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IRWIN FEIGIN

BRAIN MECHANISMS IN LANGUAGE, COGNITION, AND CONSCIOUSNESS

Introduction

In the recent past, an encyclopedia section on physiological psychology would have foresworn any attempt to deal with the brain mechanisms involved in language, cognition or consciousness. Even today most physiological texts in psychology are so behavioristically oriented that the very words *language, cognition* and especially *consciousness* are eschewed. Yet it was not always thus. During the nineteenth century, the initial strides in relating brain and behavior came from the neurological clinic, where the study of disturbances of language due to brain lesions made the names of Broca and Wernicke celebrated; where studies of brain-caused disturbances of cognitive processes led Freud to coin the term *agnosia;* where the same Freud pointed out that if consciousness is a function of cortex, then the rest of the brain must be concerned with unconscious determinants of behavior.

During the classical behaviorist period of psychology, studies of language, cognition and consciousness were deemed beyond the scope of scientific psychology. Euphemisms such as second signaling system (for language), higher nervous functions (for cognitions), and complex mental states (for consciousness) were used to keep psychology pure, much as in Victorian times women were said to have limbs rather than legs. But psychology as an aspiring science became liberated during the 1960s and once more is facing the raw facts of subjective experience. So once again physiologically oriented psychologists are turning to the clinic in order to study the relationships of the human brain to subjective experience.

The harvest of this new direction in physiological psychology is already surprisingly rich. New insights are continually being achieved into the structure of language, the types of cognitive processes, and the brain mechanisms operative in various states of consciousness. These insights come through the careful application of the techniques and concepts developed in experimental and animal psychology to the human condition.

Language

The specialization of the left hemisphere of (right-handed) man's brain for the understanding and production of language has been known for thousands of years. Egyptian and classical Greek medicine were informed by cases of head injury that, as a rule, only left-sided injuries would interfere with language functions. The fact that children can carry out commands and otherwise signify that they understand spoken language when they as yet cannot express themselves adequately has suggested that the *receptive (decoding)* and *expressive (encoding)* aspects of language can be separated. The names of Wernicke and Broca are associated with the locating of the receptive and expressive portions of the brain's involvement in language. However, a good deal of evidence suggests that Broca placed his locus too far forward, that what is now known as Broca's area (the third frontal convolution) may in fact have little to do with language, and that Broca's aphasia results from lesions closer to the motor representation of the vocal apparatus (the base of the precentral convolution). A more unitary view of an auditorily based language mechanism has resulted: Wernicke's locus being critical (in primary aphasia) with additional involvement of visual mechanisms leading to alexia (reading disturbance); of motor hand mechanisms leading to agraphia; and of motor vocal mechanisms leading to Broca's aphasia.

But a more profound impact on the problem of the relationship between brain and language has come from the successful training of great apes in the use of gestural sign language by Gardner and Gardner, and the communicative manipulation of visual symbols by David Premack. Well over a hundred signs can be mastered and hierarchies of visual symbols manipulated. Communication takes place in the somatomotor and visual modes rather than acoustic-vocally. This has raised the question as to how communication through speech differs from that through gestures. One obvious difference is the rapidity of sequencing in speech and the greater possibility for simultaneous signaling by gestures. Is the ape brain limited in its processing speed and thus cannot use the acoustic-vocal mode? Can aphasic humans be taught to use gestural sign language, or is the aphasic disturbance a deeper one, precluding any form of communication? Perhaps some aphasics can learn the gestural language while others cannot. Which can? And what then characterizes the deeper process? These are all questions initiated by the animal work and currently are being actively pursued in various clinics.

Cognition

Our understanding of the relationship between brain and cognitive processes has also been enriched by animal studies and by a more sophisticated approach to hemispheric specialization. Some thirty years ago, Pribram initiated a program of research aimed at the production of animal models of the agnosias. (Since, at that time, animals had not yet been shown to use signs, aphasias were not considered suitable for modeling—and even now most linguists would hold that human language cannot be readily modeled in animal communications). This program was successful in locating specific brain systems separately involved in making visual, auditory, tactile and gustatory identifications. When Brenda Milner took these results back to the clinic, she found such nonlinguistic disturbances more likely to be produced by lesions of the right hemisphere. Thus, two types of cognitive processes, linguistic and nonlinguistic, were separately served by one of the hemispheres of man's brain.

The technique of *dichotic* and *dichoptic* presentation of stimulus materials combined with computer analysis of electroencephalographic patterns gave further evidence of this separation of cognitive modes of function. The left hemisphere's electrical activity reflects verbal input, while the right hemisphere's electrical activity appears more sensitive to the figural aspects of sounds. In fact, a great deal of evidence has suggested that the right hemisphere's nonverbal speciality lies in the processing of figural information. Face recognition and musical ability are two well-known figurally dependent processes handled predominantly by the right hemisphere.

But the yield from the animal models has been greater than just stimulating reinvestigation of brain-produced cognitive disturbances in man. Studies on the animal models have shown that brain organization in cognition, at least in the nonhuman primate, is cortical-subcortical rather than cortico-cortical. This finding has raised the question as to whether the human brain is similarly organized. Up to now, human cognitive brain processes have been thought to be dependent on cortico-cortical association tracts. If, in fact, the importance of cortico-cortical organization in man stands the test of future research, a major difference between functional anatomy of the brains of men and beasts will have been established. Hitherto no anatomical differences have been accepted as accounting for hemispheric specialization or man's linguistic and other cultural accomplishments.

Finally, work with the animal models of cognitive processes has shown that the brain mechanisms involved are distributed within functional systems; that one aspect of these mechanisms (the connecting pathways) operate probabilistically, and that the probabilities become progressively constrained during learning; however, that at the same time storage (probably at *synaptic* and *dendritic* sites) continues to be distributed and reduplicates with repetition; that the learned connectivities act as programs re-membering the dis-membered, distributed stored elements much as a computer program assembles stored items from a distributed core. In fact, the use of sequential information processing by computers and parallel processing by distributed (optical, holographic) information systems has served the investigator of brain mechanisms in cognition much as in vitro analyses have served the biochemist.

Consciousness

Once again hemispheric specialization has been the takeoff point for studies of consciousness. Roger Sperry led the way with a tour de force in showing that splitting apart the hemispheres of the human brain (by sectioning the *corpus callosum*) produced "two minds in one head." Neither hemisphere appears to know what the other is about. As noted above, the left hemisphere talks, the right cognizes configurally. An embarrassing picture projected into the right hemisphere will make the patient blush and ask with his left what might be the matter. Choices given to the right hemisphere to make can be indicated instrumentally by matching from sample or pointing, and occasionally by simple verbal indicators. The left hemisphere makes its choices known verbally and has some difficulties with complex configural problems.

The question has been debated as to whether the right hemisphere of these split brains displays conscious properties. Sperry unequivocally says yes ("it can blush") while Sir John Eccles cautiously suggests that only from verbal report can we truly determine whether consciousness exists. The argument may be resolved through a more precise definition of consciousness: ordinary perception is obviously shared by both hemispheres, but that special awareness called "intentionality" by philosophers that distinguishes between the observer and the observed may be a peculiarly human (or at least anthropoid and possibly cetacian) characteristic that, concomitant with language, is primarily a left-hemisphere function.

The evidence is against this left-sided view of consciousness, however. Weiskrantz and Warrington have portrayed cases of "blindsight" due to resections of primary visual projection cortex. Their best subject is a patient with a removal limited to the right occipital cortex. This subject, as do the others, performs visual location (by pointing) and visual choice problems (by verbally or instrumentally indicating his choices) at 85% to 90% proficiency when the visual cues are presented to his "blind" field. Despite being told that he is performing well, he reports that he has absolutely no awareness of the cues, and that he is guessing to the best of his knowledge.

Somewhat similar observations have been made on patients with medial temporal lobe resections. Pribram reported a patient who, following *amygdalectomy,* ate voraciously, putting on well over 100 pounds without ever experiencing hunger or appetite. Another such patient is Brenda Milner's famous H. M. who had both amygdala and hippocampus resected bilaterally with a resultant severe "memory" loss. After twenty years of testing, the patient does not recognize Milner. Nor can he report any familiarities with events since his surgery. Yet H. M. has been trained to perform discriminations and other tasks instrumentally, and he retains what he has learned despite protestations to the effect that he has no recollection of ever having been shown such tasks. Even with problems testing verbal memory by recognition of items from repeated lists, Warrington and Weiskrantz have shown in similar patients that intrusion errors occur, indicating that the items did "get into" memory. Further, when some context is provided, such as the first two or three letters of a word to be recognized or recalled, the patients perform as well as their normal controls.

What this relationship between context, familiarity and consciousness might be remains to be researched. Currently biofeedback procedures are proving effective in gaining insights into just such problems. Some visible readout is provided of an otherwise obscure internal process in order to obtain control over that process. Often limited and occasionally some considerable awareness of the process is attained. Perhaps providing feedback is the equivalent of furnishing the context within which this form of consciousness can occur.

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KARL H. PRIBRAM

BRAIN AND PSYCHOANALYSIS

Despite the gulf which separates the modern practitioners of psychoanalysis from their neurologic colleagues, the interests and professional concerns of these two branches of medi-