Chapter 12

The Divided Brain

The human brain has long been regarded as the repository of the mind, hence its great symbolic significance. The brain has been held responsible for many of the positive achievements of human-kind, including great works of art and major scientific discoveries. But when the brain malfunctions, tragic and debilitating effects follow, including of course the bizarre patterns of behaviour found in madness and mental illness. Someone who is mentally ill is, in common parlance, 'out of his mind' or 'off his head'.

The notion that the brain is the seat of mental illness has led many people over the centuries to advocate direct action on the brain to effect a cure. Many horrifying methods of treatment have been used, one of the best known being trepanning, which appears to have been used even in the Stone Age. The patient, unanaesthetized, had a hole drilled in his skull in order to release the imagined accumulation of unwanted vapours in his head. Skulls found in Peru show evidence of healing around the hole, which means that some of these unfortunates survived the operation.

Even as far back as Roman times, there was interest in techniques that foreshadowed electroconvulsive therapy. The physician Scribonius Largus describes the application of an electric fish to a patient's head as a cure for headache, and Pliny the Elder recommends the stunning shock from such a fish as an excellent remedy for the pain of childbirth. Electroconvulsive therapy today involves administering electric shocks of

between 70 and 130 volts. These induce convulsions similar to grand mal epileptic seizures. This technique was first discovered in the late 1930s, and is sometimes useful in the treatment of depression, though it is not clear why. However, it is instructive to consider the story of the new ECT machine, installed in a hospital in England, which was used with the normal success rate for over six months—until the mechanic called and found that it was faultily connected. Obviously the power of suggestion can be a key factor in producing improvement.

Lobotomy and amygdalotomy

The most significant landmark in the history of brain surgery was a conference of neurologists held in London in 1935. Jacobsen and Fulton reviewed their work, in which they had significantly moderated the behaviour of two chimpanzees by surgically removing their frontal lobes. At the end of the talk, the Portuguese neurologist Antonio Egas Moniz rose to his feet and asked: 'If frontal lobe removal prevents the development of experimental neuroses in animals and eliminates frustration behaviour, why would it not be feasible to relieve anxiety states in man by surgical means?'

Moniz and his colleague Almeida Lima set to work to provide an answer to that question. They used the surgical method of prefrontal lobotomy in an attempt to modify the mental lives of obsessed and melancholic patients. What they did was to cut certain fibres running from the frontal lobes to other parts of the brain. The instrument used was a special knife called a leucotome, which they inserted through a small opening drilled in the skull. Film buffs will be reminded of Ken Kesey's *One Flew Over the Cuckoo's Nest*. In that film, it is a lobotomy operation that puts a permanent halt to Randle Patrick McMurphy's heroic struggle against Big Nurse.

The publicity which Moniz attracted for his new form of brain surgery led to a tremendous upsurge of interest in prefrontal lobotomy. In the 20 years between 1935 and 1955 approximately 70,000 lobotomies were performed in the United States and Britain. Walter Freeman, the acknowledged doyen of American lobotomists, personally performed more than 3,500 lobotomies. The fame and prestige of Moniz were such that he received a Nobel Prize in 1949.

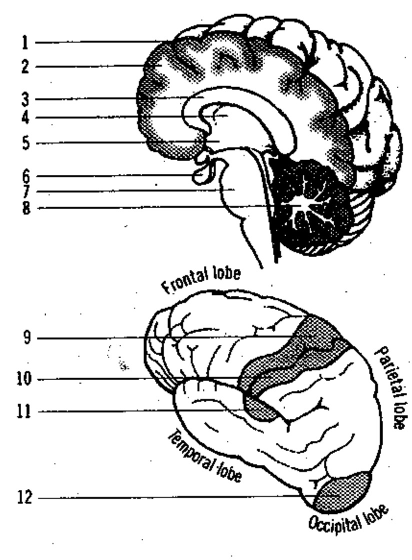
As the years went by, however, there were increasing indications that prefrontal lobotomy was not the panacea which Moniz claimed. There were frequent reports of a variety of unfortunate side-effects, including apathy, irresponsibility, diminished intellectual powers, impaired judgement, reduced creativity, and even coma and eventual death. As the disadvantages of this form of brain surgery became more obvious the number of patients receiving lobotomies dropped, until very few were being done at all. Moniz got what some regarded as his just deserts when he was shot in the spine by one of his own lobotomized patients.

But the irony of the whole saga of prefrontal lobotomy was that it eventually came to light that one of Jacobsen and Fulton's lobotomized chimpanzees had suffered a brain abscess as a result of poor surgical technique, and that the other had not actually shown the reported good effects of lobotomy!

With the abandonment of the lobotomy operation, 'psychosurgeons' shifted their attention from the frontal lobes of the brain to the limbic system. Loosely speaking, the limbic system lies between the lower and higher parts of the brain, and part of it, the amygdala, is thought to be involved in rage and aggression.

Arthur Kling and his colleagues performed amygdalotomies (lesions or cutting of the amygdala) on monkeys that had been living in a free-ranging colony. The good news was that they became less aggressive and friendlier towards their human handlers. The bad news, which failed to deter some psychosurgeons, was that these animals appeared to be

This very simplified diagram of the brain shows: 1. Cortex 2. Subcortex 3. Corpus callosum 4. Thalamus 5. Hypothalamus 6. Pituitary 7. Midbrain or brain stem, with the spinal cord below it 8. Hindbrain or cerebellum. Projected on the surface of the cortex are: 9. Main area controlling body movements 10. Main area receiving messages from the body and sense organs 11. Main area concerned with hearing 12. Main area concerned with seeing. The area concerned with producing speech sounds lies in the frontal lobe, but the areas for interpreting speech and writing lie in the parietal lobe.



confused and fearful when they rejoined their old colony in the wild. They were quite incapable of coping with the complexities of social life and rapidly became social isolates.

Psychosurgeons usually get at the amygdala by directing a fine wire electrode towards the intended target through a small hole drilled in the skull and passing a strong current through the electrode, which destroys the tissue around the tip of it.

Casualties of psychosurgery

The most notorious application of the amygdalotomy technique was in the United States, where it was used on criminals serving gaol sentences. The then Attorney General of the State of California was reported to have called publicly for amygdalotomies on all violent criminals housed in the state's prisons in order to remove 'the brain centres responsible for fear and anger'.

One case that made banner headlines involved L.S., a psychopath convicted of first-degree murder and rape, who had spent 18 years in a Michigan mental hospital. When a lawyer called Gabe Kaimowitz heard of the plan to make L.S. the first recipient of psychosurgery at the Lafayette Clinic, he told the *Detroit Free Press* of his concern and initiated court proceedings. According to L.S.'s testimony at the hearing, he had only given written consent to psychosurgery because he thought he might be released after the operation. He also claimed that he had been misled into thinking that he was agreeing only to electrode implantation and not to destructive surgery.

The three-man panel ruled that people who are involuntarily confined cannot give legally adequate consent to dangerous brain operations. They also decided that in this case psychosurgery violated the First Amendment (guaranteeing the citizen's right to free expression) in that it could have the effect of impairing memory and intellectual powers.

Another well-known case involved a 34-year-old engineer named Thomas R., who received an amygdalotomy at the hands of Vernon Mark and Frank Ervin. After surgery he was confused and delusional, and unable to work. When he was rehospitalized because of his bizarre and dangerous behaviour, he was discovered on one occasion walking about the wards with his head covered by bags, newspapers and rags. He said he did this because he was frightened other bits of his brain might be destroyed. His mother, describing his behaviour after psychosurgery, said: 'The poor guy has been almost a vegetable ... We know he was destroyed by that operation.'

Legal constraints on the use of psychosurgery have increased in recent years as a result of public outrage at some of its unsavoury consequences. California State Assembly Bill 4481, for example, restricting the use of electroconvulsive therapy and psychosurgery in California, was signed into law in late 1974 by the then Governor Ronald Reagan (it was later

replaced by Assembly Bill 1032, operative from 1 January 1977).

It is undeniably true that the complexities of the human brain make it very difficult for surgeons to operate on it without producing a number of unpleasant and disturbing side-effects. However, there are some success stories, and this chapter is mainly concerned with one such story, based on the impressive work of Roger Sperry[1] of the California Institute of Technology and his colleagues. This work has alleviated human suffering and also produced exciting new insights into the physiological and psychological workings of the brain.

Key experiment: the split-brain operation

The work of Roger Sperry and his associates at Caltec was done with a small number of advanced epileptics whose severe convulsions could not be controlled by medication. The first patient, for example, was a 48-year-old war veteran who had been having seizures for more than ten years, averaging two major attacks a week, each of which left him debilitated for at least a day.

The radical form of treatment decided upon for these epileptic patients was based on the fact that the human brain is a double organ, consisting of a right and a left hemisphere connected by a bridge of nerve tissue called the corpus callosum. This bridge of nerve tissue was severed surgically, the surgeons in this case being Philip Vogel and Joseph Bogen. Though this procedure is popularly referred to as the 'split-brain' operation, this is slightly inaccurate because the deeper parts of the brain remain connected.

Was such drastic surgical intervention justified? The basic idea was that cutting the corpus callosum would confine the epileptic seizures to one hemisphere, thus providing a measure of relief for the patients. There was also some evidence that possible unpleasant side-effects would be few (Ronald Myers and Roger Sperry had previously found that cutting the corpus callosum in cats and monkeys did not seriously impair their mental faculties).

Generally the effects of this operation were very beneficial. In the case of the 48-year-old war veteran not a single large-scale convulsion occurred in the several years following surgery. The second patient, a housewife and mother in her thirties, also remained free of seizures after recovering from surgery. A minority of the patients did continue to have seizures, but their convulsions were much less severe and less frequent than before, and usually confined to one side.

All the patients showed some short-term memory loss, problems of orientation and mental fatigue immediately after the operation. Some of them were unable to speak until two months after the operation. But in all cases there was gradual recovery. Within a few months none of them felt any different from the way they had felt before the operation. All in all, a substantial reduction in epileptic attacks was achieved, and at very low cost in terms of long-lasting side-effects.

Sperry's work achieved considerable publicity. Naturally the media sensationalized the difficulties the patients had in coping with their two half-brains, but considered objectively, the most remarkable result of the split-brain operation was its apparent lack of effect on ordinary behaviour. Indeed, Sperry had to devise a special test to demonstrate the drawbacks of split-brain functioning. This test was based on the fact that information presented visually to the left half of each eye is projected to the right hemisphere of the brain, whereas information presented to the right half of each eye goes to the left hemisphere. Provided the patient's direction of gaze was controlled and information was presented for a tenth of a second or less to prevent eye movements, Sperry could ensure that only one hemisphere of the brain received the information.

One of Sperry's first discoveries was that his patients had two separate visual inner worlds. If the picture of an object was

presented to one hemisphere, they recognized it when it was presented again to the same hemisphere. However, if the picture was then presented in the other half of the visual field, so that it was projected to the opposite hemisphere, they responded as if they had no recollection of having seen the picture before.

More striking evidence of the existence of two quite separate visual worlds in these patients was obtained when the word 'heart' was flashed across the centre of the visual field, with 'he' to the left of centre and 'art' to the right of centre. Since language and speech are very largely left-hemisphere functions, the patients said they could see the word 'art' when it was presented to the right and projected to the left hemisphere. However, when they were asked to point with the left hand to one of two cards ('art' or 'he') to identify the word they had seen, they invariably pointed to 'he', the reason being that the right hemisphere controls the movement of the left hand and 'he' had been presented to the right hemisphere!

It has been known for a long time that language is associated to a far greater extent with the left hemisphere than with the right, although the opposite is found among some left-handed people. The original evidence for this came from studying patients who had received head injuries or suffered strokes. A gunshot wound to the left side of the head, for example, or a stroke in the left hemisphere, is much more likely to affect speech or writing ability than a similar injury to the right side.

Sperry was able to confirm this very convincingly. He found that visual material projected to the left hemisphere could be described by the patients in speech and writing in an essentially normal manner. But when the same material was presented to the right hemisphere, the patient would insist that he had not seen anything, or that there had only been a flash of light. Yet if the patient was then asked to use his left hand to point to a matching picture or object, he had no trouble in indicating the very item which he had just said he had not seen!

In an amusing variation of this experiment, a female patient was presented with a series of neutral geometrical figures. A photograph of a nude woman was then flashed to the right hemisphere. The patient said that she had not seen anything, but a sly smile spread over her face and she began to laugh. When she was asked what she was laughing at, she replied: 'I don't know . . . nothing . . . oh, that funny machine.'

We have already mentioned that the right hemisphere is not usually the one which controls speech. However, other observations made by Sperry and his co-workers indicated that the right hemisphere is able to understand both written and spoken words to some extent. If the name of an object (e.g. 'eraser') was flashed to the right hemisphere, the patient was able to select an eraser from among other objects by touch alone using the left hand (controlled by the right hemisphere).

The right hemisphere was even able to respond appropriately to a command such as 'Retrieve the fruit monkeys like best'—patients were quite capable of pulling a banana from a bag of plastic fruit with their left hand. The patients varied in terms of the linguistic powers of the right hemisphere. The most adept patient was able to spell simple words by placing plastic letters on a table with his left hand, but after he had spelled a word as directed, he could not name the word he had just spelled.

So far, we have focused mainly on the problems Sperry's patients encountered in dealing with visual information. Similar difficulties were experienced when objects were placed unseen in either the left or the right hand. Information from the left hand goes to the right hemisphere and information from the right hand to the left hemisphere. Objects placed in the right hand for identification by touch were easily described or named in speech or writing. If the same objects were placed in the left hand, the patients could only make wild guesses and often seemed unaware that anything at all was in their hand.

However, if one of the objects which the patient said he did not recognize was taken from his left hand and placed among a dozen other items, he was then able to feel it out and retrieve it, again with the left hand, even after a time lapse of several minutes. The major limitation on performance here was that the patients could only retrieve the object provided that they used the same hand throughout—they could not recognize with one hand something identified only moments before with the other.

The superiority of the left hemisphere over the right across a wide range of tasks had led many people to refer to the left side of the brain as the 'major hemisphere' and to the right side as the 'minor hemisphere'. This is a profoundly mistaken view. If we move away from verbal abilities and consider other kinds of skills (e.g. spatial), the position is quite different. Tests by Sperry and Bogen at the Californian Institute of Technology showed that the right hand, which is under left hemisphere control, was unable either to arrange blocks to match a pictured design or draw a cube in three dimensions, whereas the left hand could perform both tasks quite satisfactorily.

There is interesting recent evidence that the right hemisphere may also be more intimately involved in emotional experiences. Lesions in most areas of the left hemisphere are accompanied by the feelings of loss that might be expected as the result of any serious injury, whereas damage in much of the right hemisphere sometimes leaves the patient unconcerned about his injuries and their possible consequences.

After Sperry's patients had been tested a number of times, they started using various strategies to cope with the tasks they were asked to perform. When a red or green light was flashed to the right hemisphere, the patient would at first simply guess at the colour. With practice, however, if the right hemisphere saw the red light and heard the left hemisphere guess 'green', it produced a frown and a shake of the head. This cued the left hemisphere to the fact that the answer was wrong.

Although the media have emphasized the problems that split-brain patients experience in performing relatively simple activities, Sperry found that it was sometimes a positive advantage to have two half-brains. He asked his patients to perform two different visual discrimination tasks simultaneously, with one task being presented to each hemisphere, and this they did as well as if they were performing each task on its own. In contrast, normal people find that the two tasks definitely interfere with each other if they attempt to perform them simultaneously.

Two minds in one?

One of the most challenging issues that arose from Sperry's pioneering research is whether he conclusively demonstrated the existence of two minds, each with its own consciousness. Sperry himself believed that he had. He announced to a distinguished Academy of Sciences: 'Everything we have seen so far indicates that the surgery has left these people with two separate minds, that is two separate spheres of consciousness. What is experienced in the right hemisphere seems to be entirely outside the realm of awareness of the left.' A very categorical statement indeed.

Experts have been in two minds, as it were, about whether or not to accept Sperry's bold assertion. Part of the difficulty revolves around what we mean by 'conscious experience'. It has been defined semi-facetiously as 'the dimension that makes you more like a dog than a computer', but various other definitions are possible.

The best attempt so far to come to grips with the question of double consciousness was undertaken by LeDoux, Wilson and Gazzaniga[2]. Since it is relatively easy to assess the nature and limits of consciousness in the 'talking' left hemisphere, but much more difficult to do the same with respect to the mute right hemisphere, they decided to use as

their subject Paul S. a boy who had greater language representation in the right hemisphere than had been observed in any other split-brain patient.

On one occasion, words were presented to one hemisphere of Paul S.'s brain and he was asked to evaluate them on a good–bad scale. Many of the words elicited quite different evaluations from the two hemispheres, with the right hemisphere rating being consistently closer to the bad end of the scale than the left hemisphere rating. Words such as 'Paul', 'mother' and 'sex' were rated very good by the left hemisphere and very bad by the right hemisphere. These differences suggest that each hemisphere may possess its own unique system for assigning subjective values to people and events.

It is especially intriguing that Paul was difficult to cope with on the day that these differences in hemisphere evaluations were obtained. It was almost as if he was literally at odds with himself. When he evaluated the same words on a second occasion he was calm and tractable. His improved mood on this occasion was mainly reflected in more positive right hemisphere evaluations, supporting the idea that the right hemisphere is more 'emotional' in some sense. On this second occasion the good–bad ratings were very similar in each half-brain.

Further evidence in favour of the notion that each hemisphere has a mind of its own was obtained when Paul was asked what job he would like. The left half-brain spelled out 'draughtsman', but the right half-brain spelled out 'automobile race'. It thus looks as if Sperry may not have been far wide of the mark in suggesting that two minds can co-exist in one body, but this may only happen when some language skills are present in each hemisphere.

Many popular writers have drawn sweeping conclusions about normal people, and even the inadequacies of human societies, on the basis of Sperry's work with a handful of severely epileptic patients. We have been told that the verbal, logical culture of the Western world is managed by the left hemispheres of its population, whereas the mystical, artistic and religious cultures of the East are based on right hemisphere domination.

This analysis has suggested to the psychologist Robert Ornstein that there ought to be a revolution in Western education, with much greater emphasis on non-verbal skills. Just as there are people who are politically left-wing and others who are right-wing, so also there are left and right hemisphere supporters. Hugh Sykes Davies, a scholar of English, attacked the 'rightist' movement to which Ornstein belongs, complaining that crucial left-hemisphere verbal skills are rapidly degenerating in our televisual society. Unfortunately most of the contributors to this controversy seem to have made the bizarre assumption that the two hemispheres of a normal man or woman are as divided as those of Sperry's patients. The most fruitful approach would surely be to harmonize and integrate the function of the two hemispheres rather than develop one at the expense of the other.

A very important question that has almost been lost sight of by popular writers is whether or not we can safely assume that the differences between the two hemispheres in normal individuals are the same as those found by Sperry in split-brain patients. It could well be that frequent epileptic seizures, combined with all the problems of adjustment after surgery, make such patients' brains quite different from normal brains.

How can we look at the way each hemisphere performs in normal people? One useful method is to record the brain-waves evoked by some stimulus or other via small metal electrodes attached to the scalp, and to amplify these responses electronically, using special computer techniques to distinguish them from continuous brain-wave activity. This technique measures what are known as 'evoked potentials' (see Chapter 11), and depending on where we choose to place the

electrodes we can measure brain-wave activity in either the left or the right hemisphere.

In one typical experiment subjects were asked to carry out a number of verbal tasks (e.g. vocabulary test, finding synonyms) and spatial tasks (e.g. constructing a cross out of six plastic pieces, drawing a human figure). There was more pronounced brain-wave activity in the left than in the right hemisphere when a verbal task was being performed; the opposite occurred when a spatial task was being carried out. These observations fit in well with Sperry's notion that the left hemisphere is dominant for language skills and the right for spatial abilities.

There have been attempts to apply brain-wave techniques to a well-known sex-related difference, namely that women tend to be better than men at verbal tasks, while men are better at spatial tasks. Do women have better verbal skills because they have greater language representation in the right hemisphere than men, and does the organization of their right hemispheres for language interfere with the right hemisphere's attempts to handle spatial tasks? The answer to both questions seems to be yes. Women show relatively more brain-wave activity in the right hemisphere than men when engaged in verbal activities.

However, cross-cultural studies have somewhat dented the view that the right and left hemispheres have fairly specialized functions. Tsunoda Tadanobu of the Tokyo Medical-Dental College found interesting differences between the brains of Japanese people and those of other groups. He discovered that the sounds of insects, animals, rain, wind and waves activated the left hemispheres of Japanese-speaking people and the right hemispheres of everyone else! He also found that the sounds of traditional Japanese musical instruments like the *shakuhachi* produced the same pattern.

What is the reason for this unusual response to sounds? According to Tadanobu, the explanation lies in the peculiarities of the Japanese language. In Japanese, all vowel sounds and their derivatives are meaningful words. This means that many naturally occurring sounds resemble Japanese words, and so activate the language-processing systems of the left hemisphere.

All the evidence indicates that our hemispheres typically operate in an asymmetrical fashion, that is to say, many activities depend much more heavily on one hemisphere than the other. In other species symmetrical functioning of the two parts of the brain is often found. What are the advantages and disadvantages of asymmetrical brain functioning?

One advantage can be illustrated by means of a tale related by the fourteenth-century French monk Jean Buridan. An ass was faced with the dilemma of choosing between two equally appetizing and equidistant bales of hay, but it perished because it had no logical reason for moving towards one bale rather than the other. In real life, nature forestalls such tragic behaviour by equipping animals and humans with a response bias that usually leads them to select the bale on their right.

In general terms, asymmetry can be an advantage if you are trying to do two very different activities at once. If each activity can be dealt with by a different hemisphere, interference between the two activities is reduced. On the other hand, if you are attempting to cope with a single, complex task, it may be more difficult to co-ordinate behaviour if each hemisphere is doing part of the necessary processing on its own.

Marcel Kinsbourne tested some of these ideas with a very simple task that you can easily try yourself. This involves balancing a rod on either the right or the left index finger for as long as possible. If right-handed people do this while remaining silent, they can balance the rod longer on the right index finger than on the left, because the right hand is generally more skilled. However, if people are speaking while they attempt to balance the rod, then the opposite result is obtained: they can

now balance the rod longer on the left index finger than on the right. It is as if speaking knocks the rod off the right index finger.

What is happening here? Speech and the right hand are both controlled by the left hemisphere, and so interfere with each other. In contrast, speech and the left hand are controlled by different hemispheres, and so only interfere with each other to a modest extent. This simple but ingenious experiment shows the potential advantages of asymmetry. If each hemisphere concentrates on a single task, two different activities can be successfully performed at the same time.

Conclusions

The history of attempts to modify human behaviour by direct action on the brain shows that it is all too easy to produce radical behavioural changes. The problem is that many unforeseen and unfortunate changes usually accompany the desired ones. This has led to increasing legal constraints on the use of various psychosurgical techniques.

However, there are some brain operations that have proved to be worthwhile under certain circumstances. The work of Sperry is especially important in this context, because it has provided major benefits in terms both of the welfare of epileptic patients and of the accumulation of knowledge about the complex workings of the brain.