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phenomena, then, seem to arise in a fairly direct manner from the activity of systems of neurons in the brain. If we assume for the moment that our monkeys actually 'see' motion when we stimulate MT, our experiments simply extend this principle by linking a more specific type of sensation to more precisely defined circuits within the brain.

Hopefully, this incremental approach will bring more and more of our subjective experience within the domain of empirical investigation as research continues. I must admit that I am less optimistic about obtaining really satisfying answers to other questions about sensory experience. For example, why are the subjective sensations that accompany stimulation of visual and auditory cortex so radically different? Why is it that the first cause in me the subjective quality associated with 'seeing' whereas the second cause the quality of 'hearing'? I think this is a very difficult issue and I am always embarrassed when an undergraduate or first-year medical student asks this question, because I have no good answer. Neurophysiologists tend to mumble things about labelled lines in reply to such questions because that is the best we can do, but I've never been convinced that that emperor is well clothed.

Gray: There is one further point—you are doing these experiments in a monkey. If you end up getting, as you will, evidence that is compatible with the hypothesis that the monkey perceives motion in the sense that we see motion—maybe you could show the waterfall illusion being affected by your stimulation—then we would have strong grounds to say monkeys have conscious experience. I'm not sure that you can at present demonstrate that.

Searle: The point is, Bill, philosophically, one is never satisfied until one knows exactly how it works. That's why your work is philosophically important.

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Brain mechanisms and conscious experience

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Abstract. The human brain enables a variety of unique mental capacities. Our special capacities for inference, personal insight into the reasons for our actions, deception, high level problem solving, for literally dozens of activities represent specialized systems that most likely reflect specialized neuronal circuits that have accumulated in our brain by selection processes over thousands of years of evolution. I believe many of these enriching capacities are not so much the advantageous computational products of a large neuropil as they are the product of a brain that has accumulated specific algorithms for adaptation. Our awareness, our consciousness of these capacities, is nothing more or less than a feeling about them. A correlate of this view is that there are many processes supporting human cognition of which we are neither aware nor conscious. When conscious appreciation or feeling is involved for a modality of sensation or action, neural pathways communicating this information must be intact, normally to the left hemisphere. This paper reviews evidence that supports this view of consciousness that distinguishes special human capacities and feelings about those capacities from the neural substrates that underlie these distinctions.

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The British neuroscientist, philosopher, physicist, theologian and friend, Donald M. MacKay, once commented that it is easier to understand how something works when it is not working properly. He was drawing upon his experience in the physical sciences and simply wanted to note that an engineer could decipher more quickly how something like a television worked if the picture was fluttering than if it was working normally. It is a helpful insight and one that I subscribe to. I study broken human brains. I think they can teach us a lot about that thorny topic, human consciousness.

For me, the topic of consciousness is productively approached from the neurological side. Clearing the throat, setting up formal arguments, making seemingly important distinctions between this and that, reviewing and trying to remember who said what about what before you, are all exercises that do not prepare you for seeing human patients with broken brains. The phenomenon of human consciousness as seen in patients with alterations in normal neural organization is as riveting as understanding the message is challenging. Brain scientists hope to interest philosophers in our primary observations. We also hope to avoid getting them excited about our observations for the wrong reasons—namely errors in our logic!

General background

More and more, it is time for neuroscientists to consider their field and their observations in an evolutionary context (Gazzaniga 1992). They are massively guilty of ignoring context—of ignoring the history of our species. That history, I believe, provides major clues to how our brains go about their business.

I will argue that forces of Darwinian selection established specialized circuits in our brains that are dedicated to carrying out the variety of mental functions we enjoy. These circuits reflect adaptations that were established thousands of years ago, most likely during the Stone Age. These adaptations were of cognitive mechanisms—mechanisms that allow the formation of more general hypotheses in response to environmental challenges. There is an important distinction between behavioural adaptations and cognitive adaptations (Tooby & Cosmides 1987, 1990). If our brains had merely accumulated the capacity for certain behavioural adaptations, our species would possess a dizzying array of specific capacities that could show little latitude in responding to challenges. The *sine qua non* of the human is the variation we show in response to common challenges.

The argument for specialized structures would suggest focal brain lesions or surgical interventions that disconnect one region of the brain from another might disrupt specific processing mechanisms critical to human cognition. I will illustrate this point with several examples. However, discovering that the human brain is full of specialized processors does not seem to illuminate an answer to the problem: What is consciousness?

My own view of the matter reduces to a simple truth. When all is said and done, what we mean about being conscious is that we feel about things—about capacities. Consciousness is not the capacity to see colour or shapes, or to feel pain or make inferences, interpret our actions, appreciate art and music. Those capacities reflect specialized systems in the brain that have evolved and are present as individual systems. When thinking about the phenomenon of consciousness, it is important to distinguish mental capacities which are truly wondrous and our sense of those capacities. The distinction becomes blurred and, in part, it is due to one of the specialized systems in the human brain, the interpreter module. This special left hemisphere system that provides a running account of our actions, thoughts and feelings about our specialized capacities tends to blend our actual modularity into a sensation of unity.

This view is not that different from what I take to be the view of William James. He made five points about the problem of consciousness. He felt it was subjective; it changed; it was continuous; it had 'aboutness'; and it was selective. I accept all those characteristics and propose the brain mechanisms outlined below are consistent with his view. If the human brain comprises a constellation of specialized circuits more or less dedicated to carrying out specific mental functions and if one of those systems is dedicated to interpreting the actions of the other specialized systems, then one can nearly predict the characteristics that James outlines for the nature of human consciousness as a direct consequence.

Evidence for specialized circuits

Consider the human brain. It has two halves, the left and the right. We know the left cortex is specialized for language and speech and the right has some specializations as well. Yet, each half cortex is the same size and has roughly the same number of nerve cells. The cortices are connected by a large structure called the corpus callosum. The total, linked cortical mass is assumed somehow to contribute to our unique human intelligence. What do you think would happen to your intelligence if the two half brains were divided? Would you lose half of your intelligence because the part of the brain talking to the outside world would lose half of its support staff? To answer this, consider the evidence from surgical interventions where the left brain is disconnected from the right. This procedure is called split-brain surgery and is performed in patients who suffer from epilepsy. I have been studying patients with hemispheric disconnection for years.

A cardinal feature of split-brain research is that following disconnection of the human cerebral hemispheres, the verbal IQ of the patient remains intact (Gazzaniga et al 1962, Nass & Gazzaniga 1987, Zaidel 1990) and the problem-solving capacity remains unchanged. While there can be deficits in recall capacity and on some performance measures, the overall capacity for problem solving seems unaffected. In other words, isolating essentially half of the cortex from the dominant left hemisphere causes no major change in intellectual function. This represents strong evidence that simple cortical cell number cannot be related to human intelligence.

The notion of special circuitry is supported by a vast number of observations on patients with focal brain disease as well as a host of studies from split-brain patients. For example, most patients with a disconnected right hemisphere are seriously impoverished on a variety of tasks (Gazzaniga & Smylie 1984). While the isolated right hemisphere remains superior to the isolated left hemisphere for some activities such as the recognition of upright faces, some attentional skills and perhaps also emotional processes, it is poor at problem solving and many other mental activities.

Specialized circuits for human capacities

If one accepts that the human brain has special circuits for its various mental functions, one can consider the different levels of organization within the nervous system where these circuits might appear. I shall argue that the cerebral cortex is the custodian of new circuits critical for human cognitive processes. In this light, it is commonly observed that the overall plan of the mammalian brain seems quite similar across a variety of species, particularly when one compares the primate and human brain. One of the reasons comparative studies are carried out is the belief that homologous brain structures may serve common functions in the primate and human. Yet, the human brain, quite simply, is different from the monkey brain. There are many structures that carry out different functions in the two species. Let me review work on two structures that we have studied directly and indirectly in our laboratory—the anterior commissure and the superior colliculus.

The literature on animal studies clearly shows that the anterior commissure transfers visual information between hemispheres. In cats, interocular transfer occurs via the callosum alone, whereas the anterior commissure was found to be involved in visual transfer in chimpanzees and rhesus monkeys (Gazzaniga 1966). This would suggest that the same might be true for humans. However, in humans, when the callosum is cut but the anterior commissure is spared, there is no transfer of visual information of the kind seen in the monkey and chimp (Gazzaniga 1988, Gazzaniga et al 1985). Thus, the anterior commissure, although clearly able to transfer visual information in the monkey and chimp, does not do so in the human.

The difference seen with fibre tract systems is also apparent in more nuclear structures, such as the superior colliculus. There is clear evidence from the monkey that this structure is crucially involved in the control of eye movements. Mohler & Wurtz (1977), for example, demonstrated that primates with lesions of the primary visual cortex were able to detect and direct their eyes in response to visual stimuli presented in the scotoma, the blind spot in the visual field caused by the lesion. They suggested that the superior colliculus, working alone or in complementary fashion with the visual cortex, could carry out these functions for stimuli that fell within the scotoma. Others have claimed even higher order functions are possible after such occipital lesions (Weiskrantz et al 1977, Pasik & Pasik 1971). While similar claims have been made for the human (Weiskrantz 1990), we have not succeeded in demonstrating residual function following lesions to primary visual cortex. More recently, we have carried out microperimetry of patients with occipital lesions using an image stabilizer (Wessinger et al 1991, Fendrich et al 1992). These studies have clearly shown that patients with homonymous hemianopia can have small islands of spared vision, in which there is visual function. In most of the scotoma, however, there is no visual function, as reported by Holtzman (1984). In short, when visual function is possible, there seems to be spared visual cortex. This observation was confirmed with magnetic resonance imaging. Overall, these results suggest that the spared superior colliculus in the human is not able to carry out the kinds of oculomotor functions that are possible in the monkey.

Special human circuits

If the human brain has unique organizational features and appears to have many of its major cortical surface areas specified genetically, then humans may have capacities that other primates do not. The multitudinous extra circuits in the much larger human cerebrum perform activities that other species simply cannot. One such specialization is the capacity to make voluntary facial expressions. This is a unique trait of humans that is easily accessible for study. No other animal, including the chimpanzee, can make such voluntary facial expressions.

There are a variety of beliefs about how the brain is organized to perceive and produce facial expressions. In the perceptual domain, it seems that the right hemisphere has special processes devoted to the efficient detection of upright faces (see Gazzaniga 1989). Although the left hemisphere can also perceive and recognize faces and can show superior capacities when the faces are familiar, the right hemisphere appears specialized for unfamiliar facial stimuli (Gazzaniga & Smylie 1984).

We have recently examined these and related issues in split-brain human patients. Disconnection of the two cerebral hemispheres allows the role that the corpus callosum plays in controlling voluntary and involuntary expression to be assessed. It also allows examination of the ability of each hemisphere to initiate facial expressions.

The pattern of innervation for the upper half of the face is different from that for the lower half of the face; the differences involve both central and peripheral systems. The neural mechanisms involved in voluntary facial postures are controlled by the cortical pyramidal system, while the control of spontaneous postures is managed by the extrapyramidal system (for review see Rinn 1984). This diversity of innervation is reported to be responsible for the preservation of symmetrical spontaneous facial postures in the presence of unilateral damage to motor cortex. Patients with such a lesion will show a contralateral facial droop that will resolve when smiling spontaneously. In this instance, while the pyramidal input to the facial nucleus is destroyed, the extrapyramidal input is not. It is also commonly reported that patients with extrapyramidal disease, such as Parkinson's disease, will display a masked face when at rest and look more normal when smiling to command.

We examined the capacity of each cerebral hemisphere to initiate voluntary facial postures. The results reveal marked differences in the capacities of each hemisphere, indicating that the corpus callosum plays a critical role in the normal production of voluntary symmetrical facial expressions. Examination of asymmetries in smiling to command revealed that when the command to smile was visually presented unilaterally to the left hemisphere, the right side of the mouth dramatically commenced retraction as much as 180 ms before the left side responded. When the command to smile was presented to the right hemisphere, none of the patients was able to respond. In another series of tests on patients J.W. and D.R., a drawing of a 'happy face' or a 'sad face', presented exclusively to either hemisphere, found the right hemisphere giving the correct response at a frequency no better than that obtainable by chance. On trials in which an incorrect response had been made, as in frowning to a happy face, J.W. was nonetheless able to draw a picture of the given stimulus with his left hand.

These kinds of observations emphasize the superiority of the left hemisphere in interpreting events and its dominant role in organizing responses to those events. In the present context, high level evaluative processes must be invoked to override a potentially spontaneous facial expression such as smiling. Such processes would appear to occur only in the left hemisphere, i.e. the hemisphere that appears to control voluntary expression. This sort of 'voluntary' control would appear different and involve more complex processes than those associated with adopting 'voluntary' hand or foot postures in response to a cue. Therefore, where evaluations involve more psychological aspects of a person's expressions, the left hemisphere appears dominant.

Cognitive similarity/neural similarity?

For the past few years we have been examining the brains of monozygotic twins to investigate whether monozygotic twins are more similar in cortical organization than are unrelated individuals. We first examined the corpus callosum, where we showed that this enormous fibre tract system was more similar in area and shape in monozygotic twins than in unrelated pairs (Oppenheim et al 1989). Using a new method of assessing the cortical surface areas of the human brain (Jouandet et al 1989, Loftus 1991), we have now studied the cortical surface of both male and female monozygotic twins (Thomas et al 1990, Green et al 1992, Tramo MJ et al, unpublished 1992). Such twins look alike, talk alike, behave similarly, think similarly and so on. Are their brains alike? Normally, there is great variation in the gross morphology of the brain: while all brains have a similar overall plan, they vary tremendously in the details. Some brains have bigger frontal lobes than others. The patterns of how the cortex appears, called the gyral/sulcal pattern, varies and that variation presumably reflects differences in the underlying brain organization. Is the great similarity in the overall cognitive skills of monozygotic twins due to physically more similar brains?

Until recently, no one has had information on this crucial point. Our laboratory has been working on ways of quantifying magnetic resonance images in a way that would allow one to examine various regions in each half brain and to assess their similarity in surface area. Fifty slices are made of the brain and these slices are reconstructed to make maps of the human cerebrum. With the maps, it becomes easy to measure the cortical areas of the various major lobes of the brain. We now estimate the surface area from the three-dimensional reconstruction of the cortical surface itself. We discovered that there is a significant effect of monozygosity for frontal, parietal and occipital cortical surface area. Additionally, monozygosity significantly affects regional cortical surface area and involves twice as many areas in the left hemisphere as in the right. Overall, we can conclude that the brains of monozygotic twins are more alike than those of unrelated individuals.

The final, very important factor is that if our brain represents an assembly of specialized circuits, we have to explain William James' primary observations. We do feel unified and whole and we do have integrated feelings (usually) about all of our actions, thoughts and behaviours. There must be a specialized process in the brain that contributes to this undeniable aspect of our conscious experience.

Left brain interpreter

Several years ago we began to make observations on how the left, dominant speaking hemisphere dealt with the behaviours we knew we had elicited from the specialized circuits in the disconnected right hemisphere. We first revealed the phenomenon using a simultaneous concept test. The patient is shown two pictures, one exclusively to the left hemisphere and one exclusively to the right, and is asked to choose from an array of pictures placed in full view in front of him/her the ones associated with the pictures presented laterally to the left and right brain. In one example, a picture of a chicken claw was flashed to the left hemisphere and a picture of a snow scene to the right hemisphere. Of the array of pictures placed in front of the subject, the obviously correct association is a chicken for the chicken claw and a shovel for the snow scene. Patient P.S. responded by choosing the shovel with the left hand and the chicken with the right. When asked why he chose these items, his left hemisphere replied 'Oh, that's simple. The chicken claw goes with the chicken, and you need a shovel to clean out the chicken shed.' Here, the left brain, observing the left hand's response, interprets that response into a context consistent with its sphere of knowledge—one that does not include information about the left hemifield snow scene.

This same general idea has been observed when the 'left brain interpreter' struggles to deal with mood shifts, produced experimentally by manipulating the disconnected right hemisphere. A positive mood shift triggered by the right hemisphere finds the left interpreting its current experience in a positive way. Similarly, when the right triggers a negative mood state, the left interprets a previously neutral situation in negative terms.

Connecting to the interpreter: all roads do not lead to Rome

Specialized circuits are distributed throughout the cerebral cortex. The neural mechanisms involved with the local processing of particular modalities appear proximal and closely associated with the primary inputs for that modality. Awareness of these modality activities would appear to arise by information being communicated to the left hemisphere via cortical circuits. If the information requires communication from the right to the left hemisphere, the information courses over specific callosal pathways. Our understanding of cortical circuitry comes from considering the effects of lesions to primary cortical structures and pathways. Consider patient A. W. (Baynes et al 1992, 1993).

Patient A.W. suffered a stroke which involved the mid-region of the corpus callosum and other cortical structures in her right hemisphere. She is a very intelligent woman with training in biomedical research. Inspection of her magnetic resonance scans revealed that most of the splenium and rostrum of her callosum had been spared, as well as a ribbon of fibres both dorsal and ventral to her primary lesion in the mid-two thirds of her callosum. What is of particular interest is how she processed information with her left hand.

When processing with her right hand, she behaved completely normally. In this situation, objects would be placed in hand out of view. She quickly named them, as stereognostic information from the right hand was projected directly to the left dominant speaking hemisphere. There, tactile information is in close proximity to language and speech mechanisms and the results of tactile information processing can be communicated to the examiner. Needless to say, the right hand can match objects as well. Thus, an object placed in the right hand can subsequently be retrieved by the right hand when placed in a grab bag of items.

The dramatic effects of callosal disconnection surgery can be seen when the patient attempts to retrieve with the left hand an object originally placed in the right hand. A.W.'s performance falls to near chance. At the same time, an object placed in the left hand can also be easily retrieved by the left hand when placed in a grab bag of other objects. This indicates the right cerebral hemisphere has intact those neural circuits associated with the processing of stereognostic information projected to the right hemisphere from the left hand. This information, however, cannot be communicated to the left hemisphere. Callosal disconnection produces intriguing and fascinating behaviours.

An eraser can be placed in the left hand. The left hemisphere, when queried by the examiner, says it doesn't feel anything or doesn't know what the object is. Nonetheless, the left hand can easily find the matching stimulus from the grab bag. Thus, the correct object has been retrieved by the right hemisphere. The left hand is holding the correct object, but all of this activity remains known only to the right hemisphere. Further, it remains known only to the right hemisphere even though the right hemisphere is connected to the left through millions of remaining callosal fibres: this complex experience cannot be communicated to the left through these remaining fibres. Tactile experiences must be communicated through callosal fibres dedicated to communicating tactile information and those have been damaged. In short, our awareness of experiences is tied to specific fibre systems.

Summary

There is, it seems to me, the belief that understanding something like human consciousness will be achieved as we learn more and more about the vast computational capacities of the human brain. Somehow, the argument goes, the complex neural activities of the huge cerebral mantle hold the answer to this perennial issue. Biologists, psychologists and evolutionists are forever talking about big brains and the secret big brains must hold for understanding the special feeling we hold dear as being conscious humans.

The argument put forth here would see our big brains housing specialized circuits that are involved with specific functions. The functions relating to human cognition are mostly housed in the left hemisphere and can proceed essentially normally after being disconnected from half of the cortical mantle. Further, it is argued that consciousness reflects feelings about these capacities. The feelings about these capacities are largely managed by cortical circuitry that must have connections to the left hemisphere's interpreter system, if they are to enter into our awareness and be incorporated into our beliefs about the nature of our personal reality.

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DISCUSSION

Gray: I would like to probe the analogy with language. You could be saying consciousness is like the innate language system that only the human possesses, as far as we know, even though you can teach other animals a bit of linguistic skill. Therefore, only human beings are conscious.

Gazzaniga: No, I wasn't saying that.

Marcel: Jeffrey, in this case, clearly Mike Gazzaniga is talking about reflexivity when he talks about consciousness. He is not talking about phenomenal experience. Consciousness for him is 'the feelings we have about our capacities'. Not everybody here has the same referent when they talk about consciousness; we are not all talking about the same thing.

Secondly, Mike, you suggest that consciousness is not learned. How do you know? What about different forms across cultures? You are talking about an interpreter of conscious experience. There is a long tradition—Helmholtz, Dan Dennett, Max Velmans, me—of viewing consciousness as the result of an account. But the accounts that you are talking about are communicative verbal accounts. For example, if you are going to say that our visual experience is an account, do you want to say that the interpreter is in the left hemisphere?

Gazzaniga: This starts the puzzle category. Puzzle one: why is it when you split someone's brain, after they wake up and look at you, and say 'Hi', they don't say, 'I don't see half your face', which they don't from the left hemisphere? It's as if the sense that they should see half of your face is located elsewhere. That is, of course, preposterous. Yet, why isn't there a protest from prior experience that something is radically different?

Marcel: That is like patients with anosognosia.

Gazzaniga: No, the information is there; the information is working happily in that hemisphere, it's not damaged.

Marcel: You are discussing a reaction to what one is experiencing. I am talking about experience itself. The reaction 'My experience is funny', is a second-order event.

Gazzaniga: I am suggesting there may be another quality to that, more than just a second-order event.

Marcel: If that were the case in the left hemisphere, why do patients with anosognosia fall into this category? Such patients more often have *right* brain damage. Therefore, that second-order capacity cannot reside *only* in the left hemisphere. Maybe the linguistic accounts, communicative ones, do.

Nagel: Do patients with scotomas that are caused by retinal damage also not notice them?

Gazzaniga: Those are noticed immediately.

Gray: Do the split-brain patients not adopt any changed visual habits that would allow them to see your whole face? Do they adopt habits of keeping their eyes or head turned in some direction or other?

Kinsbourne: A patient with neglect does not adopt such habits. You can only know something is missing if there's a mismatch between your representation of what should be contained within the domain in question and incoming information. If the representation itself isn't accessible, there is no mismatch signal which says something is missing.

Gazzaniga: Except the memory.

Kinsbourne: There is the completion phenomenon, which has been shown for a few split-brain patients (Trevarthen 1974). If you give them half a figure in the right half field, they will report seeing a whole figure, as if they were inferring unconsciously its extension into the left half field. So there is no experiential shock.

Gazzaniga: If you give these patients a left half figure to the left visual field, and ask them to draw what they see, the right hemisphere again draws a half figure, it doesn't complete—as if the interpreter again is not doing anything beyond . . . .

Kinsbourne: But once it has drawn a half, it sees a whole, because it completes.

Gazzaniga: No, the left hemisphere does that but not the right.

Harnad: Is there any evidence that patients with a right hemispherectomy are more literally minded about input than are patients with a left hemispherectomy, along the lines of the effects in the left and right hemispheres of split-brain patients?

Gazzaniga: If you are going to get any kind of function from the right hemisphere, the damage to the left would have to occur very early. This is also an issue with patients with hemispherectomies and residual vision. If the tests have been done correctly, these patients with hemispherectomies seem to have residual vision. But we know that early lesions of the brain lead to such reorganization of the brain that you are no longer testing the normal visual system. This occurs dramatically in cases of agenesis of the corpus callosum: there is transfer of information within the brain.

Harnad: I was thinking of late hemispherectomy.

Gazzaniga: If you take off the left hemisphere late, there is not much going on afterwards.

Newsome: One of the cardinal features of blindsight is that the classic blindsight patient denies seeing what they manifestly can see, as shown behaviourally. Do your patients with the tiny islands of spared vision deny seeing things in those islands? Or if you asked them to make a visual discrimination, would they say, 'Ah, I have a little patch out there where I can see a signal'?

Gazzaniga: That's a real hornet's nest. We can get confidence ratings of 1–5 after running patients on each trial. First, there is no question that the patient is responding to each trial and discriminating the shapes. When we set these tests up, the stimulus is presented into what is clearly a residual vision area, and we also put the same stimulus on other trials into the good visual field, as well as some marginal zones. With a 1–5 scale, the patient obviously assigns 5 to what's clearly seen, they assign 2 and 3 to what may be vaguely seen, and they assign 1 to what is really difficult. When you then ask them, 'What do you really mean by 1?', they may reply either 'I saw something' or 'I didn't see anything at all'.

If you test normal people and show them a display where you vary the signal:noise ratio on a display, and you ask for confidence ratings, you also get this range. From those data, you wouldn't argue for parallel pathways and the like. A range of confidence ratings is a property of the task—that could be all that is happening here.

Searle: Mike, the way I heard your description of the island cases is they have a blank spot in the visual field with points of light in it. Is there any reason to suppose that's not right? The data that you just gave may mean that if the stimulus is degenerate enough, the patient would say, as a person with normal vision would, either 'I didn't see it at all' or 'I just saw something vaguely'. It seems to me we have good reasons to suppose there was a conscious visual experience of those points; whereas in a standard blindsight case, there's good reason to suppose there isn't any conscious visual experience.

Gazzaniga: If you are studying blindsight in the human, you have to do microperimetry of the visual field to find out what it is like. We are studying a second patient now. When we put her in the eye-tracker, her field is like spaghetti! There's vision here, vision there. Generally, the vision is hugely impaired, no question about that. But when we place stimuli in the spaghetti lines, we get perfectly fine performance.

Dennett: What do you mean by performance in this regard? Does this patient react to stimuli without a prompt? Are you sure it's not just a forced-choice test?

Gazzaniga: We are doing our work from the ground up. We are establishing a two-alternative forced-choice, detection task.

Marcel: Forced-choice? So they don't spontaneously see consciously what is in their scotoma?

Gazzaniga: I'm not saying that. They do make a conscious choice in response to the stimulus. It's in the nature of the experiment. However, they may have low confidence about their judgement.

Dennett: So if you said, 'Press a button if you ever see a spot of light in this field', we don't know whether they would ever press the button.

Gazzaniga: Consider the visual field of the patient and consider the approximately 60 points we test where the patient is completely blind. They have the anatomy intact that should support blindsight. In tests using the most sensitive method known to detect any residual vision, we find that they see nothing.

Velmans: Doesn't that just show that those particular sensitive spots are sufficient to support a form of visual discrimination? It doesn't in itself show those spots are sufficient to support a phenomenal experience.

Gazzaniga: Related phenomena occur all the time in normal college sophomores. I have tested them on spatial tasks where they have to point to a sequence of events occurring within a grid of nine squares. When we increase the speed of presentation of stimuli, subjects swear that they are not performing above chance, yet their performance is above chance. What do you make of that?

Kihlstrom: It's the kind of thing that you can understand in terms of a distinction between explicit and implicit cognition. These effects are emerging on a two-alternative forced-choice test, where you make the person make a decision, even in the absence of phenomenal experience that would support some kind of spontaneous speech act or something. Those are the kinds of conditions under which implicit perception and implicit memory appear. So maybe there isn't phenomenal experience, maybe something is being processed nonetheless. That leads me to the question about the role of the anterior commissure here. Is there any evidence for implicit perception or implicit memory in the other hemisphere?

Gazzaniga: No.

Kihlstrom: Has it been looked at with an implicit memory test?

Gazzaniga: It's worse than that. Using the image stabilizer, you can leave the stimulus in the left visual field for five seconds. In our test, all the right hemisphere has to do is decide whether or not the left hemisphere stimulus is horizontal or vertical lines, or an apple or orange. Performance is still at chance.

Libet: With the differences you have been describing between the right and left hemisphere, and the role of the 'interpreter' in the left hemisphere, are you suggesting that the person or the self is really in the left hemisphere?

Gazzaniga: I'm saying that the special module that we have that interprets our actions is in the left hemisphere.

Humphrey: You said that consciousness was innate. We know that people with left hemispherectomy apparently can function quite normally and I think we would want to say that they are conscious. In the ordinary sense of innate, one would say that if consciousness is innately in the left hemisphere, then the brain won't re-adapt and compensate for changed circumstances. I would like Dan Dennett to come in on this issue, because Dan's view of consciousness as a virtual machine imposed on the hardware of the brain makes consciousness a learned phenomenon. I think all of us would agree that the hardware has very important innate characteristics; but I think few people would want to say that consciousness is innate.

Gazzaniga: I would love to.

Nagel: The idea that consciousness is learned is bizarre.

Searle: My interpretation of what Mike Gazzaniga said is: both hemispheres are conscious, it's just that the right one is pretty dumb. Mike makes it sound like a computer: it just gives you back what you put in. Whereas there are many other kinds of activities going on in the left hemisphere. As far as consciousness is concerned, both hemispheres are conscious. It is innate to the mechanisms of those hemispheres that they produce consciousness. Is that the position?

Gazzaniga: Yes.

Fenwick: After split-brain surgery, one of the most disabling problems is the fact that the two hemispheres fight with each other.

Gazzaniga: No they don't. That was an early mistake. In the first case, W.J., there was a lot of frontal lobe damage in addition to the callosal surgery, so there was very poor ipsilateral control of the limbs in that patient. Thus, when the left hemisphere wanted to do something, it could control the right hand; when the right hemisphere wanted to do something, it could control the left hand. But the left hemisphere had very poor control of the left hand and the right hemisphere had very poor control of the right hand. So there could be antagonism. In subsequent patients, who haven't suffered extracallosal damage, one doesn't see that situation at all. You can demonstrate the ipsilateral deficit by subtle testing of distal musculature, but the fighting between hemispheres that you are referring to was really an aspect of the first case.

Fenwick: I have recently reviewed the epilepsy literature and the split-brain studies. It is not just in one case, this antagonism is widely reported.

Gazzaniga: You have to trust me a little. I have seen these cases, all of them. Every once in a while you get some visiting medic who listens to a random story of a patient. One such medic gave a lecture at my school about one of our patients. She said: 'You don't need a tachistoscope to do visual testing, just show V.P. her closet, and you will see she has the hardest time picking out her dress. There is a deep conflict between the hemispheres.' She hadn't seen V.P. preoperatively trying to pick out her dress!

Dennett: Mike, you mentioned that there is no change in IQ after surgery. But are the IQs of patients with split-brains well below the normal range?

Gazzaniga: No, we have smart split-brain patients and their IQs don't change.

Shevrin: You mentioned the amazing conformity between monozygotic twins in their brain structure. There is also considerable evidence that their evoked potentials are very similar (Shevrin et al 1970).

What is the current status of Galin's (1974) hypothesis that the right hemisphere is more closely related to dreaming and unconscious processes in general?

Gazzaniga: I think that was fun back in the early days of thinking about left brain/right brain. Traditional dreaming studies have been done with patients after split-brain surgery. When they are woken during REM sleep and asked if they were dreaming, they reply that they were dreaming.

Shevrin: So earlier reports that the dreams of split-brain patients have a poverty of imagery and so on don't stand up?

Gazzaniga: No.

Searle: There was a period when we got a lot of pop science literature to the effect that the right brain did poetry, music, falling in love and deconstruction; and the left brain did logic, mathematics, analytic philosophy and truth-seeking. What I hear from you is that that's a load of nonsense.

Gazzaniga: The new dichotomy is Bush/Quayle.

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Consciousness, schizophrenia and scientific theory

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Abstract. The positive symptoms of acute schizophrenia are, of their very nature, aberrations of conscious experience. A recent theory of the mechanisms underlying their occurrence spans four levels: neuroanatomical, neurochemical, cognitive and the symptoms themselves. The theory is capable of being tested in animals and human subjects, and it has passed a number of experimental tests at both levels with success. Implications of the theory for the scientific treatment of consciousness are considered. Although the theory permits useful questions relating to consciousness to be put and even to some extent to be answered, it leaves the most basic issue—the theoretical link between the occurrence of conscious experience and the neural substrate of the brain—unresolved, as do all similar theories so far.

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In this paper I shall use the aberrations of conscious experience that are symptomatic of schizophrenia to illustrate the problems that face contemporary science in the attempt to bring such phenomena into its network of causal explanation. In doing so, I shall assume that there *is* a problem of consciousness (i.e. that no-one has yet succeeded in either arguing it away or solving it); that it is a problem of *consciousness*, not a mind–body problem (since there is no difficulty in principle in understanding how physical systems can carry out mental operations that remain unconscious); and that it is a *scientific*, not a purely philosophical problem (though one which still awaits a general conceptual solution to which philosophy can contribute, not one that can be solved simply by the accumulation of data or improved technology) (for justification of these assumptions, see Gray 1987). The detail of the argument rests heavily upon a recent theory of the neural and psychological bases of the symptoms of schizophrenia (Gray et al 1991a,b), which I shall first summarize. My chief concern, however, is not to set out this theory as such, but rather to draw from it certain inferences as to the limits that attach at present to any attempt to provide a scientific account of conscious phenomena of any kind. Even if, as is plausible, our particular theory of the neuropsychology of schizophrenia is