

## *Editorial*

### Review of the Split Brain

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Die grundlegende Literatur zur Aufdeckung des Split brain-Syndroms wird diskutiert.

The corpus callosum, the cerebral commissure that interconnects the left and the right half brain, had been considered an enigma to neurologists and neurosurgeons in the 1940's and 50's. It was the structure discussed most often when an example was sought to show how little was known about the brain. Even though it is the largest nerve tract in the brain, which in man contains more than two hundred million neurons, it was generally believed it could be sectioned and destroyed and have no apparent consequences for behavior. People continually quipped about the general lack of importance of the forebrain commissures.

It was in this context that the original experiments on the split-brain were carried out in the cat by Ronald Myers and Roger Sperry at the University of Chicago. Myers had successfully developed the technique of splitting the optic chiasm, thereby allowing visual information presented to the right eye to be exclusively projected to the right hemisphere and visual information projected to the left eye to be exclusively presented to the left hemisphere. He had discovered in follow-up behavioral tests that there was, nonetheless, interocular transfer. Therefore the logical structure to next surgically section to see whether one could block interhemispheric transfer of visual information was the corpus callosum. This was done and this study gave birth to the now classic "split-brain" experiments first done on the cat showing that discriminations trained to one side leaves the other half of the brain naive. Later studies carried out in both the monkey and chimpanzee confirmed these findings.

Still, however, these results stood in marked contrast to the earlier results of Akelaitis who had studied a series of some 26 patients with the corpus callosum and anterior commissure sectioned in complete or in part for the interhemispheric control of epileptic seizures. In an extensive series of studies he purported to show that sectioning of these structures did not result in any significant neurological or psychological sequela. This point was made and emerged as the dominant view even though there were several contradictory reports in the literature showing disconnection effects as a result of having the callosum sectioned or rendered non-functional by a tumor or the like (see Geschwind, 1965). It was also generally considered that cutting the callosum did not, in fact, help control epilepsy.

Then, in 1960, Dr. Joseph Bogen, who at the time was a resident at White Memorial Hospital in Los Angeles, proposed, after a careful review of the Akelaitis' literature, that the brain be split for the purpose of controlling the interhemispheric spread of epilepsy. His hunch that the surgery should work proved largely correct. It was his first patient, W. J., that was extensively studied both pre and post-operatively on a host of psychological tests that we devised at the California Institute of Technology (Gazzaniga *et al.*, 1962, 1963, 1965; Gazzaniga and Sperry, 1967). In subsequent examination of patients in the Bogen series a variety of striking and dramatic effects were observed.

### **Information Exchange between Cerebral Hemispheres**

To begin with, the interhemispheric exchange of information was totally disrupted following commissurotomy such that visual, tactual, proprioceptive, auditory and olfactory information presented to one hemisphere could be processed and dealt with in that half brain, but these activities would go on outside the realm of awareness of the other half cerebrum. Thus, the work confirmed the earlier animal work by Myers and Sperry but was in a sense more dramatic in that all processes ongoing in the left hemisphere could be easily verbally described by the patients since it is the left hemisphere that normally possesses the natural language and speech mechanisms. Information presented to the right hemisphere went undescribed and it was only through using special testing techniques that we were able to discover that the right hemisphere also had a rich mental life and was capable of experiencing most of the phenomena appreciated by the left brain.

### **Mental Properties of the Right Hemispheres**

Using non-verbal tests especially designed for the purpose, it was determined that the right hemisphere had some language, could initiate its own responses and could emote, learn, remember and do all the things of normal life without the left hemisphere knowing the why or what of it all. Thus, for example, a word could be flashed in the left visual field which is exclusively projected to the right hemisphere in man—such as “spoon” and the subject would say, “I did not see anything,” but then subsequently would be able with the left hand to retrieve the object from a series placed out of view. When the correct object was indicated by the subject holding it in his hand, the experimenter would say, “What is it you have in your hand?” they would say, “I don't know.” Here again “mind left” does not know. It did not see the picture nor did it have access to the stereognostic or touch information from the left hand which is also exclusively projected to the right hemisphere. Yet clearly the right hemisphere knew it because it reacted appropriately to the correct stimulus and made the appropriate response.

These patients, however, allow for even further studies that would allow the examiner to investigate the separate mental properties of the two half brains. We showed that the left hemisphere, as would be predicted from early clinical reports, excelled in verbal processing of information of all kinds. The right hemisphere, however, was superior in managing visual spatial tasks such as drawing cubes, arranging blocks to match designs and the like. This distribution of mental work

in the brain highlights a major difference between man and animals and raises the intriguing possibility that the various modes of consciousness have separate physical identities in the brain.

These earlier results carried out on Bogen's series of patients have recently been confirmed and extended on the patients of Dr. Donald Wilson of the Dartmouth Medical School. Wilson, using a different surgical approach than Bogen, has also carried out both complete and partial commissurotomies with the aim of preventing interhemispheric spread of epileptic seizures. Neuropsychological examination of these patients has confirmed many of the earlier findings on the Bogen series and, in brief, pointed out that visual, tactual, auditory and olfactory information cannot be transferred following forebrain commissurotomy. Moreover, the partial sectioned cases showed that a surgical lesion can be made that will block visual information from transferring between the two half brains but not tactile and *vice versa*. Interestingly, it seems to not matter which part of the callosum is intact in order to realize transfer of what might be called the superordinate function of the two half brains. Thus, the specialized activities of the right may come to the aid of the left no matter what part of the callosum is intact; whereas, more specific information from the right half brain, such as visual information in the left field, cannot be communicated to the left hemisphere if the splenium alone is sectioned.

Tests on these patients also revealed that there is a possibility that one of the costs to an individual for having this seizure-controlling surgery, is that the mental life of the left hemisphere may go on without the aid of the normal imaging mechanisms which are most likely normally housed on the right. Consistent with this is one of the complaints of the patients in the Bogen series that they no longer dream. Dreaming reflects imaging processes and what has been traditionally called the subconscious process. It would be fascinating to discover that the right half brain is primarily responsible for this side of our mental life. A series of sleep research experiments is now being contemplated to confirm this possibility.

In the past, the amount of language and mental activity discovered in the right brain, in our earlier studies, was thought to be the product of early brain damage. It is well known that if brain damage occurs early in life, there is a bilateralization of the language and speech mechanisms. However, a recent case has been reported of a patient who, at the age of 70, suffered vascular disease which specifically affected the splenium with the results that the person was a split-brain with respect to visual functions. This patient also showed the same language talents that we had outlined earlier in the Bogen series of patients. This kind of evidence suggests that in the normal developmental process there is some redundancy in the system such that all of language or all of spatial functions are not strictly and exclusively lateralized to the respective left and right hemispheres.

### Educational Significance

Indeed one of the intriguing possibilities coming from the split-brain research is the possibility that man can be explicitly specialized for a variety of aspects

of mental life with superiorities in the verbal arena not necessarily meaning superiorities in the visual-spatial and vice versa. Thus, when dealing with a cognitive task it may well prove to be the case that a particular child, for instance, might well be able to solve the problem using verbal symbols with greater ease than with visual, but that another child might be better off solving the problem using visual-spatial relations.

The motivational aspect of this observation, of course, cannot be overemphasized. If a child happens to be talented for visual-spatial relations and is being forced into a curriculum that emphasizes the verbal articulatory modes of solving a conceptual problem, he will encounter enormous frustration and difficulty which may result in a hostility towards the teacher and towards the learning process itself. If the teacher was aware that the child was specialized in these skills, the same problem could be introduced to him using these skills which would obviously bring the child in line with his special talents. Conversely, of course, the child with high verbal skills may quite frequently be unable to visualize his problems with a spatial aspect. He would be frustrated if forced into these academic areas.

In this regard, of course, the more we understand about the brain and the more we understand about the various kinds of cognitive processing systems we use in our normal mental life, the more clearly we can understand the components of what is normally called "intelligent behavior". We have recently developed an animal model for intelligence which emphasizes the importance of the short-term memory system. A test can be designed that, when combined with particular surgical lesions, can produce short-term memory deficits which has the result of making the animal appear less bright than his cage-mates. In fact, what is at stake, is merely how many variables the animal can keep in mind in a given space of time. The exciting aspect of a test of this kind, of course, is that it operationalizes the quantity of intelligence and as these tests develop they can be specifically designed to diagnose a particular individual. Where we hope to be going, of course, is to develop a series of tests that will diagnose an individual with respect to his specific mental skills. It is more than likely that we will find that many people may be spatially bright, verbally dull or vice versa. Or maybe some of us have a better short-term memory system or have a faster processing capacity when dealing with certain kinds of symbols. Once identified, of course, the teacher would be enormously aided in how to best present information for its speedy comprehension and use.

### Philosophical Implications

The more general point of split-brain research, of course, is that the surgeon's knife has revealed that the brain can be simply altered to produce a state which can best be described as allowing for the doubling of consciousness. Research of this kind encourages us to think in terms of modes of consciousness. What writers, poets and scientists have been telling us for centuries seems true and the only difference between the split-brain subject and the normal is that normal by virtue of the callosum can switch between the various modes whereas the split experiences a real decoupling.

Lastly, it would appear that if we study the cerebral commissure that gives us our normal state of conscious unity, and grow to understand its neural physio-

logical and neuro-anatomical mechanisms more fully, we might well be closer to understanding how neurological systems encode psychological information. If we knew that we would be a lot closer to breaking the code of the brain.

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