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Semantic and Syntactic Processes in Aphasia: A Review of the Literature

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Recent investigations of lexical and syntactic aspects of language comprehension in aphasia are reviewed. It is argued that these studies support theoretical assumptions concerning the functional independence of various components of normal language processing. Studies of the structure of the lexicon in aphasia provide support for componential theories of lexical semantics in that different types of features of meaning can be selectively disrupted under conditions of brain damage. Studies of sentence comprehension support the existence of a syntactic mechanism that is independent of lexically based heuristic strategies for assigning meaning. There is evidence that these independent elements of language are subserved by different portions of the dominant hemisphere of the brain. Focal brain damage can thus cause selective disruption of components, allowing the separation of elements that are highly integrated in the normal adult. Studies of aphasic language, therefore, provide a valuable source of constraints on theories of normal language processing.

In a recent influential book, Fodor, Bever, and Garrett (1974) stated: "It is . . . the sad truth that remarkably little has been learned about the psychology of language processes in normals from over one hundred years of aphasia study" (p. xiv). This view may not be far from the truth. Historically, the study of language dissolution has been almost exclusively the province of neurologists, whose concerns were not so much with the normal organization of language processes as with the correlation between brain structures and specific language behaviors. Although traditional work in aphasia has largely failed to provide direct information concerning the organization of normal language processes, it has established a solid foundation from which more recent aphasiological research can address these questions. What is most important is that this early work has established that although no two aphasics are exactly alike either in the nature of the disorder or in the consequent language performance, it is the case that there are discernible patterns of dissolution. Focal brain damage to the dominant hemisphere (left hemisphere in most right-handed individuals) does not simply result in an overall undifferentiated reduction of language capacity or a random constellation of symptoms (Geschwind, 1970, 1972; Luria, 1970). On the contrary, it appears that different parts of the brain subserve different linguistic functions.

For psychologists, however, of more importance than the brain/function correlation is the identification of different types of aphasias characterized by predictable constellations of symptoms. The occurrence of such well-organized patterns of dissolution may reflect natural divisions in the organization of language processes in normal adults. Armed

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with this well-established fact that language dissolution follows predictable patterns, recent investigators of aphasic language have begun to ask questions that are of concern not only to aphasiologists but also to psychologists concerned with normal language functioning.

There are two arguments that can be made concerning the importance of aphasia research to the study of normal processes. First, models of normal language functioning should not be inconsistent with the data obtained with aphasic populations. Since current theories of language are so underdetermined by data, it would be foolhardy to ignore a source of constraint on permissible theories of language. The second and more important argument is based on the belief that there is ultimately more than a trivial connection between psychological processes and the brain. This stronger claim is the one that motivates this review. It is specifically argued that in the ideal case, brain damage selectively impairs discrete components of language, so processes that are highly interdependent in the normal adult can be more clearly identified. Even in cases involving complex patterns of dissolution, it is possible by a judicious process of comparing various patient types to identify components of processing that are so closely intertwined in the normal adult that they are irretrievable. Ultimately, research motivated on the basis of this claim should generate new hypotheses about the structure of language processing.

This review focuses on aphasia research that addresses two components that are involved in sentence comprehension: lexical and syntactic processing. The basic issues addressed at the level of lexical processing concern the question of the representation of lexical information. At the syntactic level, the concern is with determining whether syntactic processes are independent of semantic and heuristic processes in sentence comprehension.

Comprehension in Aphasia

Research in aphasia has typically focused on deficits in the productive capacities of brain-damaged patients, that is, on overt speech behavior. Discussion of impairment of the ability to comprehend spoken language has been limited, for the most part, to impressions that a patient's comprehension is relatively "impaired" or clinically "intact." Such global descriptions of the phenomenon of language comprehension obscure the fact that a highly complex interactive system of components and processes underlies the extraction of meaning from a particular configuration of words. It is likely that damage to different parts of the brain will differentially disrupt these components of comprehension, just as the various elements of productive speech are differentially affected.

Several recent investigations have looked more carefully at the process of comprehension in an attempt to disentangle the components involved and to determine whether they can be selectively impaired in comprehension failure (Goodglass & Baker, 1976). One result of these efforts has been the identification of elements of comprehension deficit that are not readily apparent to clinical observation. For example, the class of patients usually said to have relatively intact comprehension (those with anterior damage)[1] is now believed to be deficient in the ability to integrate correctly understood lexical items into certain types of syntactic frames (Caramazza & Zurif, 1976). The impression of intact comprehension in the face of impaired syntax may be produced by the patient's adoption of communicative strategies based on redundant cues to meaning that might occur within the sentence or the surrounding context.

It also appears to be possible to examine comprehension breakdown in the class of patients who exhibit poor comprehension (those with posterior damage). On the basis of their speech production, these patients are said to lack an understanding of individual lexical items but to have retained an implicit

[1] There are several classifications of aphasic symptoms currently in use; for present purposes the general division between patients with focal damage to the anterior and to the posterior portion of the dominant hemisphere is used. Patients with anterior damage include *Broca's* and *expressive* types; those with posterior damage include *Wernicke's* and *fluent* aphasics.

understanding of the syntactic rules for combining words into grammatical sentences. Although lexical disruption is undisputed as a cause of the comprehension failure suffered by these patients, it is not known to what extent syntactic difficulties can be implicated as a contributing factor, since an understanding of syntax in the absence of lexical comprehension is difficult to measure. Nevertheless, the comprehension failures exhibited by these patients remain amenable to further analysis, since the lexical disruption experienced is rarely total (Goodglass & Geschwind, 1976). Most often, some element of a word's meaning is retained, so a patient knows the class to which a word belongs (e.g., color terms, body parts) without grasping its full meaning. Thus, the meaning components that are spared can be examined and compared with those that are lost in an attempt to identify the elements involved in comprehension failure.

In general, therefore, there is reason to expect that the process of comprehension can be analyzed into component elements to pinpoint the site of breakdown; that is, language comprehension is no more a unitary, all-or-none phenomenon than is the process of language production, and there is no reason to believe that comprehension disruption should be global. Rather, just as in productive disturbances, brain damage should cause damage selectively.

Lexical Knowledge in Aphasia

A great deal of research in aphasia has been directed at describing the parameters of individual word loss associated with various loci of brain damage (Geschwind, 1967). Some reduction of available vocabulary appears to be a very general symptom of all types of aphasia (Goodglass & Geschwind, 1976). Loss of an individual lexical item is most often viewed as a *word-finding* difficulty and may be signaled either by a patient's inability to name a single item that is presented or by his inability to find the right word to express a message he has spontaneously formulated. These two types of word-finding difficulties, which necessitate different levels of involvement of both sensory stimulation and a knowledge of syntax, would be expected to present different types of problems to the brain-damaged speaker, and indeed they do (Geschwind, 1967; Green, 1970). The present discussion is limited to problems involving confrontation *naming*, that is, the patient's ability to provide a verbal label for an object that is presented to him.

Since the main focus of this review is the problem of comprehension impairment, it is necessary to consider the possible parallels and divergences between the ability to understand a word and the ability to produce it. Such a comparison necessitates a selective treatment of language comprehension, however, in that it deals only with the referential aspect of meaning—with the relationship between the word and the object or event to which it refers. Comprehending a word's meaning involves more than merely being able to identify a referent (Alston, 1964); the *sense* and *reference* aspects of meaning are discussed below.

For present purposes, however, the processes of both naming and lexical comprehension are limited to the referential situation; in that way the similarities and differences between the two can be readily compared. For expositional convenience, the processes involved in both naming and lexical comprehension are viewed as consisting of three separate stages. Each of these stages involves many other substages and processes, any one of which may be of central importance to a particular constellation of symptoms. The purpose of this outline is not to provide a comprehensive description of the possible levels at which disruption can take place. It is instead an attempt to describe some general correspondences between what must happen for a patient to be successful in a naming task and in a comprehension task, and thereby to delimit the domain of interest of this review.

In the typical naming task, a patient is presented with a concrete object or a picture and is asked to produce a name for that object. The ability to apply a name correctly within this limited context can be said to involve the following three elements:

1. An encoding stage, in which the stimu-

lus is perceived (either visually or through some other sensory modality) and the features that permit its identification are abstracted from the total perceptual event.

2. A central stage, in which the information abstracted from the stimulus in the encoding stage is integrated and mapped onto a semantic representation—a conceptual category of which the stimulus object is a member. A second mapping process then relates that semantic representation to a particular lexical item, that is, the word that is its name.

3. A production stage, in which the lexical representation that has been accessed is translated into a set of motor commands that make possible the articulation of the correct phonological sequence.

Comprehension tasks take several different forms; the interest here is in tasks that assess understanding of individual lexical items rather than combinations of words. A patient is most typically asked to point to a particular item whose name is supplied aurally. In some cases the referent object is part of a relatively open-ended set; that is, it can be anything in the immediate environment—body parts, pieces of furniture, and so forth. Often, however, a set of items is presented to the patient, and he must point to the referent of the word presented. The stages involved in this process can be described as follows:

1. An encoding stage, in which the acoustic stimulus is encoded as a particular phonological shape.

2. A central stage, in which the phonological matrix representing a particular word is mapped onto a semantic representation that contains, among other things, descriptive information about the physical form a referent of the word would take.

3. A response stage, in which the description of the referent object generated by the semantic representation (in the form of a mental image, a perceptual frame, a set of propositions, etc.) is compared with the possible objects available in the environment and a response is made based on that comparison.

These parallel three-part schemes segment the processes of both naming and comprehending single words into stages that can be thought of as either peripheral or central to the task at hand. The peripheral processes involve those aspects of functioning that link the central cognitive operations and linguistic structures to the outside world. In the encoding phase of the naming paradigm and in the response phase of the comprehension task, the mechanisms involved are perceptual, most often visually perceptual. Both the production phase of the naming task and the encoding phase of the comprehension task involve aspects of phonological processing.

There is great potential for selective disruption of one of these peripheral processes such that the capacities of verbal production and comprehension are differentially affected. The operations that have been labeled here as *peripheral* involve finely tuned powers of discrimination and integration within several different sensory modalities. Although disruption at the level of these peripheral mechanisms has received a large share of the attention of workers in the field (e.g., Geschwind, 1965; Luria, 1973), the concern of this review is with the potential for disruption of the component that is central to both naming and comprehension in the normal adult. This *central* processing phase, involving both procedural and structural elements, has only recently been considered as the possible level at which the aphasic patient's semantic system is disrupted.

At the core of all of the mechanisms and operations involved in determining a word's meaning there must be some form of semantic representation of the informational elements that make up a particular conceptual entity. Although no assumptions will be made at this time about whether that information is represented as sets of features, or propositions, or as a mental image, the assumption is made that the processes of both understanding a word's meaning and finding the right word for a particular situation involve accessing this stored representation. Also included as part of this central component are the processes involved in translating perceptual input (auditory, visual, etc.) into a form that permits access to the correct representation. In addition, another set of mapping procedures is needed to relate the information

contained in the semantic representation to the proper output mechanisms.

It is logically possible that either the mapping procedures or the semantic representation itself may be disrupted by damage to the brain. Thus, it is possible that the mapping procedures that relate input and output to the semantic representation may be disrupted while the representation itself remains intact. However, a pathological condition affecting the structure of the semantic representation would also have a disruptive effect on the procedures that mediate between the representation and the peripheral mechanisms, since a part of the information necessary for the mapping to take place would be lost. Thus, an impairment at the level of the semantic representation itself would appear to have the most generalized impact on a patient's ability to process lexical information.

The foregoing discussion is intended to specify the set of phenomena or, alternatively, the level of linguistic functioning with which this review is concerned. The domain of specific interest is limited to the central mechanisms involved in extracting word meaning, and it is believed that the same processes and structures are part of both naming and lexical comprehension. The next section examines the extent to which research in aphasia has implicated these central processes as factors in both naming and comprehension deficits.

Research on Naming Impairment

Virtually all aphasics exhibit some impairment of naming ability, but such impairment is rarely total (Goodglass & Geschwind, 1976). This situation has led to many attempts to determine the variables that influence whether a given word will be lost. Factors such as word frequency (Wepman, Bock, Jones, & Van Pelt, 1956), form class (Marshall & Newcombe, 1966), picturability (Goodglass, Hyde, & Blumstein, 1969), semantic category (Goodglass, Klein, Carey, & Jones, 1966), and operativity (Gardner, 1973) have all been implicated, to varying degrees, in naming disruption.

One important and stable result of this effort has been the delimitation of two qualitatively different types of naming disorder, which are highly correlated both with other patterns of symptomatology and with locus of damage. One group of patients (those with focal damage to the anterior portion of the dominant hemisphere) has many concrete and picturable nouns available and often performs quite well, albeit very slowly, in naming tasks. For these patients, naming disruption appears to be part of a more generalized disturbance, since other symptoms include laborious articulation and a severe disruption of productive syntax.

A second group that can be defined on the basis of naming performance displays a notable deficiency of concrete, picturable nouns and most often fails to provide the correct name for an object, although their responses are many times not far off target (Rinnert & Whitaker, 1973; Schuell & Jenkins, 1961). This impairment carries over into spontaneous speech, which is characterized by fluent articulation and intact syntax, but a lack of content words. This type of naming impairment, termed *anomia,* is generally associated with lesions in the posterior portion of the dominant hemisphere.

Although this standard classification of aphasic symptoms captures the gross differences in naming disruption, there is some indication that more finely tuned techniques of measurement are needed to isolate unitary constellations of symptoms, even within one of the major classes as described above. An important recent review of the literature on aphasia has provided the following caveat to a summary of the two major classes of naming disruption:

> Clinical impression suggests that word-finding difficulty is an inclusive term for several qualitatively different defects that are not distinguished by ordinary naming tests. Thus, the patient who appears to have dissociated the sound from the concept gives a very different impression from the patient who is slow but sure or the patient who acts convincingly as though he has recovered the inner sound of the word but has trouble in recovering the articulatory movements for it. (Goodglass & Geschwind, 1976, p. 403)

Such clinical impressions are valuable because they underscore the complexity of the problem; however, they are cited here for a

different reason. Both the clinical and the experimental literature on naming disruption tend to account for the impairment in terms of peripheral mechanisms or retrieval failures. The possibility of a disruption of the semantic representation itself is less often entertained. The passage quoted above mentions three qualitatively different types of naming disorder in which the disrupted process is inferred to be a retrieval deficit (the first and second example) or a problem of articulation (the third example).

The apparent belief that naming disruption is the result of retrieval failure, that is, that the semantic representation will be found to be intact if it can be activated, is not limited to clinical observations but pervades the experimental literature as well. One manifestation of this view has involved the attempt to differentiate the set of items that are likely to be named from those that are not. The results of this differentiation are often discussed in terms of the concept-arousing potential characterizing the items most likely to be named.

Gardner (1973) tested the ability of patients with anterior and posterior lesions to provide names for pictures of items that were either "operative," that is, discrete and readily manipulated, or "figurative," that is, not easily manipulated. Both sets of words were equally "picturable" and occurred with equal frequency in the language. The naming advantage obtained for the operative set was explained by the postulation that naming depends on the capacity of the stimulus to arouse some subset of the actions or sensory experiences usually involved in activity with the object. Gardner argued that operative items were named most easily because they aroused associations in several sensory modalities, whereas the figurative items were limited to the visual modality.

More direct evidence concerning the role of sensory modality in naming has been provided by Goodglass, Barton, and Kaplan (1968). These investigators found no difference in patients' ability to name objects based on whether they were presented for visual, tactile, olfactory, or auditory naming. This result indicates that naming disruption is not a function of peripheral problems at the level of processing sensory input. Rather, Goodglass et al. argued that the uniformity of naming ability across modalities "supports the notion of a process which intervenes between the perception of any stimulus and the arousal of its name" (p. 494). Goodglass et al. cited the research of Bisiach (1966), which demonstrated that obscuring the perceptibility of an object adversely affected patients' ability to name it but did not affect ability to recognize it. In addition, if information about the object was available through several different sensory modalities, even though it was partially obscured, the probability that a name would be provided was greatly increased (North, 1971). Thus, North argued that the various sensory modalities contribute information additively toward the arousal of an object's name. Again, retrieval of the (presumably intact) concept is believed to be disrupted.

The research on sensory modality reported above did not discriminate between patients with different types of naming difficulties, but there is some evidence that the amount of information present in a stimulus item might not have the same importance for patients with anterior and with posterior damage. In a large-scale investigation of the effects of semantic category on naming and comprehension deficits, Goodglass, Klein, Carey, and Jones (1966) found that the items with the greatest informational value (objects and actions) were not named more easily than the items with little informational value (letters, numbers, and colors). Anterior aphasics exhibited uniform ability to name across all categories, and the posterior aphasics did most poorly with the object names.

The difficulties of posterior aphasics in naming concrete objects do not appear to be amenable to a concept-arousal explanation. The most frequent nouns in the vocabularies of these patients are nonpicturable, abstract, and often very general terms that convey little information (e.g., "something," "anybody"). Although early work explained the presence of this type of word as a simple overrepresentation of high-frequency words in the vocabularies of these patients (Wepman et al., 1956), more recent work has argued that such indefinites are not only of high fre-

quency but are highly predictable elements within the context of a sentence (Goodglass, Hyde, & Blumstein, 1969). Since patients of this type can produce grammatical sentences and have difficulty finding words, they maintain fluency by substituting words that are highly predictable and high in frequency but low in informational content.

The available literature on naming disorders has not provided a great deal of information concerning the level at which the process of naming is disrupted. The work reviewed here favors a view that a concept mediates between the level of sensory stimulation and the production of the word. No specific information is provided about how that concept might be structured, and dissolution of structure as a correlate of naming disorder is not considered. Disruption is presumed to be at the level of retrieval; that is, the pathology is believed to impose a limitation on the processes necessary to arouse the concept, such that increased information may be necessary before the concept can be activated.

Naming and Semantic Structure

It is somewhat surprising that an explanation of naming impairment has historically avoided a consideration of disruption at the level of the semantic representation, since it has long been recognized that the incorrect names produced by aphasic patients are generally not random (Head, 1926). Rather, the word that is generated is often related in meaning to the target word. This phenomenon would seem to require an explanation based on the representation of semantic information, since that is what appears to be confused. Nevertheless, early attempts to account for this "out-of-focus" naming invoked retrieval difficulties. For example,

> The patient may not . . . be able to perceive the word so well that he is able to understand it or to repeat it, but sufficiently enough so that the sphere of meaning to which it belongs is elicited, and the patient may summon up another word belonging to this sphere. (Goldstein, 1948, p. 91)

More recent research has focused on the relationship between the words that are involved in naming substitution. Schuell and Jenkins (1959, 1961) observed that the erroneous naming responses of aphasic patients resemble the word associations of normal individuals. More recently, Rinnert and Whitaker (1973) analyzed a large corpus of published data in an attempt to determine the semantic relationship between what a patient said (or wrote) and the correct target item. When the two words (the word produced and the target) were compared on the basis of shared semantic features, it was found that the two terms tended to share features representing major semantic categories. The features on which they differed were specific functional distinctions. For example, substitutions of *pen* for *pencil* and *pipe* for *cigar* retain information about the superordinate category of *writing implements* or *smoking materials,* but confuse some specific but important distinguishing features. When these data were compared with word association norms for normal speakers (Postman & Keppel, 1970), a striking similarity was found. Rinnert and Whitaker postulated that the word associations of normal adults are based on the same lexical organization that is disturbed in aphasia.

If the naming errors produced by aphasic patients are comparable to normal word associations and if both can be taken as an indication of how the internal lexicon is structured (cf. Whitaker & Whitaker, in press), then it is reasonable to think that language-impaired patients could themselves produce word associations that might provide information about semantic structure. A direct test of the extent to which normal word associations are impaired in aphasia was reported by Howes (1967). A standard word association paradigm was used to elicit verbal associates, and results indicated selective disruption of the associational network, based on site of damage. Patients with anterior lesions produced essentially the same set of associations as did a normal control group, although they responded quite slowly. Patients with posterior damage, on the other hand, produced erratic associations bearing little resemblance to the normal data. Thus, the patient class with the most severe word-finding difficulties displayed a serious disruption of associational structure.

A study has recently been reported that attempted to specify more precisely the dissolution of associational structure in aphasia and to link that breakdown directly to naming impairment (Goodglass & Baker, 1976). Using a procedure designed to determine a patient's knowledge of the verbal associates of a target word without necessitating the production of the associate, these investigators attempted to determine how semantic structure was affected in various types of comprehension impairment. In addition, they were interested in finding out whether the structure of the semantic network was a factor in the patient's naming ability. Target words were eight high-frequency and eight low-frequency picturable nouns depicted on cards and presented visually for naming to groups of anterior and posterior aphasics, nonaphasic brain-damaged patients, and nonneurologically impaired controls. The pictures were shown a second time while a series of 14 words was read. Of these, 7 were unrelated distractors and 7 bore specific types of associational relationship to the target. One of these was the name of the item, and other types of associations were the superordinate category to which the item belonged, the name of an attribute typically characterizing the item, the name of another (coordinate) member of the same category, the name of an action associated with the item (functional associate), and the name of a situation or context in which the item would be expected to be found (functional context). Subjects were instructed to squeeze a response bulb whenever one of the aurally presented words "reminded" them of the pictured target. Responses were analyzed in terms of both reaction time and error rate, which revealed similar patterns.

All subjects recognized the name of the pictured objects equally well. With regard to semantic structure, the nonaphasic control subjects and those with anterior lesions exhibited a similar pattern of associations. For all three of these groups the clearest associates were the superordinate category name, the descriptive attribute, and terms related by situation or context (functional context). Although the other associates were also included in the semantic network by these two groups, responses to these items were markedly slower than responses to the three strongest associates.

The subjects with posterior damage (and generally more severe comprehension deficits) differed from the other patients in their pattern of responding in that they had great difficulty recognizing both functional contexts and functional associates as related to the target. Goodglass and Baker suggested that the failure to recognize this type of association between words signaled a qualitative change in the semantic organization of these patients. Further, they suggested that the inability to retrieve words in a naming task may be in part a function of breakdown of the semantic structure. Thus, even though all patients could recognize the name of the depicted object, many patients had not previously been able to produce that name. All patients responded most quickly to associates of words they had been able to produce, and the patients with posterior damage were much less likely to respond to associates of words they had failed to produce. Thus, the ability to produce a name for an item seems to involve a rather complete understanding of the many elements that are associated with that name.

Goodglass and Baker postulated that the retrieval of a name depends on the convergence of concurrently activated associations that trigger the appropriate naming response. To the extent that a picture of an object arouses an incomplete set of associations, naming ability will be impaired. This position seems to be somewhat different from the additive model of information accumulation mentioned above, in that now the semantic network that converges to trigger naming is presumably structured in accordance with principles that may predict the pattern of dissolution. That is to say, breakdown in structure would be expected to follow an orderly pattern, with some elements (in this case functional correlates) being disrupted before others.

In this view, then, brain damage can have a direct effect on the elements normally associated with a word's meaning, such that some elements are not aroused by a stimulus object. There is no clear indication of whether

these associational elements have been lost in the process of disruption or whether they may be more difficult to retrieve for some reason. Within this context, it becomes interesting to consider the effect on naming of providing functional information with the presentation of the stimulus. That is, will posterior patients (who appear to have lost the functional associations of some words) improve in their ability to name if the functional information is provided in the stimulus context?

A recent study has attempted to assess directly the contribution of various types of information residing in the to-be-named stimulus to patterns of naming disruption (Whitehouse, Caramazza, & Zurif, in press). The central question was whether aphasic patients could attend to variation in several types of perceptual elements, as well as functional context information, in applying a label to an object. Using a paradigm designed for use with normal adults (Labov, 1973) and subsequently modified for use with children (Andersen, 1975), Whitehouse et al. designed 24 stimulus pictures that were variations of a modal *cup*. Both discrete (presence or absence of handle) and continuous (height/width ratio) features were varied in the stimulus items to yield a set of 24 line drawings of containerlike objects.

Functional context was provided by additional pictures presented to the subjects along with one of the container drawings so that the context picture showed some form of pouring into the container. A *cup* context depicted a coffee pot pouring coffee into the container; a *bowl* context showed a cereal box pouring out into the container, and a *glass* context presented a picture of ice water being poured.

In applying a name to these items, normal speakers integrate stimulus information in a manner that underscores the interdependence of perceptual and functional information (Labov, 1973); that is, when the perceptual information presents a clear member of one of the available categories (e.g., a cup, bowl, or glass) the naming decision is predicated on that information alone, and shifts of functional context do not affect the name that is applied. However, if the perceptual information adds up to an object on the boundary between two categories (e.g., neither a clear-cut bowl nor cup), then functional information will be utilized in determining the label to be applied.

Therefore, two questions are addressed in presenting this task to aphasic patients. First, it is important to determine whether such patients can use the perceptual information in a stimulus item to determine whether that item is a clear or borderline member of a category. That is to say, performance should indicate the extent to which aphasic patients are sensitive to the fuzzy boundaries between conceptual categories. Second, this task allows a straightforward test of the ability of aphasic patients to use functional information in determining a name to be applied.

The first question is addressed by analyzing the consistency with which a particular name is applied to each stimulus item. The clear (prototypical) members of each of the three categories should be consistently named, whereas the borderline members should be named inconsistently across subjects and trials. In general, the anterior aphasics in this study exhibited this pattern; they named prototypes consistently and appeared sensitive to the fuzzy boundaries between concepts. The posterior aphasics showed no such pattern and either named all items inconsistently or appeared to base their selection of a name on only one perceptual feature, for example, presence or absence of a handle.

The effect of functional context on the application of a name is determined by noting the number of times an item named in the neutral condition is given a different name when a particular context is provided. Again, the anterior aphasics appeared sensitive to the functional context provided, appropriately changing the object's name with shifts in context. The posterior aphasics, on the other hand, did not appear to be sensitive to the functional information that was provided. Several posterior patients shifted the name inappropriately as often as appropriately; others failed to show any naming change as context was shifted but perseverated in a unidimensional perceptually based strategy.

These results for the posterior aphasics

provide compelling evidence that the semantic representation of the elements comprising the meaning of the words *cup, glass,* and *bowl* is not well structured. Because the domain of interest was constrained to the category of *food containers,* because perceptual variation was controlled, and because functional information was explicitly provided in part of the task, it is difficult to believe that the naming difficulty was the result of failure to activate an intact representation. The possibility of retrieval was maximized in several of the experimental conditions (e.g., when a prototypical cup was presented in the *cup* context) and yet these occurrences were named as inconsistently as the borderline cases in an incongruent context. It seems an inescapable conclusion that these posterior patients did not have sufficient information in the semantic representation of these items to differentiate between them.

This review of some pertinent work on naming disruption has been structured to show that there has been a discernible change in thinking about the level of processing that is disrupted when a patient fails to provide a correct name for an object. Naming impairment is no longer viewed as a unitary phenomenon; the level at which a naming response is disrupted may not be the same across all types of this difficulty. The major division based on symptomatology—between patients with anterior and posterior damage—appears to involve different degrees of involvement of the central processes outlined earlier. The important point is that the possibility of disruption at the level at which semantic information is represented is beginning to be considered, especially for patients with damage to the posterior portion of the dominant hemisphere.

Comprehension: Sense and Reference

As mentioned above, little research has been undertaken to disentangle the elements that may be involved in impaired lexical comprehension. However, unlike the situation summarized here for naming disorders, there appears to be general agreement among workers in the area that comprehension deficits involve some kind of semantic disruption (Goodglass & Geschwind, 1976, p. 406). This view has gained support from a recently reported study of phonological factors in auditory comprehension that has ruled out the involvement of a phonemic-discrimination deficit as a major cause of comprehension disruption (Blumstein, Baker, & Goodglass, 1977).

Of course, several studies of naming reviewed in the previous section implicitly involved comprehension. The semantic confusions exhibited by patients in a naming task are also evidenced in comprehension, with the result that a patient may point to his leg when asked to point to his ankle (Goodglass & Geschwind, 1976). In addition, the word association arguments used to explain naming behavior are based on aspects of meaning comprehension not usually implicated in referential meaning, that is, the *sense* relation of the word. The *referential* part of meaning specifies the information that is needed to identify members of a conceptual category; the *sense* elements trace the relationships among several different but related concepts. Thus, hierarchical relationships, similarity relationships, functional relationships, to name but a few, are part of the sense of a particular word meaning and comprise the associational network, or semantic field, discussed in the previous section.

The point has already been made that disruption of these sense relations may be a factor in naming disability; the structure and organization of sense elements within a semantic domain is also of interest in its own right. That is, "intact" comprehension presumably implies more than the ability to recognize an item as the referent of a given word; it implies a complete network of conceptual elements organized in such a way that the relationships between concepts within a given semantic field are accessible.

Two studies have been reported recently that attempted to ascertain the extent to which these sense relations are disrupted in the semantic organization of aphasic patients. Lhermitte, Derouesne, and Lecours (1971) presented patients exhibiting various symptomatology with two tasks that involved sorting cards containing printed words. In the first task, each of 12 words was to be sorted into

one of three columns based on its "degree of relationship" to a target word. For example, the target word *fish* would be closely related to words such as *ocean* and *fisherman,* somewhat related to the words *odor* and *cooking,* and not at all related to the words *chair* and *fantasy.* In a second task, the ability of these patients to shift among various senses of a polysemous word was tested. Patients were required to sort seven words into one of two columns based on whether the word evoked some sense of a target word. For example, the target word *division* has different senses that may be evoked by the words *army* and *calculation* but has no sense that is related to the words *sky* and *couch.*

Patients' incorrect responses were categorized into three groups: disruption of the hierarchical relationship among the words, and "narrowing" and "broadening" of the semantic field. Patients with all types of symptoms produced responses in these three groups, but patients with anterior damage were highly represented only in the group making hierarchical errors. Errors of this type indicate that category boundaries are somewhat ill defined, but they do not represent gross errors of association. Patients with posterior damage, on the other hand, displayed a more severe disruption of semantic structure, with a tendency to broaden the boundaries of the category.

Another study directed at charting the disruption of semantic organization in aphasia began with somewhat stronger assumptions about the structure of lexical knowledge (Zurif, Caramazza, Meyerson, & Galvin, 1974). On the basis of recent attempts to describe the organization of the lexicon in the normal speaker (e.g., Fillenbaum & Rapoport, 1971; Miller, 1967, 1969, 1972), semantic information is assumed to be represented as an internalized data structure based on semantic features. These features, typically mapped as single words (e.g., + *male*) or phrases (+ *who is married*) are taken to represent the lexical information available to the language user. They are meant to capture the conceptual elements in a word, as well as to define the range of semantic relations into which a word can enter with other words.

Zurif et al. used as stimulus items 12 high-frequency concrete nouns chosen to capture several different types of relationships among their semantic features. One primary criterion was that the features of the words chosen should be cast into a hierarchical arrangement. The central or dominating feature of the stimulus items was specified as ± *human,* which provided a basic distinction between two semantic domains, animal terms (*shark, trout, dog, tiger, turtle, crocodile*) and words used to describe human roles (*mother, wife, cook, partner, knight, husband*).

Components such as + *human* and + *animal* are very basic conceptual features of many entries in the mental dictionary and are thus relatively systematic in the language (Katz & Fodor, 1963). However, there are other features that are not central to the word's definition but represent often idiosyncratic referential and affective information growing out of a speaker's experience in the world rather than his knowledge of the language (Miller, 1972). This distinction parallels the difference between "defining" and "characteristic" semantic features that has recently been included as an integral element of a model of normal semantic memory (Smith, Shoben, & Rips, 1974). The words selected for this study were related through overlap of both defining and characteristic features.

The aim of the study was to determine how aphasic patients differ from normals in their appreciation of the formal hierarchical relations between the words presented and to ascertain whether the defining and characteristic features of words were differentially important to the organization of the lexicon in aphasia. To this end, aphasic patients with anterior and posterior damage, as well as neurologically normal control patients, were presented with three of the stimulus words at a time and required to indicate which two were the most similar in meaning. All possible combinations of the words were presented, and the patients' similarity judgments (by group) were analyzed using both a hierarchical clustering technique and a nonmetric multidimensional scaling program to determine the structural relationship that the patients imposed.

The major patterns in the data can be summarized as follows: The control patients clearly clustered the human items separately from the animal items. The anterior aphasics also recovered the basic semantic feature of human versus nonhuman. The posterior aphasic patients, on the other hand, did not convincingly separate the human items from the animal terms, despite having been able to recognize the definitions of the nouns on a pretest.

However, the anterior aphasics produced a cluster within the domain of animal terms that clearly differed from that produced by the controls. The nonneurologically impaired patients combined the items in terms of shared species membership, discriminating among fish, reptiles, and mammals. The anterior aphasics, in contrast, generated two major clusters: one consisting of *shark, crocodile,* and *tiger,* all ferocious, wild, and remote; and the other consisting of *trout* and *turtle,* both partially edible and harmless.

Within the framework of the distinction between defining and characteristic features set out above, it seems reasonable to suggest that by focusing on the species membership of the items, the control patients applied technical semantic features when judging the similarities and differences among the meanings of the animal terms. In contrast, the anterior aphasic patients, by using a feature based on *ferocity,* appeared to carry out the task on the basis of incidental or characteristic features; that is, compared with *species membership, ferocity* seems more tied to empirical knowledge (first- or secondhand) and less dependent on an understanding of systematic interlexical relations. *Ferocity* is not part of the dictionary definition of these items but is in large measure a function of extralinguistic setting. Thus, even though it may be argued that all semantic features ultimately derive from a knowledge of the world, *ferocity* appears to be a much more empirical or perceptual concept than *mammal,* for example.

This result suggests that compared with the lexical structure underlying normal language use, the semantic representation in anterior aphasia is more restricted in its range of conceptual integration. In effect, verbal concepts in anterior aphasia appear to be more tightly tied to affective and situational data. Thus, it appears as if the normal adult has a number of levels at which he can organize his lexicon—some referentially practical, others linguistically practical—whereas the aphasic primarily retains those features of words that relate to perceived or imagined environmental situations.

This study provides another piece of evidence that the semantic structures of anterior and posterior aphasics are qualitatively different. What is more important, it defines an element of structural disruption for anterior aphasics that has not emerged in tests of naming ability or referential comprehension; that is, the part of word meaning tapped by the traditional tasks, namely, referential meaning, may be spared independently of the sense relations that provide the links between lexical concepts.

The investigations of lexical disruption in aphasia that have been reviewed here have not resolved the question of which processes or structures are impaired when a patient has difficulty with individual word meaning. Retrieval problems and conceptual disorganization have both been implicated. For the most part, retrieval problems in naming have been viewed as a failure of the sensory input to provide sufficient information to access a semantic representation. The fact that some words are more successfully accessed than others is regarded as a function of the redundancy of information provided by the elicitor-stimulus. Thus, items that are concrete and picturable, easily manipulated, and processed through several sensory modalities are most likely to be successful in activating the representation.

However, recent investigations of the structure of the lexicon have raised the possibility that the same stimulus factors (e.g., picturability, operativity) are more than factors affecting retrieval. Rather, they are elements that lend themselves to referential encoding, which is the aspect of meaning that appears least subject to disruption. Thus, the pattern that dissolution of the lexicon takes may involve selective disruption of elements, with those features that have been acquired and exercised in many different contexts through

several sense modalities showing the greatest resistance to disruption.

There is evidence that this referential aspect of the meaning of concrete nouns can be processed solely in the right hemisphere of the brain, which is not normally viewed as dominant in subserving linguistic processes (Geschwind, 1970). Recent studies of split-brain patients—individuals whose interhemispheric commissures have been severed (allowing a relatively pure investigation of hemispheric differences)—have shown that derivationally simple concrete nouns can be correctly processed in the right hemisphere (Gazzaniga, Bogen, & Sperry, 1965). Similarly, studies with normal subjects in which stimuli have been presented separately to each visual half-field, have shown that high-frequency concrete nouns can be recognized when processing is limited to the right hemisphere (Ellis & Shepherd, 1974; Hines, 1976).

Again, the suggestion is made that high-frequency concrete nouns enjoy a special status in the lexicon that allows resistance to loss in conditions of damage to the left hemisphere and appears to allow some level of representation in the right hemisphere. It is possible that these easily picturable nouns can be recognized by the right hemisphere because of the capacity for visual imagery that is believed to be highly lateralized to the right (Caramazza, Gordon, Zurif, & DeLuca, 1976; Whitehouse, 1977). However, as suggested above, the fact that the referents of highly concrete nouns can be experienced through several sense modalities and can be manipulated as well as visually perceived, may indicate that the meanings of those nouns are more diffusely represented in the brain; that is, the representation of items associated with a multitude of experiences in the world may not be as specifically localized as other words (such as abstract nouns) which are known only through a linguistic channel.

Lexical and Sentence Meaning

It has been argued that the meaning of an individual lexical item is a complex conceptual representation with aspects of both *sense* and *reference*. In addition, the effect of brain damage on this representation was shown to be selective; that is, part of the word's meaning may be lost while other aspects are spared. In this section, discussion of the disruption of the semantic component of comprehension is extended to include meanings conveyed by combinations of words.

There are many important differences between lexical and sentence meanings, and these differences may provide new potential for selective disruption. First, lexical and sentence meanings are not coextensive in the semantic ideas they can express. The semantic idea of predication, for example, can be expressed only by a phrase or a sentence, not by a single lexical item. The suggestion has been made (Luria, 1970) that specifically syntactic meanings such as predication may be selectively impaired by brain damage.

A second difference between lexical and sentence meaning centers on the function words. Although these items are not believed to have a specific semantic representation (and have little importance as individual items), they play a crucial role in conveying sentence meaning by communicating such important distinctions as definite and indefinite reference (Goodenough, Zurif, & Weintraub, 1977).

Most important for our purposes, lexical and sentence meanings differ in the very nature of their semantic representations. Lexical meanings can be considered to have fixed representations, but sentence meanings are novel, complex representations constructed by combining the meanings of single lexical items. This view is not universally held, but it has received considerable support in the literature, which is summarized here. There is some debate as to whether a lexical item has a fixed semantic representation for each of its major senses (or meanings) or whether it is even possible to talk of lexical meaning outside of a sentential context (Kempson, 1975). The meaning of a lexical item undoubtedly takes on different senses in different sentential contexts, yet it is possible to consider the meaning of a lexical item as the conceptual representation or range of conceptual values that an item can take in various contexts. The position advocated here is that word meaning involves an invariant *core* rep-

resentation made up of the range of conceptual values accepted by a linguistic community (Caramazza & Grober, 1976). That core meaning can be combined with other lexical items in the sentential matrix and in the communication of an idea.

There is agreement among psycholinguists on a number of issues that concern the structure of the lexicon. First, the lexicon can be structured along separate dimensions corresponding to the four components of each lexical item—phonological, graphemic, syntactic, and semantic—each of which is specified as a matrix of primitive elements. The representation of a single lexical item is preonce acquired, remain unchanged over time. In fact, the phonological, graphemic, and syntactic representations of a lexical item, once acquired, remain unchanged over time. The semantic component may undergo some changes, but these are of a relatively minor nature, such as the addition of fine nuances within a semantic network.

Another important characteristic of the lexicon is that it is an open-ended system; that is, it consists of a very large number of entries with an indefinite upper bound. In addition, information specified for any lexical item can be in any one of a combination of sensory modalities—visual, auditory, tactile, and olfactory. This latter characteristic suggests that the information that specifies the semantic structure of a lexical item may be more diffusely represented in the brain than is information that is specified in a single modality.

The topic of sentential semantics has received a great deal of attention in the past 10 years, with considerable debate about how the processes that are involved should be characterized (Katz, 1972; Lakoff, 1971). For present purposes, it is most important to note that there is a combinatorial operation implicated in sentential semantics that is not present in any formulation of lexical semantics. It is assumed here that the syntactic system is structured along the lines of a generative-transformational system. That is, the syntactic system (like the phonological system) consists of a closed set of rules that can be recursively applied to produce an unlimited number of sentence structures. In this system, no specific sentence structure need be represented in the human mind; instead, it is the syntactic rules that produce the sentence structures that are stored.

The major point is that syntactic rules constitute a finite and relatively small set of operations that are acquired early in life and undergo no major changes in adult life. Furthermore, unlike the lexical system, the representation of syntactic information is not modality specific, even though it is primarily acquired through the auditory system. These two considerations lead to the suggestion that syntactic operations are less diffusely represented in the brain than is lexical knowledge (cf. Zurif & Caramazza, 1976).

In light of these differences between the lexical and syntactic systems of language, it should not be surprising that they appear to be functionally independent upon an analysis of language dissolution and that the systems are subserved by distinct brain areas. That is, focal brain damage to the dominant hemisphere does not result in an across-the-board reduction of language capacity (cf. Schuell & Jenkins, 1959) but instead gives rise to remarkably stable patterns of abnormal performance. In fact, it could be argued that aphasia probably offers the strongest evidence for the functional independence of lexical and syntactic operations (Marin, Saffran, & Schwartz, 1976), as well as evidence for the independence of syntactic and heuristic processes (Caramazza & Zurif, 1976).

The next section provides a review of some of the literature that addresses the question of the disintegration of the ability to use syntactic operations in language performance.

Agrammatic and Paragrammatic Speech

Over a century of research has led to some agreement on the identification of two major forms of aphasic speech that are primarily characterized by abnormal syntactic organization—agrammatic and paragrammatic speech.

Agrammatic speech has a strikingly telegrammatic form in which syntax seems to be restricted to a single declarative form, function words are infrequently present, and verbs, when used, are most often uninflected. Frequently associated symptoms are effortful-

ness of speech and distorted articulation. This constellation of symptoms is usually present with lesions of the anterior portion of the dominant hemisphere. Early explanations of this form of behavior most often attributed the telegrammatic nature of speech to a neuromuscular problem. The belief was that the strain of speaking is so great that the patient speaks asyntactically in order to economize effort (Lenneberg, 1973). An alternative view (Jakobson, 1964; Luria, 1970) attributes the problem to a more central disruption: Agrammatism results from a disturbance of the mechanisms that subserve the ability to structure a string of words syntactically (see also Zurif & Caramazza, 1976).

Paragrammatic speech seems to involve not so much a restriction of syntactic organization as the inappropriate juxtaposition of lexical items. The speech of these patients is marked by facility of articulation and by many long sequences of words in a variety of grammatical constructions. However, the output is informationally empty—Indefinite noun phrases are often substituted for an appropriate noun, and when a noun of specific reference is chosen it is often the wrong one. Because these patients can produce a variety of syntactic forms, it is often assumed that syntactic impairment is minimal. However, it should be noted that the situation may be somewhat more complicated in that the inappropriate juxtaposition of lexical items often results in serious grammatical distortions, such as category violations (e.g., the use of a noun in a verb or adjective position) and selectional restriction violations (e.g., the use of an animate noun in a sentence that requires an inanimate noun). Nevertheless, the speech of these patients generally gives the appearance of being syntactically well structured. The lesion site most often associated with disturbances of this type is the posterior part of the dominant hemisphere.

As in the case of lexical disruption, a disproportionate amount of attention has been paid to verbal production, with neglect of detailed analysis of comprehension performance. Furthermore, most of the early work relied primarily on clinical data, with little emphasis on experimental considerations. However, since the mid-1950s, Goodglass and his collaborators have done much to improve the situation, and in the last several years a more balanced view of the problems of syntactic breakdown has emerged. The following section presents a review of some of the work that has addressed the question of the effect of focal brain damage on syntactic mechanisms.

Research on Syntactic Breakdown

Production. Detailed studies of both free-conversation data and controlled experimental tests have revealed several factors that are implicated in agrammatic and paragrammatic speech. These factors include a disruption of lexical availability (primarily associated with paragrammatic speech) and the more grammatically based difficulties, such as problems with prosody, morphology, and syntax (typically found in agrammatic speech).

In several articles, Goodglass and his associates have shown that agrammatic aphasics differ from paragrammatic aphasics on several dimensions of syntactic ability. One study (Goodglass & Hunt, 1958) investigated aphasic patients' ability to produce the inflectional markers for the possessive case and the plural form of nouns. In English these markers are phonologically indistinguishable because the same allomorphic variations /s, z, əz/ can indicate both the plural and possessive forms. Consequently, any differential effects in the ability to produce these morphemes for the plural and possessive cannot be attributed to a peripheral disorder, but must be considered as the result of a more central, syntactic disorder.

Goodglass and Hunt found that the possessive marker was omitted nearly twice as often as the plural, suggesting that syntactic operations can be differentially affected by focal brain damage. Unfortunately, there are several alternative hypotheses as to the basis for the differential effects. Grammatical complexity, redundancy, and frequency of usage can all account for the observed effect. In addition, unselected aphasic patients were tested in this study, so it is difficult to make any inferences about site of lesion and functional breakdown.

Goodglass (1968) replicated these findings and extended the inquiry in two specific

respects. First, patients were subdivided into agrammatic and paragrammatic groups on the basis of a length-of-utterance criterion (Goodglass, Quadfasel, & Timberlake, 1965). Second, the morphological changes that mark verb tenses were included in the task. There were no differences between agrammatic and paragrammatic aphasics on the order of difficulty among morphological markers: Plurals were easier than possessives and the third person singular /s/ for the verb. However, there was a marked difference between aphasic groups on their ability to produce the allomorphic variations /z vs. əz/ and /d vs. əd/ for plural and tense markers, respectively. Specifically, paragrammatic aphasics had more difficulty with the more complex syllabic allomorphs /əz and əd/, just as children do (Berko, 1958), and agrammatic aphasics displayed the opposite pattern. This result suggests that the effect of anterior brain damage on language ability at the syntactic level is more than just an overall reduction in syntactic capacity; instead, syntactic operations are impaired selectively (see also Goodglass & Berko, 1960).

There is also evidence for differential performance of agrammatic and paragrammatic aphasics at the level of prosody. Goodglass, Fodor, and Schulhoff (1967) used a sentence repetition task to assess the effect of stress on the production of a word. The results clearly indicated that anterior aphasics are much more likely to omit an unstressed word than are posterior aphasics.

Two other studies by Goodglass's group, Meyerson and Goodglass (1972) and Goodglass, Gleason, Bernholtz, and Hyde (1972), have further charted the syntactic abilities of agrammatic aphasics. Both studies were concerned with a single agrammatic patient's ability to produce syntactically well-formed structures. However, Meyerson and Goodglass (1972) analyzed speech obtained in free conversation, whereas Goodglass et al. (1972) attempted to elicit specific syntactic forms. The major finding was that syntactic ability, as specified by the presence or absence of transformational rules, is quite clearly compromised in anterior aphasia.

This brief review has tried to show that focal brain damage may selectively affect the syntactic system independently of the lexical system. However, the force of this argument is attenuated by the claim that anterior aphasics, though agrammatic in their output, display good comprehension, suggesting that their agrammatic speech may simply be the result of some peripheral disorder that does not impair syntactic knowledge. However, the clinical claim that anterior aphasics usually present nearly normal comprehension does not necessarily mean that the patient may not be "agrammatic" in comprehension as well. To illustrate this point, assume that when an anterior aphasic is presented with the sentence *The boys are coming tomorrow,* he processes the sentence only enough to recover the sequence *boy come tomorrow.* On the basis of this recovered sequence, he may be able to understand the intended message, especially since there is usually sufficient contextual information to help disambiguate potential ambiguities. Thus, the dissociation of production and comprehension ability in anterior aphasia may be more apparent than real. In fact, in the last several years, evidence has accumulated that the comprehension abilities of anterior aphasics closely parallel their agrammatic productions.

Comprehension. Caramazza and Zurif (1976) assessed comprehension capacities in aphasics with anterior and posterior lesions of the dominant hemisphere. The task employed in this study was a sentence–picture matching task. Patients were presented orally with a sentence and were asked to choose from two pictures the one that depicted the proposition described by the sentence. There were two major manipulations that are of interest here: One was the type of sentence used; the other was the type of information contrast depicted by the picture pair. The important variable in the sentence material was whether the center-embedded sentence was reversible or nonreversible, that is, whether the lexical items contained in the sentence permitted one or more readings if one ignored syntactic constraints. Thus, in the reversible sentence *The lion that the tiger is chasing is fat,* the lexical items alone permit the readings *The tiger is chasing a fat lion, The lion is chasing a fat tiger, The fat tiger is chasing the lion,* and *The fat lion is*

chasing the tiger. However, in the nonreversible sentence *The bicycle that the boy is holding is broken,* selectional restrictions on the lexical items permit only the reading *The boy is holding a broken bicycle.* Four types of picture contrasts were used, three of which could be solved using lexical information alone. The fourth contrast required the patient to recover the correct syntax of the sentence in order to make the correct choice.

There was a clear effect of contrast type for the agrammatic (anterior) aphasics, who responded correctly about 90% of the time on the lexical contrasts but only about 70% of the time on the syntactic contrasts. The paragrammatic patients showed no reliable pattern but were significantly poorer in overall performance than the agrammatic patients. Furthermore, the performance of agrammatic and paragrammatic patients showed a clear and consistent difference based on whether the sentence was reversible or nonreversible. The agrammatic patients performed at the 90% level of accuracy on nonreversible sentences, but their performance dropped to chance with reversible sentences. The paragrammatic patients' performance was unaffected by this manipulation. These results clearly show that the agrammatic aphasic's ability to comprehend sentences is seriously compromised. What is more important, the locus of disruption appears to be at the level of syntactic processing.

This limitation of anterior aphasics' ability to process syntactic information has emerged in several other recent studies of comprehension (Marin, Saffran, & Schwartz, 1976; Scholes, 1978) and in studies of linguistic intuitions on the structure of sentences (Andreewsky & Seron, 1975; Zurif, Caramazza, & Myerson, 1972; Zurif, Green, Caramazza, & Goodenough, 1976; Ulatowska & Baker, Note 1).

This last set of studies indicates that the anterior aphasic's intuitions about his language are as agrammatic as his output. Zurif et al. (1972) required patients to judge which words of a sentence "went best together." The patients were presented with triads of words from the sentence (which was always in their view) and were asked to point to the two words that were most closely related. These judgments of proximity were analyzed using a hierarchical clustering procedure (Johnson, 1967; Levelt, 1970) to obtain for each sentence a treelike hierarchical structure. The implicit hierarchical organization that emerged for the normal control group corresponded to the familiar parsing tree of the surface structure of a sentence. The structures that emerged for the anterior aphasics, on the other hand, were quite distorted—The aphasics grouped together only the content words and for the most part ignored or inappropriately placed the function words. Thus, it appears that the anterior aphasic's agrammatism extends to his intuitions about language.

Several recent studies of the linguistic abilities of individuals who had undergone surgical removal of the cortex of one cerebral hemisphere (hemidecortication) during infancy have further supported the functional independence of syntactic processes (Dennis & Kohn, 1975; see also Dennis & Whitaker, 1976). Two groups of matched subjects, functioning with only a right or a left hemisphere, were presented with six spoken sentences varying in syntactic form. Subjects were required to select a picture from two alternatives that depicted the meaning of the sentence. Subjects with an intact right hemisphere had increasing difficulty comprehending the sentences as syntactic complexity increased. Thus, for example, right- and left-hemisphere groups processed simple active sentences equally well (measured by percent correct and latency to respond), but the group who had undergone removal of the cortex of the left hemisphere performed significantly worse with more complex constructions, especially the passive negative. These two groups were comparable in verbal IQ, and both were capable of processing the information contained in simple sentences. The functions underlying comprehension of syntactic forms, however, had apparently not developed comparably in the two groups. These syntax-related functions thus appear to have some measure of independence from other language capacities, and an intact dominant hemisphere seems to be necessary for their full utilization.

Nonlinguistic Cognitive Operations: Memory and Syntactic Processing

The foregoing treatment of comprehension performance has proceeded as if the only mechanisms involved were language-specific ones. It is obvious, however, that there are nonlinguistic cognitive operations that come into play in processing a sentence for comprehension. Lexical meanings involve retrieval mechanisms that access prestructured conceptual entities, but sentence meanings additionally involve the operation of a syntax, a system of rules that works over time to determine the logical relations that hold among the lexical items in a sentence. The operations of a syntactic system necessarily implicate the functioning of a working memory that temporarily stores parts of a sentence while the remainder of the sentence is being encoded.

To the extent that memory mechanisms are impaired in patients with damage to the dominant hemisphere, comprehension performance will be disrupted (Cermak & Moreines, 1976; Lesser, 1976; Saffran & Marin, 1975). Consequently, it is critical that a specific memory deficit be ruled out as a basis for the abnormal comprehension performance in the anterior aphasic in order to maintain the position that structures of the anterior part of the dominant hemisphere subserve syntactic operations.

It is unlikely that a single memory deficit can account for the findings that have been reported, particularly the disruption of aphasics' metalinguistic judgments, which were performed outside the demands imposed by real-time processing. A direct test of this contention was provided by a recent investigation of sentence memory in aphasics with anterior and posterior brain damage (Caramazza, Note 2). The specific purpose of this study was to determine the level to which syntactic processing in a memory task is carried out by agrammatic aphasics. This approach was motivated by the contention that grammatical morphemes are processed at some level of auditory representation but not beyond (i.e., not to a level of meaning representation) and also by the assumption that memory for a sentential item is a function of the degree of processing at different levels that the item receives at the time of input (the "depth-of-processing" hypothesis—Craik & Lockhart, 1972; Craik & Tulving, 1975). It would seem that the relatively shallow processing of functors would result in less stable memory traces for these items relative to content words, which would most likely receive more elaborate processing.

The experimental paradigm employed a modified memory-probe technique. The patients were presented orally with a sentence and immediately afterward were given a probe word from that sentence. The patients' task was to produce the word from the sentence that followed this probe item. If a patient failed to make a response or produced a sound that could not be readily identified as one of the words in the target sentence, he was given a multiple-choice alternative. The object was not to penalize the patient for any difficulties he may have had in the implementation of speech, but to obtain a sensitive measure of his memory. A response was scored as incorrect if it was an item other than the one immediately following the probe word.

Results were analyzed in terms of transitional error probability (TEP), that is, the probability of recalling an item other than the one that actually followed the probe in the sentence. Two different patterns of results were expected depending on whether the patients were affected by a generalized memory deficit or a specific syntactic processing impairment. In the case of a generalized memory deficit, TEP would be expected to be qualitatively the same as that for a normal control group, but with a higher level of errors. If, on the other hand, the patients could not adequately process syntactic morphemes, then the TEP pattern should be markedly different from that of the normal control group. The difference should be primarily in the relative effectiveness of function words to probe content items versus the effectiveness of content words to probe function words.

The results clearly supported the hypothesis that agrammatic aphasics cannot adequately process grammatical morphemes. The functors seem to be processed to a level that

does not permit the words themselves to be retrieved but does allow their traces to be reinstated. This study thus provides further evidence that focal brain damage can selectively impair syntactic processing while sparing semantic processing.

In this section, a number of recent studies were reviewed that clearly point to the functional and neurological independence of syntactic and semantic processing in sentence comprehension. Data obtained from studies of sentence processing in aphasia are important for a number of reasons. First, they establish a clear brain/function relation in which the anterior portion of the dominant hemisphere subserves syntactic processes. Second, they demonstrate that in sentence comprehension, syntactic processes are independent of processes such as strategies based on lexical comprehension. Third, they demonstrate the psychological reality of linguistic processes by showing that although these processes interact with other cognitive operations (e.g., memory), they can be selectively affected by brain damage. Even though these conclusions are of a rather general nature at this time, they form the basis on which more detailed experimental studies can be conducted.

Some General Conclusions

This review was begun with the statement that traditional studies of aphasic language have not contributed appreciably to our understanding of normal language processes. It was suggested that this situation may have arisen in part because of the aphasiologist's concern with brain/function relations as opposed to language processes for their own sake. Paradoxically, then, this review has led to the conclusion that a clear formulation of the functional organization of the dominant hemisphere can lead to important insights into the structure of normal language processes; that is, even though there is logically no reason why the study of language breakdown cannot proceed independently of concerns about brain structures, it is an empirical fact that there is a strong correlation between brain structures and linguistic processes. This is a substantive neurolinguistic conclusion that is of heuristic value for psycholinguistics in that it provides strong constraints on the generation of hypotheses about language processes. Thus, knowing that damage to a particular area of the brain affects a specific language component can lead to the formulation of testable hypotheses about the structure of that component and the interaction of that component with other cognitive processes. For example, on the basis of prior observations that damage to the anterior part of the dominant hemisphere affects syntactic processes, hypotheses could be tested concerning the operation of syntactic mechanisms in sentence comprehension. Caramazza and Zurif (1976) were able to demonstrate that anterior aphasics achieve a relatively high level of sentence comprehension through the application of lexical and heuristic processes. This result lends support to the hypothesis that heuristic procedures can independently assign a semantic interpretation to a sentence. What is interesting is that this latter hypothesis is one of several competing hypotheses that, according to Fodor, Bever, and Garrett (1974), cannot be differentiated on the basis of data obtained in studies with normal subjects.

It must be emphasized, however, that concern with issues of brain/function relations is not a necessary component of the study of aphasic language. Psycholinguistic investigations can proceed quite independently of such issues, concentrating instead on patterns of language dissolution in an attempt to define the componential structure of language processes. The material reviewed here shows this to be not only a feasible but a fruitful endeavor: Lexical, syntactic, and heuristic language processes, as well as other cognitive capacities, can be investigated in relative isolation.

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