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INTRODUCTION TO THE

SECOND PRAGUE CONFERENCE ON HUMAN LEARNING

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Professor Linhart, Ladies, and Gentlemen:

This is the <u>second</u> Prague conference on human learning and I take it to be my task to provide some continuity with the proceedings of the <u>first</u> conference. In the opening session of that meeting, I proposed that:

"Learning is a change in performance which comes about with experience. Experimental psychology has attempted to discover the laws of learning on the assumption that learning is all of a piece, that a paradigm such as classical or instrumental conditioning can be used to chart the route to discovery. At one level -- I am tempted to say the rat level and will not resist the temptation -- this assumption may prove valid. But at the rational, human level and even in non-human primates, studies of brain function in learning have shown the assumption to be of little use."

"The primate brain is a complex organ composed of many systems and subsystems. Damage to one system influences some learning but not all; damage to another system will affect learning processes considerably different from those influenced by injury to the first. In my laboratory we have therefore distinguished a variety of types of learning: some basic such as configural learning, discriminative learning, and learning to transfer experience gained in one situation to another; and some of a higher order such as the development of learning skills, and of linguistic learning--in other words, thinking. The laws of learning that apply to each type are considerably different as are the parts of the brain involved."

In the summary of the proceedings, I carried this theme further by suggesting that the problems of human learning, though multiple, could be ordered according to simple principles and that the large diversity of often brilliant contribution should be ascribed to the variety of languages that had been developed to cope with the data produced in seeking solutions to this more restricted set of problems.

"The task has been given me to summarize this informative and exciting conference on human learning. When I listed for myself the topics covered, however, they presented such a bewildering, if brilliant, array of terms that at first the task of managing a reasonable synthesis seemed prohibitive. Listen to some of the key words which regularly recurred in the presentation: Discrimination, Arousal, Confirmation, Incentive, Information, Reward Value, Dissonance, Achievement, Salience, Utility, Representational, Stimulus Recoding, Associative, Set of Values, Control, Short Term Memory, Long Term Memory, Repetition, Interference, Uncertainty, Competence, Semantics, Surface Structure, Deep Structure, Markers."

"This variety in expressions, however, seemed to me to cloak a smaller number of problems common to the participants of the conference. Perhaps a diversity of tongues had developed in psychology that made it difficult for subdisciplines to communicate. The diversity had enriched the parent science but at the same time brought the danger of disruption."

"Several of the discussion leaders recognized this problem, having faced it in the analysis of their own experimental results. Thus both Berlyne (1960) and I (1967) have emphasized that arousal as used in psychological and clinical psychology is little different from the drive of S-R learning theorists and that both concepts can be more rigorously and quantitatively defined in terms of uncertainty as used in information-theoretic context."

"Also, Berlyne and others (including Richard Thompson and myself in personal communications) have worried a good deal about making operational distinctions between the concepts of attention, memory consolidation and reinforcement. Such distinctions are not easily made and become even harder to accomplish when one begins to suspect as have Trabasso and Bower (1968) and I (Rothblat and Pribram, 1972) that the relevance, the salience of an hypothesis to be attended, deeply depends on reinforcement history."

"Estes also voiced this concern with multiple ways to describe a common problem. Perhaps his most telling argument involved the parallels between Associative States and Memory States -- an argument for association memory which computer oriented cognitive psychologists will find both illuminating and compatible."

"Given this key to the problem of finding the commonalities that bound this conference together, I proceeded to explore the different languages used at the conference. The psycholinguists' contributions were, of course, especially useful in such a search. To abbreviate here what was a fairly long route, I came to the conclusion that psychologists, just as children, divided their world into two main categories, the category of existences and the category of occurrences: the nominate and the predicate. Thus there were the psychologies of how we perceive the world and the psychologies of how we are moved to act on the world."

"This dichotomy took me a long way -- into this morning, in fact. But this morning, the cognitive psychologists and some other groups as well, in their discussions approached their subject matter from a different set of distinctions. The concern was with mapping problem solution into coordinate systems so that transformations could readily be achieved. Again two major categories appeared -- very simple and fundamental -- the spatial and the temporal."

"So, suddenly, I was given a matrix, a 2 X 2 table, into which most of the interests expressed in the conference might be fitted. Here it is:"

Symbolic → Coordinate ↓	Nominate	Predicate
Spatial	Perception	Motivation
Temporal	Cognition	Conation

"My own opening presentation fits well into this matrix: As detailed in the sections on learning skill and linguistic learning, I believe the key to all of these investigations is the fact that learning, and its operational counterpart remembering, is in large part the development of Configuration and Incentive, of Discrimination and Direction, in short operations of the brain. There has been in both psychology and biology and even more so in the simulation efforts of the computer sciences too great an emphasis on the quantitative aspects of memory storage to the exclusion of the equally important problem of efficiency. Efficiency depends on perception and on planning -- on ways of coding information so as to make it accessible. My data lead me to believe that all brains are prime coding instruments and that man's is distinguished by the power of his coding abilities. Just as ruminants spend their time munching cud, so man ruminates his codes. The resulting product is vastly different in the two cases: the beast's activity degrades structure into dung; man's productivity constructs and reconstructs his universe."

"Research on brain functions has in these results shown me that to learn is to code, that learning is not mere associative storage but a productive activity making available alternatives. Multiple constructions, options among alternatives, these are the hallmarks of human learning. Thus enriched through learning man's brain, in time, creates his freedoms."

	Nominate	Predicate
Spatial	Configuration	Incentive
Temporal	Discrimination	Directive

Nor was it difficult to fit other presentations into this framework, and I have enjoyed and profited in going back from time to time to that summary for translations of the work of others in the field into this, to me more easily understandable basic formulation.

Basic Behavioral Processes:

In bringing to the current conference these earlier thoughts, I again turn to my laboratory analyses of brain function. Essentially, this involves a systems analysis which has shown the functions of certain anatomically specifyable neural systems to coordinate with certain behavioral processes involved in learning. These processes are ordinarily referred to by many names, but perhaps the easiest to comprehend are arousal, readiness, selection, and reasoning. As noted in the first conference, arousal is dependent on configuration; readiness on incentive; selection on discrimination; while reasoning involves directive mechanisms. The defining operations performed in the laboratory are:

Arousal: simple response to a simple change in monotonous repetitive stimulation.

Readiness: single response to recurrent (but not monotonous) change in repetitive stimulation.

Selection: single response to one of a group of monotonous repetitive stimuli.

Reasoning: multiple responses to one of a group of recurrent (but not monotonous) stimuli -- the response thus dependent on the context provided by the regularly recurrent stimuli.

The functional systems of the brain that are involved in each of these basic behavioral processes have been extensively investigated and fairly clearly identified. With Diane McGuinness I have recently made a detailed review of the results of these investigations (1974) and want not to summarize them as guidelines that might anchor our discussions of human learning over the next days.

Arousal.

When a sudden change occurs in a previously stable stimulus configuration, the organism orients to that change. The now classic studies of Sokolov demonstrated that any change -- even a diminution of intensity or a shortening of stimulus duration -- would initiate the orienting reaction. Sokolov suggested, therefore, that a neuronal model, a representation, is constructed by the brain which allows any change in input to become registered as novel. A decade of neurophysiological research has shown that there are in fact neurons that decrement their activity when repetitively stimulated, while other neurons increment theirs, at least for a while. It has been established that the decrementing is not due to neuronal inhibition but to some form of desensitization at the synaptic junction; it has also been shown that incrementing results from sensitization (see review of this evidence in Horn and Hinde, 1970). In the spinal cord, and probably in the brain stem, the sites of these two classes of neurons are separate: for the most part desensitization occurs in the dorsal horn and sensitization in the cells of Clarke's column which is intimately related to viscero-autonomic regulation (Groves and Thompson, 1970).

Thus far, only in cortical structures such as the hippocampus and visual areas, have the two processes been found juxtaposed (Vinogradova, 1970; Grandstaff and Pribram, 1972), although units showing initial incrementing with subsequent decrementing exist elsewhere. The activity of these units is thought to be composed by convergence from sensitizing and desensitizing neurons. Such convergent processes would account for the ordinary facts of orienting, habituation and dyshabituation but would not explain Sokolov's results. Only the juxtaposition of both types of neurons as in cortex allows the construction of a spatially patterned neural response -- a true representation of configural input. Such patterns of neural responses have, in fact, been found limited to cortical sites (Grandstaff and Pribram, 1972).

What then does arousal consist in? From the neurophysiological evidence at hand, arousal temporarily disrupts the patterned neural activity representative of a stable input configuration. This disruption is due to the excitation of neurons whose synapses are susceptible to sensitization over brief periods and there is reason to believe that such neurons are related to viscero-autonomic regulating mechanisms.

Readiness.

The representation process involved in habituation is thus subject to progressive configural differentiation as the environmental "figure" changes. But what about responses to recurrences in stimulus configurations? After all a great share of our lives is spent attempting to solve problems that recur and having solved them we respond with habit patterns not by the inactivity of habituation. Again neurophysiology has provided a considerable amount of data over the past decade, but in this area there has been a great deal of difficulty in conceptualizing the results. This difficulty stems largely from a failure to distinguish arousal from readiness, the term neural activation having been used to cover both. The difficulty is overcome when the behavioral situations are classified as I have proposed in the previous section. When this is done, we find two changes in neural function to relate to vigilant readiness: a negativity produced by such contingencies and a simultaneous increase in the power of the identifyable rhythmic electrical activity of the brain structures involved. The negativity (CNV) was initially described by Grey Walter (1967) and has been studied in some thousand experiments since (see review by Tecce, 1972). My own investigations (Donchin, Otto, Gerbrandt and Pribram, 1973), as well as those of others (Rebert, 1972; Grey Walter, 1967) of this neural phenomenon have shown that such negativity is recorded primarily from those structures specifically involved in a particular performance -- that the CNV is not some overall change in total brain functioning. The same result holds for the increase in power in the rhythmic electrical activity recorded from various brain structures -- occipital alpha, hippocampal theta, etc. (see review by Bremner and Pribram, 1974).

Readiness is thus achieved by some mechanism that overrides the propensity of neural tissue to habituate. Observations on both monkey and man have shown that the frontal cortex and the amygdala are both critically involved in the orienting-habituation-readiness mechanism. An internal rehearsal process appears to be disrupted by the lesions (Pribram, 1969a). And the evidence suggests that this internal rehearsal is initiated whenever the organism proposes to do something about the stimulus configuration -- in more operational language: when aspects of the situation are due to the consequences of the organism's own behavior, these sequences and their context (con-sequences) tend to become reinforcing, i.e., more and more readily repeatable. That reinforcing occurrences override habituation has been experimentally demonstrated (Glickman and Feldman, 1961; Glickman and Schiff, 1967); by what mechanism reinforcement occurs is as yet not established, although the suggestion has been made that norepinephrine secreting fibers composing the medial forebrain bundle (coursing to and from the amygdala and frontal cortex) are especially important (Stein, 1968).

<u>Selection and Reasoning:</u>

The cortical structures involved in simple discrimination performances are well known and comprise what is usually known as the posterior association areas. In non-human primates each of these cortical areas serves only a single sensory modality; in man, the problem of higher order poly-sensory association cortex remains an open question (see Pribram, 1971). When discrimination reversals are given or when alternation and delayed response problem solving is demanded frontal and limbic systems are involved. These studies have been extensively reviewed (see e.g., Pribram, 1969b). Most recently my research has aimed to demonstrate the brain mechanisms which make possible selection and reasoning. This research has shown efferent pathways from the association cortex coursing to motor structures such as the basal ganglia and colliculus and to the input systems per se. The effects of posterior and frontal stimulation appear to be largely reciprocated in their effects on the electrical activity of these more peripheral structures (Spinelli and Pribram, 1966, 1967). This may account for the finding that during selection the coherence of rhythmic brain activity is enhanced thus narrowing the contour of the power spectrum obtained (this is true of both hippocampal theta and cortical alpha). When reasoning is demanded however, a juggling of dominant frequencies occurs. During reversal training for instance, the power peak developed during the original discrimination is retained for a considerable period while a new peak is developed independently at a neighboring frequency (Bremner and Pribram, 1974).

Summary:

During the opening session of the first conference on human learning, I emphasized the fact that all learning is not alike. I developed the theme by identifying four basic processes and today I have delineated some of the specific brain mechanisms involved in each. Obviously, these four basic processes can be combined to form some 24 identifyable types of learning ($4! = 4 \times 3 \times 2 = 24$). Nor do I claim that this classification of basic processes is exhaustive. Nonetheless, I do claim that it is essential to continue the search for a simplifying basis for understanding the variety of forms of learning that confront us. Not only is this necessary to our scientific theoretical formulations, but also to applications in education where practical applications of our efforts finally bear fruit. As of now the laboratory developed "laws of learning" have had very little to say to the practitioner. I believe this is due to the misconception that learning is simply determined -- that some single drive-reduction, or drive-induction (incentive), or reinforcement mechanism can account for the facts of learning. A more subtle analysis is required -- and brain systems research can contribute substantially to such an analysis as I hope to have demonstrated.

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