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BRAIN AND MEANING

Abstract

Meaning has two distinguishable meanings: (1) extensional reference which can be ostensively identified, and (2) intensional context which is evoked. These two types of meaning are served by two classes of brain systems: those of the posterior convexity for reference and those of the fronto-limbic forebrain for context. Syntactic procedures based on still another set of brain systems coordinate these two types of meaning in the production of natural languages and other language-like systems, such as music. This essay reviews the evidence for these relationships and some of the issues that remain to be resolved.

BRAIN AND MEANING

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There are few species-specific behaviors that characterize homo sapiens, and even these are found in primordial form in the great apes. The list is interesting: the fact that females have the potential for being sexually active throughout their cycle, also true of pygmy chimpanzees (Rumbaugh, 1980); humor and laughter, also present in Koko the gorilla (Patterson & Lindon, 1981); the ability to create cognitive commodities (such as bicycles, automobiles, agricultural crops, musical instruments, churches and the like), observed by Goodall in chimpanzees in the wild (Lowick-Goodall, 1973). But, as in the case of the natural languages, where signs in American Sign Language can be taught to the extent of three-word strings, these abilities remain primitive (Gardner & Gardner, 1969; Patterson, 1979). Only humans make complex natural languages and language-like structures such as mathematics and music. Of these, the natural languages are the most universal. The question therefore arises as to what is different about homo sapiens that allows linguistic communication.

One answer is that human brains make the difference: brain damage localized to separate brain systems is accompanied by disturbances of language which distinguish different linguistic aspects from one another. This essay reviews the evidence for these distinctions.

Reference

The Development of Referential Processing

A neurolinguistic analysis of language systems can profitably begin with speculations on the origins of language framed in the distinctions derived from Charles Peirce (1934). Linguistic processing most likely began as visual-gestural communication, and only later became audiovocal. There is considerable evidence that initially primate communication proceeded by establishing a reciprocal relationship between image (icon) and information (indicant, index) using visual-gestural mechanisms. Thus, as noted, apes have been taught to indicate their communications by American Sign Language and the cave paintings of early man suggest considerable skill at iconic symbolization. A plausible scenario of the origins of speech might be that frustrations with visual-gestural communication due to darkness around campfires, distance, or other awkward circumstances became expressed in vocalizations which then became differentiated into tokens for the unseen gestures. In this fashion, the vocal expressions became symbols and signs initially standing in lieu of images (icons) and information (indicating objects and events), and then supplanting the gestures entirely because of overwhelming adaptive advantage. In short, the expressions became words.

It is likely that these first expressions of frustrations were holophrases related to actions. The human propensity is to nominalize and so holophrases indicating experienced processes became nouns denoting things. But things deprived of action become static and therefore fail to adequately represent experience. Predication resolves this inadequacy and the propositional utterance is born.

Image and Information in Referential Processing

As documented by Piere Marie (1926), Bay (1964), and Hecaen and Angelergues (1964), a central language processor based on the auditory projection system and its associated cortex accounts for much of language processing. With use of adjacent accessory "poles" in the precentral, parietal, and occipotemporal cortices, expressive, somatic, and visual communication is established simply by an overlap of functional areas. The primary auditory projection is ideally placed for such overlap. The derivation of the acoustic system from gill and jaw is reflected in the cortex by the fact that auditory projections encompass both somatic area II superiorly, and motor face and mouth areas anteriorly Pribram, Rosner & Rosenblith, 1954). Even when such proximity does not exist, "associations" within the primary projection are present innately or established through learning (Pribram, Spinelli & Kambak, 1967). Electrocortical evidence obtained in the visual mode shows cells to be present that react to auditory stimulation (Spinelli, Starr & Barrett, 1968), to the presence or absence of reinforcement, and to the intention of making a specific movement (Spinelli & Pribram, 1970). The route by which such "associations" are established is unknown, but in the auditory cortex the path need not be long.

For the most part, the central language processor is located in the left hemisphere in right-handed individuals. As noted, words and propositions initially refer to objects and events, and as such become indicants pointing to alternatives. In view of the fact that when such indicators are audiovocal they are arbitrary, they constitute symbols (according to Peirce's definition). Shannon and Weaver (1949) developed a measure of the number of alternatives indicated by a communication. This measure was called the quantity of uncertainty reduced by the amount of information conveyed. Symbolic linguistic communication, primarily a left-hemisphere function, thus reflects the information processing competence of this hemisphere.

What then is the role of the homologous fomations of the right hemisphere? To the extent that parts of images can "stand in" for the whole, such standins become signs of the images --- and of the objects and events which are imaged. The corner of a mouth, a raised eyebrow, becomes a sign not only of the fact of a person but of the expressions being communicated by that face. Signification, non-verbal communication, primarily a right-hemisphere function, thus reflects the image processing competence of the right hemisphere.

Pragmatics

Syntagmatics and Rhetoric

But by what mechanism are these higher-order symbols and signs achieved? A most likely possibility is that pragmatic processing involving the functions of the frontolimbic forebrain continuously modifies image and information processing once vocal expression becomes involved in communication. The limbic systems are primarily concerned with monitoring the states of the organism that are expressed as hunger, thirst, sex, etc. (Pribram et al., 1967; Pribram, 1971). In addition, the intensive aspects of pain and temperature are regulated by these systems (Pribram, 1971, chapters 9 & 10). These basic functions are reflected in higher-order processes as establishing the needs and desires, i.e., the basis for the utilities that determine what reinforces the organism's behavior (Douglas & K. H. Pribram, 1966; Douglas & B. J. Pribram, 1969; Pribram, 1977a, b). In essence, therefore, these systems establish an internally determined pragmatic <u>context</u> within which the organism approaches the world. This internal context is expressed in aphasics when they communicate their feelings through gestures and explicatives, and with "emotional" language and simple songs (Myers, 1967; Robinson, 1976).

The limbic forebrain shares regulation of context-dependent behavior with that part of the frontal cortex which has been developed so highly in humans, and which has been shown to function as the "association" area of the limbic systems (Pribram, 1958). This polar portion of the frontal cortex makes possible the distribution of behavioral responses according to the probability that the behavior will have an effective outcome, i.e., that it will be reinforced (Pribram, 1961). Thus frontal cortex participates in determining the utilities which, as noted, organize the context within which an organism approaches his world. (Utilities are defined in economic theory as derived multiplicatively from desires and probabilities.)

Linguists and psychologists have up to now paid little heed to the pragmatics of language. The line of evidence and reasoning pursued here suggests that pragmatic processes are derived from mechanisms that establish desirabilities and the probabilities of reinforcement given a particular state of desire. The linguistic expression of such pragmatic processes would therefore be episodic, i.e., would be dependent on momentary state. Some mnemonic mechanism must also be involved since state change is monitored and outcome (reinforcement) probability estimates are made. Cognitive psychologists often refer to such mnemonic processes as short-term, but more recently and accurately the process has been defined as "episodic" memory (Pribram, 1984; Tulving, 1970, 1972) to distinguish it from more universally applicable semantic stores.

Forming a Language: The Role of Pausing and Parsing

In nonhuman primates, lesions of the frontolimbic forebrain but not of the posterior convexity, interfere with the performance of a task which can be used as a model for relating episodic, context-dependent constructions to linguistic processing. This task is the delayed alternation procedure during which a subject is reinforced for alternating his responses between two boxes. During the interval between opportunities for response, an opaque screen hides the boxes. The screen is kept in place for 5--60 seconds, depending on how difficult one chooses to make the task. When the interval between opportunities is equal, subjects with frontolimbic lesions invariably fail the task; i.e., they seem to forget which box they previously chose, successfully or unsuccessfully. When, however, the intervals between opportunities are made unequal though regular --- e.g., 5 sec before box 1 must be chosen and 15 sec before box 2 is the correct choice --- then the deficit is quickly overcome (Pribram, Plotkin, Anderson & Leong, 1977; Pribram & Tubbs, 1967).

The reason for performing the above experiment was that it seemed as if a monkey's failing the alternation task were in much the same situation as a person hearing or reading a paragraph in which letters and words were separated by equal intervals. Thus MARESEATOATSANDDOESEATOATSANDLITTLELAMBSEATIVY is unintelligible until parsed into words. In general, chunking (Miller, 1956) has been found to be an essential processing mechanism when the limits of competency are involved (McGuinness & Pribram, 1975). In humans, the pragmatic, prosodic aspects of frontal portion language are handled primarily by the right hemisphere (Moscovitch, 1983; Zaidel, 1983), perhaps its frontal portion. The tests used to determine this are flashes --- noise, pattern masks, and tests for rhyming based on meaningful and non-meaningful words, i.e., matched semantically or phonetically.

It is remarkable that the same parts of the brain are responsible for the operations that determine context by way of pragmatic processing and those that determine the pauses necessary to parsing utterances, i.e., expressions into phrases and words. This identity of neural substrate suggests that <u>pauses</u> in speech provide the contextual cues within which the logical content becomes related to the speaker's state: his mood, his momentary desires, and probability estimates of success in meeting those desires. Pragmatic processing <u>forms</u> (gives form to) the linguistic production. The prosodics, the pauses, inflections, and the dynamic range of speech form the context in which the content of the communication occurs. This rhetorical, idiosyncratic aspect of language formation may responsible for the rapid transformation of a language into dialect by an intimate group and thus the variety of languages used by man.

Further, this relationship between pragmatics and the <u>form</u> of language expression may underlie the process of predication. Making words into sentences would not be necessary unless a statement about state, about desire and belief (probability), etc., were at stake. Thus predication stems from pragmatic processing while nomination, i.e., making words more universally meaningful, results from semantic image and information processing.

Syntactics

The Structural Aspects of Language

What then is the role of syntax? Syntax must reflect both the pragmatic form, the rhetoric, of language and its referential meaning, its semantics. Neurologically, both the frontolimbic forebrain and the posterior convexity of the brain are directly connected to such subcortical motor structures as the basal ganglia, which are known to regulate postural and sensory sets (Miller, Galanter & Pribram, 1960). These basal structures are, in turn, intimately connected with the centrally located motor cortex which organizes skills.

Over the past three decades a great deal has been learned about the hierarchical nature of processing information by the use of symbols (Pribram, 1977). The construction of programs that make serially operating computers into effective data storage and retrieval mechanisms has shown that such programs must categorize data into items which can be universally retrieved and are thus essentially context-free. Hierarchies of such context-free items (bit —> bytes —> words) are then compiled into assemblers, which in turn are the elements of more complex programming languages.

The importance of this distinction between syntactic forms is brought home by the types of grammar that have been found useful in analyzing linguistic performances. The simplest of these are the stochastic and state-dependent grammars in which any particular utterance falls out, as it were, of the probabilities set up by previous utterances. Flesch counts of the incidence of usage of words in the English language are based on such a model and have been found wanting in explaining not only natural speech (Howes, 1964, 1957a, b) but also language disabilities due to brain damage (Winograd, 1977). A more effective, though still limited, model has been phrase structure grammar in which the hierarchic relationships between groupings of utterances are mapped. One of Chomsky's major contributions has been to demonstrate the limitations of the phrase structure grammar and to suggest (1) that transformations (operations on redundency, on the repetitive aspects of language) occur in language; (2) that these transformations are governed by rules which transcend the hierarchical organizations of phrase structures; and (3) that these rules evoke meaning. What has occupied Chomskian linguistics for the past twenty years is to specify what such rules might look like.

Procedures

More recently, cognitive psychologists interested in simulating human experience and behavior have found that exclusive reliance on hierarchical organization does not reflect the full nature of human perception, action, and communication. Even the relatively simple process of compiling demands arbitrary decisions that are specific to the "episode" or situation, e.g., the particular computer in use. More and more, these investigators have resorted to the construction of episode-specific program clusters that can be flexibly switched into an ongoing program whenever a situation so demands (Miller, Galanter & Pribram, 1960). As noted earlier, in primates evidence has accumulated to support the hypothesis that the frontal cortex operates such a context-sensitive mechanism and becomes, in this sense, the executive organ of the brain (Schank & Abelson, 1977).

Computer scientists have also been developing organizations of programs that can make them function more usefully. The new developments go under such names as "procedures" (Miller & Johnson-Laird, 1976; Schank & Abelson, 1977), "scripts" (Pribram, 1973), etc. They are eminently pragmatic in that they group together ina cluster those routines (parts of programs) that are repeatedly used, mark the cluster, and call up that marked cluster whenever it is needed. The advantage of such procedures is that computation can simultaneously proceed in several clusters and the results of the computation flexibly addressed in response to some overarching "executive" program (Pribram, 1973).

Music and Language

I have elsewhere (Pribram, 1973) drawn the comparison between the functions of the frontal cortex of primates and such executive procedures. The neurobehavioral evidence thus suggests that a procedural pragmatics is the basis for transformational rules. Bernstein has identified in his pursuit of linguistic analysis of music (1976) one very powerful set of procedures for us: (a) repetition, (b) variation in repetitions that generate novelty (note that "invention" and "inventory" share the same root), and (c) deletions of repetitions which generate potential meanings through ambituity (thus we are dealing once again with a generative syntax). My neurobehavioral results obtained on nonhuman primates suggest that this set of procedures is generally applicable to the problem of specifying the nature of transformations and of a generative grammar. It is for this reason that I found Bernstein's contribution exciting and valuable.

The analysis, should it prove viable, has an interesting consequence for understanding music and natural language --- especially as used in poetry. These consequences are that the evocative aspects of cognitive competencies are not so much due to transformational rules as they are to transformational procedures. The search for hierarchically organized rule-structures leads in every instance to a phrase-structure grammar. Transformations on these phrase structures are episode-specific, involve a large amount of historicity, occur within the context of phrase structures, and are extremely context-sensitive. Whether one wishes to call such relatively arbitrary (i.e., context-dependent) procedures "rule"-governed remains an open question. The resemblance is more to a case than to a phrase structure, as has been emphasized by Fillmore (1968). The important point is that the structure of transformational procedures is distinct from a hierarchically organized phrase-structure grammar, and that different brain systems are involved in organizing the hierarchical and transformational structures.

I believe that comparing music with natural language is most rewarding: Despite the severely limited information processing and resulting referential semantics, music is rich in meaning. This meaning is derived from pragmatic procedures which also enrich natural languages, especially in their poetic usages. Pragmatic procedures are based on repetition, on variations of repetitions, and on deletions of expected repetitions. It is processes such as these which have been shown to be functions of the frontolimbic formations of the forebrain which can therefore be considered to construct the long sought-after principles of transformations which are the cornerstone of Chomskian generative grammar. Transformations are shown, however, to be procedural in that they are episode- and context-specific rather than hierarchically organized: Case-structural rather than phrase-structural. Pragmatic variations on repetitions, deletions of expected phrases, associative clusterings involving a large amount of historicity can be sharply distinguished from hierarchically organized rule structures. This analysis, based on the study of music, has thus proved a fascinating and unsuspectedly fruitful foray into cognitive science.

The Inside and Outside of Language

A Cultural Hypothesis

The fact that aphasics can still express their feelings through expletives, and even "emotional" language and simple song (which, as noted above, have been shown to be related to the limbic portions and the right hemisphere of the forebrain) would fit the conception that the neurolinguistic system damaged in aphasia primarily addresses semantic processes and does not involve pragmatics. How, then, does the pragmatic aspect of human language become involved in communication? It is possible that this occurs only through the environment --- that there is no corticocortical connection nor subcortical convergence involved at all. When the neural information processing system becomes sufficiently powerful (i.e., has sufficient memory and coding capability), it can treat the tokens of expression (of others and of self) as signs, signifying social rather than physical situations. This power, of course, would be immensely enhanced when memory is augmented externally, and the evocative as well as referential meaning feedback to the brain's language processor by way of the senses.

Pylyshin (1983) has suggested a test of cognition penetrability to determine to what extent brain networks are essential to a linguistic processor. When the process is shown independent of global cognitive experience, it is likely to be "wired in." However, Pylyshin is addressing only the hierarchical aspects of referential processing, not the pragmatics of language as outlined here. Thus his test of cognitive penetrability might be a test of the involvement of pragmatic mechanisms, not a test of extracranial participation.

Localization

With this neurolinguistic analysis as background, and given the cultural hypothesis as a viable alternative, let us nonetheless examine carefully the possibility that somewhere within the brain, the semantic and pragmatic aspects of language become integral. There is little question that in the human cerebral cortex areas can be found that are either absent in subhumans or present only in rudiment. The large development of frontal cortex in terms of man's vaulting forehead was already noted by the early phrenologists. Equally impressive is the growth of the posterior nonprojection cortex centering on the angular gyrus, the confluence of parieto-, temporal, and occipital cortical formations (Blum, Chow & Pribram, 1950). Does the quantitative increase in these cortical structures herald the qualitative transformational change expressed as human language?

My answer to this question is a tentative "no." I reason as follows: if the cortical growth is per se to be responsible for the development of human language, evidence should lead to two major language "centers": one well forward in the frontal cortex, the other in the tissues around the angular gyrus. The evidence for and against a major category of aphasia centered on the third frontal convolution provides an excellent starting point. If the far frontal cortex (Broca, 1861, 1878; Pribram, et al., 1967) is to be given weight equal to Wernicke's (see Pribram, et al., 1967; Pribram, 1971), the idea that new cortical accretions are responsible for human language is tenable. So let us look at the problem handed us by Broca.

All of the evidence (Luria, 1964, 1966; Penfield & Roberts, 1959; Teuber, 1960; Pribram et al., 1967) shows that expressive aphasia does not result from damage as far forward as the frontal pole. To fit the facts of a cortical topography peculiar to man, even Broca's area (the third frontal convolution) is too ventral and posterior a location for a new language "center" to be developed in tissue not present in subhuman primates. Electrical stimulation of the third frontal convolution, in all primates including man, arrests facial mimicry as well as syntatic processing. It is thus a parapyramidal motor area. Further, this is not the locus of the new cortical accretion.

The place of the territory around the angular gyrus in the development of human language is not so easily disposed of. Aphasic symptoms result when the cortex of the angular gyrus is damaged. But again the match is imperfect (Bogan & Bogan, 1976). All of the evidence points to the posterior part of the superior temporal gyrus as the locus involved in Wernicke's syndrome and holds that Wernicke's is the locus of processes involved in referential comprehension. Also, as in the case of the frontal cortex, although the fit is better, the angular gyrus is not exactly the place of maximum new accretion of cortex in man; it is somewhat too close to the Sylvian fissure to be equated with the considerable anatomical development of intrinsic nonprojection cortex.

These mismatches, although some of them are slight, give me an uneasy feeling when the origin of human language is attributed simply to the growth of new areas in the frontal and posterior intrinsic cortex.

Connections and Disconnections

If not the new areas directly, perhaps their development brings with it new functional pathways that allow expressive and conceptual aspects of communication to interact. This possibility is detailed in the aphasia literature under the heading of disconnection syndromes most recently advocated by Geshwind (1965). Earlier versions of the disconnection view were voiced by Freud (1953), Liepman (1912), and Dejerene (1914). All these authors adduce specific case histories in support of their suggestion that one or another major pathway is pathologically involved in the production of a language (or language-related) disorder. Unfortunately, to date comprehensive and quantitative behavioral analyses such as those produced by Bay (1964), and Hacaen and Angelergues (1964), have not always been performed on such patients. Often the anatomical verification of the lesion also leaves a good deal to be desired: multiple damage may be reported when a single focus is held responsible for the disorder; histological serial analysis of the entire brain is seldom performed.

Furthermore, Zaidel (1983) has shown a dissociation between prosodic and phonemic reference in patients with callosectomy. The connections may well play an important role in normal linguistic processing and disconnections under certain pathological conditions may produce severe disruption of such processing. Nonetheless, it is equally well documented that these connections in and of themselves are not always <u>the</u> essential ones necessary for normal processing to occur.

Arraigned against the corticocortical disconnection hypothesis are a great number of subhuman primate experimental findings. In the monkey it appears that intrahemispheric corticocortical connections play a minor, if any, role in the organization of the psychological process. But monkeys do not talk the way humans do. Is the difference in importance of corticocortical pathways the critical reason why they do not? Or do the corticosubcortical connections shared by all primates, which up to now have been ignored, play the critical role?

The Centrencephalic Hypothesis

Convergence of pragmatic and conceptual processing at some subcortical locus or loci is, on the basis of subhuman evidence, a serious contender as an explanation for the emergence of human language. Subcortical formations are rarely given more than cursory inspection when the brains of aphasics are studied. When the lesion is caused, as it so often is, by disease of the middle cerebral artery, the basal ganglia, parts of the thalamus, and many fiber tracts are affected. Penfield, among others, opted on the basis of his experience for a centrencephalic mechanism in the production of human language (Penfield & Roberts, 1959). Careful surgical excisions of cortex so rarely produce lasting changes in man or monkey that one is literally driven to the subcortical formations for an answer to questions of localizing the site of disturbances.

The one exception to this is, of course Wernicke's zone in the posterior part of the superior temporal gyrus (Bogan & Bogan, 1976). Here, because neurosurgeons tread with extreme caution, data are hard to come by but opinion is strong and to the point: in the adult, at least, damage is not to be hazarded.

The centrality of Wernicke's zone and the possibility that subcortical convergences are critical to the production of human language make up the centrencephalic hypothesis. This hypothesis takes strength from the subhuman primate experimental results that show that the nonprojection cortex associated with the auditory mode lies in the midtemporal region (Dewson, Pribram & Lynch, 1969); that most likely this cortex exerts its role in audition through efferents coursing to subcortical stations in the auditory projection systems (Dewson, Nobel & Pribram, 1966; Nobel & Dewson, 1966); that removal of this cortex results even in monkeys in the inability to discriminate vowel sounds (Dewson & Cowey, 1969); and that contrary to any other cortical removals in subhuman primates, unilateral damage plays havoc with certain (conditional) types of sensory discriminations (Dewson et al., 1966; Dewson & Burlingame, 1975).

The subcortical locus upon which the symbolic and signifying processes can conveniently converge has not as yet been conclusively established. From the results of experiments on nonhuman primates, however, the basal ganglia and related nuclei in the upper midbrain are the best candidates (though Ojeman (1983) suggests that the thalamus should be seriously considered). These are motor structures involved in producing the muscular settings necessary to action. It should therefore not be too surprising that communicative and linguistic acts also depend on the function of these motor structures.

Recently, data obtained in the computerized tomographic image reconstructive technique (CAT Scans) have provided strong evidence that lesions of the basal ganglia are indeed involved in aphasia. Thus Naeser 1983) has shown that the head of the caudate nucleus is ordinarily damaged in Broca's aphasia and from our own laboratory evidence presented by William Gordon (1983) has indicated that basal ganglia lesions <u>rather than</u> cortical involvement characterizes the syndrome. Gordon has reviewed his findings and those of others in a lucid and robust support of the centrencephalic hypothesis.

In addition, other work by Gordon and Illes (in preparation), utilizing patients with Huntington's Chorea, has related linguistic structure, such as pausing and the relative frequency of use of open- and closed-class words, to the severity and presumed location of brain damage. These studies have implicated the farfrontal cortex and head of the caudate nucleus in prolonged pausing and excessive reliance on open-class words (which becomes extreme in Broca's type of non-fluent aphasia). Only when the chorea is far advanced and damage to Wernicke's area of cortex and the underlying basal ganglion, the putamen, occur, does linguistic communication become semantically impoverished.

Thus both the corticortical disconnections and the centrencephalic hypothesis continue to be tenable. Techniques to test them are available. Quantitative behavioral evaluations of aphasic patients and serial histological reconstructions of their lesions and resulting degeneration (e.g., retrograde change in the thalamus) will go a long way toward supporting or disconfirming the disconnection hypothesis. Especially important is a comprehensive evaluation of whether language-related and nonlanguage disturbances are correlated or whether they are separable when a disconnection syndrome is suspected.

With regard to the centrencephalic hypothesis, the current vogue in electrical stimulations of deep brain structure should uncover evidence regarding possible subcortical language mechanisms, as should the lesion evidence coming from computerized tomography and nuclear magnetic resonance. Such studies, over the next decade, should provide the necessary crucial facts to test the centrencephalic hypothesis.

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