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IN SEARCH OF THE ELUSIVE SEMIOTIC

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INTRODUCTION

The contributions to primatology of the Yerkes Laboratories have been legion. Most of these contributions have centered on the biological, psychological and social nature of the chimpanzee - and occasionally the other great apes. There was a period in the history of the laboratory, however, when the focus of interest shifted to the primate brain. It was during this period that I came under the spell of the laboratories. They were then headed by Karl Lashley and staffed by persons who in due time have become eminent in their own right: Donald Hebb, Roger Sperry, Josephine Semmes, Edward Evarts, Kao Liang Chow, Austin Riesen, to name a few. All of us felt deeply the heritage left to us Robert M. Yerkes and in our research attempted to blend this heritage of behavioral research with Lashley's genius for asking penetrating questions about mechanism.

Today I want to address still another focus of interest that has pervaded the work of the laboratories in the more recent past. This third focus is man himself. Comparing man to his nearest relative should provide insights which might otherwise escape notice. Most ambitious of these comparisons are those which deal with the chimpanzee's social-cultural and communicative achievements to which some form of "language" is central.

The work of the Kellogs, then that of the Hayes with Vicky (in which I became intimately involved when Lashley retired and I helped guide the laboratories through the next few difficult years), and now the current studies by Rumbaugh and his colleagues attests to the continuity of this theme in the concerns of the Yerkes laboratories. It is this theme which I

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want to elaborate in my presentation - feeling, however, that I am bringing goals to Newcastle. Project Lana appears to me to be much more fascinating than what I am about to report. Nonetheless, since my interests are so parallel to those that motivate Project Lana, perhaps avenues of productive interchange will be opened by the presentation.

The nineteen-sixties were marked by a great interest in human language and the structure of its grammar -- an interest rooted in the conviction that the syntactic organization of ordinary linguistic communication is similar in its construction to programs used by digital computers (Chomsky, 1957; Miller, Galanter and Pribram, 1960). More recently, however, it has become increasingly clear that semiotics -- the study of the manner in which meanings become linguistically communicated -- must go beyond syntax to semantics if it is to achieve a coherent view of what occurs when words are used in thinking and speaking.

I want to take this opportunity to recapitulate and extend an earlier proposal (Pribram, 1973) relating meaning to grammar in terms of the concepts of information measurement theory and of mathematical psychology by applying this formulation to data on the organization of brain function. The basic tenet of the proposal is a simple one: grammar relates to meaning as partitions relate to the sets which they partition. Its application to human language however is not so simple. Although considerable progress has been made in our understanding of the elementary syntactic structures underlying the partitioning process, we are only on the threshold of comprehending what it is that becomes partitioned. Here we will attempt to tackle issues such as the distinction between information, in its strict definitional sense, and meaning; the nature of distinctive features and poetic connotation; and the brain organizations which dispose toward context-free, and those which dispose toward context-sensitive constructions.

VARIETY AND CONSTRAINT IN THE DETERMINATION OF MEANING

Early attempts at applying information theory to human linguistic communication failed to provide fundamental insights largely due to the fact that the theory itself remained confused on one basic issue -- the distinction between uncertainty-reducing and uncertainty-enhancing communications. Information measurement was based on the ability of a communication to resolve a specified uncertainty established by prior communications on a set -- a circumscribed domain within which the communication occurs. The amount of reduction of uncertainty was measured in bits of information, uncertainty describing the complexity of the number of partitions on the set necessary to specify the organization of that set. A cursory look at the functions of communication, however, reveals that all communications do not reduce uncertainty. Some merely repeat prior communications, leaving the uncertainty unaffected; and some in fact increase it by demonstrating a mismatch, a prior erroneous partitioning of the communicative domain. The confusion arose because "errors" were uniformly labelled "information" in the sense defined above as the reduction of uncertainty.

The original Shannon-Weaver (1949) definition of information proved extremely useful in handling problems of artificial communication systems such as the telephone network. But Shannon-Weaver "information" has nothing in common with the demonstration of error or mismatch; the amount of information contained in a message does not depend on the processing of its errors. A long-distance telephone conversation, for example, may be interrupted by a periodic beat frequency resulting in errors in interpretation on the part of the receiver -- uncertainty as to intention demanding repetition of the communication. Such repetitions -- redundant communications -- however contain no additional information. They are aimed at overcoming errors produced by the form of transmission of the communication. Seven years after the advent of Shannon-Weaver information theory Ross Ashby (1956) detailed this distinction in terms of variety and constraint, variety defined as independence of functioning of parts of the set and constraints defined as the limits on this independence -- or dependence amongst parts of the set. Variety is thus measured as information and constraint as redundancy.

According to the Shannon-Weaver interpretation, variety and constraint are reciprocals: a bit of information reduces variety, thus enhancing constraint. The example of the long-distance telephone conversation, however suggests such a simple conceptualization of the relationship to be mistaken. Specification of information and redundancy, to be useful in human communication, must be sought in other terms. Specifically, in any communication system endowed with memory -- the ability to compare successive communications -- measures on variety and constraint refer to wholly different aspects of a message. In such systems variety entails novelty (see e.g. Brillouin, 1962), thus coming closer to the ordinary meaning of information. Further, in such systems with a memory component, constraints operating on a communication deal with its form -- the structural relationships among communicative events, among parts of the communicative set. In short, in such systems variety and constraint operate among relationships between partitions. Only when the partitions produce complete independence among parts of the set can strict

Shannon-Weaver information theory be applied; when, on the other hand, the partitions can be shown to be partially dependent, as in the hierarchies or net-like configurations of computer programs, a theory of meaning -- of relationships -- becomes necessary. The theory of information thus becomes a special case of the theory of meaning.

The problem can be stated in other terms. A human communication may have a referent. Ordinarily referent communication conveys information. Philosophers have long distinguished, however, between reference and meaning. Meaning goes beyond reference into use, the use which information conveyed can have to the sender or receiver. Pierce, for example, has stated, "We are apt to think that what one means to do and the meaning of a word are quite unrelated measurings of the word meaning." (Pierce, 1934; see also Pribram, 1972). He points out that meaning is always related to doing, the pragmatic, in some way. In short, meaning relates to the actions of organisms, actions which have survival value.

The relative dependence among parts of a communication, and their dependence on use, cannot be ascertained from the syntactical structure of the communication alone. The relationship among the parts of the set is only trivially given by the structure of the partioning system. Thus the many popular examples of meaningless but grammatically correct utterances ("the pillow runs the dog") or sentences with ambiguous meaning ("they are flying planes"). Meaning is given not by the fact of partitioning per se, but by the dependence among parts of the set and among successive sets. It must thus derive from some additional property of the parts which defines their relationship to one another. It is this property which has proved so elusive.

BRAIN AND SYNTAX

In attempting to come closer to the elusive semiotic let us first describe, as did linguists of the nineteen-sixties, some properties of syntax with the hope that in so doing we will be able to specify more precisely what it is that is missing. Rather than rely exclusively on an analysis of human language, however, let us reach into the annals of comparative behavior and brain function for guidance.

In his address of acceptance of the Chair at Edinburgh, as well as elsewhere, Vowles (1970a; 1970b) suggested that phylogeny could perhaps be characterized by the evolution of a grammar of behavior. The proposal was that whereas invertebrates show finite-state Markov-type constructions and vertebrates have developed phrase-structure type hierarchies, human behavior, including communicative behavior, can be distinguished by its transformational components. This sweeping theoretical statement, though perhaps wanting in detail (now gradually being provided by other ethologically oriented scientists such as Beer, 1973) struck a deep responsive chord as, at the time, Peter Reynolds was busy organizing observations on the development of primate play by attempting to specify the rule structure -- the syntax -- characterizing these interactions (Reynolds, in press). The grammar of play, however, is but a specific instance of the plans, programs, or syntax by which behavior in general becomes organized.

The essence of a grammar is its capacity to order sequential dependencies among behaviors, including communicative behaviors. When a behavior reflects only the immediate state of the organism doing the communicating, according to Vowles' proposal that behavior or communication can be thought of as being determined by a Markov type process, very much as a set of dice or the image produced by a kaleidoscope depends only on the configuration of the parts at the moment they cease to be perturbed. When a behavior or communication becomes organized according to some set of rules determining the order in which the parts take place, however, a phrase-structure grammar, to use the terminology of linguistic grammarians, becomes entailed. To the student of comparative animal behavior it is quite obvious that human linguistic communications are not the sole examples of such phrase-structure grammars. A good deal of the concatenation of egg-rolling, mating, or maternal behaviors in birds, for instance, depends on "phrases" of behavior triggering some state in the communicant to whom such behavior is addressed, this state then giving rise to another set of behaviors in turn retriggering a change in state of the original communicant, etc. (see for example Hinde, 1959; 1966). The important point to be made here is that it is never a single communicative act or single behavior that is triggered by such changes of state: an entire sequence is generated. The concept of generative grammar, so popular in current linguistics, is thus applicable to many forms of animal as well as human communication. What is believed to be unique in human communication is both the intentionality of the "triggering" and the communicant's ability to transform the rules which determine sequences. Transformational rules must be imposed upon the more primitive, phrase-structure rules to account for the complexity of human utterances.

Brain research has distinguished two types of rule structures, those which are context-free and those which are context-sensitive. Specific brain mechanisms have been identified for each of these categories. Context-free constructions are ordinarily produced by way of making a sensory discrimination -- visual, auditory, somatosensory or gustatory.

Discriminations allow one to identify objects and events and, ultimately, to name them irrespective of the environmental situation in which they may occur. A rose is a rose is a rose whether it appears one one's lapel or in a garbage pail, in an arrangement or alone in a context-free construction.

About twenty years ago that part of the monkey brain dealing with context-free constructions was discovered (Blum, Chow and Pribram, 1950; Harlow, et al., 1952). For vision this is located in the inferior part of the temporal lobe. For many years lesions of the temporal lobe in man had been known to give rise to visual disturbances; it had been thought, however, that this was due to involvement of Henle's loop, a portion of the optic radiation believed to course round the anterior portion of the temporal horn of the lateral ventricle. When neurosurgeons, then, began performing anterior-temporal lobectomies without producing visual deficits, the existance of Henle's loop was seriously called into question. In fact, visual difficulties in man, especially those resulting from disturbances in the subdominant hemisphere, arise as they do in the monkey from involvement of the temporal cortex itself (Milner, 1971; 1974).

Behavioral analysis of discrimination deficits in monkeys is thus relevant to the present problem. What this analysis reveals is that cortex lying in the posterior portion of the hemisphere, bounded by the projection areas, can be divided into zones, each associated with a primary sensory modality: somesthesis, taste, audition and vision (Pribram, 1969). Disturbances in sensory discrimination are not due to an inability on the part of the animal to distinguish features differentiating two objects. Monkeys who have learned to visually discriminate between an ashtray and a tobacco tin in a simultaneous situation, for instance, though they show a deficit as compared to their normal controls are not able to use this ability in a successive discrimination in which the tin and ashtray are placed in a central location and the animal is required to go right if the ashtray is present and left if the tin is present (Pribram and Mishkin, 1955). Further tests have shown the difficulty to be the monkey's relative inability to utilize distinctive features of the stimulus. The number of such features utilized by operated as compared to control animals has in fact been quantitatively related to the severity of the deficit (Pribram, 1960; Butter, 1968). Neurological analysis of the mechanism involved in this utilization of distinctive features shows that the pathways involved course downward from the temporal cortex into the visual system, as far as the retina intself (Spinelli and Pribram, 1966; 1967).

The temporal cortex may thus be conceived of as a mechanism for generating rules which categorize more primitive stochastic imaging processes determined by input within the primary visual system (Pribram, 1974). Such rules would allow invariances in input to be identified (Pribram, 1960). When the temporal cortex is removed and environmental context altered, these invariances can no longer be utilized to guide behavior. Context-free constructions are therefore dependent upon rules (i.e. phrase-structure rules) generated by the temporal cortex. The significance of differences in sensory input is a function of such rules of utilization. Significant meanings, or signs, are therefore due to context-free, phrase-structure-type constructions, the mechanism involved being the generation of such rules by the temporal cortex and their imposition through efferent control on sensory input.

A great deal of work has also been done on context-dependent constructions. The basis of poetic connotation, context-dependent communications in animal behavioral studies have as their paradigm delayed response or delayed alternation performance so extensively used in physiological psychology. The usefulness in these tasks of a particular behavioral act, or stimulus, depends not on the momentary situation but on what has gone before: on the context in which performance occurs. In this instance the context is a temporal one. Here again the discovery was made some twenty years ago that the frontal portion of the monkey's brain is involved in the performance of this type of task (Pribram, 1954). Later the limbic systems and frontal lobe were shown to be anatomically related (Pribram, 1958) and the limbic portion of the forebrain also implicated in the proper performance of delayed response or delayed alternation type tasks (Pribram, Wilson and Connors, 1962; Pribram, Lim, Poppen and Bagshaw, 1966).

Many years ago the delayed response paradigm was modified, thus: instead of showing the animal where a piece of food might be hidden, interposing a delay, and then asking him to find it, a token was instead placed in sight of the animal, removed, and then the animal was asked to locate food where the token had appeared. This task, the so-called indirect version of the delayed response problem, was in turn made more complex until animals were shown to be capable of working for tokens themselves, useable only at a later occasion for retrieval of food by deposit in a "chimpomat" (Pribram, 1971). Tokens with use specific to the situation in which they occur are usually referred to as symbols, symbolic meaning differing from significant meaning by this very fact of context dependence. The monkeys were thus shown to be capable of a considerable degree of symbolic behavior.

One shortcoming of initial tests used in brain research to establish significant and symbolic behavioral capabilities of primates and trace the neural mechanisms involved in such behavior has been that we have asked animals to communicate only through some very simple instrumental act. This deficiency was recently overcome in two studies performed with the chimpanzee. The Gardners (1969), working at the University of Nevada, taught their chimpanzee Washoe the use of American Sign Language. They succeeded in constructing a vocabulary of approximately 150 words by which Washoe could communicate. Premack, in another experiment at the University of California at Santa Barbara (1970), developed the token technique with his chimpanzee, Sarah, until she could eventually communicate with the trainer by organizing tokens in several orders of complexity. As might be expected from the context sensitivity of tokens, Premack found Sarah's behavior to be highly sensitive to changes in training personnel. The meaning of the tokens seemed to be too dependent on the specifics of the training situation. Subhuman primates, in short, have been taught to communicate with both signs and symbols, using both context-free and context-sensitive constructions.

These studies of brain function have distinguished several orders of constraint among communicative events, of "use" of syntax-finite state, significant and symbolic-relevant to understanding the meaning of human communication. It is customary to think of these orders as being hierarchically organized. Perhaps this is so. However, the fact that the limbic and frontal parts of the forebrain are so intimately related in delayed alternation and delayed response problems, while posterior cortex seems to deal with discriminations of every sort, suggests that instead of a trichotomy, as outlined by Vowles, four fundamental processes may actually be distinguishable. When discriminations are involved, the relationship between sign and referent seems to be a straightforward one: a sign refers to an invariant part of a stochastically determined kaleidoscopic image. Perhaps there is a similar relationship between some finite-state-type processes(es) and the symbolic domain. One of the puzzles plaguing brain research on the frontal lobes and limbic system is that, whereas delayed alternation is disrupted by lesions of any limbic or frontal system, delayed response is not (Mishkin and Pribram, 1954). Delayed response behavior thus seems more specific to the frontal cortex than to the limbic forebrain. Could it be that the more ubiquitously involved delayed alternation behavior represents a finite-state-type process? If so, what is the difference between the state determining alternation and the finite state process involved in discrimination? We have already noted that referent behavior addresses an invariant in a communication. It is tempting then to suggest that alternation addresses some, but not all, variances in a communication: i.e. only those variances which recur with some discernable regularity. Recurrent regularities are, of course, ubiquitous in the internal environments of organisms. They lead to "steady" states characterized by the alternation of satiety with hunger, thirst, sexual and respiratory need, and the like. Hence homeostatic, rather than stochastic, properties determine these states.

Basic to homeostatic processes are the spontaneously recurrent cyclicities of neuronal networks. Circadean rhythms and other biological clocks derive from such cyclicities and Pittendrigh (1974) has suggested a description of such rhythmicities in terms of systems of mutually coupled oscillators. In such systems dominant foci of packmakers evolve by virtue of "entrainment", or capture, of neighboring oscillators into a single periodicity. Pattee (1971) has constructed a functional model of such a system and developed a set of theoretical views linking this model with linguistic modes of operation. Thus "entrainments" can be viewed as the primitives of symbolic processes, just as stochastic, Markov mechanisms are conceived as basic to communication with significant referents. In such a scheme entrainment deals with recurrent variances, while stochastic mechanisms serve to process invariances. A good deal is becoming known about entrainment; the thesis put forward here should therefore yield readily testable hypothesis. A guide to their formulation can be taken from Sherrington's classical analysis of spinal cord mechanisms, in which the difference between the organization of antagonistic and allied reflexes can be discerned. Some years ago an attempt was made to pursue this insight (Pribram, 1960), and it may be worthwhile to review the distinction in the light of more recent information.

The difference between stochastic and entrainable systems is that stochastic processes can be mathematically described in finite terms whereas entrainable processes fall into the domain of infinite algebras. Mathematical learning theories of the nineteen-fifties and -sixties developed the potentialities of stochastic processes in great deal (Bush and Mostellar, 1955; Estes, 1959). More recently G. Spencer Brown has developed a simple calculus explicating some of the logical paradoxes occurring in the "infinite", entrainable, context-dependent domain (1972). The formal properties of context-dependent processes have also been explored both in terms of graph structures (Harary, Norman and Cartwright, 1965) and by computer programmers (e.g. Quillian, 1967). But perhaps the most penetrating insights have come from Shaw's application of the mathematics of symmetry groups to the problem (Shaw and Wilson, in press). He points out that such groups are infinite as opposed to finite and thus capable of handling the persistent puzzle of the generativity of grammars. Such generativity derives from the fact that an infinite set "provides a structure for which it is true that a proper subset is equal to the total set". Thus symbols can apply to a potentially infinite equivalance class of instances.

BRAIN ORGANIZATION AND MEANING

As we have seen, insights obtained from studies of brain function address the question of the structure of syntax; they do not, however, directly address the fundamental issues of the organization of meaning. In Chomsky's terms, what has so far been discussed concerns 'surface' rather than 'deep' structure. In Jakobsen's vocabulary, a fundamental question still to be explored is the nature of features and what makes them distinctive.

Again brain physiology has recently had a good deal to say about these issues. Units in the nervous system have been discovered which are sensitive to surprisingly specific features of the envirnoment (e.g., Mountcastle, 1957; Werner, 1973; Evarts, 1967; Hubel and Wiesel, 1962; Barlow and Hill, 1963; Spinelli, Pribram and Bridgeman, 1970). Further, these features appear to be differentially organized into configurations in each hemisphere of the human brain. Thus after age seven or thereabouts damage to the right hemisphere in most of us results primarily in the impairment of spatial relationships while damage to the left hemisphere impairs primarily temporal relationships, including the linguistic abilities which are the concern of this paper. In an elegant series of experiments Sperry (1970) demonstrated the separateness of these functions in patients whose hemispheres have been severed by sectioning of the corpus callossum -- the major commissure which ordinarily connects them.

These important contributions, however, also pose significant problems of interpretation for the neurolinguist. Are we to search for a unique brain cell for each distinctive feature of language? If so, do such brain cells respond innately to their respective features, or do they become responsive only through 'experience'? As most feature sensitive units discovered so far deal with the spatial aspects of input, how do such feature sensitivities relate to linguistic structure in a hemisphere supposedly not processing these features?

Many of these puzzling questions resolve themselves when the evidence is looked at from a somewhat different theoretical perspective. The common interpretation that feature sensitive cells serve as "detectors" for their respective features has been found wanting. Thus Pollen and Taylor (1974), for instance, have shown that the output of "complex" cells in the visual cortex (assumed by most to be detectors of lines of specified length and/or orientation) is not invariant across all transformations of input other than orientation. Changes in luminance, line width, number of lines, and their spacing all influence the final output of such cells. Only a network of neurons could thus separate their orientation specificity from that to one of these variables, say to luminance. Several groups of investigators (Pollen and Taylor, 1974; Campbell and Robson, 1968; Glezer, Ivanoff and Tscherbach, 1973) have shown that a more accurate interpretation is that such cells are sensitive to spatial frequencies, as opposed to lines of particular length and orientation *per se*, and that it is therefore in error to think of them as simple "line detectors".

The change in interpretation from sensitivity to line orientation to one of sensitivity for spatial frequency has major consequences. As discussed elsewhere (Pribram, 1971; 1974; Pribram, Nuwer and Baron, 1974), a spatial frequency sensitive mechanism allows image reconstruction with a richness and resolution of detail not possible given only outline feature detection. Perhaps of greater importance, however, is that fact that spatial frequency analysis of light in the visual system, just as temporal frequency analysis of sound in the auditory system, is accomplished wave mechanically and not in the digital, quantal domain characteristic almost exclusively of the operation of present-day computers. This radical shift in emphasis allows us to formulate alternative hypotheses as to the organization of deep structure in the brain and, as a special case, what might be involved in distinguishing features in speech.

Phoneticians have already clarified the fact that distinctive features of spoken language are most readily analyzable in terms of wave forms generated by the vocal apparatus - vocal cords, larynx, oral cavity, tongue and lips. The Haskins Group for years has been simulating sounds using spectral techniques (e.g. Liberman, Cooper, Shankweiler and Studdert-Kennedy, 1967), and one recent study was able to decompose speech sounds into some six to eight separate components by performing a Fourier analysis taking into account both spatial and temporal relations (Port, personal communication).

If, in fact, distinctive features of human linguistic communication may be identified as wave forms, the deep structure of such communications may be found in the wave mechanical domain. The computer, with its programmable digital information processing capabilities, has been of great service both in date analysis and as a model of syntactic superficial structure. Is there not, then, an information processing system which can serve with equal efficacy as a model (and in due time perhaps also for data analysis) in our search for the elusive semiotic -- the deep, semantic structure of language?

Optical information processing systems are just beginning to be recognized as useful analogues in studies involving the wave mechanical domain. Aside from their image-constructing capabilities they partake in organizations characterized by the distribution of information produced by interference among wave fronts. This distributed aspect of their organization makes them especially attractive to brain scientists who have been puzzling for years over storage via apparent distribution of input over reaches of brain surface resulting in functions strongly resistant to local damage.

Organizations in which information is optically distributed are called holograms (Gabor, 1969; Stroke, 1969). The proposal therefore has been made that spatial and temporal frequency analysis performed by the brain are indicative of holographic-like neural processes (see Pribram, 1966; 1971; in press; Pribram et al, 1974). It must be borne in mind, however, that it is only the organization of the paths taken by light in optically distributed information systems which is intended when we say that holograms serve as a model for neural processing. The energy involved in the latter case is electrical, not photic.

The suggestion to be seriously entertained is that deep structure, in the final analysis, is semantic structure, and that semantic structure derives from a distributed neural organization akin to that found in the holograms of optical information processing systems. Note that deep structure is not synonymous with holographic organization but derived from it. Syntactic structures, as delineated in the earlier parts of this paper, partition -- map -- a holographic, distributed store of information into useful, meaningful organizations for the organism.

Mapping of a distributed, more or less homogeneous matrix into useful organizations is a commonplace of biology. Thus the morphogenetic field becomes organized into useful structures through the action of inducers which derepress the potentialities of the DNA molecules imbedded in those fields. Thom (1972) recently developed a topological mathematics to describe such mappings. The approaches of Pattee (1971) and Shaw (Shaw and Wilson, in press) described in the section on grammar achieve the same end using even more powerful, mathematically distinct techniques. All of these related approaches can be used to define the origin of the distinctive features of language. Each feature would be occasioned by continuous interactions but the ensuing stabilities, the distinctive features per se, would result when interactions gel into non-linearities -- a process Thom terms a "catastrophe".

Perhaps the difference between right and left hemisphere function may best be conceptualized in terms of whether processes leading to image formation or non-linear catastrophic processes come to be emphasized. More likely, however, a simpler distinction based on sensory (e.g. auditory versus visuosomatosensory) and especially motor mode is responsible. Reynolds (in press) has suggested that differential use of the hands by primates necessitated specialization of function of the cerebral hemispheres. Abler (personal communication) has further suggested that when such specialization occurs a unique problem for innervation of midline structures such as the tongue arises. He has experimentally demonstrated that unless one innervation (usually the right in right-handed persons) dominates, conflicting signals from the two hemispheres disrupt function. In short, once hemispheric specialization has occurred, dominance must follow if the midline structures involved in speech are to function harmoniously. And dominance entails some catastrophic-like "decisional" mechanism which more or less stably "takes over" the innervation of the midline.

CONCLUSION

Neurolinguistics in the near future may be able to contribute as richly as has psycholinguistics in the immediate past to classical problems of human language. Definitions of variety and constraint within the framework of information measurement and processing theory can be used to provide the defining properties of grammar and meaning. Comparative behavioral conceptualizations can be invoked to relate many of the details of syntactical structure to brain organization. Three levels and two modes of organization can be identified: significant (context-free) and symbolic (context-dependent) modes each can operate on a transformational, a phrase-structure or a primitive level. The primitive in the significant mode may be stochastic and finite state; in the symbolic mode entrainable, infinitely recurrent regularities are the most likely candidates. Thus infinite as well as finite state mathematics can be fruitfully applied to the fundamental problems of human linguistic communication.

Not only is the concept of distinctive features capable of being analyzed neurologically, but the nature of the elusive deep structure itself related to our current knowledge of characteristics of information storage in the brain. Models of linguistic organization based on both digital computers and optical information processing systems, such as holograms, may be invoked to resolve essential questions. The hope here is that these proposals and outlines will serve to organize the attack against some of the hitherto intransigent problems which continue to plague an otherwise rapidly advancing linguistic enterprise.

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