Meetings

Information Processing in the Nervous System

The correlation of "neuronal machinery" with psychophysiological phenomena was the subject of a symposium, "Information Processing in the Nervous System," held at the State University of New York at Buffalo, 21–24 October 1968. The program reflected the interests of various disciplines in common problems. It included sessions on linguistics and automata theory, which have implications for developing new viewpoints; sessions on psychophysiology, anatomy, and physiology, concerned with the fundamental biology; and a session on models and theory.

While language and mathematical logic are both products of the brain, the temporal effects are paramount in the former but not in the latter. Language could not exist without short-term memory; in a sequence of words, nearest neighbors are not necessarily closest in logic, nor are they usually strung together by the use of simple logical principles. Hence linguistics and automata theory may be expected to shed light on different aspects of brain operations.

W. A. Wickelgren addressed himself to the importance of context and proposed a context-sensitive code in which each symbol is associated with its nearest neighbors. He discussed some possible implications for speech development, articulation, and recognition. Automatic speech recognition has proved a surprisingly difficult problem. A. M. Liberman pointed out one difficulty of this in that the sounds of speech are not mapped one to one onto phonemes. In fact phonetic segments, particularly formant transitions, carry a great deal of parallel or simultaneous information which is vital in human speech recognition. The perception of speech, like perception in general, is highly nonrepresentational but quite specific, as some recent work has shown, in which speech and nonspeech were compared in their effects on right ear and left ear perception, with the obvious implications for left and right hemispheric localization. The connection between linguistics and automata theory made by Chomsky was discussed by P. S. Peters, who concentrated on the structure of language and the constraints on brain models imposed by automata theoretic formulations.

M. A. Arbib reviewed some of the developments of automata theory in relation to brain modeling and discussed, among others, stimulus-response theory, pattern recognition, and complexity of computation in finite networks. He pointed out that, whereas automata theory may be a help in setting boundary conditions on certain functions and in suggesting metaphors, care should be taken with regard to identifying automata with brains. R. Rosen considered problems of hierarchical representation and whether automata theory is an adequate framework for theories of the nervous system. He concluded that the fundamental nature of automata theory precludes an isomorphic representation but that functional properties could well be modeled. H. C. Longuet-Higgins discussed some interesting parallels between memory and holography. In both, the emphasis is on a distributed form of information storage and a large part or the whole of the original information can be recovered when only a fraction is supplied as input or cue. Moreover, an intriguing observation concerning holographs is that several pictures can be superimposed on the same storage matrix. While holographs are fine for spatial storage, temporal storage is also of some importance in biological memory. Longuet-Higgins showed how to construct an automaton, the "holophone" as he called it, which would be analogous to the holograph in the temporal domain. One question which Longuet-Higgins raised in thinking of possible parallels between the holophone and brain operations was this: Do neurons only respond (speak) when they are stimulated (spoken to), or do they keep chattering away for some time after—are there any natural neural oscillations which can be excited by brief stimuli and which, by constructive interference, can resynthesize some past signal? W. Kilmer recounted the argument that the reticular formation commits the animal to a behavioral mode. He described his present work with McCulloch on a computer program for a system of decision modules with flexible coupling; the system simulates some hypothesized functions of the reticular formation.

In psychophysiology, R. N. Haber was concerned with isolating perceptual variables which can be assigned to a peripheral or central processing level, so that psychophysical experiments can give a deeper insight into information processing. He described some skillfully designed experiments—one series concerned with the problem of visual persistence or short-term memory. He showed that even without physiologically detectable summation of successive stimuli, recognition was improved, showing the importance of central effects. A second series of experiments, in which visual noise was used at various intervals after a stimulus, showed that clarity and recognition are not equivalent. In other words the perceived clarity of a sensory presentation is a precondition of recognition, which requires additional processing. Visual noise serves as a mask and masking studies are proving most fertile in elucidating sensory phenomena, since one can interfere in a controlled way with the sensory apparatus, get quantitative measures, and compare these with electrophysiological data, which have in the past been more easily quantified than psychophysical phenomena. P. Schiller distinguished masking with and without contour interaction and metacontrast. He discussed how one may reveal the contributions of different stages in the visual pathway to the observed phenomena. The numerous psychophysical data have now been supplemented by single-cell recordings in the visual pathway and this is an area where "neuronal machinery" is being actively correlated with psychophysical data. Quite commonly one observes successive stages of stimulus transformation (weighting) and summation throughout the nervous system. It is important to be able to separate these out when studying the brain as an information system. R. M. Boynton did this with masking flashes and showed that the weighting stage apparently precedes the summation peripherally in the visual system. The final paper in the session on psychophysiology was an ambitious attempt by M. Clynes to quantify feelings or what he called "sentic" states. He recounted some fascinating evidence for precision in conductors like Toscanini. He presented some quantitative identifications for qualitative states like anger, love, or grief. Having thus discussed the whole man, the participants turned their attention to the activity in single cells from which the brain is built.

The session on anatomy and physiology was chaired by W. A. H. Rushton. H. B. Barlow elaborated the proposition that increasingly fewer signals are generated in more numerous fibers, as information is relayed in sensory pathways. He adduced examples of receptive fields in the retina and the visual cortex and discussed adaptation and his recent work on binocular stereopsis in support of the argument. V. B. Brooks gave a beautiful account of some recent work by himself and his colleagues on elucidating the functions of the motor-sensory cortex. The afferent information flow in this part of cortex consists of somatic and kinesthetic, as well as visual and auditory, stimuli. The motor-sensory cortex is arranged functionally in radial columns, similarly to the somatosensory and visual cortex. The input receiving columns are about 0.2 millimeter in diameter and the output columns about 1 millimeter in diameter. Thus one efferent column contains about 25 afferent columns. There is extensive overlapping of afferent and efferent columns among themselves and with each other. Decisions to move and how to move are not made in the motor-sensory cortex. Rather, the latter is concerned with receiving afferent information and executing movements involving positive feedback. This is well suited for the tactile placing reaction, the instinctive tactile grasping reaction, and the act of accurate stepping. J. C. Eccles reviewed cerebellar structure and physiology, including the pathways that link the cerebellum to the spinal cord and the cerebrum. He emphasized that the cerebellum is part of a dynamic loop. It does not contain precise somatotopic maps as, for example, the sensory or motor cortex. Instead, there is a large overlap of somatic inputs and any small region in the cerebellum will receive inputs from a very large number of sources. The cerebellum does not hold information of ongoing activity for long periods of time. It operates, as if it were giving advice, moment to moment, on ongoing activity. Experimental evidence for dynamic loop control of movement is provided by the tremor of about 9 cycles per second which is found superimposed on movement.

The session on models and theory was chaired by Otto Schmitt who put forward an ingenious idea of treating nervous systems as interpenetrating domains—for example, three, of which one would represent the intracellular space, another the extracellular space, and a third the space occupied by nerve membranes. Such an approach could achieve the advantage of lumping some properties of individual cells into characteristics of the domains. Warren McCulloch gave a paper on digital oscillators. He showed that under certain conditions a randomly connected net of shift registers under the control of a logic network will produce a surprisingly large number of different sequences without repetition and mostly of relatively short length. This would overcome some of the earlier problems of too few or too long sequences in neural net models. McCulloch stressed the importance of looking at irreducibly triadic relationships in place of two valued logical ones, since our thought processes are concerned essentially with relationships ARB such as "A is conscious of B" or "A thinks that B" and the relation R cannot be left out of account. R. F. Reiss presented some ideas on how to deal with the potentially very large number of possible states of sequential machines and presented certain quantitative measures for this problem. K. N. Leibovic and N. H. Sabah surveyed synaptic input-output relations, signals in nerve fibers, and the functional significance of small network structures, such as reciprocal synapses. Among some novel ideas which they presented they postulated, on theoretical grounds, a synaptic mechanism mediated by neural activity-dependent K^+ concentrations in adjacent cells and in the intercellular space. They also proposed a new type of signal, which they named "g-pulses" and which is intermediate between electrotonic signals and "all or none" spikes. These "g-pulses" behave somewhat like damped spikes and they can be deduced from a modified form of the Hodgkin and Huxley equations for excitable tissue. The "g-pulses" are of interest in view of the numerous, strange signals recently recorded in nerve preparations which look, in fact, like something between spikes and electrotonic polarization. They could be a flexible and reliable form of signal with regard to information processing. Some psychophysical implications were briefly mentioned.

The size of the symposium was sufficiently small to enable all participants to interact with one another and sufficiently large so that each of the various groups—whether primarily mathematical or biological—could make a significant contribution. In fact, one of the most successful features of the symposium was the degree of interaction which was achieved and the feeling that new horizons had opened up.

The meeting was organized in cooperation with the John C. Eccles Laboratory of Neurobiology; the Departments of Biophysical Sciences, Mathematics, Computer Sciences, and the Center for Theoretical Biology of the State University of New York at Buffalo; and the Center for Visual Science of the University of Rochester.

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Mental Retardation Caused by Physical Trauma

The relationship of physical trauma to the production of mental retardation was considered 13–16 October 1968 at the University of Nebraska, Lincoln, by 45 participants including neurosurgeons, neuropathologists, obstetricians, pediatricians, and psychologists from the United States and overseas. It was the fourth of seven research conferences on the etiology of mental retardation recommended in 1962 by the epidemiology of postnatal and perinatal trauma, clinicopathologic correlations, and pathogenesis of traumatic damage to the developing brain.

The opening address underscored some of the problems confronting observers and research workers in the definition and estimation of the qualitative differences in function which are called mental retardation. The scope, incidence, and size of the patient population at risk or affected is not accurately known or defined.

All parameters of behavioral change are not examined in the standard testing of children, thus making it difficult to estimate the incidence of minor neurological impairment following physical trauma. The question was raised whether, with such tests, we uncover a diffuseness of representation or a diffuseness of lesion. The possibility that an elementary function might be spared at the expense of a general loss of higher functions was suggested.

The use of animal models is a direct approach to the problems, experimental reproduction of events with time and specific cortical areas are controlled. Work was reviewed which demonstrated the capacity of the young animal to compensate for large losses of brain mass, but with not always predictable results.

Results of experimental cortical ablation suggested that with the maturation of subcortical motor systems, the presence of the inhibitory functions of the localized areas of the cortex become increasingly important, although not necessarily a function, of the mass of cortical tissue removed. The inability of the operated adult or older infant subjects to do better on testing would appear to be intimately associated with the appearence of hyperactivity and distractability. These studies point to the need for both long-term clinical