Visions of the Split Brain

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From the 1960s, a radical treatment for intractable epilepsy was to cut the corpus callosum, the main commissure connecting the two sides of the brain. In 1981, Roger W. Sperry won the Nobel Prize for his work on the apparent division of consciousness between the two cerebral hemispheres in these patients. Our own work has focused on vision. Each half of the visual world projects to the opposite side of the brain, yet split-brained patients show surprising integrity of perception across the visual midline, especially in elementary perceptual processes. This work has shown greater unity of consciousness in the patients than implied by the earlier work, and shown how mental life depends on both cortical and subcortical processes. It also provides a glimpse of the evolution of the human mind.

In the 1960s, two neurosurgeons in Los Angeles, Phillip J. Vogel and Joseph E. Bogen, decided to treat intractable multifocal epilepsy by cutting the main fibre tracts linking the two cerebral hemispheres, with the primary intent of preventing the development of full-blown seizures. By far the largest and most important fibre tract to be cut was the corpus callosum, but in early operations other tracts were also sectioned, including the anterior commissure and the hippocampal commissure. Later operations were typically less radical, restricting surgery to the corpus callosum, and in some cases involving only selected regions of the corpus callosum. Subcortical connections were left intact. The operations succeeded better than expected in treating epilepsy, and in some cases, with the help of medication, seizures were effectively eliminated. Moreover, so-called "split-brained" patients seemed on the surface to be largely mentally and emotionally unaffected by the operation.

The idea of splitting the brain had long been of interest from psychological and philosophical perspectives, especially as a crucial test of Cartesian dualism. Gustav Fechner, the 19th-century experimental psychologist, and William McDougall, a prominent British psychologist of the early 20th century, both wondered what would happen to consciousness if the brain were split. Indeed McDougall is said to have tried to persuade the esteemed physiologist, Charles S. Sherrington, to sever his, McDougall's, corpus callosum if he should become incurably ill. McDougall was a convinced dualist who believed his mind would remain intact if his brain were divided, but his personal request was never fulfilled.

When the operation was performed for the relief of epilepsy, the psychologist Roger W. Sperry initiated research to test the unity of the mind. Despite their outward appearance of normality in these patients, clever experiments soon revealed striking evidence of mental disconnection. The patients were unable to read words or name pictures of objects flashed to the left visual hemifield, or name objects felt by the left hand, since in these cases the information was relayed to the right cerebral hemisphere, revealing that this hemisphere does not possess the power of speech. These tasks were readily accomplished when the information was relayed to the language-dominant left hemisphere. The patients could not decide whether words or shapes presented on either side of visual fixation, or shapes held simultaneously to the two hands, were the same or different. Sperry received the Nobel Prize in Medicine for this work in 1982, and in an article based on his address to the Nobel Foundation in Stockholm he summarised as follows:

> *Each disconnected hemisphere behaved as if it were not conscious of cognitive events in the partner hemisphere ... Each brain half, in other words, seemed to have its own largely separate cognitive domain with its own private perceptual, learning, and memory experiences, all of which were seemingly oblivious to corresponding events in the other hemisphere [Sperry, 1982, p. 1224].*

The work of Sperry and his collaborators also pointed to apparent specializations of the mute right hemisphere, which seemed to include perceptual abilities, as in performing block design tests or drawing cubes, as well as self awareness and social consciousness. The discovery of complementary specializations in the two hemispheres led to what might be termed the dual-brain cult, with calls

for greater attention to the creative, emotional right hemisphere in activities as diverse as art, education, literature, and even business (see Corballis, 2007, for a sceptical account). This may have been exacerbated by the tumultuous events of the 1960s, with the western world divided by the Vietnam War. The left hemisphere came to be associated with the militaristic establishment and the right with the creative, peace-loving East; in the slogan "make love not war," the left hemisphere no doubt stood for war and the right for love and peace (Corballis, 1980).

In fact, however, right-hemisphere specializations have often been elusive, and often a matter of degree—unlike the seemingly near-absolute left-hemispheric specialization for speech production. One exception was our own work showing that only the right hemisphere was capable of mental rotation, but this result was obtained in only a single split-brained patient (Corballis & Sergent, 1988, 1989); subsequent testing of other patients has failed to elicit mental rotation in either hemisphere, perhaps because the right hemispheres of these patients, with limited language resources, have been unable to follow the task instructions..

Although the work of Sperry and his collaborators seemed to strongly refute dualism, the subsequent picture that has emerged is more complex. Here, I focus on vision, since most of our work has been concerned with the study of visual integration between the visual hemifields. Integration between the visual hemifields implies integration between the cerebral hemispheres, since each visual hemifield projects to the opposite cerebral hemisphere. Visual-hemifield studies provide the cleanest evidence for psychological disconnection between the separated hemispheres, but have also shown strong evidence for integration.

Visual integration in the split brain

Earlier evidence had shown that split-brained patients cannot match digits, letters, colours, or line drawing of faces between visual hemifields (Johnson, 1984), and our own work extended this to the matching of even such elementary features as luminance and stimulus size (Corballis & Corballis, 2001). This might be taken to mean that commissurotomy effectively divides the world perceptually down through the vertical meridian. Surprisingly, though, there are a number of visual tasks in which the visual world in these patients appears to be integrated.

One split-brained patient showed essentially normal ability to judge whether diagonal lines flashed in the two visual hemifields were aligned or not. That is, he could tell with good precision whether one line, if continued across the vertical meridian, would meet and follow the other line. The same patient could perceive apparent motion across the midline. If a dot appeared in one visual hemifield followed shortly by a dot in the other, he saw the dot apparently jump from one side to the other (Ramachandran, Cronin-Golomb & Myers, 1986)—this is the well-known phi phenomenon. This result seemed clearly to reflect interhemispheric integration, since there is no apparent motion within each visual hemifield. In further exploration of this phenomenon, we showed the same effect, with added controls to rule out possible artifacts. For example, if the patient's attention was drawn to a dot on one or other side, and asked to report on direction of motion, he could infer that the motion must have been from the other side, but we added controls to exclude this possibility (Naikar & Corballis, 1996).

A more subtle study of apparent motion also reveals that visual attention can straddle the visual midline. This study was based on the so-called line-motion illusion: If a straight line is presented all at once, and if attention is directed to one or other end of the line, it appears to spread from the attended side to the non-attended side. We found that if a vertical line is presented to one visual hemifield, and attention is directed to a location either high or low in the other visual hemifield, the line seems to spread either downward or upward, depending on the location of the cue in the other visual hemifield (Corballis et al., 2004). That is, an attentional gradient invoked in one visual hemifield, and thus in one hemisphere, induces apparent motion in the other, indicating that the gradient spreads from one hemisphere to the other.

A more realistic vision of the split brain

I have presented just a small sample of split-brain studies showing that consciousness is not totally divided in these patients. Integration between visual hemifields need not support a dualist view of the mind, though, since there are subcortical connections that serve to connect one hemisphere with the other. The primary subcortical visual centres are the superior colliculi, which are connected via the tectal commissures. This subcortical system is sometimes referred to as the second visual system, and studies of its role in the split brain strongly suggest that it plays an important role in normal vision. This reinforces the growing view that vision itself is not a holistic process, but depends on the activity of many different pathways, including separate areas within the cortex itself for the processing of shape, color, movement, location, and so forth. The brain is not like a camera; rather it dismantles the retinal image before assembling its various features into a model of the visual world.

The particular functions that are integrated in the split-brain reveal something of the action of the second visual system, and offer a glimpse of how vision itself evolved. The subcortical system may be considered to date from a more primitive era before the evolution of the cortex itself, and survival depended on such elementary visual functions as the detection of motion, linear continuity, and visual attention. The evolution of the cortex added more sophisticated components, such as the analysis of colour and shape. Early split-brain work was overly dedicated to these more specialized percepts, as in such activities as reading, object recognition, and perception of faces, but the unified core of perception lies in the subcortical system. One of the patients I tested regularly used to

drive a motor vehicle on the highways of New Hampshire, and passed his driving test.

This unified core probably extends beyond vision to other sense modalities, and indeed to consciousness itself. This can explain why split-brain patients appear unified in everyday behaviour, displaying what Joseph Bogen, one of the early split-brained surgeons, called "social ordinariness" (Bogen, 1993). To be sure, there were anecdotes of conflict between the disconnected hemispheres, as in tales of one hand buttoning a coat and the other following along by unbuttoning it. But such examples are extremely rare, and possibly apocryphal. The closest I have observed is when a patient is having difficulty performing a task with one hand and the other hand, controlled by the hemisphere more adequate to the task, tried to intervene. But this probably has more to do with hemispheric specialization and control of the contralateral hand than with divided consciousness.

The current view of the split-brain may not attract the attention of the Nobel Foundation in Stockholm, but offers a more realistic view of the unity and evolution of the human mind. Curiously, Sperry himself seemed to regard the split-brain work as evidence for mental unity, but attributed this to "emergence consciousness" rather than to subcortical integrity (Sperry, 1966-1967, 1969; see Corballis 1998 for discussion). Perhaps he had a more enlightened view than most of us realized at the time. He remains the true hero of the split brain.

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