Hemispheric Lateralization

AIMS

At the end of the lecture, you should be able to understand and discuss:

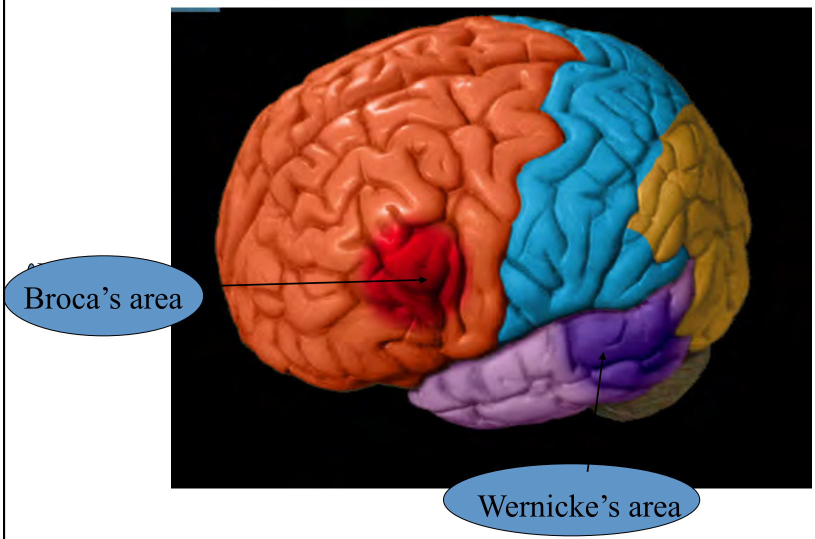
- What hemispheric lateralization is;
- The history behind its discovery;
- The different methods that have been used to investigate it and relevant findings.

What is hemispheric lateralization?

It is the doctrine that the two hemispheres are specialized for different tasks and/or mode of processing.

At first, it was considered synonymous with hemispheric dominance, but today we know that the two hemispheres have different areas of competence.

1865: The date of birth of the doctrine of hemispheric lateralization.
"We speak with the left hemisphere." --Paul Broca



Evidence presented not long afterwards suggested that:

- The right hemisphere is dominant for visual spatial processing.
- Language is represented differently in right and left-handers.

Language is localized in the left hemisphere in:

95% of right-handers

85% of ambidextrous

70% of left-handers; in left-handers :

15% have bilateral dominance

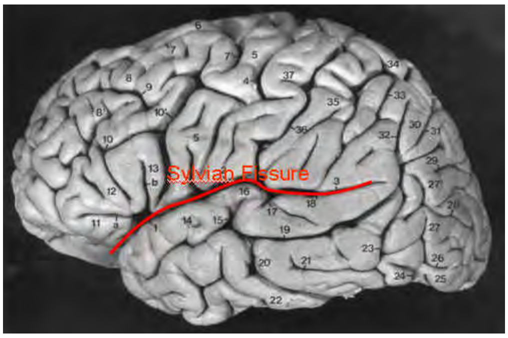
15% have language in the right hemisphere

Studies have further explored differences between the two hemispheres by investigating:

- Anatomical differences
- Brain asymmetries in other species
- The behaviour of split brain patients
- The behaviour of normal subjects in lateralization experiments
- The effects of unilateral lesions

Anatomical differences

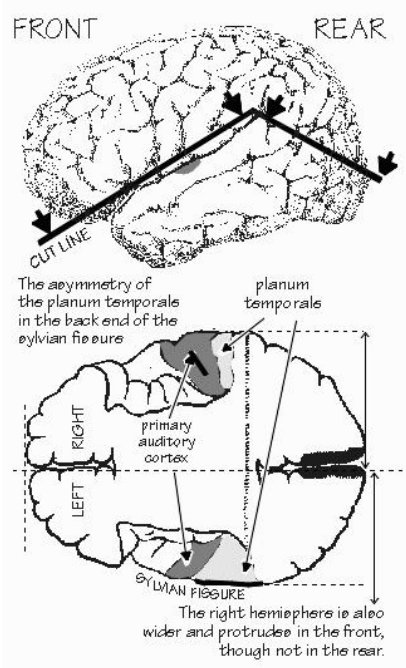
- The right hemisphere is slightly larger and heavier than the left, but it contains less grey matter.



- The Sylvian fissure is longer in the left hemisphere and its slope is gentler.

- The right frontal lobe extends further forward and it is wider than the left frontal lobe. On the other hand, the left occipital lobe extends further backward and it is wider.

- The planum temporale is larger on the left than on the right side of the brain.



These anatomical differences are interesting because they *could* relate to differences in function.

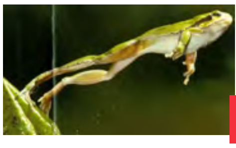
- The size of the planum temporale/ slope of sylvian fissure may be related to language dominance since they are not equally present in left-handers.

However,

- Some of the same anatomical differences -- a heavier right hemisphere, a longer left fissure and a larger left planum temporale -- are also present in other non-human primates

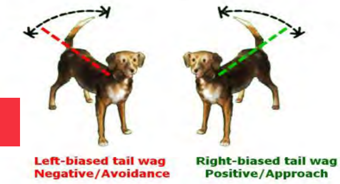
Famed bonobo 'Kanzi'

Dr. Gammon describes Kanzi as a "an incredible individual who understands a lot of human spoken language and communicates via lexigrams"



Escaping preference: left

Why brain asymmetry?



- Having different behaviours controlled by different sides of the brain may maximize efficiency, but this does not explain why the pattern is reversed in a subset of individuals.

- **Biological functions** are sometimes carried out by asymmetric organs (hear, liver), but this is true in *all individuals*. **Behavioral functions,** however, display **incomplete asymmetries.** This is common across the animal kingdom. Is there an advantage ?

- The advantage of being a minority.
  - Surprise/ disorient your enemy
  - Provide new solutions/reach where the majority cannot

Feeding preference: right

Picking preference: left foot

Research with split-brains patients

Who are split-brain patients?

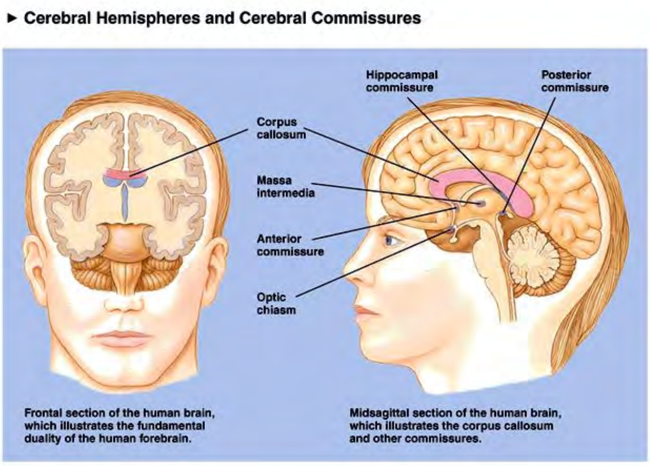
- They are patients who have undergone a **commisurotomy**, that is, a surgery that has severed the main tracts of fibres connecting the two hemispheres such as the corpus callosum and the anterior commissure.

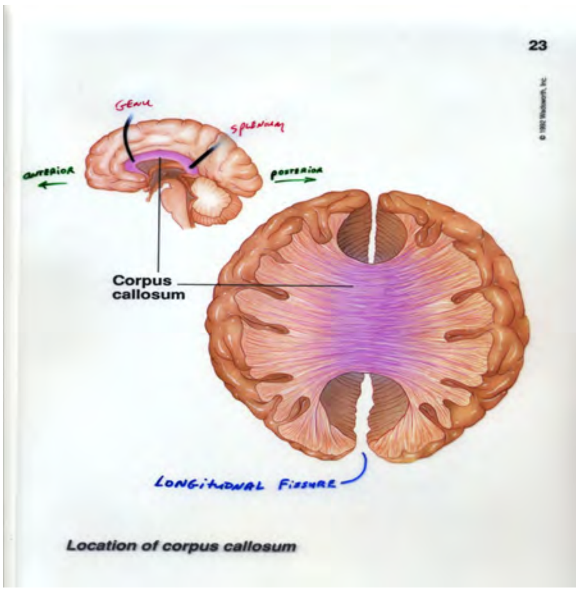
- This surgery was carried out in the sixties on a small number of patients to relieve intractable epileptic seizures.

- The surgery was successful in treating the seizures and clinical effects on behaviour were minimal.

- These patients were left with two normal (or close to normal) hemispheres. However, the two hemispheres could no longer communicate with one another.

The structures responsible for communication between hemispheres





__Corpus callosum:__

Splenium
posterior part

Genu
anterior part

Methodology

- It is possible to **direct input selectively to one hemisphere**. In split brain-patients, this input is unable to cross over to the other hemisphere. Thus, one may then investigate the capacity of one hemisphere in isolation.

- Input can be selectively directed to one hemisphere because **pathways of sensory input are generally crossed** so that an input presented in one side of space is directed first to the contra-lateral hemisphere.

- Lateralization experiments take advantage of this anatomical organization of sensory inputs.

'Cross-over' pathways of sensory input

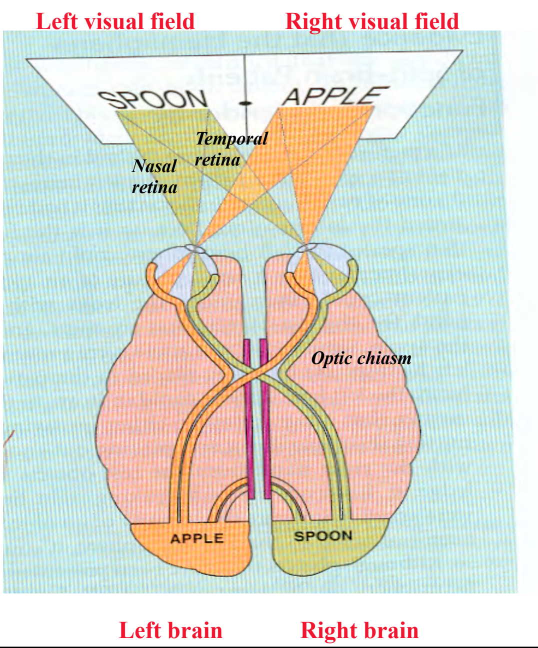
Visual Input

It is crossed for information presented in the visual periphery.

To be crossed,input needs to be presented very briefly on the far periphery (e.g., < 100 ms).

As soon as you move your eyes and fixate a stimulus, both hemispheres will receive the information.

Very brief presentation =tachistoscopic presentation



Auditory Input

Information from each ear connects **to both** hemispheres. Thus, auditory lateralization has been studied less with split-brain patients

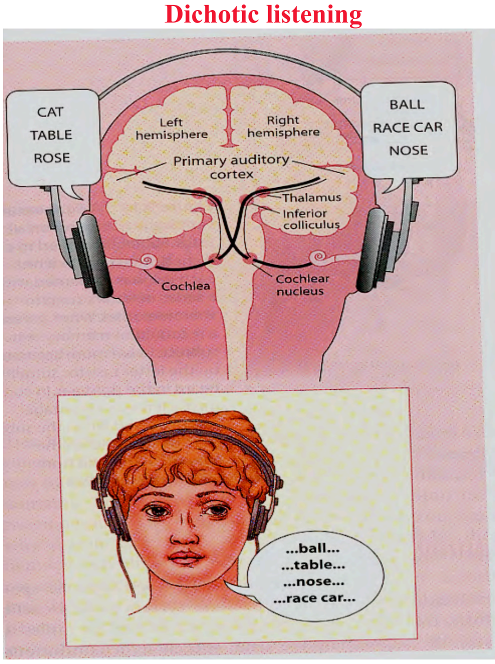
However,

•More numerous and faster fibres connect each ear to the **contro-lateral** hemisphere.

•We tend to attend mainly to one ear when inputs are simultaneously presented to both ears.

This still allows us to assess lateralization for different auditory inputs.

Dichotic listening



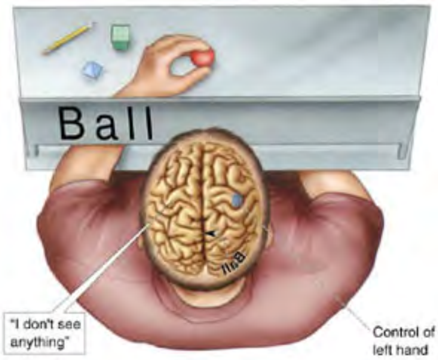
Tactile input

Tactile input is completely crossed. In a split-brain patient, in the absence of visual information, what is touched/ manipulated by one hand will be known only by the contralateral hemisphere.

Fndings from split brain research

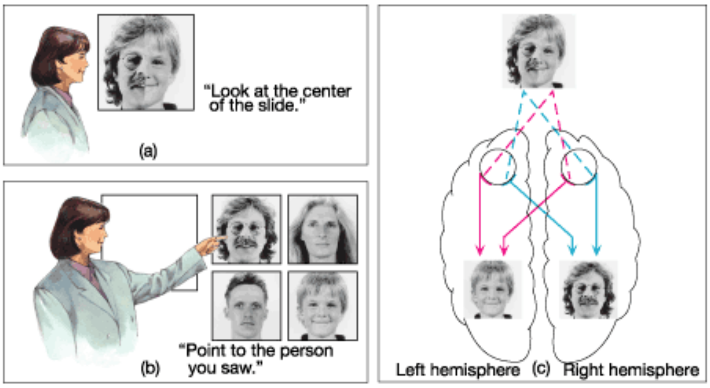
- Results with split-brain patients have confirmed that the left hemisphere is dominant for language. They also have given us insights into the linguistic abilities of the right hemisphere:

- The right hemisphere is not completely illiterate
- It cannot speak, understand abstract words or grammar BUT
- It can understand common, concrete words and simple sentences (even if written)

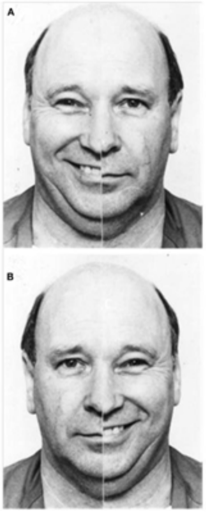


Experiments carried out with patients and control participants

The **right hemisphere is dominant in the processing of faces**.
A split-brain patient will tend to recognize the face corresponding the left part of a chimera face.



The right hemisphere is dominant in in the recognition of emotional expression; thus the left part of the face will draw recognition of emotions.



People tend to select the image in which emotion is presented in the left visual field (A) as more expressive than the identical image reversed to show emotion in the right visual field (B) (Reprinted from Failla et al., 2003,

The right hemisphere is dominant for music. In a dichotic listening experiment, music is better recognized if presented to the left ear.

LET's TRY some questions….

1. **What happens when a split-brain patient is asked to name an object presented tachistoscopically on the left?**

A Cannot name because only the right hemisphere has seen the object

B Can name because the right hemisphere has seen the object and can produce the name

2. What happens when a split-brain patient is asked to name an object that he cannot see but he can feel with his left hand ?

A Cannot name because only the right hemisphere has recognized the object

B Can name because the left hemisphere has recognized the object

3. What happens when a split-brain patient is asked to identify an object that has been presented tachistoscopically on the right?

A Can pick the corresponding objects among alternatives with both hands
B Can pick the right object with the right hand
C Can pick the right object with the left hand

4. **What happens when a split-brain patient is asked to name an object which has been briefly presented on the right?**

A. Cannot name, but can pick the right objects among alternatives with his left hand
B. Can name and select the right object with his left hand
C. Can name and select the right object with his right hand

A couple more questions to do in your own time..

5. **What would a split-brain patient say when briefly presented with the stimulus above**

A. Fish
B. Eye

6. **Which object will a split-brain patient indicate when briefly presented the stimulus above and asked to point with left hand?**

A. Tusk
B. Egg

Limitations of split brain research

- Protracted epileptic seizures may have determined unusual lateralization of functions.

  For example, the right hemisphere may have more language competence than in the general population.

- The surgery may have caused some brain-damage.

HOWEVER

- Research with split-brain patients has produced results remarkably consistent with what has been found with other research paradigms.

Research with intact participants

Visual and Tactile Input.
The same methodology used with split-brain patients is also used with control participants with broadly consistent results.

Specialization is inferred when input from one visual field lead to faster and/or more accurate responses.

Theoretical interpretations:

Transferring information to the non-specialized hemisphere takes time and it is error prone.

The non-specialized hemisphere carries out the task when it receives the input first but it does a worse job.

Research with brain-damaged patients

- Differences between hemispheres are as marked as differences between different lobes/areas within the same hemisphere.

- The functions of contralateral lobes in the two hemispheres are quite symmetrical but for different materials (e.g., the left temporal lobe is involved in memory for words; the right temporal lobe is important for memory of visuo-spatial patterns).

Lesions to the left hemisphere lead to:

Aphasia – difficulties in comprehending and producing speech

Dyslexia and Dysgraphia – difficulties with reading and spelling

Agnosia – difficulties in knowing the meaning of objects

Apraxia – difficulties in carrying out complex movements

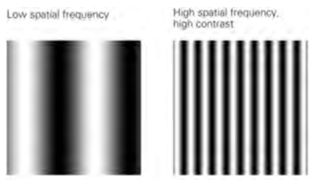
Poor STM and LTM for verbal materials

Lesions to the right hemisphere lead to:

- Difficulties processing music
- Difficulties reading in Braille
- Agnosia – difficulties in recognizing faces and complex spatial objects
- Apraxia – difficulties with movements in spatial patterns
- Difficulties with directions and spatial orientation
- Poor STM and LTM for visuo-spatial materials

How can we more broadly characterize the processing of the two hemispheres?

		Left Hemisphere		Right Hemisphere
• What is processed:		languagevs. language	vs.	visuo-spatial patterns music
• How it is processed:		detailed/ analytical	vs.	global/holistic
• Sensory input preferred:	visual	high frequency	vs.	low frequency
	tactile	fine grained	vs.	coarse grained



Recommended readings

- Banich, M.T., & Compton R.J. (2011). *Cognitive neuroscience and neuropsychology, 3rd edition*. Wadsworth, Cengage Learning. Chapter 4 –Lateralization of Function.
- Kolb, B., & Whishaw, Q. (2015). *Fundamentals of Human Neuropsychology*, *7th edition*. New York: Worth Publishers. Chapter 11, Cerebral Asymmetry, Chapter 12, Variation in Cerebral asymmetry, pp 309-313.
- Parkin, A.J. (1996). *Explorations in cognitive neuropsychology*. Oxford: Blackwell. Chapter 6, The split brain.

For additional readings:

Springer, S.P. & Deutsch, G. (1993). *Left brain, right brain*. New York: Freeman.

Grant, B. (2014). On the other hand. Handedness, a conspicuous but enigmatic human trait, may be shared by other animals. What does it mean for evolution and brain function? *The Scientist.*

Gainotti, G. (2016). Lower and higher-level models of right hemisphere language. A selective survey. *Functional Neurology, 31*(2), 67-73.

At the end of the lecture and after the reading you should be able to:

- Understand anatomical and functional differences between the two hemispheres.
- Understand the origin of theories of hemispheric lateralization.
- Understand the different methodologies which have been used to assess lateralization, including the neuroanatomical characteristics which allow different paradigms to be used.
- Discuss why hemispheric lateralization may be advantageous.

Test your acquired knowledge!!

1. If a patient with a commissurotomy is asked to name an object which is placed in his left hand, but which is out of sight, he will:

a) be able to name the object
b) be unable to name the object, but be able to describe its tactile features
c) be unable to either name or describe the object
d) be unable to name the object, but be able to match it with a picture presented in the left visual field

2. If a patient with a commissurotomy is briefly shown a picture in his right visual field he will:

a) be able to name the picture
b) be unable to name the picture, but be able to point to it among alternatives with his right hand
c) be unable to name and point to the corresponding picture among alternatives with either hand
d) be able to match the picture with an object felt with the left hand

e) 3. To make an eye movement it takes:

a) 100 milliseconds
b) 150 milliseconds
c) 200 milliseconds
d) an accurate estimate is not possible

4. The left hemisphere is dominant for speech in:

a) 70% of left-handers
b) 50% of left-handers
c) 30% of left-handers
d) 10% of left-handers

5. The right hemisphere:

a) has no language abilities at all
b) can understand language perfectly, but has no spoken speech
c) has a limited language capacity across comprehension and production
d) has no spoken speech but some comprehension ability

6.The right hemisphere has been shown to be superior to the left in several general respects; the three best-documented are:

a) slow movement, facial recognition and cognition
b) abstract reasoning, grammar and musical ability
c) spatial ability, prosody and musical ability
d) thinking, mathematics and emotion