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CONSCIOUSNESS, PERSONAL IDENTITY AND THE DIVIDED BRAIN*

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I

IT HAS NOW become a familiar story in neuroscience that when you divide the brain surgically by midline section of the cerebral commissures the mind also is correspondingly divided. Each of the disconnected hemispheres continues to function at a high level, but most conscious experience generated within one hemisphere becomes inaccessible to the conscious awareness of the other. The parallel mental functions of the separated hemispheres are found to differ further in important ways, the most conspicuous being that the disconnected left hemisphere retains the ability to speak its mind, much as before, whereas the right hemisphere, for most practical purposes, is unable to express itself either in speech or in writing.

In turning to examine more closely these and related phenomena, as they bear on our present topic, I shall be drawing on studies by a long line of associates and myself conducted

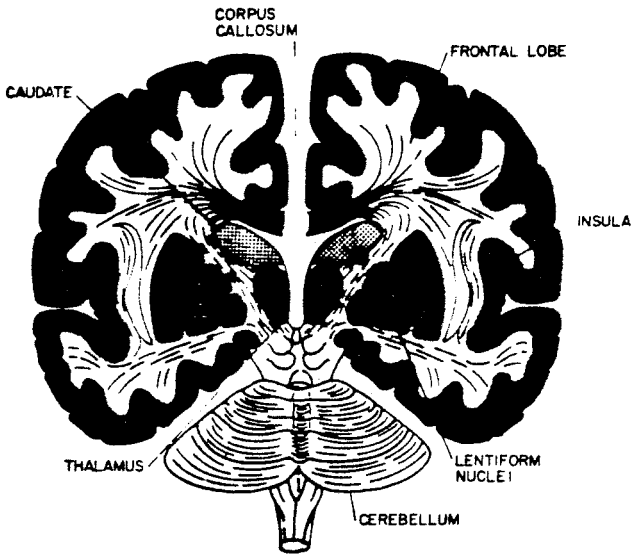
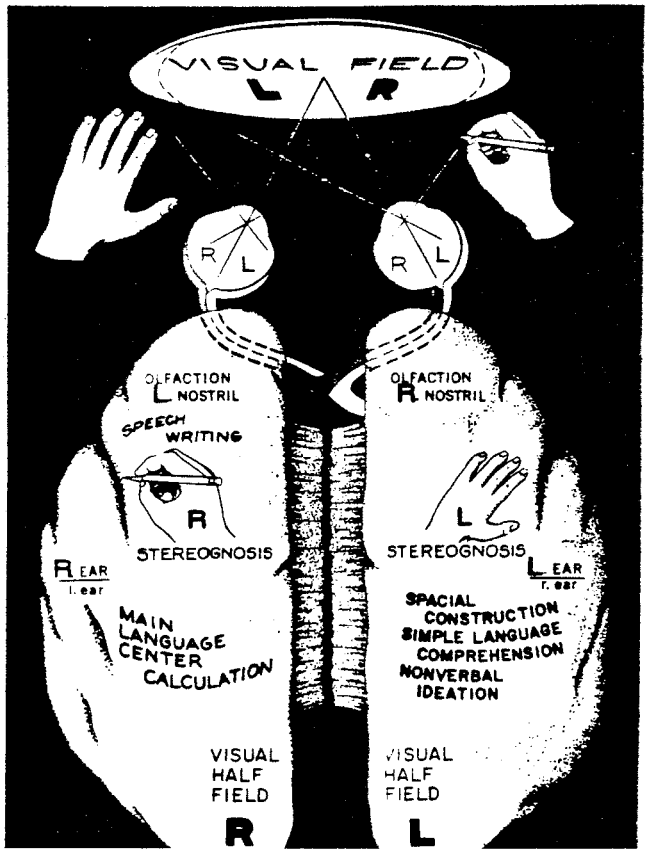


FIG. 1. Nature of hemispheric separation effected by surgical section of forebrain commissures. Some indirect cross communication remains possible through intact midbrain and associated brainstem structures.

predominantly by the right hemisphere. In addition, the surgery cuts off the functions of the right hemisphere from speech and the main language centers located (in approximately 95% of the population) in the left hemisphere (see Fig. 2)

A leading question with which we shall be concerned can be stated as follows. Are there really in the brain thus divided, two separately conscious minds, in effect two co-conscious selves sharing the one cranium? And, if so, what does this signify regarding the nature and the substrate of mind and the unity of the conscious self in the normal intact brain?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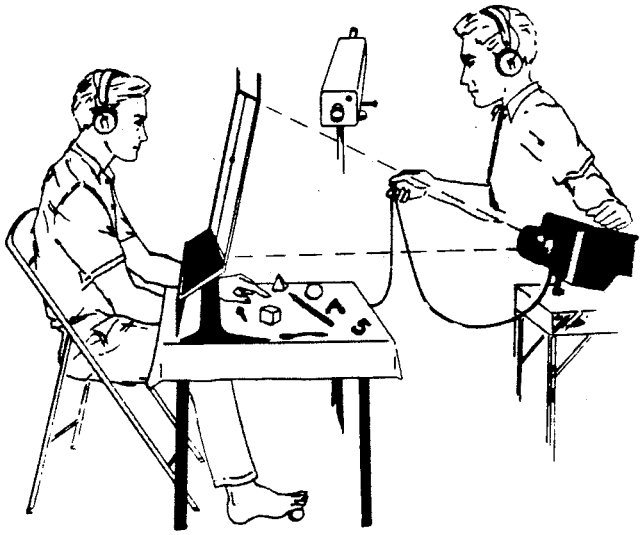

FIG. 3. Testing set-up for determining laterality of mental functions in the surgically separated hemispheres.

through one nostril are not recognized through the other. Split-brain subjects fail to identify by verbal report objects felt with the left hand, seen in the left visual field or smelled through the right nostril—in other words, things experienced within the right hemisphere. Meantime good perception and comprehension of these same test stimuli, of which the subject *verbally* disclaims any knowledge, is readily demonstrated *manually*, for example, by selective retrieval with the left hand, or by pointing to the correct picture in a choice array, or by appropriate hand signals or gestures (see Fig. 4).

From the collective results of these and similar kinds of tests, it is inferred that both disconnected hemispheres retain mental function at a rather high level but are no longer cognizant of most mental functions of the partner hemisphere. The two disconnected hemispheres can further be shown to function concurrently but independently in parallel, by presenting different stimulus items simultaneously to the two hands or to the two visual half fields. Under these conditions each of the two hemispheres are found to process concurrently their own separate perceptual–cognitive–mnemonic functions, and these may be grossly incompatible or even mutually contradictory, without either hemisphere noticing that anything is wrong—so separate are the inner experiences of the disconnected hemispheres. The basic hemisphere disconnection syndrome is apparent as well in experiments with animals, as shown ealier in extensive studies on cats and subhuman primates during the 1950s [20, 22]. As in man the surgically separated hemispheres were found to perceive, learn and remember independently at a high level apparently with equal proficiency on left and right sides.

Some authorities, concerned for the essential unity of the conscious self have been reluctant to accept the conclusion that the mind is divided by commissurotomy, maintaining instead that the mind and self remain unified within the language hemisphere or centered in the intact brain stem or in the person as a whole and that the nonspeaking, subordinate hemisphere operates only as a computer-like, unconscious automaton. (A recent treatment of this controversy may be found in ZANGWILL [24]. See also [14].) While these alternative interpretations may better conform with common concepts and traditions regarding the essential unity of the inner being, we have not been able to see any real justification in our test findings for denying consciousness to the disconnected mute hemisphere. Everything we have observed in many kinds of task performances over many years of testing reinforces the conclusion that the mute hemisphere has an inner experience of much the same order as that of the speaking hemisphere though differing in quality and cognitive faculties as will be outlined later. Clearly the right hemisphere perceives, thinks, learns and remembers, all at a

the retention of an intact, undamaged right hemisphere. Although this disparity is still not fully resolved the evidence seems to be settling out in favor of the conclusions drawn from commissurotomy. In particular, the language profile of the right hemisphere after commissure section conforms rather well to that seen after rare surgical removals of the speech hemisphere for malignancy [17]. The vocabulary in the disconnected right hemisphere for comprehension of single spoken words about 10 years after surgery is found to have a mental age rating only slightly below that of the language hemisphere [33].

Earlier interpretations based on the symptoms produced by focal lesions which pictured the minor or subordinate hemisphere as a comparative retardate in brain evolution have had to be revised. The mental performance of this hemisphere after commissurotomy has been found repeatedly to be superior and dominant to that of the speaking hemisphere in a growing series of nonverbal, largely spatial tests. The tasks involved are of the kind where a single spatial image processed as a whole proves to be more effective than a detailed verbal or mathematical description. Examples include the copying of designs, reading faces, fitting forms into molds, discrimination and recall of nondescript tactual and visual forms, spatial transformations and transpositions, judging whole circle size from a small arc, grouping series of different sized and shaped blocks into categories, perceiving whole plane forms from a collection of parts and intuitive apprehension of geometrical properties (this literature is still scattered but see reviews in [20, 22, 25, 29]; also see [7]).

Commissurotomy makes possible precise left–right comparisons for positive performance within the same brain, where most of the usual confusing background variables cancel out. Also the deceptive interhemispheric interference effects that complicate inferences drawn from focal lesions are eliminated or greatly reduced. Earlier doubts regarding the presence of advanced mental function in the minor hemisphere are now largely dispelled and the concept of a complementary evolution of both hemispheres has come to replace our older classic view of a single one-sided dominance.

In any case, after watching repeatedly the [illegible]

hemisphere, even slight cognitive differences on left and right sides become meaningful. The same person is observed to consistently employ one or the other of two different kinds of mental strategy much like two different people, depending on whether the right or the left hemisphere is in use. The first evidence for this was obtained by Levy in 1969 [9] and has been repeatedly confirmed many times since. The discovery of complementary cognitive mode asymmetries following commissurotomy has prompted many further studies in normal, in brain damaged and in other select populations helping to better pinpoint and delineate the left–right cognitive differences and their variations.

Correlations of cerebral laterality have been extended to handedness, sex, occupational preferences and ability, special innate talents, eye dominance, genetic variations like Turner's syndrome, endocrine pathology, congenital dyslexia, autism, dreaming, hypnosis, inverted writing—and so on (an introdution and references to this large and rapidly expanding literature can be found in [10]). This has become a rapidly developing and fascinating story in itself of which I mention briefly a few summary points in passing. One important outcome is the increased insight and appreciation, in education and elsewhere, for the importance of nonverbal forms and components of learning, intellect and communication. By the early seventies it already had become evident, from the standpoint of brain research, that our educational system and modern urban society generally, with its heavy emphasis on linguistic communication and early training in the three Rs, tends increasingly to discriminate against the nonverbal, nonmathematical half of the brain which has its own perceptual–mechanical–spatial mode of apprehension and reasoning [23, 26]. The amount of formal training given to right-hemisphere functions in our public schools traditionally has been almost negligible compared to that devoted to the specialities of the left hemisphere. The need now for better methods by which to detect, measure and develop the nonverbal components of intellect before their critical development periods have passed is becoming widely recognized.

These and related developments help bring also an increased respect and regard for the

differentially specialized forms of intellectual potential becomes increasingly evident.

One must caution in this connection that the experimentally observed polarity in right-left cognitive style is an idea in general with which it is very easy to run wild. You can read today that things such as intuition, the seat of the subconscious, creativity, parapsychic sensitivity, the mind of the Orient, ethnocultural disposition, hypnotic susceptibility, the roots of counter-culture, altered states of consciousness—and what not—all reside predominantly in the right hemisphere. The extent to which extrapolations of this kind may eventually prove to be more fact or fancy will require many years to determine. Meantime it is important to remember that the two hemispheres in the normal intact brain tend regularly to function closely together as a unit and that different states of mind are apt to involve different heirarchical and organizational levels or front-back and other differentiations as well as differences in laterality.

IV

In face of the mounting evidence for higher cognitive faculties and a complementary specialization in the right hemisphere, earlier claims that this hemisphere is not conscious have given way to intermediate positions. One of the latest concedes that the mute hemisphere may be conscious at some levels, but denies that the nonlanguage hemisphere possesses the higher, reflective, and self conscious type of awareness that characterizes the human mind and is needed, so it is said, to qualify a conscious system as a "person" [5, 15]. Self-consciousness is said to be predominantly a human attribute according to present thinking based on evidence drawn mainly from mirror tests for self-recognition [8]. On these terms, self-awareness seems to be largely lacking in animals below the primates and appears only to a limited extent in the great apes. In human childhood, self-consciousness is reported to emerge relatively late, somewhere around 18 months of age. Thus, self-consciousness, by developmental as well as by evolutionary criteria, is rated as a relatively advanced phase of conscious awareness.

being used to test for a sense of time and concern for the future in the right hemisphere, with thus far no evidence of abnormal deficit. The nonvocal hemisphere appears to be aware of daily and weekly schedules, important dates of the year and to make appropriate discriminations with regard to possible future accidents and family losses, life, fire and theft insurance and the like.

V

Accepting the dual conscious state of the hemispheres following surgical separation, students of the problem of personal identity and the nature of the conscious self have used the split-brain findings, along with cases of fugue states or multiple personality, to support the argument that it is no longer correct to think of a "person" as being correlated one-to-one with a body, that we need now to sharpen and refine the concept in terms of the critical brain states and neural systems involved. Such refinement becomes important in medicolegal decisions dealing, for example, with prolonged states of coma, stages in fetal development, vital organ transplants and so on.

An extreme position in regard to selfhood and "personal identity" is held by PUCCETTI [16] and BOGEN [2] and their followers who infer that each hemisphere must have a separate mind of its own, not only after brain bisection but also in the normal intact brain as well. The surgery, they argue, simply reveals what already is there, namely, that we are all of us actually a dual compound of right and left minds, or "persons" as Puccetti puts it and that this bicameral condition normally goes undetected because the experiences of right and left hemispheres are kept in close synchrony when the commissures are intact. I myself have favored the view that the conscious mind is normally single and unified, mediated by brain activity that spans and involves both hemispheres. This assumes first, that the fiber systems of the brain mediate conscious awareness as well as do the switching mechanisms, synaptic interfaces and other properties of the gray matter; and second, that fiber cross-connections between the

the face. The same is true for audition and other systems like those mediating crude pain, temperature, pressure and position sense, especially from the more axial parts of the body. Bilateral motor controls also are extensively present in both hemispheres. For lateralized testing we must necessarily be highly selective and take considerable pains to avoid activity that cannot be reliably confined to a single hemisphere. We thus depend heavily on moderately sophisticated input from the hands and from the half fields of vision.

Bilateral representation within each hemisphere is further achieved by factors of a more functional kind. Exploratory movements of the eyes, for example, can provide bilateral representation of a perceived scene or object in both disconnected hemispheres. Similarly, exploratory movements of the hands with interchange and overlap can provide for a bilateral unified percept of an object in both hemispheres. These kinds of factors must be routinely guarded against and excluded in our lateralized testing.

Another fundamental way in which the conscious mind is not divided by commissurotomy is illustrated in the tests for self and social awareness mentioned above in which mental–emotional ambience or semantic surround generated in one hemisphere promptly spreads also to the second hemisphere. These "deep structure" components in conscious awareness which appear to include attitudinal, orientational, emotional, contextual, semantic and related cognitive factors, are presumably mediated through undivided deep components of cognition. I have described the structure of the conscious system in the divided brain as being Y-shaped, i.e. divided in its upper, more structured levels but undivided below [28]. Each of the separated hemispheric limbs of the "Y", it should be remembered, contains within itself extensive bilateral representation. Each hemisphere, for example, functions with much the usual sense of awareness of the positions and movements of all body parts on both sides, a sense of being able to initiate and direct motor commands for the whole body and an awareness also of the environment on all sides. Visceral sensations and central states like those involved in hunger, fatigue, etc. also are bilateralized. Even where the ipsilateral representations are weak or absent, there is

unified. On these terms the qualities of subjective experience need not correlate with the diverse particulate components of the neuronal infrastructure, only with the function of the active process as a whole. By these operational criteria for generation of subjective meaning the mind may be seen to be largely divided after commissurotomy but unified in the normal intact brain.

VI

Another thing to come out of these concerns for the unity and/or duality of mind, with and without the commissures, is a modified concept of the nature of consciousness. A revised view of the conscious self is involved that includes a formula for mind–brain interaction. For many decades science was traditionally careful to explicitly exclude from its objective explanations any use of conscious or mental forces or phenomena as causal constructs. Mind or subjective experience was accordingly treated in science as an acausal epiphenomenon or as a passive parallel correlate of brain activity, a semantic artifact or most commonly as an inner aspect of the one main physical brain process. On these terms the physiological brain process is assumed to be causually complete in itself with no need, nor any place for the causal intervention or operation of conscious or mental forces.

The more we learned about the neuronal circuitry and electromechanical mechanisms of brain activity the more incredible it became to think that the course of these physicochemical events could be influenced in any way by the qualities of conscious experience. As ECCLES [6] phrased it in 1964, "We can, in principle, explain all our input–output performance in terms of activity of neuronal circuits; and consequently, consciousness seems to be absolutely unnecessary" and again ". . . as neurophysiologists we simply have no use for consciousness in our attempt to explain how the nervous system works". This was the kind of reasoning that had prevailed widely for more than half a century and had led to the philosophy of scientific materialism with its firm renunciation of consciousness and mentalism in science

overriding higher level dynamics of the mental properties—just as the flow of electrons in a TV receiver is differentially determined by the program content on different channels.

Without going into further detail, it follows on this revised scheme that mind does actually move matter within the brain [21], and outside as well, indirectly through physical behavior. Further, it now becomes "mind over matter" in a very real sense. This is all within the brain hierachy, of course. There is no implication that mind is separate from matter in the dualistic sense. Mentalism is no longer equivalent to dualism in the framework of today's modified paradigm. The revolution of the past decade towards increased scientific acceptance of consciousness does not do anything directly to bolster dualist beliefs in the mystical, the paranormal or supernatural. At the same time, the new position directly opposes prior materialist doctrine that has been telling us for more than half a century that "Man is nothing but a material object, having none but physical properties" and that "Science can give a complete account of man in purely physio-chemical terms". These quotes are from the late 1960s by ARMSTRONG [1], a founding father and leader of the materialist, so-called "mind–brain identity" theory, which still today finds support, though with major reinterpretations to bring it now into close concordance with the causal emergent views of mind outlined above.

Once science thus modifies its traditional materialist–behaviorist stance and begins to accept in theory, and to encompass in principle, within its causal domain the whole world of inner, conscious, subjective experience (the world of the humanities) then the very nature of science itself is changed. The change is not in the basic methodology or procedures, of course, but in the scope of science and in its limitations, in its relation to the humanities and in its role as a cultural, intellectual and moral force. The kinds of interpretations that science supports, the world picture and attendant value perspectives and priorities and the concepts of physical reality that derive from science all undergo substantial revisions on these new terms. The change is away from the mechanistic, deterministic and reductionistic doctrines of pre-1965 science to the more humanistic interpretations of the 1970s. Our current views

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