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BRAIN, CONSCIOUSNESS AND REALITY

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PART I: SOURCES OF A MODEL OF BRAIN FUNCTIONS IN CONSCIOUSNESS

Introduction

A patient has a tumor removed from the occipital lobe on one side of his brain. The surgery leaves him unable to report the sight of objects presented to him on the side opposite the removal, yet he can correctly point to the location of the objects and even correctly respond to differences in their shape (Weiskrantz, Warrington and Saunders, 1974). Even when repeatedly told that he is responding well, he insists that he is not aware of seeing anything and is only guessing.

Another patient has the medial structures of the temporal lobes of his brain removed on both sides. He performs well on tests of immediate memory such as recalling a telephone number just read out loud to him, but a few minutes later is not only unable to recall the number but the fact that he had heard a number or even that he had been examined. Even after twenty years of regular exposure to an examiner, the patient fails to recognize her as familiar (Scoville & Milner, 1957). Yet, this same patient, when trained to respond skillfully to a complex task, or to discriminate between objects, etc., can be shown to maintain such performances over years despite the disclaimer on his part that he was ever exposed to such a task (Sidman, Stoddard and Mohr, 1968).

Still another patient with a similar but more restricted bilateral lesion of her temporal lobe has gained over a hundred pounds of weight since surgery. She is a voracious eater, but when asked whether she is hungry or has any special appetites, she denies this even when apprehended in the midst of grabbing food from other patients (Pribram, 1965).

This is not all. A patient may have the major tracts connecting his cerebral hemispheres severed with the result that his responses to stimuli presented to him on opposite sides are treated independently of one another. His right side is unaware of what his left side is doing and vice-versa. The splitting of the brain has produced a split in awareness.

More common in the clinic are patients who are paralyzed on one side due to a lesion of the brain's motor system. But the paralysis is manifest especially when the patient attempts to follow instructions given to him or which he himself initiates. When highly motivated to perform well ingrained responses, as when a fire breaks out, or as part of a more general action, the paralysis disappears. Only intentional, volitional control is influenced by the lesion.

Observations such as these have set the problems that brain scientists need to answer. Not only do they demonstrate the intimate association that exists between brain and human mind; they also make it necessary to take into account the dissociation between conscious awareness, feelings and intentions on the one hand and unconscious, automatic behavioral performances on the other.

Perhaps it is not too surprising therefore, that a division in approach to the mind-brain problem has recently occurred. While philosophers and behavioral scientists have for the most part eschewed a Cartesian dualism in an attempt at rigorous operational and scientific understanding, thoughtful brain scientists have inveterately maintained that a dualism exists and must be taken into account. A brief review of my own struggles with the problem may be helpful in posing some of the issues involved.

Plans

The struggle began modestly with a recounting in the late nineteen-fifties and early nineteen-sixties of case histories such as those used in the Introduction of this paper. These were presented as an antidote to the radical behaviorism that then pervaded experimental psychology. The formal properties of a more encompassing view were presented in terms of a computer analogy in Plans and the Structure of Behavior (Miller, Galanter, & Pribram, 1960) under the rubric of a "Subjective Behaviorism." The analogy has since become a fruitful model or set of models known as "Cognitive Psychology" which, in contrast to radical behaviorism, has taken verbal reports of subjective conscious experience seriously into account as problem areas to be investigated and data to be utilized.

The computer has proved an excellent guide to understanding and experimental analysis. Further, it has become clear that a host of control engineering devices can serve as models for the brain scientist. Of special interest here is the distinction that can be made among such models between feedback and feedforward operations, a distinction which is critical to our understanding of the difference between automatic and voluntary control of behavior. Feedback organizations operate like thermostats, Cannon's (1927) familiar homeostatic brain processes that control the physiology of the organism. More recently it has become established that sensory processes also involve such feedback organizations (see Miller, Galanter & Pribram, 1960 and Pribram, 1971, Chapters 3, 4 and 11 for review). Thus, feedback control is one fundamental of brain organization.

But another somewhat less well understood fundamental has emerged in the analyses of brain function in the past few years. This fundamental goes by the name of feedforward or information processing (see e.g., McFarland, 1971, Chap. 1). I have elsewhere (Pribram, 1971, Chap.5; Pribram and Gill, 1976, Chap. 1; Pribram, 1981) detailed my own understanding of feed-forward mechanisms and their relation to the feedback control. Briefly, I suggest that feedbacks are akin to the processes described in the first law of thermodynamics (the law of conservation of energy) in that they are error processing, reactive to magnitudes of change in the constraints that describe a system. They operate to restore the system to the state of equilibrium.

By contrast feedforward organizations process "information" which increases the degrees of freedom of the system. The manner by which this is accomplished is often portrayed in terms of Maxwell's demon and Szilard's solution to the problem posed by these "demons," i.e.how can energy be conserved across a boundary (a system of constraints), a boundary which "recognizes" certain energy configurations and lets them pass while denying passage to others (see Brilluin 1962 for review). In such a system the energy consumed in the recognition process must be continually enhanced or the "demon" in fact tends to disintegrate from the inpact of random energy. Feedforward operations are thus akin to processes described by the second law of thermodynamics which deals with the amount of organization of energy, not its conservation. Information has often been called neg-entropy (see e.g., Brilluin 1962) entropy being the measure on the amount of disorganization or randomness in a system. In the section on Consciousness and Volition we will return to these concepts and apply them to the issues at hand.

Nineteenth century psychophysics and psychophysiology dealt directly with feedforward operations. Thus Helmholtz describes the mechanism of voluntary control of eye movements in terms of a parallel innervation of the muscles of the eye and a "screen" upon which the retinal input falls so that voluntary eye movememts are accompanied by a corollary corrective innervation of the cerebral input systems . When the eyeball is pushed by a finger, this corrective innervation is lacking, and the visual world jumps about. Merton and Brindley performed the critical experiment: when the eye muscles are paralyzed and a voluntary eye movement is undertaken, the visual world rushed by even though the eye remains stationary.

Of especial interest is the fact that Freud (1895) anticipated this distinction between feedback and feedforward in his delineation of primary and secondary processes (Pribram and Gill, 1976). Freud distingushed three types of neural mechanisms that constitute primary processes. One is muscular discharge; a second is discharge into the blood stream of chemical substances; and a third is discharge of a neuron onto its neighbors. All three of these neural mechanisms entail potential or actual feedback. Muscular discharge elicits a reaction from the environment and a sensory report of the discharge (kinesthetic) to the brain. The neurochemical discharge results, by way of stimulation of other body chemicals to which the brain is sensitive, in a positive feedback which Freud labels "the generation of unpleasure." (This is the origin of the unpleasure - later the pleasure - principle.) Discharge of a neuron onto its neighbors is the basis of associative processes that lead to a reciprocal increase in neural excitation (cathexis) between neurons (a feedback) which is the basis for facilitation (a lowering of resistance) of their synapses (learning).

By contrast, secondary or cognitive processes are based on a host of complex neural mechanisms that delay discharge through neural inhibition. These delays convert wishes (the sum of excitatory facilitations) to willed voluntary acts by allowing attention (a double feedback that matches on the wish to external input - a comparison process)to operate a reality testing mechanism. Thus, an attentional conscious comparison process is an essential mechanism allowing voluntary cognitive operations to occur.

For Freud and nineteenth century Viennese neurology in general, consciousness and the resultant voluntary behavior was a function of the cerebral cortex. Thus the greater portion of brain which is noncortical regulates behavior of which we are not aware - behavior which is automatic and unconscious. What then becomes of cortical function and conscious awareness?

Images

Thus, I found that Plans are not enough. As indicated by the case histories described in the introduction, today's neuroscientist shares with nineteenth century neurology the necessity to understand the special role of the brain cortex in the constructions that constitute consciousness. Freud tackles that problem by distinguishing "the "qualitative imaging" properties of sensations from the more quantitative properties of association, memory and motivation. The distinction remains a valid one today: In Plans and the Structure of Behavior, the sums of the tests, the comparisons between input and reports of the consequences of operations are called Images. How then are "images" constructed by the brain cortex?

Images are produced by a brain mechanism characterized by a precisely arranged anatomical array which maintains a topographic isomorphism between receptor and cortex but which can be seriously damaged or destroyed (up to 90%) without impairing the capacity of the remainder to function in lieu of the whole. These characteristics led me to suggest in the mid-sixties (Pribram, 1966) that in addition to the digital computer, brain models need to take into account the type of processing performed by optical systems. Such optical information processing is called holography, and holograms display exactly the same sort of imaging properties observed for brain: i.e., a precisely aligned mechanism that distributes information. In the brain the anatomical array serves the function of paths of light in optical systems and horizontal networks of lateral inhibition perpendicular to the array serve the function of lenses (Pribram, 1971; Pribram, Nuwer and Baron, 1974).

I have proposed a specific brain mechanism to be responsible for the organization of neural holograms (Pribram, 1971, Chap. 1). This mechanism involves the slow graded potential changes that occur at junctions between neurons and in their dendrites. Inhibitory interactions (by hyperpolarizations) in horizontal networks of neurons that do not generate any nerve impulses are the critical elements. Such inhibitory networks are coming more and more into the focus of investigation in the neurosciences. For instance, in the retina they are responsible for the organization of visual processes - in fact, nerve impulses do not occur at all in the initial stages of retinal processing (for review see Pribram, 1971, Chaps. 1 and 3). The proposal that image construction (a mental process) in man takes place by means of a neural holographic mechanism is thus spelled out in considerable detail and departs from classical neurophysiology only in its emphasis on the importance of computations achieved by the reciprocal influences among slow, graded local potentials which are well established neurophysiological entities. No new principles of mind-brain interaction need be considered.

For the mind-brain issue, the holographic model is also of special interest because the image which results from the holographic process is located separately from the hologram that produces it. We need therefore to be less puzzled by the fact that our own images are not referred to eye or brain but are projected into space beyond. Von Bekesy (1967) has performed an elegant series of experiments that detail the process (lateral inhibition - the analogue of lenses in optical systems - as noted above) by which such projection comes about. Essentially the process is similar to that which characterizes the placement of auditory images between two speakers in a stereophonic music system. From this fact, it can be seen how absurd it is to ask questions concerning the "locus" of consciousness. The mechanism is obviously in the brain - yet subjective experience is not of this brain mechanism per se but of the resultant of its function. One would no more find "consciousness" by dissecting the brain than one would find "gravity" by digging into the earth. Let us therefore look at the brain processes that make consciousness possible, the control programs that organize the distributed holographic process into one or another image. Ordinarily we speak of such control operations as governing "attention."

The digital computer and optical hologram thus provide models of mechanism which when tested against the actual functions of the primate brain go a long way toward explaining how human voluntary and imaging capabilities can become differentiated from unconscious processes by man's brain.

PART II: DEFINITIONS OF CONSCIOUSNESS

Consciousness and Attention

Just as did Freud, William James (1901) emphasized that most of the issues involved in delineating "consciousness" from unconscious processes devolve on the mechanism of attention. James, however, took the problem one step further by pointing out that attention sets the limits in competence - the limits in an attention span - of the organism to process information from the external and internal environments. Gilbert Ryle (1949) has reminded us that in fact the term "mind" is derived from "minding", i.e., attending. Viewed from this vantage consciousness is a state that results from attentive processes - consciousness ceases to be cause but rather is itself caused. Two separate issues can therefore be discerned in relating consciousness to brain: 1) description of the attentional processes, the control operations that determine consciousness, and, 2) description of the brain state(s) coordinate with consciousness. These two issues are, of course, the same as those delineated in the previous sections: the brain mechanisms responsible for the programming of psychological processes and behavior, and those involved in image construction. Let us turn once more, therefore, to the programming, the control operations performed by the brain that allocate attention and thus differentiate conscious from unconscious processes.

For over a decade and a half my laboratory (as well as those of many others) has been investigating the neural mechanisms involved in the control of attention. A comprehensive review of these data (Pribram & McGuinness, 1975) discerned three such mechanisms: one deals with short phasic response to an input (arousal); a second related to prolonged tonic readiness of the organism to respond selectively (activation); and a third (effort) acts to coordinate the phasic (arousal) and tonic (activation) mechanisms. Separate neural and neurochemical (Pribram, 1977) systems are involved in the phasic (arousal) and tonic (activation) mechanisms: the phasic centers on the amygdala, the tonic on the basal ganglia of the forebrain. The coordinating system critically involves the hippocampus, a phylogenetically ancient part of the neural apparatus.

The evidence suggests that the coordination of phasic (arousal) and tonic (activation) attentional processes demands "effort." Thus the relation of attention to intention, i.e., to volition and will comes into focus. Again, William James had already pointed out that a good deal of what we call voluntary effort is the maintaining of attention or the repeated returning of attention to a problem until it yields solution.

Consciousness and Voliton

William James had apposed will to emotion and motivation (which he called instinct). Here, once again, brain scientists have had a great deal to say. Beginning with Walter Cannon's experimentally based critique of James (1927), followed by Lashley's critique of Cannon

(1960), to the anatomically based suggestions of Papez (1937) and their more current versions by MacLean (1949), brain scientists have been deeply concerned with the mechanisms of emotional and motivational experience and expression. Two major discoveries have accelerated our ability to cope with the issues and placed the earlier more speculative accounts in to better prospective. One of the discoveries has been the role of the reticular formation of the brain stem (Magoun, 1950) and its chemical systems of brain amines (see e.g., review by Barchas, 1972; and Pribram and McGuinness, 1975) that regulate states of alertness and mood. Lindsley (1951) proposed an activation mechanism of emotion and motivation on the basis of the initial discovery and has more recently (Lindsley and Wilson, 1976) detailed the pathways by which such activation can exert control over the brain processes. The other discovery is the system of brain tracts which when electrically excited results in reinforcement (i.e., increase in the probability of occurrence of the behavior that has produced the electrical brain stimulation) or deterrence (i.e., decrease in probability that such behavior will recur) by Olds and Milner (1954).

In my attempts to organize these discoveries and other data that relate brain mechanisms to emotion, I found it necessary to distinguish clearly between those data that referred to emotional experience (feelings) and those that referred to expression, and, further to distinguish emotion from motivation (Pribram, 1971b). Thus feelings were found to encompass both emotional and motivational experience, emotional as affective and motivation as centered on the readiness (activation) mechanisms already alluded to in the discussion of attention. Not surprisingly the affective processes of emotion were found to be based on the machinery of arousal, the ability to make phasic responses to input which "stop" the ongoing activity of the organism. Thus feelings were found to be based on neurochemical states of alertness and mood which become organized by appetitive (motivation, "go") and affective (emotional, "stop") processes.

The wealth of new data and these insights obtained from them made it fruitful to reexamine the Jamesian positions with regard to consciousness and unconscious processes and their relationship to emotion, motivation, and will (Pribram, 1976b and in press c). James was found in error in his emphasis on the visceral determination of emotional experience and his failure to take in to consideration the role of expectation (familiarity) in the organization of emotional experience and expression. On the other hand, James had rightly emphasized that emotional processes take place primarily within the organism while motivation and will reach beyond into the organism's environment. Further, James was apparently misinterpreted as holding a peripheral theory of emotion and mind. Throughout his writings he emphasizes the effect that peripheral stimuli (including those of visceral origin) exert on brain processes. The confusion comes about because James' insistence that emotions concern bodily processes, that they stop short at the skin. Nowhere, however, does he identify emotions with these bodily processes. Emotion is always their resultant in brain. James is in fact explicit on this point when he discusses the nature of the input to the brain from the viscera. He comes to the conclusion, borne out by subsequent research (Pribram, 1961), that the visceral representation in the brain shares the representation of other body structures.

The distinction between the brain mechanisms of motivation and will are less clearly enunciated by James. He grapples with the problem and sets the questions that must be answered. As already noted, clarity did not come until the late 1960's when several theorists (e.g., MacKay, 1966; Mittelsteadt, 1968; Waddington, 1957; Ashby, personal communication; McFarland, 1971; Pribram, 1960, 1971b) began to point out the difference between feedback, homeostatic processes on the one hand and feedforward, homeorhetic processes on the other. Feedback mechanisms depend on error processing and are therefore sensitive to perturbations. Programs, unless completely stopped, run themselves off to completion irrespective of obstacles placed in their way.

Clinical neurology had classically distinguished the mechanisms involved in voluntary from those involved in involuntary behavior. The distinction rests on the observation that lesions of the cerebellar hemispheres impair intentional behavior, while basal ganglia lesions result in disturbances of involuntary movements. Damage to the cerebellar circuits are involved in a feedforward rather than a feedback mechanism (as already described by Ruch in the 1950 Stevens Handbook of Experimental Psychology, although Ruch did not have the term feedforward available to him). I have extended this conclusion (Pribram, 1971b) on the basis of more recent microelectrode analyses by Eccles, Ito and Szentagothai (1967) to suggest that the cerebellar hemispheres perform calculations in fast-time, i.e., extrapolate where a particular movement would end were it to be continued, and send the results of such a calculation to the cerebral motor cortex where they can be compared with the aim to which the movement is directed. Experimental analysis of the functions of the motor cortex had shown that this aim is composed of an "Image of Achievement" constructed in part on the basis of past experience (Pribram, Kruger, Robinson and

Berman, 1955-56; Pribram, 1971b, Chapters 13, 14, and 16; Pribram, in press).

Just as the cerebellar circuit has been shown to serve intentional behavior, the basal ganglia have been shown to be important to involuntary processes. We have already noted the involvement of these structures in the control of activation, the readiness of organisms to respond. Lesions in the basal ganglia produce tremors at rest and markedly restricted expressions of emotion. Neurological theory has long held (see e.g., Bucy, 1944) that these disturbances are due to interference by the lesion of the normal feedback relationships between basal ganglia and cerebral cortex. In fact, surgical removals of motor cortex have been performed on patients with basal ganglia lesions in order to redress the imbalance produced by the initial lesions. Such resections have proved to be remarkably successful in alleviating the often distressing continuing disturbances of involuntary movement that characterize these basal ganglia diseases.

Self-Consciousness and Intentionality

A final observation is in order regarding William James' analysis of this set of related problems. James clearly distinguishes consciousness from self-consciousness and suggests that self-consciousness occurs when attention is paid (i.e., willed, effort is made) to internal body processes. Today we would perhaps call this meta-consciousness. James sees no special problem here, but his contemporary, Brentano, Freud's teacher, identifies the issue of self-consciousness or intentionality as central to what makes man human.

Brentano derives his analysis from the scholastics and uses intentional inexistence (usually referred to as "intentionality") as the key concept to distinguish observed from observer, the subjective from the objective. I have elsewhere (Pribram, 1976b) somewhat simplified the arguement by tracing the steps from the distinction between intentions and their realization in action to perceptions and their realization as the objective world. Brentano is credited along with James as the source of current American realism of which my own version "constructional realism" (Pribram 1971a) can be considered a part.

How then is Brentano's dualism, the distinction between subject and object, related to that of Descartes? Cogito and intentionality are of course the same. Brain must always be a part of the objective world even if it is the organ critically responsible for the subjective - from which in turn the objective is constructed. Brentano is perfectly clear on this point, and suggests that only the study of intentional consciousness, i.e., self-reflective consciousness, is the province of the philosopher-psychologists, not the brain physiologists, to unravel. Recent work, reviewed below, on the occurrence of neglect syndromes, indicates that brain physiology does, in fact, have something to say even about intentional consciousness. Of historical interest is the fact that a pupil of Brentano's, Sigmund Freud, later to become an outstanding neurologist, (and competent brain physiologist) also became the champion of the importance of unconscious processes in determining everyday and pathological behavior (Pribram & Gill 1976). The case histories presented at the outset of this paper make Brentano's general point perhaps more strongly than any philosophical argument: minding is of two sorts, instrumental and intentional.

Part III: DIMENSIONS OF CONSCIOUSNESS

Neural States as Instruments of Consciousness

The instrumental aspect of consciousness is perhaps most readily illustrated by asking the following question: would you say that your pet dog is conscious? Why, you answer, of course he is. We all attribute awareness to organisms when they mind their environment, when they appear to pay attention. Gilbert Ryle (1949), the behaviorist philosopher, made note of this when he pointed out that the English term "mind" is derived from minding - and William James in his Principles of Psychology (1950) asks whether in fact we need the term consciousness since what we mean by it is so intimately interwoven with attention and its limited span. We ordinarily distinguish consciousness from unconsciousness much as does the physician and surgeon: when someone responds to prodding (e.g. by grumbling, "Oh leave me alone! Can't you see I'm trying to get some sleep!) we attribute to him a conscious state. When, on the other hand hisresponse is an incoherent thrashing about, we say he is stuperous and if there is no response at all, we declare him comatose.

Note that we are now distinguishing between various nervous states of consciousness such as sleep and wakefulness (and perhaps a hypnotic state and others as well) and states of unconsciousness - unresponsiveness (such as stupor and coma). The interesting thing about such states is their mutual exclusiveness regarding experience: what is experienced in one state is not available to experience in another. Such state exclusiveness emerges in all sorts of observations: state dependent learning in animal experiments; the fact that salmon spawning pay no attention to food, while when they are in their feeding state sexual stimuli are ignored; the observation in hypnosis that a person can be made unaware post-hypnotically of suggestions made during hypnosis (although he carries out these suggestions; and the dissociation between experiences (and behavior) taking place during "automatisms" in temporal lobe epileptics and their ordinary state. I would add to these the mutual exclusiveness of natural language systems which makes translation so difficult. The evidence obtained in all of these situations suggests that the same basic neural - or more likely, on the basis of current evidence (for review see Pribram, 1977), neurochemical - substrate becomes variously organized to produce one or another state. Hilgard has conceptualized this substrate as a "hidden observer" and the manifestations of various organized states as a more or less "vertical" rearrangement of the substrate. One might picture such arrangements to resemble those that take place in a kaleidescope: a slight rotation and an entirely new configuration presents itself. Slight changes in relative concentrations of chemicals and/or in neural firing thresholds in specific neural locations could, in similar fashion, result in totally different states.

Consciousness as Process

These state, i.e. instrumental, definitions of consciousness are not what Freud or most philosophers have meant by the term. Recall the emphasis by Brentano on intentional consciousness which arises from the distinction between the contents of awareness and the person who is aware; the dualism of subjective mind and objective matter (brain) in the writings of Ernst Mach and that of Renée Descartes. Although Cartesian dualism is perhaps the first overt non-trivial expression of the issue, the duality between subject and object and some causal connection between them is inherent in language once it emerges from simple naming to predication. Neuman (1954) and Jaynes (1977) have suggested that a change in consciousness occurs somewhere between the time of the Iliad and the Odyssey. My interpretation of this occurrence links it to the invention and promulgation of writing. Pre-history was transmitted orally/aurally. Written history is visual/verbal. In an oral/ aural culture a greater share of reality is carried in memory and is thus personal; once writing becomes a ready means of recording events they become a part of extrapersonal reality. The shift described is especially manifest in a clearer externalization of the sources of conscience - the Gods no longer speak personally to guide individual man.

This process of ever clearer distinctions between personal and extrapersonal realities culminates in Cartesian dualism and Brentano's intentional inexistence which was shortened by Von Uxkull to "intentionality." It is this reading of the subject-object distinction which philosophers ordinarily mean when they speak of the difference between conscious and unconscious processes.

Freud had training both in medical practice and in philosophy. When he emphasized the importance of unconscious processes, was he implying the medical definition or the philosophical? Most interpretations of Freud suggest that unconscious processes operate without awareness in the sense that they operate automatically much as do respiratory and gastrointestinal processes in someone who is stuperous or comatose. Freud himself seems to have promulagated this view by suggesting a "horizontal" split between conscious, preconscious and unconscious processes with "repression" operating to push memory-motive structures into deeper layers where they no longer access awareness. Still in the "Project", memory-motive structures are neural programs - located in the core portions of the brain which access awareness by their connections to cortex which determine whether a wish comes to consciousness. When the neural program becomes a secondary process, it comes under voluntary control which involves reality testing and thus consciousness, thus to use language as an example, one might well know two languages but at any one time connect only one to cortex and thus the other remains "unconscious" and voluntarily unexpressed.

The linking of reflective consciousness to cortex is not as naive as it first appears. As the recently reported cases of Weiskrantz and Warrington (1974), which introduced this manuscript have shown, "blind-sight" results when pateints are subjected to unilateral removal of the visual cortex. As noted, these patients insist they cannot see anything in the field contralateral to their lesion but when tested they can locate and identify large objects in their blind hemifield with remarkable accuracy. Furthermore there are patients with unilateral neglect following parietal lobe lesions (see Heilman and Valenstine, 1972, for review.) Neglect patients can often can get around using their neglected limbs appropriately and H.M., the patient described in the introduction who sustained an amygdala-hippocampal resection defect, has been trained in operant tasks and the effects of training have persisted without decrement for years, despite protestations from the patient that he doesn't recognize the situation and that he remembers nothing of the training (Sidman and Mohr, 1968).In monkeys with such lesions we have shown almost perfect retention of training over a two year period, retention that is better than that shown by unoperated control subjects. These monkeys and H.M.

and the blind-sight patients are clearly conscious in the medical and ordinary sense. What has gone wrong is their ability to reflect on their behavior and experience, an inability within the impaired sphere of clearly distinguishing personal from extra-personal reality. This leaves them with impaired consciousness in the philosopher's sense: behavior and experience are no longer intentional.

The thrust of some recent psychoanalytical thinking as well as that of experimentalists such as Hilgard (noted above) is in the direction of interpreting the conscious-unconscious distinction in the philosophical sense. For instance, Matte Blanco (1975) proposes that consciousness be defined by the ability to make clear distinctions, to identify alternatives, to process information. Making clear distinctions would include being able to tell personal from extrapersonal reality. By contrast unconscious processes would, according to Matte Blanco, be composed of infinite sets "where paradox reigns and opposites merge into sameness". When infinites are being computed the ordinary rules of logical and rationality do not hold. Thus, dividing a line of infinite length results in two lines of infinite length, i.e one = two. Being deeply involved allows love and ecstacy but also suffering and hate to occur.

My interpretation of the conscious-unconscious distinction as it relates to human behavior and experience is in line with Matte Blanco's and others which are closely related to the philosophical distinction and not to the medical. Thus bringing the wellsprings of behavior and experience to consciousness means to provide alternatives, to become informed. Carl Jung defined unconscious processes as those involving feelings. In current terminology this would mean identification between an intensive dimension of experience which I have called "protocritic" (see above and Pribram, 1977) and unconscious processes on the one hand and on the other, between epicritic (as defined by Henry Head 19) and conscious processes. I would add to the epicritic dimension of consciousness the personal dimension which clearly constructs and identifies personal reality and differentiates this from external reality and from feeling states via cortical-basal ganglia connectivity.

An important change in views becomes necessary when these interpretations are considered seriously: unconscious processes as defined by psychoanalysis are not completely "submerged" and unavailable to experience. Rather, unconscious processes produce feelings which are difficult to locate in time or space and difficult to identify correctly. The unconscious processes construct the emotional and motivational context within which extrapersonal and personal realities are constructed. As the classical experiments of Schachter and Singer (1962) have shown, emotional and motivational feelings are to a large extent undifferentiated and we tend to cognize and label them according to the circumstances in which the feelings become manifested.

It is in this sense that behavior comes under the control of the unconscious processes. When I have burst out in anger, I am certainly aware that I have done so and of the effects of the anger on others. I may or may not have attended the build-up of feeling prior to the blow-up. And I may have projected the build-up on to others or introjected it from them. But I could have become aware of all this (with the guidance of a friend or therapist) and still found myself in uncontrolled anger. Only when the events leading to the anger become clearly separated into alternative or harmoniously related distinctions is unconscious control converted into conscious control. It is ridiculous to think that a person with an obsession or compulsion is unaware, in the medical sense, of his experience or behavior. The patient is very aware and feels awful. But he cannot without aid, differentiate his feelings into viable distinctions in personal and extra-personal reality, distinctions which allow his alternative and/or more harmonious behaviors and experience.

PART IV: NEURAL SYSTEMS AND THE CONTENTS OF CONSCIOUSNESS:

Extrinsic and Intrinsic Systems:

I wish this were all there were to the problem of defining consciousness. But we are not yet finished with the issue. So far we have noted that the conscious-unconscious distinction is sometimes defined instrumentally (as in medical practice) in terms of alternative states; that in other contexts (such as when philosophers and psychoanalysts are discussing it) the distinction is made "intentional," in terms of process. A third basis for the distinction is one that is intertwined with the intentional aspects of the problem but emphasizes the contents of consciousness rather than the processes by which consciousness is achieved.

Surrounding the major fissures of the primate brain lie the terminations of the sensory and motor projection systems. Rose and Woolsey (1949) and Pribram (1960) have labelled these systems extrinsic because of their close ties (by way of a few synapses) with peripheral structures. The sensory surface and muscle arrangements are mapped more or less isomorphically onto the perifissural cortical surface by way of discrete practically parallel lines of connecting fibre tracts.

When a local injury occurs within these systems a sensory scotoma or a scotoma of action ensues. A scotoma is a spatially circumscribed hole in the "field" of interaction of organism and environment: a blind spot, a hearing defect limited to a frequency range, a location of the skin where tactile stimuli fail to be responded to. There are the systems where Head's epicritic processing takes place. These extrinsic sensory-motor projection systems are so organized that their functioning allows the organism to project the results of processing away from the sensory (and muscular) surfaces where the interactions take place, out into the world external to the organism. Thus processing within these extrinsic systems constructs an external extrapersonal reality for the organism.

In between the perifissural extrinsic regions of cortex lie other regions of cortex variously named association cortex (Flechsig), uncommitted cortex (Penfield, 19) or intrinsic cortex (Pribram). These names reflect the fact that there is no apparent direct connection between these regions of cortex on the convexity of the cerebrum and peripheral structures.

Elsewhere (Pribram, 19) I have presented evidence which shows the frontal intrinsic cortex deals with probability distribution (Pribram, 19) and the posterior intrinsic cortex with the setting of sample size, functions which depend on processing prior experience (Pribram, 19). The evidence was obtained on non-human primates in research aimed to make animal models of human neuropsychological disturbances produced by lesions of the intrinsic regions of the cortex. Such models allowed prolonged and precise experimental analyses of the functions of these regions, analyses precluded in patients with similar disturbances. However, non-human primates and humans differ considerably in their behavioral repetoire and in processing experience - and much of the difference is attributed to the very regions of cortex under consideration. It is therefore necessary now to turn to human as well as monkey neuropsychological studies to ascertain how mechanisms of probability estimation and those of setting sample size manifest in man.

<u>Personal and Extrapersonal Reality:</u> As is well known, frontal lesions were produced for a period of time in order to relieve intractable suffering, compulsions, obsessions and endogenous depressions. When effective in pain and depression, these psychosurgical procedures portrayed in man the well established functional relationship between frontal intrinsic cortex and the limbic forebrain in non-human primates. Further, frontal lesions can lead either to perservative, compulsive behavior or to distractability in monkeys and this is also true of humans (Pribram, Ahumada, Hartog and Roos, 1964; Oscar Berman, in press). When compulsions and obsessions have become established - perhaps by weighting the probability of their effectiveness in diminishing risk, much as conceived in psychoanlytic theory - then damage to the probability assigning tissue might well change the probability of assignment as it seems to do. Certainly clinical observations attest to the fact that an impressive array of patients with frontal lesions whether surgical, traumatic, muscular or neoplastic fail to be guided by the consequences of their behavior (Luria, Pribram and Homskaya, 1964; Konow and Pribram, 1970).

Lesions of the intrinsic cortex of the posterior cerebral convexity result in sensory specific agnosias in both monkey and man. Research on monkeys has shown that these agnosias are not due to failure to distinguish cues from one another but due to making use of those distinctions in making choices among alternatives (Pribram and Mishkin, 1955, 1956a, b). As noted this ability is the essence of information processing and the posterior intrinsic cortex determines the range of alternatives, the sample size which a particular informative element must address. A patient with agnosia can tell the difference between two objects but does not know what that difference means. As Charles Peirce (1935) once noted, what we mean by something and what we mean to do with it are synonymous. In short, alternatives, sample size, choice, cognition, information and meaning are closely interwoven concepts. Finally, when agnosia is severe it is often accompanied by what is termed "neglect." The patient appears not only not to know that he doesn't know but to actively deny the agnosia. Typical is a patient I once had who repeatedly had difficulty in sitting up in bed. I pointed out to her that her arm had become entangled in the bedclothes - she would acknowledge this momentarily only to "lose" that arm once more in a tangled environment. Part of the "person" seems to have become extinguished.

These results can readily be conceptualized in terms of extrapersonal and personal reality. For a time it was thought that personal reality depended on the integrity of the frontal intrinsic cortex and that the posterior convexal cortex was critical to the construction of extrapersonal reality (See e.g. Pohl, 1973). This scheme was brought to test in my laboratory during the past decade in experiments with monkeys (Brody and Pribram, 1978) and patients (Ruff, Hersh and Pribram, 1981; Hersh, 19) and found wanting. In fact, the personal and extrapersonal distinction involves the parietal cortex. Perhaps the most clearcut example of this comes from studies by

Mountcastle and his group (Mountcastle, Lynch, Georgopoulos, Sakata and Acuna, 1975) which show that cells in the convexal intrinsic cortex respond when an object is within view but only when it is also within reach. In short, our studies on patients and those of others have been unable to clearly separate the brain locations which produce agnosia from those that produce neglect. Furthermore, the studies on monkeys indicate that agnosia is related to personal meaning and use.

We distinguish, therefore, 1) the extrinsic peri-fissural systems which construct for us external reality and 2) the intrinsic convexal systems - frontal and posterior - which construct for us a personal reality: frontal cortex providing a probabalistic context of dispositions to behave; parietal cortex the space/time references which relate personal to extrapersonal reality. We found, much to our surprise, that the intrinsic systems are heavily connected with the basal ganglia (including the amygdala)(Reitz and Pribram, 1969). Furthermore, in monkeys the disturbances produced by restricted lesions of the convexal intrinsic cortex are also produced by lesions of the parts of the basal ganglia to which those parts of the cortex project. This finding takes on special meaning from the fact that lesions of the thalamus (which is also intimately connected with this cortex) fail to produce such effects. Further, recent experiments have shown that the neglect syndrome can be produced in monkeys by lesions of the dopaminergic nigrostriatal system (Wright, 1980. This special connection between intrinsic (recall that this is also called association) cortex and the basal ganglia (including the amygdala) further supports the conception that these parts of the cortex deal with the construction of self: when to stop and when to go, when to switch and when to remain steady are certainly very personal processes.

I do not want to leave you with the idea that agnosia and neglect are produced by identical mechanisms. Nor do I want to suggest that separate systems will not be - and perhaps already have been - located for each. Also there are other syndromes, apraxias, prosopagnosia and the language related disturbances such as aphasia and alexia which are produced by lesions in the general region of the posterior intrinsic cortex of the convexity. My point is that all of these disturbances are disturbances of personal reality and that together they make up our conception of self which in the psychoanalytic frame is called the "ego." In the "Project" Freud used this term in several different ways - one, a functional definition dealing with delay and executive functions,the dispositions to behave and thus frontal; and the other a more structural definition which addresses the space/time referents of that function which appear to necessitate the operations of the posterior convexity. I believe that currently psychoanalysts also use the term in both ways and may thus be helped to distinguish them by the results of the neurobehavioral and neuropsycho-logical studies reviewed here. The results of these investigations have also shown that one of the major functions of the ego, the self, is to bias behavior toward risk or caution (posterior convexity) and that this biasing is a function of self-confidence. Of course good clinicians have known this all along but perhaps they did not know that the brain is built along the lines suggested by their clinical experience.

The Spiritual Nature of Mankind

The Spiritual Nature of Mankind

The contents of consciousness are not exhaustively described by feelings (which in psychoanalysis are the basis of unconscious processes as we have seen) nor by perceptions of common sensory extra-personal and personal reality. The esoteric tradition in Western culture and the mystical traditions of the Far East are replete with instances of uncommon states that are achieved by a variety of techniques such as meditation, Yoga or Zen. The contents of processing in such states appear to differ from ordinary feelings or perceptions. Among others, experiences such as the following are described: 1) oceanic, i.e. a merging of personal and extra-personal reality which at the same time are still clearly distinguished; 2) out of body, i.e. personal and extra-personal reality continues to be clearly distinguished but are experienced by still another reality (personal reality is termed the ego; the new reality, the self); or 3) the "self" becomes a transparent throughput which experiences everything everywhere, merging the oceanic and out of body types of experience. All of these experiences have in common a transcendental relationship between ordinary sensory-motor based mental experience some more encompassing organizing principle. It is this relationship which, as noted by Jose Delgado (this volume) is ordinarily termed "Spiritual." The "spirtual" contents of conscioness can be accounted for by the holographic-like microstructure which characterizes cortical receptive fields.

This holographic-like microstructure is manifested in addition to the gross correspondence cortical receptive field and sensory surface organization. The internal organization of receptive fields embodies, among other characteristics, a frequency sensitive domain: Over the past 15 years evidence has accumulated that, indeed, neurons

in the extrinsic sensory-motor cortex are tuned to limited bands of frequencies in the specific sensory mode in which they operate (i.e. with respect to the sensory receptors to which they are relatively directly connected). I have reviewed this evidence extensively on a number of occasions (1974; 1982).
Perhaps the most dramatic of these data are those which pertain to vision. The cortical neurons of the visual system are arranged as are the other sensory systems so as to reflect more or less isomorphically the arrangement of the receptor surfaces to which they are connected. (Thus, the "hommunculi" which Wilder Penfield and others have mapped onto the cortical surface of the extrinsic projection systems). However, within this gross arrangement lie the receptive fields of each of the neurons — a receptive field being determined by the dendritic arborization of that neuron which makes contact with the more peripheral parts of the system. Thus the receptive field of a neuron is that part of the environment which is processed by the parts of the system to which the neuron is connected. By studying the micro-organization of receptive fields at various levels of the system, we can unravel the sensory processing mechanism. It is this micro-organization which has been shown to reflect the operation of sets of neurons each of which is sensitive to approximately an octave (range from 1/2 to 1 1/2/ octaves) of spatial frequency. It is the frquency selective microprocess which transforms the input into a holographic-like mechanism.

The gross and micro-organization of the cortical neurons in the extrinsic systems thus resembles to some extent the organization of a multiplex hologram. Such holograms are composed by converting (e.g. via Fourier transformation) successive sensory images (e.g. frames of a movie film) into their frequency re-presentations and stripping (or patching) these micro-representations into orderly spatial arrangements which represent the original temporal order of successive images. When such conversions are linear (as e.g. when they employ the Fourier transform) they can readily be reconverted (e.g. by the inverse Fourier transform) into moving (i.e. successive) sensory images. This domain is peculiar in that information becomes both distrib- uted over the extent of each receptive field and enfolded within it. Thus sensory image reconstruction can occur from any part of the total aggregate of receptive fields. This is what gives the aggregate its holographic holistic aspect. All input becomes distributed and enfolded including the dimensions of time and space. It is this timeless/spaceless aspect of processing which could be responsible for the extra-sensory dimensions of experience which characterize the esoteric traditions.

Because of their enfolded property these dimensions are as likely to be attributed to extrapersonal as to personal reality. Conscious properties are therefore, in these traditions, not limited to personal reality.

An intriguing and related development (because it deals with the specification of a more encompassing, "cosmic" order) has occurred in quantum and nuclear physics. For the past 50 years it has become obvious that when certain measurements are taken, others are excluded. Thus there is no way to characterize all of the properties of the microstructure of matter without specifying the observations that led to inferring those properties. This has led many noted physicists to write some sort of representation of the observer into the description of the observable and some of these physicists have noted the similarity of this sort of representation to the esoteric descriptions of consciousness. Books with such titles as The Tao of Physics (Capra, 1975) and The Dance of the Wu Li Masters (Zukav, 1971) have resulted.

Conclusion

There is therefore in the making a real revolution in Western thought. The scientific and esoteric traditions have been clearly at odds since the time of Galileo. Each new scientific discovery and the theory developed from it, has up until now, resulted in the widening of the rift between objective science and the subjective spiritual aspects of man's nature. The rift reached a maximum toward the end of the nineteenth century: mankind was asked to choose between God and Darwin; heaven and hell were shown by Freud to reside within us and not in our relationship to the natural universe. The discoveries of twentieth century science briefly noted here but reviewed extensively elsewhere, do not fit this mould. The recent findings of science and the spiritual experiences of mankind are for once in consonance. This augurs well for the upcoming new millenium - a science which comes to terms with the spiritual nature of mankind may well outstrip the technological science of the immediate past in its contribution to human welfare.

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