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SUMMARY OF THE CONFERENCE

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Second Prague Conference on Human Learning

SUMMARY OF THE CONFERENCE

Professor Linhart, Ladies and Gentlemen: This has been a very different conference from the first. The field of human learning has changed considerably from the initial forays reported four years ago. Whereas at that time the issue was to find commonalities among the diversity of languages used to describe a wealth of experimental results, the issue today is to define the richness of the problems of human learning beyond those addressed here. For, the outstanding change in four years has been the complete and utter victory of the cognitive approach in all our deliberations. If there have been difficulties in communication, they have not been due to any failures in the language we have used to describe -- rather they must be due to inherent limitations of that language as it has developed so far.

Philosophy:

Let me begin by referring to Professor Madsens interesting presentation -- perhaps the only one of the conference that addressed these overall issues of where we stand with respect to our data. Madsen suggests that we may divide the issues into (1) those of method, i.e., philosophy; (2) those of model building; and (3) those of describing data. With regard to philosophy and method, he discerns empiricism, rationalism and intuitionism (also called metaphorism). As befits a scientific meeting held in the heart of continental Europe, we almost wholly eschewed empiricism and intuitionism. Our approach fell into one or another form of rationalism -- we were interested in describing -- almost to the point of boredom -- the rational cognitive structures by which we organize our perceptions and actions.

Models:

Madsen suggests that model building follows the methods we use: empiricists, describe; rationalists use data as instruments for understanding; while, paradoxically, those who view their experiments as metaphors refer them to a "real" world and so become sophisticated (as opposed to naive) realists. It is in this area that the movement which has taken place since our last congress can be appreciated most vividly. The first conference was largely empiricist in tone; this one is overwhelmingly instrumentalist. But there are trends observable in the direction of metaphorism and realism. I remind you, therefore, that both of the speakers at the opening session of the first conference were and are structural realists, a position clearly announced by Professor Metzger in his address and one gradually achieved by me as detailed in my recent book, Languages of the Brain (1971). Perhaps my own bias colors my view, but I heard in some of the presentations from Germany and in Professor Inhelders contributions movement toward this form of realism -- an attention to the "world-out-there" as well as to the rational "world-within".

Data:

Yet, when we come to the data level of analysis, we see how overwhelmingly an instrumental rationalism held sway at this conference. As structuralists we could address ourselves to the structure of the task presented to our subjects; to the state in which our subjects approached such a task; or to the operations the subjects performed in the task. Structure of task was addressed in approximately a dozen presentations; structure of state in about the same number. By contrast the nature of the operations performed were addressed five times as often -- at least 60 papers were devoted to this topic by the end of yesterday -- I had to miss this morning's harvest in order to prepare my summary, but from the titles, it appears that the operations as instruments were even more the major substance of this morning's fare since it was devoted to the applications of our common interest.

Madsen told us that we have choices among language systems in reporting data. These choices are given by the sets (1) materialistic, i.e., physiological; (2) neutral, usually engineering; and (3) mentalistic or psychological. Only in the session I chaired and in my own presentation were materialistic physiological terms used to any considerable extent. Otherwise mentalistic and neutral terminology was almost equally applied. Thus, in describing tasks and states, "perceptual" and "memory" terms frequently defined the psychological frame of reference, as did "sign" and "symbol". "Information" and "information storage" served the same purpose when neutral language was used. When operations, processes, were the subject of the inquiry, the psychological frame of reference abounded in cognitive terminology such as motivation and attention and recognition and recall. Neutralists presented their data in terms of transformations, programs, control processes, heuristics, and retrieval.

<u>Overview:</u>

In short, this has been a conference overwhelmingly devoted to process, to the cognitive instruments, the transformations and controls operating in human learning. As noted, this emphasis of 5 to 1, has to some considerable extent ignored the issue of what these processes, these operations, are operating upon. The implicit assumption at a methodological, i.e., philosophically naive level would be that the operations are performed on the task -- but most of you have shown that you do <u>not</u> hold the naive view and that you believe that tasks must first be apprehended (perceived) to be solved; that the structure of memory has a good deal to do with both apprehension and solution; that, in fact, the operations you describe are internal -- in neutral language, they are information processing operations. This raises the issue of the organization of both input and store and the transformations involved in the operations performed by the organism's nervous system.

I shall, therefore, in concluding, again turn to my own research to point out that we have considerable evidence that the memory mechanism has two identifyable aspects. Structurally, items held in a distributed store appear to be addressed by control programs which "get it together" whenever occasion demands.

<u>Holograms:</u>

Clinical evidence has for years pointed up an anomaly in the relation of brain function and memory. Brain injury often severely impairs memory but such impairment rarely singles out categories of related items. Thus, following a stroke involving the visual system, a patient does not fail to recognize a part of his family -- either he recognizes no one or everyone. This observation has been taken into the laboratory and in Lashley's hands (1929) gave rise to the law of mass action. The converse of this law is that whatever is involved in recognition has become distributed over a sizeable mass of brain tissue. We now have direct neurophysiological evidence that input becomes encoded in such a distributed fashion. Monkeys were trained to view a panel upon which vertical stripes or a circle were flashed briefly whenever the monkey pulled a lever. The resulting electrical response evoked by the flashed stimulus was recorded from some 50 electrodes implanted in the primary visual cortex by means of a small general purpose computer which was programmed to analyze the difference in wave forms produced by the flashed circle and the flashed stripes. Figure 1 diagrams the fact that such differences were obtained in only some of the electrodes and there was no apparent order to the location of these electrodes. Whenever an electrode did show the difference it did so reliably over many months of testing. Other electrodes encoded other events when we began to train the monkeys to respond differentially to the cues. Thus, response information and reinforcement information usually became separately encoded in the visual cortex -- again complete stability over months of testing, but no apparent order to the location of such encoding sites. An occasional electrode would, however, reflect stimulus, response and reinforcement information simultaneously (Pribram, Spinelli and Kamback, 1967).

Figure 1 about here

A psychophysical experiment (Moyer, 1970) enhances our understanding of the way in which such distribution is attained. Nonsense syllables were flashed into a particular quadrant of a human subject's retina. A recognition task was then administered using the other quadrants. When only one initial exposure had been given there appeared to be no recognition of the test syllable. When, however, multiple exposures, still limited to a single quadrant, were given -- then recognition using other quadrants was almost as good as when the initial quadrant was used. Apparently, distribution depends on repetition -- either external as in this case, or on rehearsal as in some of the experiments reported by Voss (1969).

My interpretation of these results is that this structure of the information store of the brain may well account for the results of experiments such as those presented here by Berynkov and Maschen which led them to suggest that the memory store resembles a thesaurus, a view also developed by Endel Tulving (1972) who speaks of input as stored according to the episodes in which it occurs. Such episodic memory, a thesaurus, must therefore, contain a great duplication of items and our electrophysiological evidence suggests that these items are relatively randomly distributed over a large extent of the input systems of the brain.

In the first section of Languages of the Brain, I present the neural mechanisms by which a distributed store might be achieved; in the last section of the book, I present the evidence -- alluded to in my talk at the opening session of this conference, as well as the summary of the first conference as the "temporal" processes of selection (discrimination) and reasoning (direction), that the association cortex of the brain functions as the origin of control processes that re-member this distributed, dismembered, store. These control operations apparently structure two different types of operations: one from the posterior association cortex (which is selective) results in signs determined by a hierarchically organized dictionary-like categorizing process. Signs are thus context-free constructions invarient across a considerable range of transformations of input configurations.

The other control operation, initiated in the fronto-limbic systems of the brain (is directive and the basis of reasoning), constructs tokens, symbols. Symbols are not hierarchically organized and are formed by context dependent processes, and are thus paradoxically more "in touch" with the episodic, thesaurus-like structure of the memory store -- an observation that so puzzled Peirce in his struggles to formally present his pragmatism (1934). The graph structure that represents context-dependent processes recognizes nodes distributed through a highly interconnected network -- these nodes are the memory store.

Here again we see the juxtaposition of metaphor (symbol) and reality (store) noted earlier. And observe also that the store is organized according to episodes that presumably occur in the world in which the organism is embedded.

My final thought is therefore that perhaps we should view the brain as a microcosm of its universe -- or, to put it the other way 'round, the universe is a macrocosm of the brain. I have conceptualized the distributed structure of the memory store of the brain in terms of the technology of optical information processing -- holography -- just as we are accustomed to conceptualizing control mechanisms in terms of computers. Optical information processing, holography, is analogue rather than digital, parallel rather than sequential. According to the line of reasoning pursued here we might view, not only our brain, but our world as composed of distributed holographic structures, each part representing the whole, each portion "doing its own thing" as it were, yet representative of the whole. This view bears a remarkable resemblance to that developed by Leibnitz in his Monadology (1898), and it must be remembered that Leibnitz invented the mathematics used by Gabor (1949, 1951) to construct the first hologram.

But also there are control processes essential to "getting it all together", to constructing and reconstructing this whole. This insight into social organization may account for the dialectic tension we all face continuously between our own actualization and the constraints and controls necessary to achieve it. Here in Prague this dialectic is so poignantly portrayed -- but if my view of the matter is correct, the reach of the synthesis to be achieved is proportional to its difficulty and thus well worth the struggle.

REFERENCES

GABOR, D. Microscopy by reconstructed wave fronts. I. Proc. Roy. Soc. (London) A197, 454-487, 1949.

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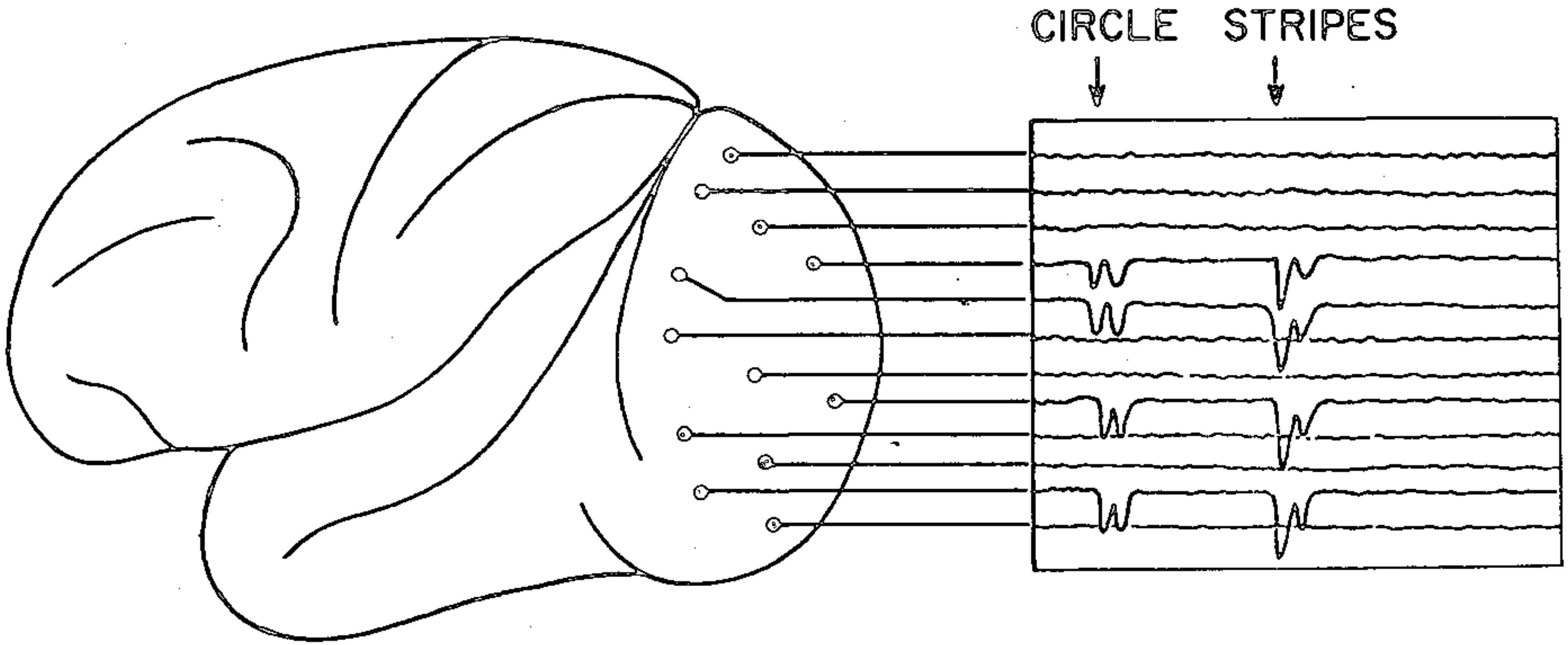
VOSS, J. F. Associative Learning and Thought: The Nature of an Association and Its Relation to Thought. In J. F. VOSS (Ed.) Approaches to Thought. Columbus: Charles E. Meredith, 1969.

FIGURE LEGEND

1. A diagramatic representation of the finding that the differences in the potentials evoked by circles and stripes are distributed over the striate cortex. Note that not every lead shows the difference.


CIRCLE
STRIPES

CLOSING REMARKS	**ЗАКЛЮЧИТЕЛЬНОЕ СЛОВО**
Pribram K.H.	Прибрам К.Г.
Linhart J.	Лингарт Й.

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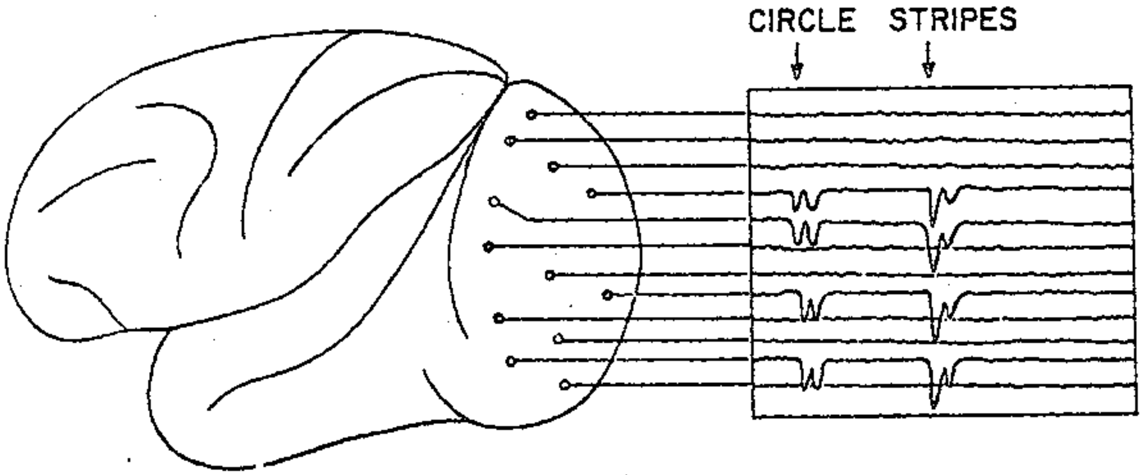

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