven or moving surfaces.

We take this for granted, but depriving our brain of sensory information from one of these three systems (visual, vestibular or proprioceptive) is enough to affect our balance. We can still compensate, but if two of the three are missing, it greatly impairs our balance and increases our risk of falling.

You experience this for yourself in the exhibit! Standing on one foot, you feel more unsteady than before because you lose some proprioceptive input from the foot that is lifted off the ground. If you now close both eyes, it becomes even harder to stay balanced as you lose visual input.

6| In particular, the sensory association areas, cerebellum and motor areas of our brain. The cerebellum is the part of our brain largely involved in coordination.

Extended thinking

Find an example of a disease where balance is impaired due to loss of sensory information. Share this with your friends!

Answer: Some patients with poorly-controlled diabetes lose the sense of proprioception in their extremities. Standing with their feet together and arms by their sides, they tend to lean dangerously to one side and fall if not supported once they close their eyes. In this case, with their brain deprived of proprioceptive and visual feedback, the information from their vestibular system alone is not enough to compensate, and they become unable to maintain their balance.

VERSION BUGS AND OTHER MODELS

13 Coordination Conflict Ⓢ

Exploratory questions

- How does our brain control the movement of our limbs?
- Are the limbs on each side of our body controlled by the same or different halves of our brain?
- If you answered "different", which half of the brain controls which half of the body?

On the exhibit

Nerve fibres from the left side of the brain cross the brain stem, travel down the spinal cord and connect with limbs on the right side of the body, and vice versa, helping us move. Search online for "decussation" to find out more!

When both actions involve the right side of the body, the left side of the brain may struggle to manage two opposite movements at once.

Try doing this with your right hand and left foot instead and see what happens!

Exhibit interaction

1. Lift your right foot off the ground and move it clockwise in circles.
2. Whilst doing that, draw the number 6 in the air with your right hand. What happens to the movement of your right foot?
3. Confused? Try the same task, this time using your left foot and right hand. What is the difference?

Knowledge expansion

Electrical signals are sent along "pathways" of nerve cells from the motor cortex, the part of our brain in charge of controlling movement, to either side of our body. These pathways are called the corticospinal tracts, and cross the midline at the brainstem before travelling down the spinal cord to the limbs on each side of the body. This is known as "decussation". [Figure 13]

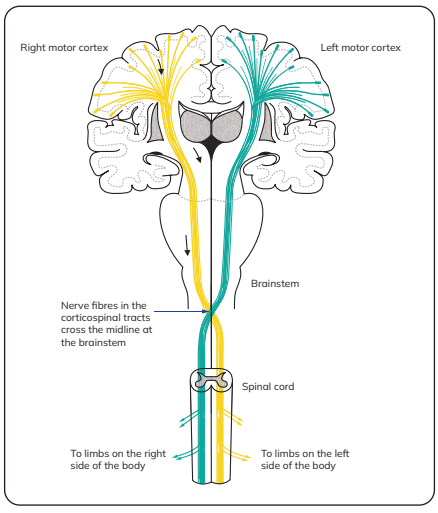


Figure 13: The corticospinal tracts. These are "pathways" of nerve cells from the motor cortex of our brain that cross the midline at the brainstem before travelling down the spinal cord to the limbs on each side of our body.
Adapted from: https://study.com/learn/lesson/corticospinal-tract-overview-function-pathway.html

One corticospinal tract connects the right motor cortex and the left side of our body. The other corticospinal tract connects the left motor cortex and the right side of our body. This means that the movement of your right hand and right foot are both controlled by the same side of your brain, namely the left motor cortex.

One side of the brain has difficulty managing movements in opposite directions at the same time. So, instead of moving clockwise like you want it to, your right foot tends to follow the anticlockwise movement of your right hand as you try to draw the number 6.

Switching to your left foot, this "coordination conflict" is resolved, as a different side of your brain is involved in performing each task. The clockwise movement of your left foot is controlled by the right motor cortex, while the anticlockwise movement of your right hand is controlled by the left motor cortex. So, you will find it much easier to do both at the same time!

Extended thinking

In a stroke, the nerve cells in a particular area of the brain are damaged, either due to blockage of its oxygenated blood supply or bleeding into the brain tissue. As a result, the function of body part(s) controlled by this area of the brain may be impaired. For example, the patient may experience a loss of sensation, weakness and/or worsened coordination.

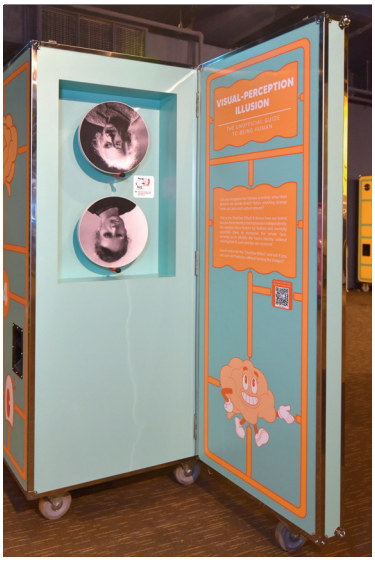
Using this principle, doctors are able to tell roughly which areas of the brain have been affected just by examining the patient (e.g. by testing the sensation, movement and coordination of their limbs). So, in a patient who experiences weakness in his right arm and leg after a stroke, has the right or left motor cortex been affected?

Answer: Left motor cortex.

14 Visual Perception Illusion (P)(S)

Exploratory questions

- What is an optical illusion?
- Have you come across any examples before? If yes, how do they work?



On the exhibit

Can you recognise two famous scientists when their pictures are upside-down? Notice anything strange when you turn each picture around?

This is the Thatcher Effect! It shows how our brains process facial identity and expression independently. We analyse faces feature by feature and mentally assemble them to recognise the whole face, allowing us to identify the face's identity without noticing that its eyes and lips are reversed.

Search online for the "Thatcher Effect" and see if you can spot odd features without turning the images!

Exhibit interaction

1. Look at the pictures. Do you recognize which famous scientists they are?
   One is Sir Albert Einstein, the Nobel-Prize-winning physicist who developed the theory of relativity. The other is Marie Curie, the first lady to have won the Nobel Prize, who is famous for her research on radioactivity.
2. Now, turn each picture around. Likely, you'll notice that the eyes and lips look strange. This is because they have been flipped upside down in the original image! Didn't realize that earlier, did you?

Knowledge expansion

What you experienced in the exhibit is known as the Thatcher effect, where our brain has difficulty picking up odd features in an upside-down face despite the same features being obvious in an upright face. Studying this optical illusion has given scientists some insights into the science behind facial recognition.

The first is that rather than interpreting and analysing the face as a whole, our brain gathers information about each part of the face and then pieces them together to form a congruent image. This is why we can recognize each picture as a face with eyes, nose and lips without realizing that the eyes and lips are oriented differently with respect to the rest of the face.

The second is that our brain's analysis of facial identity and facial expression are somewhat separate processes that are not dependent on each other. When each picture is upside down, we can recognize the identity of the person whose face is shown. However, we fail to notice their strange facial expression.

Extended thinking

We often take for granted our ability to recognize faces and facial expressions. That is, until we experience optical illusions like the Thatcher effect. But did you know that there are medical conditions where patients are unable to recognize facial identity or expressions? Find out the names of these disorders.

Answers:

- Prosopagnosia: An impaired ability to recognize faces. Some individuals may have difficulty recognizing familiar faces or even their own face. Others may not be able to tell unfamiliar faces apart. And yet others are unable to differentiate a face from an object.
- Expressive agnosia: An impaired ability to perceive facial expressions, body language and tone of voice.

References

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- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4298288/
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15 Visual-Audio Conflict ⓅⓈ

Exploratory questions

- Have you ever tried lip reading before? How effective is it in helping you to understand what someone is saying when you are not able to hear them well?
- From your answer to the previous question, how important do you think visual information is to our brain's interpretation of speech?

On the exhibit

Could you confidently tell what the sound was in the video? If not, you might have been tricked by the difference between the mouth movement and the sound.

This is known as the McGurk Effect! We tend to lip-read despite not being aware of it. So, what we see can alter what we think we hear. Next time you watch a video, remember, your eyes might be playing tricks on your ears! Can you really trust what you see, even if it does not match what you hear?

Exhibit interaction

1. Press the Start button.
2. Watch the video and listen carefully to what the speaker is saying. Ba, da, ga – which sound(s) do you hear?

Knowledge expansion

Only the sound "ba" was being played throughout the video... but the image of the mouth making "ga", a sound different from the one being played, changed your interpretation of what the sound actually was! This is called the McGurk effect.

The science behind this strange phenomenon is still being actively researched, but it does shed some light on the inner workings of our brain.

Our brain's interpretation of speech depends on not just what we hear, but also what we see. Visual information (e.g. of the movement of the lips, teeth and tongue) can greatly influence our brain's identification of a syllable or word being heard.

In addition, if presented with conflicting visual and auditory information (e.g. in the form of speech dubbed with a mismatched set of mouth movements like in this exhibit), our brain tries to reconcile the two. This can result in a compromise between the visual and auditory signals ("da"), or the visual signal "overriding" the auditory signal ("ga" being heard whilst "ba" is being played).

Extended thinking

Find out more about lip reading if you have not already done so.

Which parts of the body are you getting visual clues from?
Answer: The lips, face and tongue.

In what medical condition(s) might this technique be useful as a coping mechanism?
Answer: Hearing loss.

Are there any drawbacks of lip reading or situations in which it might be difficult? To get you started, watch this video: https://youtu.be/n1jLkYyODsc

Possible answer:

- Lip reading may not always give an accurate impression of what is being said due to phenomena like the McGurk effect, where seeing a mismatched set of mouth movements can alter what we think we hear.
- Lip reading may also be difficult when there are multiple speakers to keep track of, or if the speaker's mouth cannot be seen clearly (e.g. in a dim/dark environment, if the speaker covers their mouth, dense facial hair).

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- https://www.livescience.com/58047-mcgurk-effect-weird-way-eyes-trick-brain.html

16 Sensorial Conflict (P)(S)

Exploratory questions

- How do we sense temperature? Which organ(s) is/are involved?
- Do you think temperature is relative or absolute? Why do you say so?
- Are there any factors that affect how we perceive the temperature of an object?

On the exhibit

Why does the middle of the grille feel weird while the ends feel normal? Our skin contains lots of nerve endings that help us feel different things, like temperatures. Depending on where you touch the grille, different temperature signal patterns go to your brain. When you feel a mix of hot and cold, the signal pattern sent from your nerve endings to your brain gives the illusion that you are touching something painfully hot, giving a "burning" sensation. Search online for the "Thermal Grill Illusion" to find out more!

Exhibit interaction

1. Touch the cold end of the grill. How does your hand/wrist feel?
2. Touch the heated end of the grill. How does your hand/wrist feel?
3. Touch the middle of the grill where the cold and heated grills meet. How does your hand/wrist feel?

Knowledge expansion

When you touch the cold end of the grill, your hand/wrist feels cool. When you touch the heated end of the grill, your hand/wrist feels warm. But when you touch the middle of the grill where the cold and heated grills meet, you feel a burning sensation when it's not even that hot! Why?

This is known as the Thermal Grill Illusion, and it can be explained with the disinhibition theory by the scientists Craig and Bushnell.

Within our skin, there are many tiny nerve endings which pick up a variety of sensations - from light touch and pressure to temperature and even pain. Among the nerve cells or neurons that help us sense temperature, there are different types:

Type of neuron	Heat sensitive	Heat and pinch-sensitive	Cold-sensitive	Heat, pinch and cold-sensitive
Acronym	-	NS	COLD	HPC
Sense...	Temperature	Temperature and pain	Temperature	Temperature and pain
Activated by...	• Harmless hot stimuli (usually <45°C)	• Harmful hot stimuli (usually ≥45°C) • Pinch	• Harmless cold stimuli (usually 20-30°C)	• Harmful hot stimuli (usually ≥45°C) • Harmful cold stimuli (usually <15°C) • Pinch
Activity pattern	• Activity increases with an increase in temperature • Generally inactive >45°C	• Activity increases with an increase in temperature • Generally inactive <45°C • Also active when there is a painful stimulus (e.g. the skin is pinched)	• Most active from 20-30°C • Activity increases with a decrease in temperature	• Most active <15°C and >45°C • Activity increases with a decrease in temperature, especially <15°C • Activity increases with an increase in temperature, especially >45°C Also active when there is a painful stimulus (e.g. the skin is pinched)

Figure 16: The different types of temperature and/or pain-sensing neurons mentioned in Craig and Bushnell's study on the Thermal Grill Illusion. Do note the following points: (a) This list of neurons is not meant to be comprehensive – it is a simplification to aid understanding. (b) The temperatures in this table are estimates – the threshold at which each type of neuron is activated is still under active research.

When you touch the cold end of the grill, the cold grills there give a ***harmless cold stimulus***, which activates cold-sensitive (COLD) neurons. This causes you to feel a ***cool sensation without pain***. When you touch the hot end of the grill, the heated grills there give a ***harmless hot stimulus***, which activates heat-sensitive neurons. This causes you to feel a ***warm sensation without pain***.

However, when you touch the middle of the grill where the cold and heated grills meet, ***harmless cold and hot stimuli*** are introduced at the same time. Neither of these stimuli are harmful and there is ***no painful stimulus*** present. Yet, heat, pinch and cold-sensitive (HPC) neurons are active! Why? The activity of COLD neurons is lower than when only a harmless cold stimulus is present. Reduced activity of the COLD neurons permits increased firing of the HPC neurons in a phenomenon known as disinhibition or unmasking.

Activity of the HPC neurons in the presence of relatively low activity of the COLD neurons is similar to the pattern of neuron activity triggered by a ***harmful temperature stimulus that would normally cause pain***. This gives an unexpected "burning" sensation despite the middle of the grill being neither cold nor hot enough to cause harm!

To further simplify the explanation: When your hand/wrist is placed on the cold end of the grill, the signal pattern sent by the nerve endings in your skin to the brain is that of a ***non-painful cool sensation***. When your hand/wrist is placed on the hot end of the grill, the signal pattern sent from the nerve endings in your skin to the brain is that of a ***non-painful warm sensation***. However, when exposed to harmless cold and hot stimuli at the same time, the signal pattern sent from the nerve endings in your skin to the brain is that of a ***harmful temperature stimulus that would normally cause pain***! This gives an unexpected "burning" sensation when you place your hand/wrist in the middle of the grill.

Extended thinking

The skin is the largest organ of the human body. As mentioned earlier, it contains many tiny nerve endings that detect various sensations. These are scientifically known as receptors.

Find out the names of the different groups of receptors in the skin and which sensations they are responsible for detecting. Hint: The names of these groups of receptors all end with the suffix "-receptor".

Answer:

- Mechanoreceptors sense touch, pressure, stretch and/or vibration.
- Thermoreceptors sense temperature.
- Nociceptors sense pain and noxious (i.e. harmful) stimuli.

References

- https://pubmed.ncbi.nlm.nih.gov/8023144/
- https://www.tandfonline.com/doi/full/10.1080/08990220.2021.1986382

17 Perception of Time (P)(S)

Exploratory questions

- How do we measure time?
- What affects our perception of time (i.e. how quickly time seems to pass)?
- Do you think the perception of time is the same for all animals, including humans, or does it differ from animal to animal?

On the exhibit

Ever noticed that time goes by quickly when you are having fun but drags when you are bored? It is not just humans who feel this way – all creatures experience time, but each in their own way! The quicker an animal's brain handles what it sees, the slower time feels for it. Search online for "Flicker Fusion Rate" to find out more!

Watch this video and see how different animals perceive time.

Exhibit interaction

1. Press each of the 3 button icons in turn.
2. Observe what happens to the speed of the video. This simulates how quickly time seems to pass for a human, fly and turtle respectively.

Knowledge expansion

The perception of time (i.e. how quickly time seems to pass) differs from species to species.

We perceive what is happening around us like a continuous video. However, what is actually happening is that our brain is piecing together a series of signals sent from our sense organs at a set number of times per second to form an unbroken flow. This is similar in other animals, except that this "piecing together" happens at varying speeds. The faster the brain pieces together the incoming information, the slower time seems to pass.

For images sent from the eyes, the speed at which those images are pieced together by the brain is represented by the "flicker fusion rate", i.e. how fast a light has to be turned on and off before it is perceived by the brain as a continuous light. For humans, our average would be 60 flashes per second. For turtles, this would be 15 flashes per second, and for flies, a whopping 250 flashes per second!

This is why if we look at a clock ticking, the second-hand of the clock would appear to be moving **more quickly** from a turtle's perspective, but **more slowly** from a fly's perspective.

Extended thinking

What other factors affect our perception of time? Ever heard of the saying "time flies when you're having fun"? Is there any scientific basis for this statement? Read this article to get you thinking: https://www.livescience.com/64901-time-fly-having-fun.html

Possible answers:

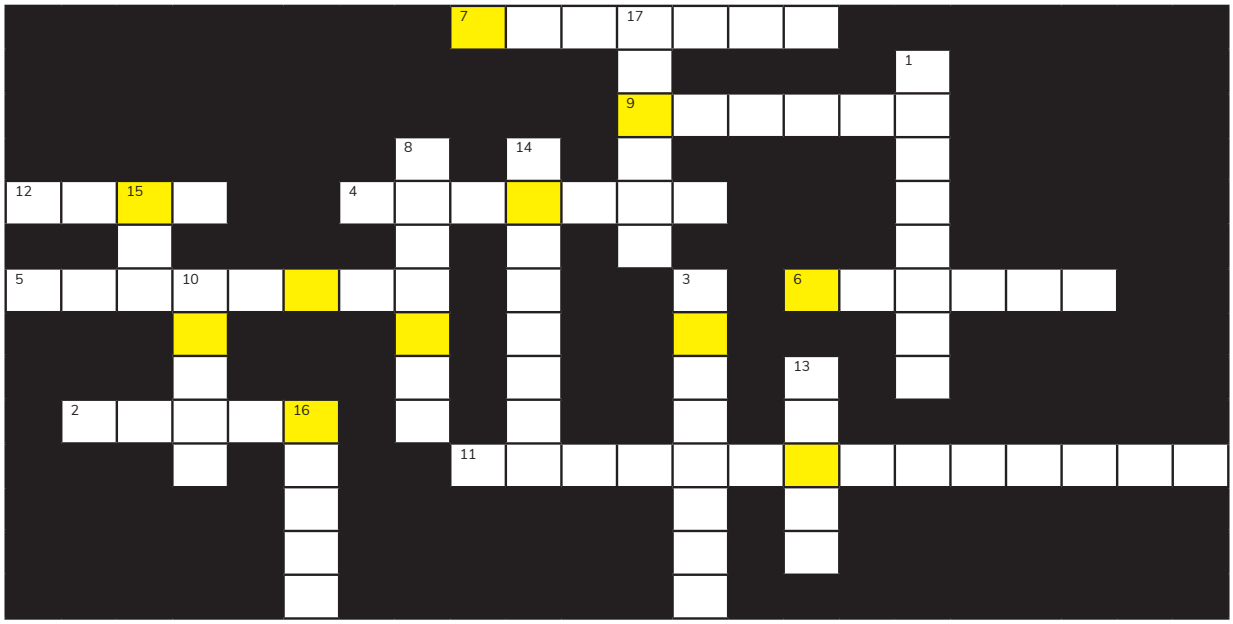
- Dopamine release:
  - When we're having fun, nerve cells in reward-related pathways in our brain are more active and release more dopamine. This causes our brain to perceive that less time has passed than actually has.
  - When we're not having fun, these nerve cells are less active and do not release as much dopamine, causing the brain to perceive that time is passing more slowly.
  - There thus may be a scientific basis for the saying "time flies when you're having fun"!
- The interval between events that our brain anticipates will occur:
  - Time seems to pass more slowly when our brain anticipates events that are closer together (e.g. the end of each sentence in a set of instructions).
  - However, time seems to pass faster when our brain anticipates events that are further apart (e.g. the beginning and end of a game).
- The speed at which nerve cells along certain pathways in our brain activate when we perform an activity.
- How dense the neural networks laid down during memory formation are: The denser the neural network laid down during formation of the memory, the slower time seems to pass in that memory and the longer the event that the memory is about seems to last.

Do note though that these factors are still under active research by scientists!

References

- https://www.bbc.com/news/science-environment-41284065
- https://www.sciencefocus.com/science/animal-time-perception/

CROSSWORD PUZZLE



DOWN		ACROSS	
1	The ratio of arm span to height.	2	The part of our body that helps process images from our eyes so that we see objects in their upright, non-reversed form.
3	A spinning drum that makes use of how the brain holds onto images from our eyes to create a moving animation.	4	The seashell-like organ in our inner ear that helps us to hear.
8	The type of memory that helps us keep a small amount of information in mind, ready for use in our current activities: _____ memory.	5	The process of using sounds we hear from ourselves to fine-tune our speech is called the auditory _____ loop.
10	Reaction time is the result of a _____ in the passing of signals from our sense organs to the central nervous system to the organ(s) performing the response.	6	Which finger contributes most to grip strength? The _____ finger.
13	The left side of our brain controls the limbs on the right side of our body and vice-versa. This is because nerve fibres from the brain _____ the midline before they travel down the spinal cord to the limbs.	7	The ability to identify a musical note without seeing how it was played on an instrument and without reference to other notes: _____ pitch.
14	We can recognize a face that is upside down without realizing that its eyes, nose and lips are not the right way around. This is known as the _____ effect.	9	We tend to notice the colour spelt by a word rather than the colour of the word, because of the _____ effect.
15	Our brain identifies words or syllables being spoken based on what we hear and what we _____ (e.g. movement of the lips, teeth and tongue).	11	The sense that helps us keep track of the position of our different body parts in space.
16	Within our skin, there are many tiny _____ endings that help us sense temperature, light touch, pressure and even pain.	12	Balance relies on sensory information from our eyes, the balance canals in our inner ear and the nerve endings in our muscles and joints. If we _____ sensory information from any of them, our balance will be affected.
17	What is the relationship between processing speed of the brain and perception of time? The _____ our brain pieces together incoming information, the slower time seems to pass.		

The letters in the yellow boxes form a mystery word. Unscramble them to figure out what it is!

_ _ _ _ _ _ _ _ _ _ _ _

Clue: The scientific name of our species.

(1)Ape Index (w/o spacing); (2)Brain; (3)Zoetrope; (4)Cochlea; (5)Feedback; (6)Middle; (7)Perfect; (8)Working; (9)Stroop; (10)Delay; (11)Proprioception; (12)Lose; (13)Cross; (14)Thatcher; (15)See; (16)Nerve; (17)Faster; (Mystery word)Homo Sapiens

ADDITIONAL RESOURCES

The following is a list of resources recommended by the National Library Board. Do check them out if you are curious to find out more about the human body and how it works!

For Children

Books (Physical and/or digital)		
Title	**Synopsis**	**Link**
Unsolved Questions About The Human Body	Why do we yawn? Are left-handed people more creative? Why do we have fingerprints? When it comes to our bodies, there are a whole lot of questions we're still trying to answer. Get ready to explore the unknown and discover how scientists are working to solve the mysteries of the human body.	https://go.gov.sg/scb-human-p-ebook1
The Bizarre Body	Takes a look inside the human body to understand its most interesting and unusual facts and functions. Leveled by the respected Fountas and Pinnell leveling system, the Extreme Readers series is designed to enhance and nurture your child's reading development. Featuring high-interest topics, this unique nonfiction series offers dramatic photography, graphic illustrations, amazing facts, and a thrilling "extreme facts" list that will engage young readers and keep them turning the pages. Plus, the fact-based books are the perfect supplement for reading and science curricula.	https://go.gov.sg/scb-human-p-ebook2
Body Oddity Projects : floating arms, balancing challenges, and more	Step away from the screen and learn science in the real world. Discover amazing tricks of the human body with these hands-on projects like optical illusions, involuntary movement, and balance challenges. Step-by-step instructions and photos guide readers through each activity and Science Takeaway sidebars explain the science behind the results. All projects use common materials found around the house.	https://go.gov.sg/scb-human-p-ebook3
Human Body Learning Lab : take an inside tour how your anatomy works	Pediatrician Betty Choi invites kids ages 8 and up to explore the marvels of the human body with lively hands-on projects and activities. Packed with colorful diagrams of how each major body system works, fun facts, and easy tests that kids can use to learn about and evaluate their own body functions, The Human Body Learning Lab makes biology more exciting and engaging than ever	https://go.gov.sg/scb-human-p-ebook4

Videos		
Title	**Synopsis**	**Link**
Tricks to Play on Your Friends	April Fools Day is just around the corner, so tune in to learn a lot of incredible tricks to play on your friends! Convince your friends you can read their minds, prove to them how strong you are and much much more through these fun tricks taught by Dr Chris and Dr Xand. You do not want to miss this!	https://go.gov.sg/scb-human-p-video1
What Colour Is This Dress? (SOLVED with SCIENCE)	What colour do you see? Yellow and white, or blue and black? Mitchell Moffit and Greg Brown explain the science behind the dress that broke the internet.	https://go.gov.sg/scb-human-p-video2
Why do humans have a third eyelid? - Dorsa Amir	You know that little pink thing nestled in the corner of your eye? It's actually the remnant of a third eyelid. In humans, it's vestigial, meaning it no longer serves its original purpose. There are several other vestigial structures in the human body, quietly riding along from one of our ancestor species to the next. But why have they stuck around for so long? Dorsa Amir investigates.	https://go.gov.sg/scb-human-p-video3

For Youths

Books (Physical and/or digital)		
Title	**Synopsis**	**Link**
Sleights of Mind : what the neuroscience of magic reveals about our everyday deceptions	Magic tricks fool us because humans have hardwired processes of attention and awareness that are hackable-a good magician uses your mind's own intrinsic properties against you in a form of mental jujitsu. Now magic can reveal how our brains work in everyday situations. For instance, if you've ever bought an expensive item you'd sworn you'd never buy, the salesperson was probably a master at creating the "illusion of choice," a core technique of magic. The implications of neuromagic go beyond illuminating our behavior; early research points to new approaches for everything from the diagnosis of autism to marketing techniques and education. Sleights of Mind makes neuroscience fun and accessible by unveiling the key connections between magic and the mind.	https://go.gov.sg/scb-human-s-ebook1
The Body : a guide for occupants	Bill Bryson, bestselling author of A Short History of Nearly Everything, takes us on a head-to-toe tour of the marvel that is the human body. As compulsively readable as it is comprehensive, this is Bryson at his very best, a must-read owner's manual for everybody. Bill Bryson once again proves himself to be an incomparable companion as he guides us through the human body--how it functions, its remarkable ability to heal itself, and (unfortunately) the ways it can fail. Full of extraordinary facts (your body made a million red blood cells since you started reading this) and irresistible Bryson-esque anecdotes, The Body will lead you to a deeper understanding of the miracle that is life in general and you in particular. As Bill Bryson writes, 'We pass our existence within this wobble of flesh and yet take it almost entirely for granted.' The Body will cure that indifference with generous doses of wondrous, compulsively readable facts and information	https://go.gov.sg/scb-human-s-ebook2
Brains Explained : how they work & why they work that way	Neuroscientist Alie Caldwell and clinical psychologist Micah Caldwell created the Youtube channel Neuro Transmissions in 2015 to make learning about the nervous system as entertaining and fascinating as the brain itself. Their first book will have you ditching the textbooks and having fun while learning about the organ that makes you who you are. This book will answer questions about anxiety, memory, the subconscious, and so much more- helping you understand your own mental processes and opening avenues for self-improvement and development.	https://go.gov.sg/scb-human-s-ebook3

Videos		
Title	**Synopsis**	**Link**
Meta Cookie at Exploratorium After Dark	Takuji and Takashi from the University of Tokyo have created a system that uses augmented reality to control the flavor of an actual cookie. By presenting the image of a cookie through a virtual reality headset, then reproducing the scent through perfume tubes, Meta Cookie may trick you into thinking that a plain sugar cookie is actually an almond or chocolate cookie!	https://go.gov.sg/scb-human-s-video1
The science of spiciness - Rose Eveleth	When you take a bite of a hot pepper, your body reacts as if your mouth is on fire -- because that's essentially what you've told your brain! Rose Eveleth details the science and history behind spicy foods, giving insights into why some people continue to pay the painful price for a little spice.	https://go.gov.sg/scb-human-s-video2
Neuroscientist Explains the Laurel vs. Yanny Phenomenon | WIRED	The Laurel vs. Yanny debate- once took the internet by storm. WIRED's Louise Matsakis speaks with Tyler Perrachione, PhD, about why certain people hear Laurel when playing the now-infamous audio clip and others hear Yanny.	https://go.gov.sg/scb-human-s-video3
Do you see a face? You're actually hallucinating - Susan G. Wardle	Imagine opening a bag of chips, only to find Santa Claus looking back at you. Or turning a corner to see a building smiling at you. Humans see faces in all kinds of mundane objects, but these faces aren't real—they're illusions due to a phenomenon known as face pareidolia. So why exactly does this happen, and how far does this distortion go? Susan G. Wardle explores why we see illusory faces.	https://go.gov.sg/scb-human-s-video4
How Every Movie & Video Game Tricks Your Brain	**Caution: This video may contain flashing images that could trigger seizures or discomfort in individuals with epilepsy, photosensitivity or other visual conditions.** Movies. Video games. YouTube videos. All of them work because we accidentally figured out a way to fool your brain's visual processing system, and you don't even know it's happening. In this video,BeSmart talks to neuroscientist David Eagleman about the secret illusions that make the moving picture possible.	https://go.gov.sg/scb-human-s-video5
How optical illusions trick your brain - Nathan S. Jacobs	Optical illusions are images that seem to trick our minds into seeing something different from what they actually are. But how do they work? Nathan S. Jacobs walks us through a few common optical illusions and explains what these tricks of the eye can tell us about how our brains assemble visual information into the 3D world we see around us.	https://go.gov.sg/scb-human-s-video6

For Parents and Adults

Books (Physical and/or digital)		
Title	**Synopsis**	**Link**
Sleights of Mind : what the neuroscience of magic reveals about our everyday deceptions	Magic tricks fool us because humans have hardwired processes of attention and awareness that are hackable-a good magician uses your mind's own intrinsic properties against you in a form of mental jujitsu. Now magic can reveal how our brains work in everyday situations. For instance, if you've ever bought an expensive item you'd sworn you'd never buy, the salesperson was probably a master at creating the "illusion of choice," a core technique of magic. The implications of neuromagic go beyond illuminating our behavior; early research points to new approaches for everything from the diagnosis of autism to marketing techniques and education. Sleights of Mind makes neuroscience fun and accessible by unveiling the key connections between magic and the mind.	https://go.gov.sg/scb-human-ep-ebook1

Videos		
Title	**Synopsis**	**Link**
Why You're Taller In The Morning Than At Night	If you've ever woken up and felt on top of the world it may be because you're actually a little taller in the morning than at night. Here's the science behind it.	https://go.gov.sg/scb-human-ep-video1
What are those floaty things in your eye? - Michael Mauser	Sometimes, against a uniform, bright background such as a clear sky or a blank computer screen, you might see things floating across your field of vision. What are these moving objects, and how are you seeing them? Michael Mauser explains the visual phenomenon that is floaters.	https://go.gov.sg/scb-human-ep-video2
Understanding Dementia and The Latest Therapies In Singapore | On The Pulse | Full Episode	In this video, host Germaine Tan gets the low-down on a new drug for those with Alzheimer's disease, learns how Asian dementia differs from the west and how murals on flats can help. She also gets her hands on a new therapy tool designed to jog the memory of elderly folks. And does writing things down help you remember them better? Germaine puts herself to the test!	https://go.gov.sg/scb-human-ep-video3
Why You Can't Smell Yourself (and Other Ways Your Senses Lie to You)	There is an absolutely weird, but surprisingly common phenomenon called sensory adaptation that you experience every day in countless ways without even realizing it. Without this very strange phenomenon, you would be lost, overwhelmed, and completely unable to navigate the external world. In this episode, we'll explore the many ways your brain "tunes out" most of what's going on around you so that you can be the high-functioning smart people that we know you are.	https://go.gov.sg/scb-human-ep-video4

Why Some People Don't Have an Inner Monologue	Do you always have an inner monologue? Can you imagine not having one? Or maybe you've never had an inner monologue and wondered what it would be like? Psychologists are beginning to study that voice inside your head—and it's much more complicated than you might think!	https://go.gov.sg/scb-human-ep-video5
Aphantasia: The People Who Can't Visualise | 'Out of Mind' | Wired UK	If you close your eyes and picture an apple, how clear is that apple in your mind? Most people can visualise images in their head instantaneously - this known as the mind's eye. But in 2015, a scientific study shed new light on the relatively unheard-of phenomenon known as aphantasia, a mental blindness where the brain is unable to call images to the mind eye. This short documentary uncovers the root cause of a person's emotional detachment from people and events - and the unexpected advantages that come with it.	https://go.gov.sg/scb-human-ep-video6
Every 'Useless' Body Part Explained From Head to Toe | WIRED	Dr. Jeffrey Laitman joins WIRED to break down every 'useless', vestigial organ and structure in our evolved human bodies. From the "wisdom" teeth and our simian tailbones down to muscles made less important by our double-arched feet, Dr. Laitman highlights where it came from—and how it ended up still inside of us.	https://go.gov.sg/scb-human-ep-video7

NLB also curates Science resources for children and teens, to encourage appreciation of Science in our everyday lives. Visit the LearnX Science website here or scan the QR code.

Users can also borrow NLB's digital collections for free via the NLB Mobile app. Download the app here or scan the QR code.

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