The Summarization of Split Brain Study of Last Few Decades

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Abstract. At the end of last century, scientists began to explore cortical circuit of cognition and memory with split-brain surgery. Later, they tried to treat epilepsy with split-brain surgery and achieved certain results. Since then, scientists have tried to understand the functional differences between the left and right hemispheres and the effects of the split brain on behavioral cognition by working with different animals as well as patients with the split brain. The ongoing study of split-brain provides theoretical explanations for clinical brain imaging findings and continues to help us understand the mechanisms of cognition and memory. Split-brain patients are always valuable samples for scientists to study inter-hemispheric structural and functional connectivity, differences in the two hemispheres, integration of sensory, motor, and spatial information, and general behaviour. The following information summarizes split-brain related concepts and includes methods and experiments to find the results for the studies mentioned above to help readers understand how these achievements were reached.

Keywords: Split Brain; Stimuli; Brain Hemisphere Function; Redundancy; Neurology.

1. Introduction

'Split brain' is typically a way for doctors to cure certain brain disease like epilepsy by cutting commissure, white matter fibers that connect the two hemispheres of patients. Collasotomized patients are valuable samples for scientist to study the mechanism of inter-hemisphere by behavioral testing, neuropsychological tests, *intelligence quotient* tests, electroencephalogram, Functional Magnetic Resonance Imaging, and Magnetic resonance imaging test. [1] In addition to patients who have undergone surgery, scientists will also perform similar resection on animals like monkeys, mice and other mammals as reference under eye-stimuli related experiment.

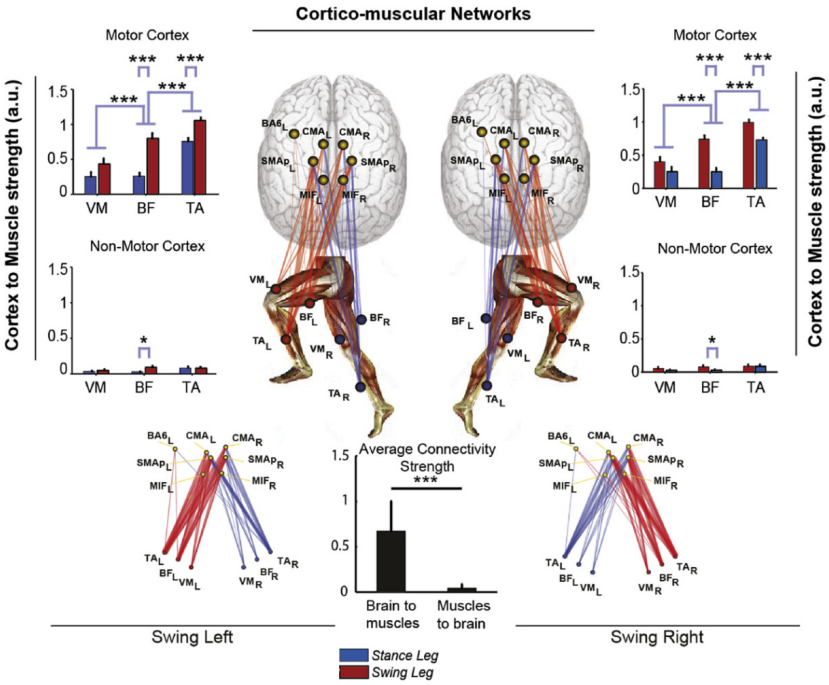


Figure 1. Legs' muscle movement controlled by two brain hemisphere

The brain is divided into left and right hemispheres, each of which controls the upper muscles of the arms, but the muscles that control the movement of the hands and fingers can only be coordinated by the opposite hemisphere. That is, the right hemisphere controls only the left hand and the left hemisphere controls only the right hand. The two hemispheres control very different thoughts and actions. Each half has its own specialties and limitations. The left side of the brain is mainly responsible for language and speech, while the right side is good at visual-motor tasks, and these experiments can help us refine the connections between hemispheres and how they work.[2]

During treadmill walking at a speed of 3.5 km/h, the left and right legs in the Swing phase diagram show a diagram of the network of effective brain-to-muscle connections for each leg in the Swing phase. Brain and muscle connections are shown in red and blue, with red indicating that the legs are not touching and blue indicating that the legs are touching the ground during the gait phase. The thickness of the connection wire is directly proportional to the connection strength. The figure shows that the motor areas of the brain (especially the cingulate motor cortex, the post auxiliary motor area, and the primary motor cortex of the foot) have a stronger causal influence on the signals of the lower limb muscles than the non-motor areas, and are also more pronounced in the swinging leg, with the strongest influence on the tibialis anterior muscle -TA, followed by the biceps femoris -BF and the medialis femoris -VM

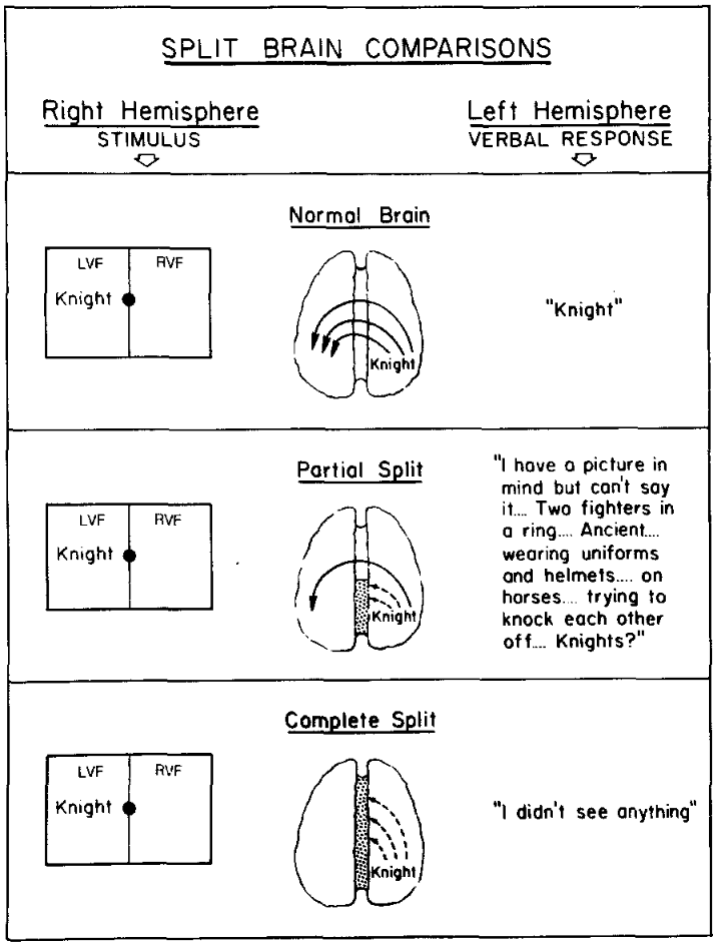


Figure 2. Visual impact caused by split brain surgeon

The more thorough the operation of the split brain, the more difficult the integration of visual information. Case JW underwent staging of the corpus callolotomy, in which the posterior part of the corpus callosum was first excised. The surgery prevented the transfer of information related to the sensory dimension of the stimulus, rather than the semantic information, and also showed that more

areas in the anterior corpus callosum were more responsible for the transfer of higher-level information

2. Interhemispheric Connectivity

The left and right hemispheres work almost as if they were two separate brains in the one body. Experiment of severe intractable epilepsy patients who undergone the 'split-brain' operation shows that information exchange between left and right brains of collasotomized patients still exists. Although a decrease in EEG coherence of the collasotomized patients suggests that the two hemispheres have less communication than before, crude touch and vision can still be transmitted between them.[1] The following confusion is that whether the coordination of the two hemisphere is reached subcortical contact or corticocortical connection. EEG is not detailed enough to analyze structural connectivity, in order to understand more details of the mechanism, scientists later adopted RSNs test which can map major cortical networks.[1] Restng-state functional connectivity of brain in fMRI test can reflect the connection between homologous brain regions and neural activity, and thus more targeted analysis of inter-hemispheric structural connectivity. Scientists conducted experiments by choosing 42 adult patients as control group and a collasotomized female patient N.G. as experiment group under two methods, Independent component analysis and Seed-based functional connectivity. The results showed great level of functional connectivity between specific homologous regions, and two hemispheres are partly subcortically connected in patient N.G.[3-7].

3. Sensory and Motor Procession

3.1 Split-brain Patients

Results showed that split-brain patients were unable to integrate information between the two halves of the field.[4] When confronting visual information that is complex, like bilateral stimulus arrays, information processing efficiency of split-brain patients is higher. This is because the normal people processes all the visual information as a whole, while the split-brain patients automatically divide the visual information to the two sides of the brain, making it much easier to process information.

Some crude spatial information can still be crossly integrated in split-brain patients since they can still move their eyes to point that is opposite to its previous focus point in its opposite vision field.[4]

3.2 Split-brain Rhesus Monkeys

In general, split brain would limit the fine movement of monkeys.

Further research showed that vision and touch information can be transmitted but cannot be integrated, shown in the difference in two hands' motion in split-brain Monkeys experiments. By visually stimulating the brain hemispheres, animals-split brain experiments found that post-visual and tactile information was no longer transmitted to the opposite hemispheres.

When the vision is limited, the ipsilateral hand is affected especially obvious. Both cerebral hemispheres are able to control the movement of the contralateral hands, arms and fingers, but they could only control the arm activity of the ipsilateral hand. Meanwhile, scientists made split brain experiments of different degrees on different parts of the monkeys through anatomical and behavioral experiments and then checked the impact of the brain's specific parts on the monkeys' behavior through experimental observations.

The simple observation results are as follows. Immediately after complete commissurotomy surgery, monkey' pupils will dilate and eyelid will contract. And they will be unable to have upward gaze.[5] Besides, monkeys would not show the hand preference within the short period, but grasp things with both hands. However, after a while, the original hand preference would be presented and the above mentioned other abnormalities of the body would not show again.

Then scientists detected the impact of these factors on the fine movement of monkeys by taking the visual range and ipsilateral and contralateral hands as variables. Split-brain monkeys were required to grasp food with ipsilateral and contralateral hands respectively in the experiment and their vision was affected by different limitations in different trails, including covering the left eye, covering the right eye and covering both the left eye and right eye. The results show that the split-brain monkeys would not adopt precise grasping gestures (grasp with index and thumb) unless grasping the food with contralateral hands, which has nothing to do with the vision of monkeys. When the vision is limited, the movement of the ipsilateral hand to take articles appears to depend on the tactile sense more. That is to say, the movement order of the ipsilateral hand does not need to pass through the cerebral hemisphere being responsible for covering the vision, but is completed directly through the tactile sense of the body and spinal cord brainstem. In other words, when the vision is limited, the fine movement of the ipsilateral hand would also be limited due to commissurotomy. In another experiment of food picking, when the split-brain monkey only owns the monocular vision, the contralateral hand could take the act of grasping food correctly and independently under the guidance of vision. In comparison, the ipsilateral hand of the split-brain monkey also depends more on tactile sense. The monkeys whose optic chiasm and telencephalon are cut off show the status of blind persons and reflect the lack of accurate movement by the ipsilateral hand.

However, there are still differences between the experiments of monkeys and those of human patients. For instances, after the corpus callosum is cut off, monkeys can transmit information through anterior commissure while human patients are not able to do that[6-12].

4. Consciousness and Psychological Properties

4.1 Differences in Two Hemispheres

The functions of the left cerebral hemisphere and those of right cerebral hemisphere are asymmetric and they have different functions.

Split-brain patients are precious samples in testing the cognitive and conscious functions of the cerebral hemispheres. Scientists could stimulate the cerebral hemispheres through visual stimulation to check the response of two cerebral hemispheres. Scientists also took split brain patients as samples to analyze functions of left and right cerebral hemispheres.

The left brain is recognized as the dominant hemisphere, being responsible for language and problem processing, such as speech and calculation, while the right brain processes visual, tactile and spatial information, such as conceptual perception of geometric objects, apparent motion detection, spatial matching and mirror image discrimination. [7] In most people's brains, the left hemisphere is responsible for language, and language can only be produced by the left hemisphere. Although the reading ability of right hemisphere is limited, the left hemisphere also specializes in processing written language. The right hemisphere can read the whole word (ideograph/semantic access), but can not convert letters into phonemes.This task could be fulfilled by the language dominated left brain easily. However, many studies on split-brain patients have changed scientists' cognition on the nervous system. F For instances, the patient V.J. can produce language by the left hemisphere and process written language by the right hemisphere, which makes scientists realize that oral and written language can be processed by a single cerebral hemisphere independently.[6] Once the connection between the left and right brain is cut off, it means that patients can feel tactile and visual stimuli and their body could respond to it, but they can't describe their feelings with words. Both the left and right hemisphere can spontaneously produce facial expressions. The right hemisphere is good at perceiving facial expressions, but only the left hemisphere can issue detailed instructions for facial expressions.[4]

4.2 Attention System

Originally, both hemispheres can move their visual focus to the left and right visual fields respectively, and would rely on spatial information to ensure a single visual focus. The question is that if split-brain patients with two independent sensory systems could control the visual focus of

their visual field independently, that is, if the left hemisphere could place the focus on the right visual field while the right hemisphere places the focus on the left visual field at the same time.

Common people could not divide their attention and scientists would like to check whether split-brain patients are able to divide spatial attention. The results show that split-brain patients can't address the events occurred in two spatial locations at the same time, for they have no more than one focal system in the space. Both hemispheres cannot process the same focal system simultaneously. Some scientists raise that the cerebral hemispheres of split-brain patients could deal with their separate attention system independently and not affect each other. Others hold that the work of any hemisphere indicates that the ability of the other hemisphere in processing information would be reduced. Experiments prove that the overall ability of the brain in processing attention information is limited. Scientists made visual test which is classified into hard model and easy model. The hard model was called mixed condition, which includes two sets of completely different graphics. Each set featured three separate graphics, which appeared in two visual fields at the same time and moved to two sides. The easy model was called redundant condition. That is, complicated and different graphics were shown in one visual field and the other visual field had exactly same three graphics. Then, observes would find a single-sided detection graph in front of themselves. They must press the select key to decide if it fits any graphic within the detection area, which was used to check the information processing ability of observers. As shown by the results, when one hemisphere is facing the easy model, the ability of the other hemisphere facing hard model in processing information would be improved greatly. When both hemispheres are facing the hard model, the working efficiency two hemispheres would be reduced, which verifies that the overall attention resource of the brain is limited.[4]

4.3 Memory

Free recall mechanism is largely affected by posterior commissurotomy surgeon which will affect hippocampal commissure while the recognition memory system remains intact. That is because recall mechanism requires a subject to trigger previous memory while recognition memory only need the subject to confirm whether the subject have been once remembered [6].

5. Conclusion

In general, under behavioral testing and neuropsychological tests, patients who have complete commissurotomy do not have significant mental disabilities and their lives are largely unaffected. Split-brain patients generally would not have cognitive impairment, but the fine movement, information processing by visual sense and tactile sense are limited after suffering the split brain. Although the two cerebral hemispheres are still connected, the connection is through subcutaneous pathways in majority. Visual information can effectively guide the action of the contralateral hand, but it can not effectively guide the action of the ipsilateral hand. Visual sense and tactile sense could be perceived, but the information of both hemispheres could not be integrated. The spatial information could be integrated. In addition, the experiments of split-brain patients help scientists verify the functions of labor division for left and right hemispheres. For instances, the left hemisphere and right hemisphere are responsible for language and perception respectively. Verbal and written language output can be controlled by separate brain hemispheres. At the same time, the abilities of the left and right hemispheres are complementary. The dominant role of the left hemisphere in language is complemented by the specialization of visuospatial processing in the right hemisphere.

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