The Split Brain

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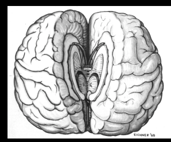
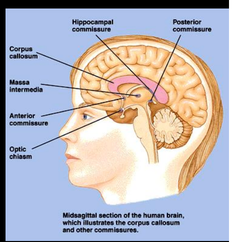
Lecture Overview

- What is a split brain?
  - Communication in the Intact Brain
  - The Corpus Callosum
  - The Split Brain Operation
- Behavioural Effects of a Split Brain
- Agenesis of the Corpus Callosum
- Summary



What is a Split Brain?

- In a normal (average) brain, stimuli entering one hemisphere are rapidly communicated to the other via the Cerebral Commissures.
- Anterior Commissure (AC)
- Hippocampal Commissure (HC)
- Corpus Callosum (CC)



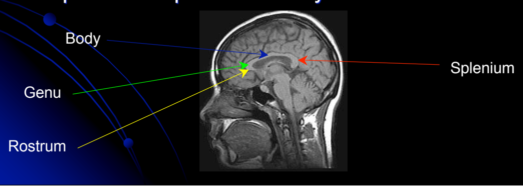
Midsagittal section of the human brain, which illustrates the corpus callosum and other commissures.

The Corpus Callosum

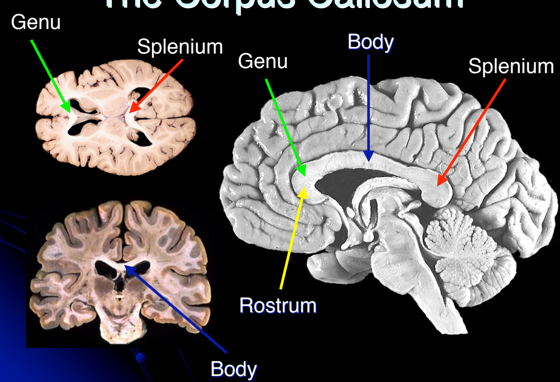
- ~ 200 million myelinated axons
- Interconnects homologous regions of the two cerebral hemispheres (not temporal fields – AC).
- CC is rostrocaudally shorter than the hemispheres; callosal fibres to frontal and occipital poles curve forwards or backwards respectively.

The Corpus Callosum

- Major parts rostrocaudally are; rostrum, genu, body & splenium.
  - Genu – prefrontal cortex.
  - Body – premotor, motor, somatosensory & posterior parietal cortex.
  - Splenium – predominantly visual.

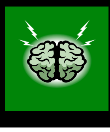


The Corpus Callosum

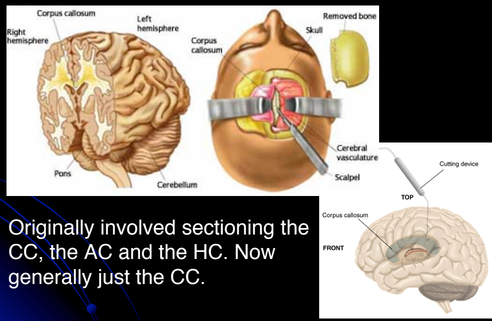


Surgical Commissurotomy

- In some forms of epilepsy a seizure will start in one hemisphere, triggering a massive discharge of neurons through the corpus callosum and into the second hemisphere.
- To prevent seizures in severe epileptics, the corpus callosum can be surgically severed.
- This leaves the two hemispheres functionally separate.



Split Brain Operation



Originally involved sectioning the CC, the AC and the HC. Now generally just the CC.

The History of the Split Brain

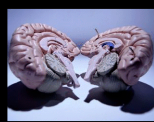
"The corpus callosum is sectioned longitudinally …no symptoms follow its division. This simple experiment puts an end to all of the extravagant hypotheses on the function of the corpus callosum."

- Walter Dandy, 1936.

- Reports by Akelaitis (1941, 1944) indicated no significant neurological or psychological effects.

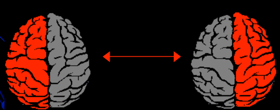
History of Split-Brain Surgery

- 1950's: Roger Sperry and Ronald Meyers began experimenting with cats, and later proceeded to study monkeys – discovered that visual and tactile information in one hemisphere did not cross over.
- 1961: First human patient (WJ) operated on by Joe Bogen & Philip Vogel.
- The procedure worked well for patients who suffered from severe epilepsy and did not respond to anti-epileptic drugs.



Behavioural Effects of a Commissurotomy

- It was discovered that patients who had a commissurotomy were not able to communicate information from one hemisphere to the other, almost as though they now had two separate brains.



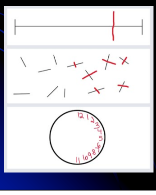
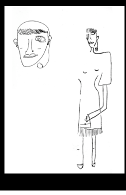
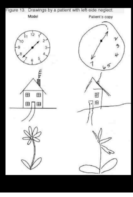
Behavioural Effects of a Commissurotomy: Disconnection Syndrome

- Anarchic Hand
  - Hands act as though independently motivated
  - Inconsistent actions with left hand
  - Hand reported to be "out of control" and therefore anarchic
  - Sometimes called alien hand (although this is another syndrome caused by stroke)
  - Rare

Innocent and carefree, Stuart's left hand didn't know what the right was doing.

Disconnection Syndrome

- Left Sided Neglect
  - Ignore the left side of body
  - Ignore input from left side of the world
  - Usually combined with anosognosia

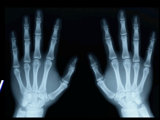




Disconnection Syndrome

- Double Hemianopsia
  - Unable to indicate the onset of a visual stimulus in left or right visual field with contralateral hand.
  - If RVF stimulus – right hand indicate stimulus onset as both are located in the left hemisphere, but right hemisphere never receives the information.
  - Happens in both visual fields.

Disconnection Syndrome

- Unilateral Apraxia
  - Cannot perform verbally commanded actions with the left hand that are easily performed with the right.
  - Still able to perform action spontaneously or in context.



- Verbal Anosmia
  - Unable to name smells presented to the right nostril (olfactory input is not crossed).
  - Smell is still intact since patient can use the left hand to find an object corresponding to the smell.

Disconnection Syndrome

- Agraphia
  - Inability to write with the left hand
  - No access to language

- Anomia
  - Cannot name objects placed in the left hand when blindfolded.
  - Can still name objects placed in the right

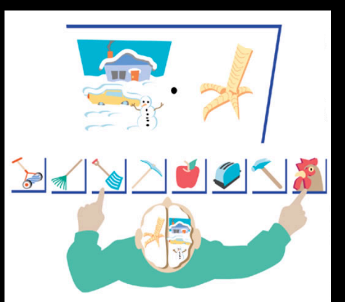
Lasting Behavioural Effects

Tachistoscope used to display visual images for a brief interval.

Ask patient to identify what was seen on screen.

Right Hand will point toward the chicken.

Left will point toward the shovel (associated with snow).



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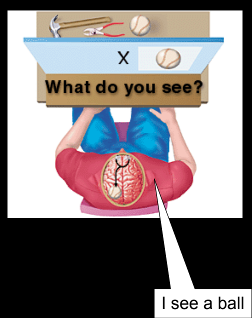
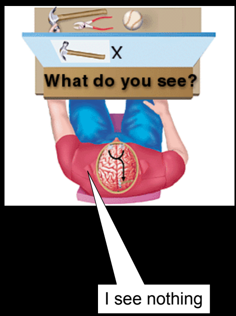
Left and Right Visual Fields

- When split-brain patients stare at the "X" in the center of the screen, visual information projected on the right side of the screen goes to the patient's left hemisphere, which controls language.
- When asked what they see, patients can reply correctly.



No Visual Information Transfer

- When split-brain patients stare at the "X" in the center of the screen, visual information projected on the left side of the screen goes to the patient's right hemisphere, which does not control language.
- When asked what they see, patients cannot name the object but can pick it out by touch with the left hand.



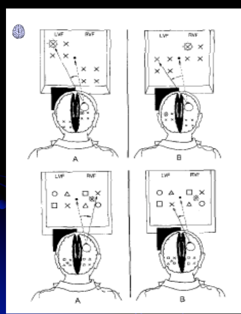
Chimeric Figures – J. Levy

- A patient is presented with a composite picture. They are instructed to focus on the dot in the middle of the forehead.
- Visual information from the left (woman) goes to the right cerebral hemisphere and information about the right (man) goes to the left.
- If asked to point to a complete picture of the face just seen, the patient will point to the woman.
- If asked to SAY whether the picture was a man or a woman, the patient will say that the picture was of a man.

Dichotic Listening Tasks

- Single words presented to each ear are reported normally.
- If different words are presented to each ear simultaneously (dichotically) a strong right ear advantage (and therefore left hemisphere) is seen.
- Ipsilateral pathway from left ear presumably suppressed by stronger, more dominant pathway from right.

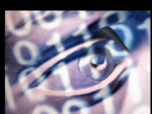
Spatial Information



- Crude information concerning spatial locations can be cross-integrated.
- Possibly mediated by subcortical pathways?

Independent Visual Search

- The more items in a visual array – the longer it takes to search the array for information (70ms per 2 additional items).
- This is characteristic of conjunction search where targets cannot be distinguished by simple feature difference.
- If the array is distributed across the midline, split-brain patients show half the RT to added stimuli.
- The two disconnected hemispheres can search the array in parallel.



Spatial De-Coupling

- Normal subjects find it difficult to impossible to draw differing shapes bimanually.
- There appear to be interactions between the spatial characteristics of movement plans for each limb during bimanual movements.
- Split-brain subjects however have no trouble drawing differing shapes bimanually.
- Therefore it appears that the interactions are mediated by the corpus callosum.

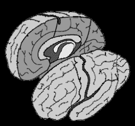
Spatial Memory Problem Solving

- Critical information presented in each visual half-field.
- Controls combine visual information automatically & perceive one large problem.
- In split-brain patients each hemisphere receives a problem that remains separate, and therefore each receives a task that is much simpler.

Tests of Memory

- The right hemisphere is better able than the left to reject new events similar to originally presented materials of several types, including abstract visual forms, faces, and categorized lists of words.
- Although the left hemisphere is capable of mental manipulation, imagination, semantic priming, and complex language production, these functions are apparently linked to memory confusions; confusions less apparent in the more literal right hemisphere.

Other Causes of Split Brain or Disconnection Syndrome



- Tumours (usually gliomas)
- Toxic/infectious lesions of the CC
- Anterior cerebral artery aneurism – haemorrhagic dissection of the CC
- Partial sectioning for surgical approaches to other structures
- Multiple sclerosis can cause disconnection signs
- Strokes can cause similar behavioural effects
- Congenital absence of the CC (although behavioural effects are not the same as sectioning).

Development of the Corpus Callosum

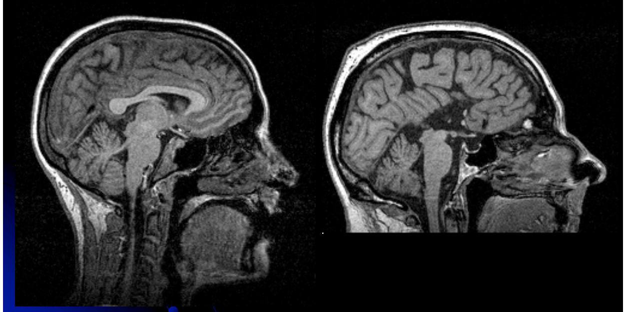
- The corpus callosum develops from the *lamina reuniens* in the *telencephalon*, and begins to appear between the anterior and hippocampal commissures between 8 - 10 weeks.
- The adult form is achieved by 17-20 weeks gestation.
- Initial formation of the corpus callosum occurs in the genu and the body, progressing posteriorly.
- The anterior genu and rostrum develops last, folding back under the genu.
- Disturbance of embryogenesis in the first trimester of gestation by some unknown insult leads to failure of the callosal axons to pass across the midline.

Congenital Callosal Agenesis

- Agenesis of the corpus callosum (ACC) can be complete, partial, or atypical and may occur in isolation or in association with other CNS or systemic malformations.
- The reported frequency is 0.7-5.3% in the US, but is unknown world-wide.
- ACC is more commonly reported in males than in females.

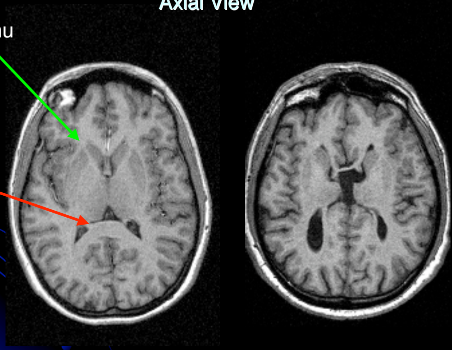
Callosal Agenesis

Sagittal View



Callosal Agenesis

Callosal Agenesis



Other Forms of Callosal Agenesis

- With partial agenesis (hypoplasia), the anterior portion (posterior genu and anterior body) is formed, but the posterior portion (posterior body and splenium) is not formed. The rostrum and the anterior/inferior genu are also not formed.
- In holoprosencephaly, callosal anomalies are atypical; the splenium may be present without a genu or body.
- In middle interhemispheric fusion, a variety of holoprosencephaly, the genu and splenium may be present without the callosal body.
- With pseudo corpus callosum, in conditions of complete or partial agenesis, the hippocampal commissure may become enlarged and appear like the posterior part of the corpus callosum.

Partial Callosal Agenesis

In partial callosal agenesis the most common presentation is absence of the posterior body, splenium and rostrum.

Callosal Agenesis: A Natural Split Brain?

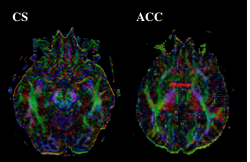
- Not Really.
- Usually display ability to combine visual information from both hemifields.
- Split brain patients perform poorly on bimanual tasks requiring rhythm whereas callosal agenesis perform normally.
- Some ACC subjects can integrate tactile information without vision.

Why the Difference?

- Since the corpus callosum never forms, other means of inter-hemispheric communication may develop.
  - Ipsilateral motor pathways
  - Bilateral representation
  - Non callosal commissures

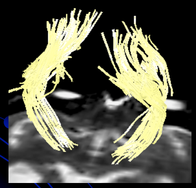
Enlargement of the Anterior Commissure in ACC

- In a number of cases, probably a minority, of ACC subjects have an enlarged Anterior Commissure which may compensate for the lack of the CC.

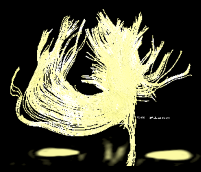


Other Factors

- Possible sub-cortical communication.



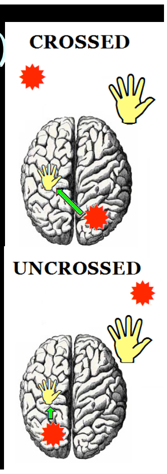
Callosal Agenesis – lateral bundles of white matter



Normal Corpus Callosum

Poffenberger Paradigm (1912)

- Visual stimuli are presented to one side of the visual field
- Subjects are then required to make a unimanual response
- RTs are longer when the response hand is contralateral to the hemisphere that received the visual input



Poffenberger Paradigm

- Lengthening of the CUD is proportional to the amount of commissural fibres lost in split brain subjects (~ 30-90ms).
- CUD is smaller in ACC subjects (~12-50ms), but is still larger than normals (~2-6ms).
- Early visual ERP components do not appear in the ipsilateral (commissural) hemisphere due to the absence of the splenium in split brain and some ACC individuals.

Summary

- Severing the corpus callosum leaves the two cerebral hemispheres functionally separate.
- Perceptual information cannot cross from one hemisphere to the other without the CC.
- The left hemisphere retains language, while the right becomes "mute".
- Callosal Agenesis can cause similar behavioural effects in some cases but is not a natural split brain.

References

- Aklaitis, A.J. (1941). Studies on corpus callosum: higher visual functions in each homonymous field following complete section of the corpus callosum. *Arch. Neurol. Psych. (Chicago). 45*: 788.
- Bradshaw, J.L. & Mattingley, J.B. (1995). Clinical Neuropsychology: Behavioural & Brain Science. Academic Press: San Diego.
- Crossman, A.R. & Neary, D. (2000). *Neuroanatomy: An Illustrated Colour Text.* (2nd Edit). Churchill Livingston: Edinburgh.
- Franz, E.A., Eliassen, J.C., Ivry, R.B. & Gazzaniga, M.S. (1996). Dissociation of spatial and temporal coupling in the bimanual movements of callosotomy patients. *Psychological Science*, *7(5):* 306-310.
- Kolb, B. & Whishaw, I.Q. (1996). *Fundamentals of Human Neuropsychology.* (4th Edit). WH Freeman & Co: New York.
- Metcalfe, J., Funnell, M., & Gazzaniga, M.S. (1995). Right-hemisphere Memory Superiority - Studies Of A Split-brain Patient. *Psychological Science, 6 (3):* 157-164.
- Pinel, J.P.J. (1997). *Biopsychology.* (3rd Edit). Allyn & Bacon: Boston.