9 NEUROPSYCHOLOGY IN AMERICA

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A time-honored pursuit of philosophers, of psychiatrists and neurologists, and of physiologists and anatomists has been a study of the neural mechanisms that critically affect behavior. But in America during recent years new impetus to discovery has been provided from several fresh sources. These are experimental psychology, electrophysiology, Russian neurophysiology of the Pavlovian type, psychosurgery, and psychopharmacology. The aim of this presentation is to trace briefly the effects that each of these tributaries has had in the development of a body of knowledge that has sufficient scope and unity by now to have acquired the label "neuropsychology."

American experimental psychology is characterized by the precision of its techniques and theories. Theories of learning and decision-making are couched in mathematical language. Factorial analyses of individual differences are used not only in the laboratory but also as standard techniques in the evaluation of competencies. Devices have been perfected that allow precise recording of the number, latency, or rate of responses in various problem-solving situations. Programming an ever increasing array of schedules of stimulus, reward, and punishment presentations has become an art. These devices allow tremendous flexibility in the type of problem set to human and animal organisms.

Still more recently, data analysis by computer has become a frequent concomitant of the ever increasing amount of data that can be gathered per unit time. These are only some of the everyday events that a visitor to American psychological laboratories would find in abundance, and, here and there, these techniques and theories are combined with those aimed at a study of the nervous system.° On these occasions, a reevaluation of earlier concepts invariably results.

The older views were usually derived exclusively from clinical and neuroanatomical observation. Often the new data, because of their quantitative character, show up old notions as fuzzy. Precision in theory construction makes possible a restatement of fact and hypothesis which is at the same time more definitive and broader in scope. And the interdisciplinary referents from which these data and concepts are derived promise to bridge the gap that now exists between the physical and biological sciences on the one hand and the behavioral sciences and humanities on the other.

The single most pervasive advance in analysis of neural mechanisms has been electrophysiology, the development of electrical techniques to amplify and measure potential changes that can be recorded from brain and nerve. Whether or not the electrical manifestations of neural activity reflect accurately the essential processes within the nervous system that affect behavior remains to be proved. Nonetheless, elec-

° K. H. Pribram, "Toward a Science of Neuropsychology," in *Current Trends in Psychology and the Behavioral Sciences* (Pittsburgh: University of Pittsburgh Press, 1954).

trical techniques have been used to study the organization of the nervous system and, more recently, to demonstrate that at least something is going on within the brain while an organism responds behaviorally in particular situations.

That the brain is critically involved in the determination of behavior has been man's faith for some time, a faith based mainly on observations made on patients who have suffered brain injury. To prove that the brain *is* actually concerned in the regulation of specific aspects of behavior has been the task that has occupied the neurophysiologist, and at last he has the tools to make the demonstration.

An extension of these preliminary results stems from the impact of Russian neurophysiology, which has pursued in several directions the techniques initiated by Pavlov. In combination with the methods of experimental psychology and of electrophysiology, some beginnings are being made in the analysis of the differences in neural processes that accompany differences in behavioral manifestations.

Pavlov's conditional reflex technique, a very simple way to demonstrate a change in behavior with experience, is combined with electrical recordings made from a variety of locations in the brain. And correlations are demonstrated between the behavioral changes and those that occur in the brain. Some of these, such as the mechanisms that allow the organism to be sensitive to "error" when it attempts to solve problems, are of fundamental importance to theory and clinical practice. These early results do show promise and should prove interesting to pursue during the next decade.*

Psychosurgery has fallen into a secondary place in therapy in the United States. However, the stimulus that the psychosurgical procedure has had in providing research funds and in interesting young people in the effects of brain lesions on complex behavioral processes is almost unmeasurable. The

* Proceedings of the Macy Conferences on "The Central Nervous System and Behavior," 1958 and 1959.

what one would expect, the most important results for research have not been the study of the effects of psychosurgery in man, but study of the effects of brain lesions on the more complex behavioral processes in animals, especially primates. Advances have been made in the description of the strategies that monkeys develop to solve problems and of what constitutes a "problem" in the first place.

The hitherto silent areas of the brain cortex have yielded some of their mystery to these explorations, and the advances in knowledge have been sufficiently great to warrant a thorough recasting of currently held notions. Interestingly, the impact of these explorations is at the moment felt most in engineering laboratories devoted to the construction of computers. Problems of memory storage and retrieval, of perception and programming, of computation and logic are common to those interested in the brain—whether it be made of metal or of tissue. What the offspring of this marriage between the communication and computer engineer and the neurobiologist will be like, it is too early to say—but hybridization in this instance, as in most others, promises vigor. If the noise and heat generated by the mating is any index, the lusty cybernetic infant will have a lasting impact not only in the behavioral sciences but in the way man makes all of his science in the future.°

In the immediate present, psychopharmacology has replaced psychosurgery as the practical focus around which basic research is crystallized. The challenge is: How do the psychopharmacological agents produce their effect? The assumption is almost universally held that the effect is mediated through neural mechanisms, and the search is on to determine what these mechanisms might be. So the visitor would

° G. A. Miller, Eugene Galanter, and K. H. Pribram, *Plans and the Structure of Behavior* (New York: Henry Holt and Co., 1960).

of biochemistry and pharmacology, as well as those of electrophysiology and even psychosurgery, are combined. At the moment this area of convergent endeavor is so new that prediction of future results is risky. Chances are that empirically useful data will emerge—here the medical clinician rather than the communication and computer engineer may reap the practical benefits.*

So much for technical advances. Now, what are some of the substantive gains which these combinations of methods have made possible? Only a few of the most striking facts and most interesting advances can be mentioned here. Of course, one never knows whether a finding that at this time appears to be of minor importance may not in the proper hands grow into something that overshadows those which now seem more significant.

Some age-old questions important to the behavioral sciences have recently received definitive answers. One such question is whether the brain is or is not a *tabula rasa* upon which experience is etched. What happens when brain tissue is completely isolated? Does it, much as does the heart, show evidence of intrinsically generated activity, or is the brain essentially quiescent? The answer, as is so often the case, fully supports neither the notion that brain activity is basically spontaneous, nor the axiom of a passive matrix. Even in the unanesthetized preparation, the isolated brain slab remains silent unless stimulated, but any brief excitation will cause electrical discharges to persist for long periods of time.

Thus, though the brain is quiescent in the absence of input, the tissue is easily aroused to prolonged activity: hence, at rest it may be conceived to be in a state just below the level for continuous self-excitation, and in the intact animal

* Abraham Wikler, *The Relation of Psychiatry to Pharmacology* (Baltimore: William and Wilkins Co., 1957).

a mechanism exists to insure excitation beyond such a resting level.* This mechanism is a spontaneous discharge of receptors and sense organs in general. Gradually, the investigations of the past several decades, involving especially the techniques of electrophysiology, have forced upon us the idea that spontaneous activity is an integral part of the performance of sensory instruments.†

Evidence has accumulated that this spontaneous activity of sense organs makes them, through their connections, one of the brain's most important activators. Sensory receptors and the brain, then, together make an active unit which interacts with the environment, and this interaction is intricately determined. Even in such simple organisms as the sea urchin, the intrinsic activities of the nervous system are patterned, not just homogeneous and generalized.

The effects of interaction depend on the ongoing neural activity and the differences between such activities at different locations in the nervous system of the organism. Differences in environmental conditions are, therefore, reacted to in terms of these differences in neural activity.‡ The response of the organism is the resultant. If this is true of the sea urchin, how much more must it be true of man?

Another important contribution made primarily by electrophysiology is the finding that in the core of the central nervous system there are tissues characterized by their relatively diffuse organization. These reticular tissues serve the organism by changing the state of excitability of the entire brain. The spontaneously active sensory receptors discharge directly into this diffuse tissue and, therefore, tend to keep

* B. D. Burns, *The Mammalian Cerebral Cortex* (London: Edward Arnold Publishers, Ltd., 1958).

† R. Granit, *Receptors and Sensory Perception* (New Haven: Yale University Press, 1955).

‡ T. H. Bullock, "Evolution of Neurophysiological Mechanisms," in *Behavior and Evolution* (New Haven: Yale University Press, 1958), Chapter 8, pp. 165–177.

the brain "awake." In fact, destruction of this reticular substance of the core of the brain results in an interminably sleeping animal.°

Equally exciting has been the finding that animals with electrodes placed deep within their brains will turn on a switch in order to stimulate themselves with electrical current. Only certain areas of the brain make the animal respond in this way, and the inference has been drawn, correctly or incorrectly, that these areas serve as "reward centers" for the organism. Mechanisms of reward and punishment have fascinated not only neurophysiologists but also experimental psychologists.† And so the varied techniques described earlier have been brought to bear on the problem, and with this increase in sophistication our areas of ignorance have expanded.

No longer can we say simply, "here is a pleasure center, here is a pain center in the brain," for stimulation of one and the same spot may produce behavior quite different depending upon the situation in which the organism finds itself. The arguments of the philosophers are taken out of the realm of the speculative and into the laboratory. The arguments remain the same, but now tissue is involved and the behavior of organisms studied. This new solidity has a twofold effect. First, it shows that the arguments of the philosophers were not just "hot air," and secondly, it shows that the naive materialism which has served the biologist so well thus far must be amplified, if not totally discarded, if his data are to make any sense to him or to anyone else.

The advent of the study of the effects of drugs on these same neural mechanisms may throw some light on just what is experienced as pleasurable or unpleasurable by an organism. But as yet only the techniques are available, and fer-

° H. W. Magoun, *The Waking Brain*, (Springfield, Ill.: Chas. C Thomas, 1958).
† James Olds, "Higher Functions of the Central Nervous System," in *Annual Review of Physiology*, 1959.

[illegible]ment is in the air. What will come out of all this activity remains to be seen.

A closely related area of investigation has been the exploration of the core structures of the brain: the reticular formation of the brain, already mentioned; the hypothalamus and thalamus; and the limbic systems of the endbrain, which lie along the innermost edge of the cerebral hemispheres. Anatomically, these structures are closely interrelated. Current theory holds that the core structures regulate the drives of the organism by mechanisms similar to the thermostat that regulates the temperature of a building.

The term homeostats is used to designate these biological regulatory mechanisms.° Each mechanism has certain components, including a receptor element which is sensitive to the hormone or metabolite that it regulates, just as the thermostat is sensitive to the temperature which it controls. In addition, each mechanism is so constructed that there is a reciprocal connection or "feed-back" loop between the sensitive mechanisms and another unit that operates in such a fashion as to increase or decrease the amount of the substance regulated. In the thermostat, this is the control mechanism of the furnace that turns it on when the temperature in the room drops and turns it off when the temperature has risen beyond a certain point.

And finally, each mechanism has a bias or setting device which controls the level around which the homeostasis takes place. In the thermostat, this setting device is usually a small dial that can be controlled by hand. In the biological homeostats, this setting device is probably the excitability level of the reticular substance of the brain stem core, to which reference has already been made.

The limbic systems are linked by multiple reciprocal connections with the internal core homeostats. Some of these connections are long and conduct impulses from one place to

° K. H. Pribram, "A Review of Theory in Physiological Psychology," in *Annual Review of Psychology*, 1960.

another without any discontinuities. Other connections have several discontinuities intercalated, and still others have a great many. The functional result of this type of multi-linking can only be guessed at the moment: when electronic models are constructed with these characteristics, an ultra-stable system results. In the face of externally initiated perturbations, such a system shows a "disposition" to return to its prior level of excitability. Such stability is necessary to an electronic or biological organism if it is to be sensitive to error. Could it be, then, that the limbic formations of the endbrain control the dispositions of organisms, dispositions that depend on the functions of the homeostatic mechanisms that regulate the organism's internal environment?

Neuro-behavioral investigations support such a notion. "Instinctive" behavior is most obviously disturbed when lesions are made in the limbic systems. Mechanisms of feeding, fleeing, fighting, maternal, and mating behavior are disrupted when portions of the limbic systems are surgically ablated. But more basically, sensitivity to error is decreased when organisms are faced with problems to solve, and electrophysiological evidence shows that the activity of certain formations within the limbic areas changes when errors are made by organisms performing certain tasks. No wonder that neurophysiologists and experimental psychologists are so excited by these findings that they are overcoming major technical difficulties and pursuing their explorations into the deepest recesses of the brain.

As a last point, considerable progress has been made by a combination of the techniques of psychosurgery, experimental psychology, and electrophysiology in delineating the functions of the so-called association areas of the brain in cognitive behavior. Two large categories can be discerned, one dealing with knowledge and information. The posterior portions of the forebrain deal with this type of cognitive activity. The other, served by the frontal areas of the brain, is more difficult to specify.* The American term "know-how" comes closest, perhaps, to characterizing this form of activity. Wisdom is a more hallowed term for the same processes when they deal less with the immediate physical environment and more with the social aspects of situations.

To know and to know how are certainly different, and experimental evidence is now available that these differences have their roots in differences between neural mechanisms. Many other things could be mentioned. The story of the simulation of brain activity by computers is one. Another would deal with the studies of the differences in chemistry between different portions of the central nervous system and how these differences are related to mechanisms of drive. Equally fascinating are the investigations, only just beginning, of memory storage in the brain. And the related problem of retrieval or recall of this stored material has as yet hardly been formulated as an experimental problem. And so one could go on and on.

In summary, then, what can be said of the past, present, and future of neuropsychology's contributions to behavioral science in America? In the past half century, the important advances have been of method and technique. Even in the realm of theory technical precision has characterized the advances. Currently, a change is taking place. There is ferment. There are new applications and combinations of already available techniques. Thinkers are beginning to range freely again and not be tied to their technical, logical rigidities.

There is some danger that the neuropsychologically-oriented behavioral scientist may lose himself in the wealth of data and the free-ranging speculations that are now possible to him. But this danger is counterbalanced by the promise of a fresh view of man by man. Western thought has alternated between two views of man's relations to his universe. One view holds that he is an essentially passive organ-

* K. H. Pribram, "On the Neurology of Thinking," in *Behavioral Science*, October, 1959.

ism shaped by the exigencies of his environment. The other emphasizes his active role, manipulative and selective not only of artifacts but of sense data as well. The American neuropsychological contributions to behavioral science point to a resurgence of the dignity of man as a scientific as well as a political and humanistic tenet.