



Basic Neural Mechanisms in Behavior

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THE RELATIONAL FRAMEWORK IN CEREBRAL FUNCTION

Let us turn now to another important aspect of cerebral function. A review of symptoms suggests that no logically derived element of behavior can be shown to have a definite localization; no single sensation, memory, or skilled movement is destroyed alone by any lesion. On the contrary the various parts of the functional areas seem equipotential for such elements, and either a whole constellation of them is affected by the lesion, or none at all. In these constellations of activities the grouping is determined, not by associative bonds, but by similarities of organization. Let me illustrate this point. In an hysterical amnesia we may find a loss of memory for all events associated with some emotional experience. The constellation is here determined by the grouping of habits. In organic amnesias the grouping is quite different. The speech most commonly retained in aphasia is that related to emotional expression, as was pointed out by Hughlings Jackson. Ejaculations, words of affirmation or negation, profanity, and words having a deep personal significance make up the residual vocabulary. The determining factor here seems to be the relation to emotional facilitation. Head's work shows other groupings, the loss of words involving the object-name relation, or of those concerned with the relations of space, time, and logical order.¹⁸ The defects can in every case be related to ways of thinking about things, but not to loss of specific associations.

Many disturbances of vision show the same characteristics. An apparent word-blindness, for example, may be due, not to a loss of visual memory for the words, but to an inability to see the letters in a definite spacial arrangement.

Even in experiments with animals there are suggestions of similar conditions. We find rather frequently a picture which suggests loss of the general sense of direction, with retention of associations with the specific turns in the maze.

I have not time to multiply examples, but I believe that there is ample evidence to show that the units of cerebral function are not single reactions, or conditioned reflexes. We have used the term in America, but are modes of organization. The cortex seems to provide a sort of generalized framework to which single reactions conform spontaneously, as the words fall into the grammatical form of a language.

THE MUTUAL INFLUENCE OF CEREBRAL ACTIVITIES

Every statement concerning independence of functions must be made with certain reservations. The early students of aphasia, using the crudest of examining methods, were able to identify a great variety of types involving entirely different defects in the

use of language. More careful study of the aphasias with finer methods of examination has failed to reveal such clear-cut distinctions, and today we have no accepted classification of the aphasias. Marie concluded that all types are the result of a common intellectual defect. Head denies that the intellectual defect is primary but admits that in all cases intellect suffers to the extent that it employs symbolism in thinking. All investigations seem now agreed that the disturbance of speech is only one symptom of a disorder which can be traced through the whole fabric of thought.

This is typical of recent developments in the clinical field. With improvement in methods of examination, the complete isolation of functions becomes more and more questionable, until it seems as though disturbance in any function implies lesser, but recognizable changes in every other.

This interdependence is not merely an expression of the subtraction of elementary functions by brain injuries. It seems to involve a genuine fusion of different processes, such as is shown in the observations of Poppelreuter¹⁹ on the 'totalizing function' of the visual area, and those of Gelb on the mutual influence of normal and hemiambyopic areas. Poppelreuter reports the completion of simple figures in the cortically blind field, much like the normal filling in of the blind spot. Gelb²⁰ describes a case in which objects were judged smaller when seen in one half of the visual field than when seen in the other. When exposed so as to include both fields they were judged intermediate in size. Evidently in such cases as this there is fusion rather than summation of elements.

SELF REGULATION IN NEURAL FUNCTION

This unity of action seems to be more deeply rooted than even the structural organization. In working with animals and with human patients I have been more and more impressed by the absence of the chaotic behavior which we might expect from the extent and irregular form of the lesions. There may be great loss of sensory or of motor capacities, amnesias, emotional deterioration, dementia - but the residual behavior is still carried out in an orderly fashion. It may be grotesque, a caricature of normal behavior, but it is not unorganized. There are certain apparent exceptions to this rule, such as the loss of control of laughter in certain thalamic and lenticular cases, jargon in aphasia, the loss of spacial organization in some cases of visual agnosia, but even here the disturbances are not chaotic. Even dementia is not wholly unintelligent. It involves reduction in the range of comprehension, in the complexity of the relations which may be perceived, but what falls within the patient's range is still dealt with in an orderly and intelligible fashion.

There seems always to be a certain spontaneous compensation or adaptive reorganization. The most definite example of this sort is the observations of Fuchs²¹ on pseudofovea. He finds that in cases of complete hemianopsia there is a shift of the center of fixation from the anatomical fovea to a variable point in the peripheral retina which acquires a greater visual acuity than can be demonstrated in the anatomical macula.

Such phenomena suggest that the nervous system is capable of a self-regulation which gives a coherent logical character to its functioning, no matter how its anatomical constituents may be disturbed. If we could slice off the cerebral cortex, turn it about, and replace it hind side before, getting a random connection of the severed fibers, what would be the consequences for behavior? From current theories we could predict only chaos. From the point of view which I am suggesting we might expect to find very little disturbance of behavior. Our subject might have to be reeducated, perhaps not even this, for we do not know the locus or character of habit organization - but in the course of his reeducation he might well show a normal capacity for apprehending relationships and for the rational manipulation of his world of experience.

This may sound like a plunge into mysticism, but an example from another field will show that such self-regulation is a normal property of living things. Wilson and later Child²² have crushed the tissues of sponges and hydroids, sifted the cells through sieves of bolting cloth and observed their later behavior. The cells are at first suspended independently in the water, but may be brought into aggregates by settling or centrifuging. Starting as flat sheets, they round up into spherical masses and begin differentiation. Embryonic stages may be simulated and eventually adult individuals with characteristic structures, mouth, hypostome, tentacles, and stalk in normal relative positions are produced. In spite of the abnormal conditions to which it is subjected, the formless mass of cells assumes the structure characteristic of the species. Of course many abnormal forms appear, but even these follow the characteristic scheme of organization.

Many lines of evidence show a close parallelism between the facts of morphogenesis and those of the organization of the nervous system. In both we have given as the fundamental fact an organization which is relatively independent of the particular units of structure and dependent upon the relationships among the parts. In both there is a capacity for spontaneous readjustment after injury, so that the main lines of organization are restored; in both there is evidence that every part may influence every other; in both there is a possibility of dissociation and independent activity of some parts.

THE MECHANISMS OF ORGANIZATION

This brings us to the question of the mechanisms by which organization of behavior is brought about. There is, I think, nothing mysterious about the problem. There is no need to assume an emergence of new properties, a transcendent influence of the whole upon the parts, a subordination of substance to form, or the like; there is certainly no need to look for nonphysical agencies. We are dealing with a complex system in which there is an influence of every part upon every other, with

all degrees of intimacy in the relations and various degrees of dominance and subordination. Our problem is to discover the means by which these influences are exerted.

We have seen that the notion of isolated reflex paths, exerting mutual inhibition and facilitation and conducting nervous impulses over pathways determined by the specific resistance of synapses, is not only inadequate to account for the simplest facts of behavior, but is also opposed by direct neurological evidence. The greatest progress in neurophysiology within the past decade has been made in the study of conduction in peripheral nerves, but the results have as yet little bearing upon the problems of central organization. At most they offer a basis for speculation concerning the behavior of nerve impulses at intercellular junctions, and recent negative results upon conduction with decrement throw some doubt upon the value of these speculations. Students of nerve conduction have taken for granted the doctrine of anatomical specialization, and their work has not been developed, in the direction of our problems. Lapique²³ has recently pointed out some of the difficulties of the anatomical hypothesis and has suggested the substitution of temporal for spacial factors in organization, but the study of chronaxie is not far enough advanced for application to the problems of psychology. The laws of conduction in nerve fibers thus far revealed are not alone sufficient for an understanding of integration. The nervous unit of organization in behavior is not the reflex arc, but the mechanism, whatever be its nature, by which a reaction to a ratio of excitations is brought about. We have as yet no direct evidence upon this problem, but the similarities of the problems of nervous function and of growth should direct our interest toward the processes which have been found important in the control of structural development.

The work of many students of experimental embryology has shown the importance of the restriction of gaseous interchange, of gradients in chemical diffusion, metabolic activity or rate of growth, the influences of chemical and electrical polarization and of the flow of action currents in determining the course of development. During its first differentiation the nervous system is subject to the same influences as any other developing tissue and the mechanisms of diffusion and of polarization play an important rôle in the determination of its structures and inherent organization. It would be strange if, with the completion of growth, these factors should no longer be important in the life of the cells. Rather, we should expect the neurons to be continuously modified by the same influences. The structure of the nervous system is such as to allow of this. The interconnections of distant parts are well insulated, where correlated functions without influence of intermediate parts is required, but within the gray matter the cell bodies and processes are not so protected. They are directly exposed in a liquid medium capable of conducting diffuse chemical and electrical changes which may readily influence the excitability of the neurons. The arrangement of the gray matter in thin sheets and the projection of the receptor and motor surfaces upon these sheets may have a real functional significance. Child²⁴ has shown that distance of separation favors the development of independently polarized systems, and the arrangement of cell bodies in the gray matter offers the optimal condition for this

and for the development of systems in which the special arrangement of stresses can be effective. Although the distant intercommunications of cells may be solely through the conduction of nerve impulses, the more immediate coördinations within the gray matter may depend upon relative amounts of excitation, the spacial arrangement of excited points, stress patterns resulting from the total mass of excitation, which may be more important for behavior than the connections of individual cells. It is here, I believe, that we must look for the next significant development in our knowledge of the functions of the brain.

Cerebral organization can be described only in terms of relative masses and spacial arrangements of gross parts, of equilibrium among the parts, of direction and steepness of gradients, and of the sensitization of final common paths to patterns of excitation. And the organization must be conceived as a sort of relational framework into which all sorts of specific reactions may fit spontaneously, as the cells of the polyp fit into the general scheme of development.

Such notions are speculative and vague, but we seem to have no choice but to be vague or to be wrong, and I believe that a confession of ignorance is more hopeful for progress than a false assumption of knowledge.

CONCLUSION

I have devoted my time to-night to problems which are not strictly psychological, yet I believe that these problems are of real significance for the progress of psychology. Certainly the development of the science up to the present has been strongly influenced by neurological theory. The frantic search for sources of motivation and of emotion in visceral activity, though initiated by introspective analysis, has been supported by the faith that the nervous system is only a conductor having no sources of energy within itself. Our preoccupation with analysis of learning by trial and error, the denial of association by similarity, the belief that transfer of training can occur only through the training of common synapses - these are a result of the belief that learning is simply a linking together of elementary reflexes. The doctrine that the intelligent solution of problems results only through random activity and selection, and that intelligence itself is an algebraic sum of multitudinous capacities, is largely a deduction from the reflex theory.

I shall not pretend to evaluate such doctrines from the standpoint of psychological evidence. They may or may not be true, but their truth must be demonstrated by experiment and cannot be assumed on a background of questionable neurology. Psychology is today a more fundamental science than neurophysiology. By this I mean that the latter offers few principles from which we may predict or define the normal organization of behavior, whereas the study of psychological processes furnishes a mass of factual material to which the laws of nervous action in behavior must conform.

The facts of both psychology and neurology show a degree of plasticity, of organization, and of adaptation in behavior which is far beyond any present possibility of explanation. For immediate progress it is not very important that we should have a correct theory of brain activity, but it is essential that we shall not be handicapped by a false one.

The value of theories in science today depends chiefly upon their adequacy as a classification of unsolved problems, or rather as a grouping of phenomena which present similar problems. Behaviorism has offered one such classification, emphasizing the similarity of psychological and biological problems. Gestalt psychology has stressed a different aspect and reached a different grouping; purposive psychology still another. The facts of cerebral physiology are so varied, so diverse, as to suggest that for some of them each theory is true, for all of them every theory is false.

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