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CHARACTERIZATION OF APHASIC DISRUPTION OF SYNTAX: THE PERCEPTION OF GRAMMATICAL RELATIONS IN RELATIVE CLAUSES

City University of New York PH.D. 1983

University Microfilms International 300 N. Zeeb Road, Ann Arbor, MI 48106

Characterization of Aphasic Disruption of Syntax: The Perception of Grammatical Relations in Relative Clauses

by

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A dissertation submitted to the Graduate Faculty in Speech and Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

1983

This manuscript has been read and accepted for the Graduate Faculty in Speech and Hearing Sciences in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

July 27, 1983
date

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Aug. 11, 1983
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Abstract

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The Perception of Grammatical Relations in Relative Clauses

by Robert A. Volin

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It has been claimed that a central syntactic processor underlies all modalities of language performance. This claim has been supported by evidence of parallel syntactic deficits in the production and comprehension of language by agrammatic aphasics. These parallels have been demonstrated across groups of subjects, but rarely within groups. The present study applied two dissimilar comprehension tasks to agrammatics (and to fluent aphasics as controls) in order to test the parallel deficit claim. One of these tasks was a paraphrase judgment paradigm using written input; and the other was an auditory comprehension paradigm. It was found that each aphasic group produced deficit patterns that were task-independent (i.e., were parallel across tasks). The deficit patterns produced by the two groups differed. Further analysis indicated that the agrammatics, lacking the use of syntactic cues to grammatical relations in relative sentences, resort to a sentence processing strategy based on the proximity of semantically compatible nouns and verbs, and on canonical word order. While the agrammatic deficit was shown to be task-independent, the use of a strategy or strategies was task-dependent in some subjects.

ACKNOWLEDGEMENTS

It seems to me that this work has been influenced, aided or abetted by practically everyone. Nevertheless, there are a few people who should be singled out in appreciation. I am deeply grateful to my chairman Louis J. Gerstman, without whose urging I would never have attempted doctoral study. I once asked him how I might begin to repay all that I believe I owe him. His reply was, "Pass it on." I'll do my best.

I am grateful to Edgar B. Zurif and Helen S. Cairns. Their influence extends beyond their academic subjects, and will endure. To Eleanor Saffran, my outside examiner, I owe special thanks for her incisive and productive comments. My thanks extend to my colleagues at the Veterans Administration, Joyce West and Michael Groher. Without their support, this work could not have been completed. I am indebted to Lori Helman who, while a research assistant at the Veterans Administration Medical Center, lent her time and considerable resourcefulness to the development and implementation of the experiment.

Finally, I am profoundly grateful to my family. They earned this doctorate along with me. They helped, tolerated, understood and much more. Their loving support has been, and will remain, the most precious dividend of these past few years.

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Introduction

Language function has traditionally been bisected into the faculties of speaking and listening. These were believed to be discretely represented in the brain: speech was assumed to be essentially a motor function mediated in the left frontal cortex while comprehension was believed to be a sensory auditory perceptual process mediated in the left temporal and parietal lobes. (See, e.g., Lichtheim, 1885.) The pattern of language dissolution following brain damage has provided the major support for this view, which has changed little, except for the elaboration of detail, to the present day (see Geschwind, 1970). Developments in modern linguistics have motivated a competing view, one that assumes that language is functionally organized in the brain in a modular fashion, along lines that roughly correspond to levels of linguistic representation, and that this organization is not modality-bound in the traditional expressive-receptive sense (Chomsky, 1980). One consequence of this view is a research strategy that seeks to identify and define aphasic grammatical disruptions that are more or less insensitive to modality: disruptions indicative of a central syntactic deficit.

The traditional view of Broca's aphasia held that agrammatism, one of its main features, was an expressive disorder referable to disrupted motor functions subserving speech. Language comprehension was thought to be essentially intact. (See, e.g., Lenneberg, 1973 for an exposition of this view.) While there were reports of impaired sentence comprehension in these patients, deficits of this sort were typically ascribed to difficulties inherent in the length and/or conceptual complexity of the material (Schuell, Jenkins and Jimenez-Pabon, 1964). More recently, however, it has become apparent that agrammatic aphasics suffer a comprehension deficit that parallels their production deficit insofar as comparable elements and structures have been implicated. Just as agrammatics tend to omit closed-class elements such as functors or bound inflectional morphemes in production, they fail to make use of these forms in comprehension. Elements such as articles, pronouns and reflexives have been shown to be involved (Berndt and Caramazza, 1980; and see discussion within). Moreover, the ordering of open-class elements in a sentence carries syntactic information, which also appears to be unavailable to some agrammatics (Saffran, Schwartz and Marin, 1980; Schwartz, Saffran and Marin, 1980; but see Heeschen, 1980 and Caplan, 1983). These findings, which will be reviewed below, support the view that the language processing system includes a dissociable syntactic component and that agrammatism involves the selective impairment of aspects of this system. A corollary claim is that the agrammatic disruption is "domain-specific": that it overarches (i.e., is shared by) modalities of input and production, and is independent from other cognitive sequelae of brain damage.

This study sought to test some of the empirical questions entailed by these claims by asking agrammatic subjects to perform two experimental tasks which differ in modalities of input and response. Both tasks employ identical linguistic materials. Intertask comparisons were carried out in order to test the prediction that a central, underlying syntactic deficit engenders parallel results across modalities and types of performance difficulty. Further analysis sought to determine which, if any, heuristic strategies are brought to bear on language comprehension when syntactic processes are disrupted. The performance of agrammatic and nonagrammatic aphasics was compared to determine whether their response patterns are syndrome-specific or are a general result of left hemisphere lesions.

Neurolinguistic studies of agrammatism

Broca's aphasia

The syndrome of Broca's aphasia generally results from extensive lesions affecting the frontoparietal cortex and insula, in the distribution of the superior branch of the left middle cerebral artery (Mohr, 1976). Right hemiplegia, usually affecting the arm more severely than the leg, buccofacial apraxia and ideomotor apraxia, which is manifested in the unaffected upper extremity, are common concomitants of Broca's aphasia (De Renzi, Pieczuro and Vignolo, 1966); Geschwind, 1965).

The spontaneous speech of these patients is halting, labored, and usually distorted. Speech prosody is typically sharply reduced, with utterances limited to one or few words. In marked contrast to their speech output, Broca's aphasics may be able to carry a tune, once they are helped to initiate the melody (Brown, 1972). Agrammatism is reflected in the spontaneous speech of these patients by a decrease in occurrence of grammatical morphemes and simplification in form (Howes and Geschwind, 1962), and by an increased proportion of nouns and adjectives, relative to function words (Jones and Wepman, 1965). Repetition generally follows the characteristics of spontaneous speech. The articulatory disturbance is extremely variable at the phonemic level, and has therefore been characterized as "verbal apraxia", a disturbance of motor speech programming (see, e.g., Darley, Aronson and Brown, 1975). Martin (1974) has strongly objected to the use of the term "apraxia" to delineate a phenomenon that is specifiable on linguistic (phonemic) grounds. However, the former view has been supported by recent studies of voice onset time characteristics (Itoh, Sasanuma, Tatsumi, Murakami, Fukusako and Suzuki, 1982) and the articulatory dynamics of velar movement (Itoh, Sasanuma, Hirose, Yoshioka and Ushijima, 1980). This research implicates a deficit in timing control of the movements of the articulators rather than a deficit of phonemic specification.

The auditory comprehension of Broca's aphasics has traditionally been reported to be spared, relative to their speech disruption, but these patients have shown deficits in the comprehension of minimally redundant, moderately complex sentences (De Renzi and Vignolo, 1962; Poeck, Kerschensteiner and Hartje, 1972). Broca's aphasics have demonstrable deficits in auditory verbal short-term memory affecting their retention of (a) items in a list and (b) of the sequential ordering of items in a list (Albert, 1976). Moreover, they display a marked comprehension deficit for sentences in which meaning depends on syntactic factors (Zurif and Caramazza, 1976; and see review, within).

Reading in Broca's aphasia follows the pattern of auditory comprehension. These patients, traditionally thought to retain relatively good -- albeit slow -- reading comprehension, have been shown to have reading impairment (Benson, 1977). They display most difficulty with material in which meaning hinges on syntactically cued relationships and is not clearly reflected by semantic content (Samuels and Benson, 1979). The writing of Broca's aphasics parallels speech production. Misspellings and distortions are common. Output is limited and effortful. When words are produced, they are almost always exclusively "content" words (Goodglass and Kaplan, 1972).

The syndrome complex of Broca's aphasia involves loss of motor function, disturbances of praxis, memory and language. The past two decades have witnessed an increased awareness of the manifold features of language impairment in this syndrome. One of these features, agrammatic sentence comprehension, is the subject of the following section.

Agrammatic sentence comprehension

Numerous recent studies have extensively investigated agrammatics' comprehension of sentences. The earliest approach to be motivated by modern linguistic theory was that of Jakobson (1964), who divided aphasic impairments into "similarity disorders" and "contiguity disorders." Within this broad framework, agrammatism would be characterized as a contiguity disorder; one involving the relations between semantic entities. More recently, research has focused on agrammatics' ability to respond to material in which correct performance depends on comprehension of specific grammatical morphemes or structural cues. The thrust of the recent work has been to show a dissociation, not between modalities of input or output, but between syntactic and semantic dimensions of language procesing.

Zurif, Caramazza and Myerson (1972) investigated aphasics' control of free grammatical morphemes with a metalinguistic word-clustering task. Subjects grouped the two words that they felt "went best together" in each of many word-triads taken from the test sentences. There were no temporal constraints on performance, as the stimulus sentences were kept in view while subjects formulated their responses. Control subjects' groupings resembled traditional hierarchical phrase structure trees. The Broca's aphasics tended to cluster major category words (N, V, Adj); the "content" words. Noun-verb pairings were most frequent, but noun-adjective pairs were also produced. For example, in the sentence "The girl was taller", the most frequent cluster was "girl - taller". In forming these clusters, the Broca's aphasics violated structural rules such as those pertaining to the role of function words in the construction of noun phrases and the distributional characteristics of copula forms. Function words were not simply disregarded, however: they were grouped together or were coupled with words of inappropriate form class (e.g., det + V). The noun phrases that were formed by agrammatics involved functors that were semantically richer than articles, as in the sentence "Where are my shoes?" This finding suggested that agrammatic aphasics might be differentially sensitive to closed-class elements as a function of their semantic information load within the context of a given sentence.

In order to pursue this question further the triadic clustering task was again employed (Zurif, Green, Caramazza and Goodenough, 1976). In this study, the so-called "semantic weight" of closed-class words in some of the sentences was manipulated as an independent variable. Differential sensitivity to articles, pronouns and prepositions as structural markers was examined. Three small groups were tested: these were Broca's aphasics with relatively good comprehension, "mixed anterior" aphasics with agrammatic speech and obvious comprehension deficits, and neurologically intact controls. The results showed that neither aphasic group was sensitive to articles. The added pragmatic importance of the article as a disambiguating marker had no effect (cf. Heilman and Scholes, 1976).

In marked contrast to their performance with articles, agrammatics approached the normal pattern in the clustering of prepositions with nouns. But when the same preposition served as an infinitive marker, the agrammatic group failed to cluster it. This again demonstrates the sensitivity of Broca's aphasics to semantic factors that affect the role of a functor in determining the meaning of a sentence (and see discussion of the special status of prepositions at the functional and positional levels of the language production model proposed by Garrett, 1982).

Within certain contexts the use of the appropriate definite or indefinite article bears important interpretive consequences. Heilman and Scholes (1976) demonstrated that Broca's aphasics are unable to use this cue to discriminate two sentences in which surface structure differed only by the position of the article. Subjects were required to choose the picture corresponding to a sentence such as (1) or (2):

(1) He showed her the baby pictures.

(2) He showed her baby the pictures.

Broca's aphasics performed at chance level on this task, and were unable to distinguish these sentences from the truly ambiguous version, (3).

(3) He showed her baby pictures.

In another study of aphasics' comprehension of articles, Goodenough, Zurif and Weintraub (1977) found that Broca's aphasics are "unable to use articles to assign appropriate reference." Presenting a visual array of three figures, e.g., a white circle, a black circle and a black square, they asked their subjects to indicate the figure referred to by prerecorded verbal instructions. These instructions indicated a single choice ("the white one", "the square one"), or they inappropriately used the definite article when two choices were possible ("the round one", "the black one"). Broca's aphasics did not demonstrate sensitivity to the function of the article: their response latencies were equivalent for appropriate and inappropriate trials, and their choices did not reflect the sense that unique specification was required by the appearance of the definite article. These studies suggest that agrammatics, who tend to omit articles in speech production, fail to fully utilize articles in comprehension.

Caramazza and Zurif (1976) reasoned that if Broca's aphasics' comprehension is agrammatic, they should have difficulty understanding sentences in which grammatical relationships are not cued semantically. They employed an auditory comprehension paradigm in which subjects were asked to point to the picture best described by a test sentence. Sentences were center-embedded and were (a) semantically nonreversible, (b) reversible or (c) implausible but well-formed. Distractors among the pictures were designed to distinguish semantic errors from syntactic errors. When distractors cued only semantic changes (e.g., wrong color or wrong verb), Broca's aphasics were fairly accurate, but when the distractor marked a syntactic change, their performance deteriorated. When forced to choose between pictures portraying the correct grammatical relationships and subject-object reversals, agrammatics chose correctly (about 90%) when semantic constraints were present, as in (4). In the absence of semantic cues, as in (5), accuracy dropped to the level of chance.

(4) The apple that the boy is eating is red.

(5) The boy that the girl is chasing is tall.

Agrammatics were also sensitive to semantic plausibility: well--formed sentences such as (6) were consistently misinterpreted in favor of the more plausible subject-object reversal.

(6) The man that the horse is riding is fat.

Caramazza and Zurif (1976) argued that these results indicate that agrammatics' comprehension parallels their production in that "they are unable to use syntactic-like algorithmic processes" while retaining heuristic procedures of semantic interpretation based on semantic plausibility and the probability that noun-verb sequences can be interpreted as actor-action relations. The available data, they continued, suggest that agrammatism reflects damage to "a general language procesing mechanism that subserves the syntactic component of both comprehension and production". Notice, however, that agrammatic performance in this study, as in those cited above, may be construed as failure to utilize information carried by function words in the comprehension of sentences.

Recently, Blumstein, Goodglass, Statlender and Biber (1983) completed a study which included an investigation of Broca's aphasics' comprehension of pronominalization and reflexivization. These subjects were found to perform perfectly on a pronoun test, which examined their ability to assign reference on the basis of the semantic information contained in the forms him, her, them, me, and you. Their accuracy dropped to about 68%, however, on a reflexive test which contrasted simple sentences such as "She washed her" versus "She washed herself." Morphological cues appear to be less effective for agrammatics than are lexical cues. This, again, suggests that agrammatics fail to utilize in comprehension those elements that they tend to omit in speech production.

In a recent study, Friederici, Schonle and Garrett (1982) tested agrammatics' production and comprehension of prepositions in sentences. Production was tested with a fill - in - the - blank procedure in which subjects were shown a series of pictures (e.g., of a cat lying under a chair). Along with each picture, subjects were shown a sentence describing the picture, but with the preposition missing. Subjects were required to verbalize the missing preposition. Two comprehension tasks were also employed. Both of these employed a multiple-choice format. In the first, correct performance depended upon recognition of the preposition itself; in the second, accuracy depended upon recognition of the preposition within a sentence corresponding to the stimulus picture. There was no difference in the accuracy of agrammatics' production of prepositions and their performance in the sentence recognition comprehension task; and performance on both these tasks was poorer than on the lexical perception task. Friederici, et. al. concluded that these results suggest that agrammatics retain their "lexicaly based inferential capacity" (which is likely why their comprehension appears to be superior to their production abilities), but not the normal capacity to use closed-class items to guide phrasal integration.

Despite a general clinical claim that the reading comprehension of Broca's aphasics is less impaired than their auditory comprehension (see, e.g., Goodglass and Kaplan, 1972), research employing the visual modality has produced results that are roughly parallel with the results of those using the auditory input modality. Moreover, a small number of studies have directly compared the performance of Broca's aphasics across input modalities, and indicate that this factor has no qualitative effect on performance. For example, Gardner, Denes and Zurif (1975) administered a metalinguistic task that compared subjects' performance on material presented in auditory and visual modalities. Pairs of sentences were presented, and subjects were required to determine which one of the pair was correct. The sentences were equated for all parameters except the syntactic or semantic variable under test. Anterior and posterior aphasics were compared. Both groups noticed semantic errors (involving lexica selection restrictions or real-world knowledge) more readily than syntactic errors. For both groups, the mode of stimulus presentation had no effect. Samuels and Benson (1979) also contrasted input modalities in a study of sentence comprehension. Subjects were required to make true-false decisions or to complete sentences that were designed to pose syntactic or semantic difficulty. The Broca's aphasics performed more poorly on syntactically loaded sentences in both visual and auditory modalities.

In summary, the foregoing research has demonstrated that the agrammatic disruption of sentence comprehension approximately parallels the agrammatic production deficit, and appears to be qualitatively insensitive to sensory input modality. Agrammatics seem to rely on lexical/semantic information; cues to syntactic structure, such as those that are carried by function words, are relatively unavailable to them. These findings offer considerable support for the notion, consistent with the modularity hypothesis (Chomsky, 1980), that the language processing system includes a dissociable syntactic component and that agrammatism involves a selective disruption affecting this component.

The locus of the agrammatic deficit

Two theoretical variants have emerged regarding the locus of the agrammatic language breakdown. It has been proposed that agrammatism is symptomatic of a general breakdown in syntactic processing (Berndt and Caramazza, 1980; Caramazza and Zurif, 1976). Most of the work cited in the previous section has been taken for support for this parsing deficit hypothesis. One aspect of the parsing deficit hypothesis focuses on a deficit in the processing of the vocabulary elements that are presumed to signal syntactic operations (Kean, 1980; Bradley, Garrett and Zurif (1980). Another variant locates the agrammatic deficit, not in the initial assignment of structure, but in the mapping of the parsed input onto a semantically interpretable representation (Saffran, Schwartz and Marin, 1980; Linebarger, Schwartz and Saffran, in press). These two variants will be discussed in turn.

Functor theory: The vocabulary elements exploited by the syntactic processor can be characterized as functors or as minor grammatical categories, and may be specified formally at the phonological level (Kean, 1980). Regardless of the formal characterizations employed, the lexicon is more or less divisible into two computationally distinct categories, the open-class and closed-class vocabularies (see Garrett, 1982 for discussion). The two classes differ in their "interpretive burden." Open-class items are "primary agents of reference." Closed-class items are essentially "vehicles of phrasal construction" and are largely nonreferential.

The importance of this distinction lies in its implications for the characterization of a computational system that employs the two classes differentially. Closed-class items support syntactic analysis, as is obvious from their effect in Lewis Carroll's "Jabberwocky." As Bradley, Garrett and Zurif (1980) point out, closed-class elements apparently have a role in the establishment of major category membership of the nonsense words in this work, thus enabling the reader to perform a sentential analysis of the nonsense strings. It is also well known that closed-class elements facilitate learning and recall of anomalous sentences (Miller and Isard, 1963). Bradley and Garrett (1979; cited by Bradley, et. al., 1980) suggested a model in which different word retrieval mechanisms, selectively sensitive to open- and closed-class elements, subserve structural and referential computational functions, respectively.

Bradley and Garrett, studying normal subjects, contrasted the effects of the two form classes in two lexical decision tasks. The first task involved the presentation of letter strings to subjects who had to decide whether stimulus items were or were not acceptable words. The dependent variable was response latency for accurate decisions. This task is highly sensitive to frequency of occurrence (Forster, 1979; Schuberth and Eimas, 1977). The second task, a lexical interference paradigm developed by Taft and Forster (1976), was a lexical decision task in which the stimuli of interest were nonword compound forms. Some of these incorporated open-class words in the initial position (e.g., "classipen"), some incorporated closed-class words ("lessipen"), and "baseline nonwords" contained no legal words ("fessipen"). Taft and Forster, studying normal subjects, reported that open-class nonwords took longer to reject than did baseline nonwords. Presumably, recognition of the valid lexical status of the initial open-class segment retards the decision to reject.

Bradley and Garrett (1979) found that the first lexical decision task produced the typical effect, but only for open-class words. There was no frequency effect for closed-class items. This indicated that open-class words and closed-class words may be accessed differentially; the open class according to frequency of occurrence and the closed class in some other way. The results of the lexical interference experiment also highlighted the distinction between the two classes. When the initial segment was an open-class item, the typical interference effect was obtained. But when the initial string was a closed-class item, rejection latencies did not differ significantly from baseline nonword rejection latencies. Thus, in normal subjects, the closed-class vocabulary seems to be accessed in a way that eliminates the interference effect engendered by recognition of the lexical status of the initial segment.

Bradley, Garrett and Zurif (1980) repeated the lexical decision tasks with a group of Broca's aphasics and a group of neurologically intact hospitalized controls. In both experiments, the normals behaved as did the previous subjects, displaying sharp distinctions between open- and closed-class elements. This contrast was not evident in the responses of the Broca's aphasics. While the normal subjects displayed sensitivity to word frequency for open-class items only, the aphasics displayed frequency effects for both classes. On the lexical interference task, normals rejected closed-class nonwords as rapidly as baseline nonwords, but the Broca's aphasics rejected closed-class words as slowly as they did open-class words. For the aphasics, both open - and closed-class items behaved like open-class vocabularies.

The fact that Broca's aphasics were able to process both classes of vocabulary items suggested to Bradley, et. al. that "the normal organization of the word system 'doubly represents' the closed class." On this view, closed-class elements may be represented both (a) with the full open-class lexicon that may be supposed to support lexical semantic procedures; and (b) in a special "bin", from which rapid access of these elements without full semantic interpretation supports on-line syntactic processing. Rapid access of closed-class elements is a necessary assumption in this scheme: closed-class access must be more rapid than open-class access, in order to "inhibit the consequences of the open-class routine." Bradley and her colleagues cautioned that these results do not prove that agrammatism is accounted for by the failure of a closed-class retrieval mechanism; but, on the other hand, they offered this as a "plausible candidate" hypothesis. They added that three fluent aphasics have also been tested on these tasks and that two of them produced the normal distinction between the form classes (the performance of the third was uninterpretable). Zurif (1980) reported that a fourth fluent aphasic had produced the normal distinction. This indicates that the pattern of the agrammatics' performance is syndrome - specific, and is not attributable to general effects of brain damage.

In a replication of the Bradley, et. al. experiment, Gordon and Caramazza (1982) found a nonlinear frequency effect for _both_ word classes in normal subjects. Higher frequency words produced a flat, rapid response curve, which is to say that they did not show a frequency effect. Lower frequency words, on the other hand, produced a response-time curve that varied inversely with frequency. Similar findings were reported by Segui, Mehler, Frauenfelder and Morton (1982), who studied normal French speakers.

Although these reports appear to undermine claims based on the frequency data, other observations continue to suggest a computational dissociation between form classes. First, the lexical interference results still stand. What is more, a recent letter cancellation experiment reinforces those results. When normal subjects are required to cross out specified letters in prose passages, they cancel letters appearing in open-class words more reliably than they do letters appearing in closed class words (Healy, 1976). Rosenberg, Zurif, Garrett and Bradley (1982) have found that agrammatics show cancellation rates that are equivalent across classes. If the normal results are taken to indicate a distinction between open- and closed-class lexical access routines such that closed-class items are subjectively more or less "invisible," then the agrammatics' performance suggests a disruption of the closed-class access route. By this reasoning, the agrammatics are relatively better at canceling letters in closed-class entries because they process them not as rapidly accessed syntactic markers, but as open-class vocabulary items. Another form of evidence for computational dissociation of open- and closed-class elements has been offered by Bradley and Garrett (1983), who have demonstrated functional hemispheric asymmetry involving these classes. They studied recognition of tachistoscopically presented open- and closed-class words in normal subjects. They found that recognition accuracies for the two classes differ only when stimuli were presented to the right visual field (left hemisphere). Closed-class items presented to the right visual field were less available to report (more "invisible") than are open-class items presented to the same field. No such distinction was observed for stimuli presented to the left visual field. The normal left hemisphere, in other words, seems to maintain a distinction between the form classes which the right hemisphere does not recognize. These studies indicate that the open- and closed-class vocabularies are computationally distinct, and that a failure to process the latter in the normal fashion figures importantly in the agrammatic deficit.

An alternative view: About the time that Bradley, et. al. published their findings, Schwartz, Saffran and Marin (1980) argued against a "phonological" account of agrammatism which was put forward by Kean in a series of papers (see, e.g., Kean, 1979). They argued that Kean's account would predict that agrammatics should be able to decode "constructions in which grammatical morphemes serve no essential role," on the basis of information encoded in the canonical ordering of major lexical items. Failure to do so, they continued, would be inexplicable in terms of an inability to utilize information encoded in minor grammatical categories. They argued that if agrammatics failed to decode say, simple active declarative sentences on the basis of canonical word order, then the scope of agrammatism must extend beyond the failure to utilize closed-class items for the computation of syntactic representation. Schwartz, et. al. tested agrammatics' ability to employ the syntax of word order to decode the grammatical relations in sentences. They found that not one of their five agrammatic subjects reliably decoded semantically reversible sentences on all three of the experimental tasks. The agrammatics did not appear to use word order strategies in sentence comprehension and, in fact, such strategies as they may have employed varied from task to task. These five subjects failed to demonstrate a consistent word order strategy collectively or individually.

In a companion article, Saffran, Schwartz and Marin (1980) showed that these same agrammatics produced appropriate word orders in production only when the sentential subject and object differed in "potency" or "saliency" (by which criterion the more salient element was the more plausible actor, as in the animate/inanimate contrast). Saffran, et. al. concluded that agrammatic comprehension and production reflects an absence of "the capacity to deal with language structures that encode relational meanings." They suggest that

> "the agrammatic selects salient elements of a cognitive representation and maps them into a surface structure of the N-V-N form, ordering the NPs on the basis of cognitive factors like animacy or potency. The order of NPs carries no semantic significance. Similarly, on the receptive side, the lack of mediating linguistic structures results in the failure to extract <u>from</u> word order the directionality of the underlying relation."

Their view departs from a parsing deficit hypothesis in that it makes the claim that the agrammatic deficit is referable to a level of processing at which logical relations are represented, a level that is conceived to be deeper than that at which syntactic computation takes place. Linebarger, Schwartz and Saffran (in press) have offered new data compatible with this view. Observing that the variants of parsing deficit theory entail the inability of agrammatics to perform syntactic analysis of sentences, they present evidence that agrammatics are able to carry out grammaticality judgments successfully on a variety of syntactic structures. They offer two hypotheses to account for their findings. The first argument is that since their subjects cannot have yielded this result without having performed syntactic analyses on the stimulus sentences, the locus of the agrammatic deficit must lie not in the computation of syntactic representation but in its exploitation for the representation of meaning. Alternatively, they suggest that, at least in the aphasic population, syntactic and semantic processing may compete for computational resources, "so that subjects achieve their optimal performance in one domain only by sacrificing accuracy in the other."

Caplan (in press) offers counterarguments, claiming that the Linebarger, et. al. results are, in his view, consistent with a functor theory. Noting that syntactic information may be bound up with the meaning of a given lexical entry as well as in phrasal structure, his argument, very briefly, is that the agrammatic language processor appears to be restricted to the syntactic information coded in the argument structures of individual words. For example, the agrammatic might demonstrate sensitivity to the fact that a particular verb takes a complement, and conversely, be insensitive to phrasal structure. On this view, the agrammatic deficit involves information structures that implicate the function word vocabulary: Caplan points out that the function word vocabulary contributes not only to the construction of syntactic structures, e.g., of phrasal nodes, but also to the

> semantic interpretation of supra-lexical syntactic structures. It provides aspects of semantic readings, such as definite and indefinite reference of noun phrases, aspect and tense in verb phrases, scope of quantification, etc. Both traditional and current treatments of these aspects of semantic structure do not attribute them to lexical categories but rather to phrasal categories and the interaction of phrasal categories with each other and with larger syntactic units such as clauses. Just as the function word vocabulary plays a critical role in determining these aspects of syntactic structure, it also plays an important role in establishing these aspects of semantic structures. The mapping from semantic to syntactic structures, which Linebarger et. al. suggest as one possible locus of the disturbance in agrammatism, may, accordingly, not be independent of the semantic role of the function word vocabulary, but, rather, intimately connected to it.

Caplan proposes that "it is the interaction of the syntactic and semantic information jointly dependent upon the function word vocabulary which is not available for processing."

To summarize: The locus of the agrammatic disruption has been variously placed. The breakdown of a parser has been proposed by Caramazza and Zurif, 1976 and by Berndt and Caramazza, 1980. Modifications of parsing deficit theory implicating closed-class vocabulary elements have been advanced. Bradley, Garrett and Zurif (1980) suggested that agrammatism is accounted for by the failure of a special closed-class lexical access routine which subserves on-line syntactic processing. Caplan (in press) has argued that the deficit occurs at the point of intersection between syntactic and semantic representations which are "jointly dependent on the function word vocabulary." The position taken by Saffran, Schwartz and Marin (1980) departed from a general parsing deficit theory in suggesting that the locus of the agrammatic deficit is at a level of processing at which thematic relations are encoded. That position was elaborated by Linebarger, Schwartz and Saffran (in press), who have claimed that agrammatics do, in fact, construct syntactic representations: they propose that agrammatism reflects either (1), a deficit in the mapping of syntactic representation onto semantic representation, or (2) a tradeoff between syntactic and semantic processing in a resource-limited computational system. The issue of the locus of the agrammatic deficit is far from resolved. In any event, the approaches we have reviewed are consistent with the modularity hypothesis (Chomsky, 1980), with which this review began.

The issue of domain-specificity

Much of the research discussed above has employed comprehension tasks that require subjects to relate linguistic -- usually auditory -- stimuli to the objects or pictures to which they refer. Other research has used metalinguistic tasks in which referential considerations are less explicit. Examples of these are triadic comparison, anagram and grammaticality judgment tasks (e.g., Zurif, et. al., 1972; von

Stockert and Bader, 1976; and Linebarger, et. al.,in press). The results of these studies have been remarkably consistent: apparent parallels exist between agrammatics' production and their performance on several modalities of receptive language tasks. These parallels, which involve comparable elements and structures, have led to the assumption that agrammatism involves the disruption of syntactic processing (or its availability) at a level that underlies and accounts for the observed behavior and is distinct from domain-neutral cognitive abilities such as inferential functions (e.g., Berndt and Caramazza, 1980; Caramazza and Zurif, 1976; Zurif, Caramazza and Myerson, 1972).

This assumption entails the claim that syntactic functions are shared by performance systems and should be qualitatively unaffected by modality of perception or expression. The claim for cross-modality parallels has been widely supported by inferential statistics developed from group studies, but, with some exceptions to be described below, has rarely been tested by subjecting a group of agrammatics to two or more tasks that differ in performance modalities. Indeed, if intraindividual comparisons fail to show qualitative paralels across modalities, one would be unable to make strong claims for the existence of a domain-specific syntactic processor.

As mentioned, a few studies have tested agrammatic subjects across performance modalities. Saffran, Schwartz and Marin reported on four agrammatic aphasics who were apparently unable to make use of word order to decode or encode sentences in the absence of disambiguating semantic information (Saffran, Schwartz and Marin, 1980; Schwartz, Saffran and Marin, 1980). Caramazza, Berndt, Basili and Koller (1981) described two Broca's aphasics whose agrammatic responses on a number of production and comprehension tasks could be clearly differentiated from the responses of a Wernicke's and a conduction aphasic. Friederici, Schonle and Garrett (1982) presented a group of Broca's aphasics who demonstrated defective production of prepositions in a sentence completion task and who were unable to accurately recognize sentences in which prepositions play important syntactic roles. These direct comparisons constitute support for the notion that agrammatism may be attributed to an overarching syntactic deficit (whatever its locus or loci may be), but each is limited in scope. Further elaboration is clearly needed. This study extends the parallel deficit claim by comparing performance across two receptive activities which impose rather different performance demands. These will be detailed in a later section.

Heuristic sentence processing strategies

This study addresses a second issue as well. It has been suggested that agrammatics, lacking the benefit of normal syntactic processing may be inappropriately dependent upon a sequencing strategy that, for example, maps a noun-verb-noun sequence onto agent-action-object roles. The evidence on this point is contradictory. As noted, Schwartz, et. al. (1980) reported that their subjects failed to employ a consistent word order strategy. Others, however, have reported the use of temporal order by agrammatics (e.g,, Caplan, in press; von Stockert and Bader, 1976). Heeschen (1982) re-ported that German agrammatics show sensitivity to word order, even in sentences that are interpretable on the basis of plausibility alone. Scholes (1982) discusses a hypothetical "verb-right" (SOV) strategy. He considers the possibility that "misorderings of (at least major) constituents of sentences may reflect a tendency in agrammatic aphasics to operate in terms of more natural, less marked, sequencing strategies." By testing subjects' performance on several forms of two-clause relative sentences, this study examines the tendency of agrammatic aphasics to employ sequencing strategies (or, more precisely, to demonstrate consistent response patterns). These sentence forms are well suited to this study, for it is possible to alter the grammatical relations these structures express by means of simple shifts in word order. There is, moreover, a considerable body of literature, concerned with the comprehension of relative clauses, with which to compare to agrammatic patterns of response. It is to this literature that we now turn.

The comprehension of relative clauses

The sentence structures to be considered here take the forms listed below. The sentences are labeled according to the contrastive roles of their relativized noun phrases. In the SS-relative, the relativized NP is the _subject_ of the main clause and is the _subject_ of the relative clause as well. In the OS-relative, the relativized NP is the _object_ of the main clause but is the _subject_ of the relative clause (Sheldon, 1974). The position of the empty NP in each relative clause is indicated here by the symbol ^.

(7) SS-relative:
The cow that ^ bumped the horse kicked the goat.

(8) SO-relative:
The horse that the cow bumped ^ kicked the goat.

(9) OS-relative:
The goat bumped the cow that ^ kicked the horse.

(10) OO-relative:
The horse kicked the cow that the goat bumped ^.

A brief word about notation: each sentence used in this study contains two NPs and two verbs. When sentences are considered structurally in the remainder in this paper, NPs will be labelled N1 or N2 in order of their appearance in the surface string. Similarly, the verbs will be labelled V1 and V2 (in the experimental sentences, to be described in another section, V2 is always the verb + particle "fell down"). Thus, for example, the notation N1-V1 (SO) indicates the first noun and first verb in SO-relative sentences.

A relative clause modifying the subject of a sentence has the effect of interrupting the linear flow of the sentence. Miller (1962) and others demonstrated that such center-embedded clauses are harder for adults to process than are right-branching relative clauses. It was argued that this is the result of the increased processing load engendered by the need to remember elements of the main clause while processing the relative clause.

Slobin (1971) considered a body of evidence showing that center-embedded constructions are more difficult to process than right-branching sentences for children as well as for adults. He suggested that sentences containing interrupted or rearranged elements are more difficult than those in which constituents follow a S-V-O order. According to Slobin, center-embedded sentences were instances of interruption by the relative clause.

Sheldon (1974) named Slobin's suggestion the "interruption hypothesis." Sheldon argued that it predicts that SS and SO relative sentences would be harder for children to process than right-branching (OS and OO) relatives. She found, to the contrary, that children three to five years old had the most difficulty enacting SO and OS sentences, and did best with SS and OO sentences. Sheldon noticed that in these sentences the grammatical function of the relativized NP of the main clause matches that of the empty NP of the relative clause. Accordingly she proposed the "parallel function hypothesis" to explain her data. The parallel function hypothesis claims that children will interpret the grammtical function of the relativized NP to be the same as that of its antecedent, and that sentences in which coreferent NPs have the same grammtical function will be processed more readily than those whose coreferent NPs have different grammtical functions.

Sheldon (1977) subsequently extended her study to adults, who yielded a different pattern. College students did not show a parallel function effect. Instead, Slobin's predictions concerning word order rearrangement (as in OS relatives, in which the object NP is relativized) and interruption (as in SS and SO relatives) were supported. Sheldon accounted for these findings by proposing an "adjacency strategy":

> In parsing a noncompound sentence, starting from the left, group together as constituents of the same construction two NPs...and an adjacent noninitial verb that has not already been assigned to a clause. Interpret the first NP as the subject of the verb, and the second NP as the object of the verb (Sheldon, 1977, p. 312).

The adjacency hypothesis predicts that adults will make fewest errors on OS sentences, and most on SO. OO and SS errors would fall in an intermediate range. These are the results reported by Sheldon (1977). To explain the full range of her findings with both children and adults, Sheldon claimed that strategies vary with age and sentence form. While the notion that strategies may vary as a function of age is eminently plausible, the argument that strategies may vary with sentence type seems to be ad hoc.

Lahey (1974) investigated children's comprehension of SS, SO and CO sentences. The sentences were presented under several conditions, in which the presence or absence of syntactic markers and/or normal prosody were manipulated as experimental variables. Lahey found that the SO form was, overall, the most difficult. She took this data to be support for the parallel function hypothesis. Lahey found, in addition, that most of her subjects took the first-mentioned NP in a sentence to be the agent of both of the actions encoded by that sentence. Note that this "first-mention" strategy and the parallel function hypothesis make identical predictions for SS and SO sentences, but not for OS sentences.

Smith (1974; cited in de Villiers, et. al., 1979) suggested that children's processing of relative constructions might be accounted for by the simultaneous application of two strategies. An SVO strategy (after Bever, 1970) interprets an NVN sequence such that the first noun is subject and the second noun is the object of the verb. The second strategy, the "minimum distance principle", dictates that in a relative sentence an NP immediately preceding a syntactically marked relative clause will be interpreted as subject of that clause. If these strategies are applied, then OS sentences should be easiest, since both strategies predict correct interpretation. SO relatives should be most difficult, since both strategies predict failure. Smith (1974) obtained the predicted order of difficulty, using an elicited imitation task.

De Villiers, Flusberg, Hakuta and Cohen (1979) examined several conflicting hypotheses by testing children with an enactment procedure. Sentences were scored for the number of correctly marked grammatical relations (following the method of Lahey, 1974). The resultant order of accuracy was OS = SS > OO > SO (the directionality this notation is opposite that of many of the papers cited here, which tended to report results in terms of errors produced). De Villers, et. al. concluded that their data are consistent with an NVN surface structure processing strategy.

Tavakolian (1978) found that the predominant error type produced by children matches the analysis required to interpret the role of the missing NP in conjoined sentences. In relative sentences of the types used in this study (see the Methods section), this leads to the same predictions as the "first-mention" strategy. The predicted order of response accuracy is SS > SO = OS.

Many of the findings and interpretations reviewed above are contradictory. Some of the differences may be more apparent than real. For example, there is substantial variety in methodology and in the ages of the child subjects. There is another, possibly confounding factor, worth noting: it has been reported that children's performance is radically improved when the number of nouns (or NPs) in relative sentences is reduced from three to two (Goodluck and Tavakolian, 1982). Since most of the work on children's comprehension of relative sentences revolves around their responses to three-NP constructions, the conclusions derived from this work may be questioned. While it is true that these conclusions my be compromised, this review has been presented in order to introduce various hypotheses that have been advanced to account for children's comprehension of relative sentences. These will serve, in the present work, as the basis for an attempt to characterize comprehension strategies used by aphasics.

The comprehension of relative sentences by adults has not been studied as extensively as it has been in children. This is natural enough, since adults rarely fail to comprehend them. Investigators such as Cook (1975) and Larkin and Burns (1977), employing multiply-embedded constructions, elicited responses that led them to claim that mnemonic limitations account for incorrect performance. Such conclusions are no doubt valid for multiply embedded sentences, but they are of doubtful utility in consideration of the clausal processing of singly-embedded constructions. In passing, notice that predictions based on mnemonic limitations are within the scope of the interruption hypothesis.

Feier (1977) found support for the parallel function hypothesis (SS = OO > OS > SO) among normal elderly subjects. She noted, however, that parallel function does not predict OS > SO. To account for this finding she proposed a "temporal strategy" which assumes that the sequence N1-V1-N2 is the SVO sequence of the first enactment. Since the SO form is the only one that violates this assumption, the theory predicts greatest difficulty for SO relatives. In effect, Feier's work supports that part of Slobin's arguments pertaining to the rearrangement of constituents. Within the context of the relative sentences under consideration, the temporal strategy is consistent with the minimum distance principle.

Brain-damaged adults appear to be unable to assign grammatical relations in relative sentences without pragmatic and/or semantic cues (Caramazza and Zurif, 1976). Blumstein, Goodglass, Statlender and Biber (1983) have suggested that aphasics use an heuristic strategy which relates an anaphor to the nearest preceding antecedent. Thus, in relative sentences, this "minimal distance strategy" (MDS) assumes that the antecedent of the empty NP in the relative clause is the nearest preceding NP. Blumstein, et. al. observed that their subjects were likely to erroneously assign reference in sentences which violated the MDS.

Caplan (in press) has proposed that agrammatics have access to syntactic/semantic information carried by individual lexical entities, but not by supra-lexical nodes. This "lexical node" hypothesis predicts that agrammatics will process relative constructions (indeed, any sentence forms) as though they are strings of major lexical items and will interpret them according to their lexically-encoded argument structures. If it is assumed (as does Caplan, for example) that temporal order figures in the assignment of nouns to verb argument structures, then sentences in which the major lexical items are ordered as in (11)

(11) N1-V1-N2-V2,

(e.g., The man bumped the woman that fell down) will be interpreted as N1-V1-N2, and N2-V2 (the man bumped the woman, and the woman fell down). This form, (11), corresponds to CO, SS and OS sentences having two NPs. The interpretation given here is, of course, correct only for OS sentences. This interpretation of the lexical node hypothesis also predicts a somewhat more erratic performance on SO relatives, since the ordering of the lexical items in that form does not conform to the argument structures of the verbs. Notice that this prediction conforms with that of the minimal distance strategy.

In summary, it has not been possible to unambiguously characterize the heuristic processing strategies presumably applied to relative sentences by young children and/or language-impaired adults. Reviewing this literature, one is confronted with conflicting data and claims. There are many salient variables, such as subject selection, number of NPs in stimuli, data analysis, and the like that tend to make comparisons difficult. Four major candidate strategies emerge from this review, each predicting a somewhat different set of responses to relative sentences. These are the minimal distance (MDS), adjacency (ADJ), parallel function (PFS) and first noun phrase (FNP) strategies. Each will be briefly described, and the behaviors predicted for each will be outlined. These predictions, projected for each of two experimental tasks, are represented in Tables 7 and 8.

Minimal distance strategy. This strategy, as it is construed in the present work, closely resembles the "minimum distance principle" described by Smith (1974). It is presumed to result from the simultaneous operation of two heuristic principles. The first of these is the canonical order strategy (Bever, 1970), which assumes that in an NVN sequence, the first noun is agent and the second noun is the patient. The second heuristic is a departure from Smith's formulation, and does not require recognition of syntactic markers as such for its operation. According to this second heuristic, thematic relations will be assigned among the most proximate semantically plausible items. Thematic relations holding between the first noun and final verb in two-clasue relative sentences will not be accurately perceived by a user of this principle.

Several of the strategies reviewed here are compatible with the minimal distance strategy. It incorporates the interruption hypothesis (Slobin, 1971) and, despite the fact that it does not require recognition of a function word marking a relative clause, makes predictions identical to those of Smith (1974). Similarly, this minimal distance strategy makes the same predictions as does the like-named heuristic proposed by Blumstein, et. al. (1983). This strategy is also consistent with the lexical node hypothesis as well, except in SO-relatives, where the latter predicts ambiguity with regard to thematic relations around the verb in the NNV sequence.

The minimal distance strategy predicts that object-subject relatives, e.g.,

The man greeted the woman that fell down

should be most readily understood, since neither canonical order nor proximity constraints are violated. Subject-subject relatives, e.g.,

The woman that watched the man fell down

should elicit errors. The minimal distance strategy predicts an interpretation of this surface string such that the first noun is the agent and the second noun the patient of the first verb, while the second noun is agent of the second verb. Subject-object relatives, e.g.,

The man that the woman bumped fell down

should also elicit errors. The violation of canonical order is expected to disrupt perception of relationships around the first verb, and the correct noun 1-verb 2 agent-action relationship violates the proximity principle. Since both principles are violated by subject-object relatives, this form should engender the greatest number of errors among users of this strategy.

<u>The adjacency strategy.</u>. This strategy was originally proposed by Sheldon (1977). Its definition is repeated here:

> In parsing a noncompound sentence, starting from the left, group together as constituents of the same construction two NPs...and an adjacent noninitial verb that has not already been assigned to a clause. Interpret the first NP as the subject

> of the verb, and the second NP as the object of the verb (Sheldon, 1977, p. 312).

This strategy assumes that any combination of two nouns and a transitive verb will be interpreted such that the temporally first noun is the agent and the second noun the paatient. As defined by Sheldon, the adjacency hypothesis is restricted to noncompound sentences, and it makes no prediction regarding thematic relations involving the second verb in sentences of the types used in this study. It will be assumed, then, that proximity applies in these cases. This assumption allows a distinction between the adjacency strategy and a first noun phrase strategy, to be described below. This formulation leads to correct interpretation of object-subject relatives, and predicts equivalent error proportions for subject-subject and subject-object sentences. Since the lexical node hypothesis (Caplan, in press) seems to be neutral with regard to the assignment of thematic roles in NNV sequences, it is compatible with both minimal distance and adjacency hypotheses.

<u>The parallel function strategy.</u> As defined by Sheldon (1974), this strategy is one in which relative sentences will be interpreted such that the grammatical function of the relativized NP will be perceived to be the same as that of its antecedent. Thus, among subject-subject, subject-object and object-subject relatives, subject-subject relatives should elicit fewest errors. In projecting responses for this strategy it was again assumed that it depends on surface

structure processing. On this assumption, the first agent-action relationship to be encountered in a left-to-right scan of the surface string would determine the interpretation of the second agent-action relationship. This interpretation is correct in subject-subject relatives, but not object-subject relatives. The interpretation of subject-object forms was projected as follows: noun 2 is agent of both verb 1 and verb 2. This is, of course, incorrect.

The first noun phrase strategy. This strategy simply assumes that the first noun encountered in the surface string is the agent of all subsequent actions. By default, other nouns are assumned to take patient roles. This strategy predicts correct responses to one form of relative sentence, the subject-subject relative. In subject-object sentences, the agent of the first verb will be misinterpreted; and in object-[subject sentences, the error will involve the second verb.

The predicted responses for these four strategies will be compared with the responses of two groups of aphasic patients to determine which, if any, strategy is employed by each group. The research hypotheses and methods follow in the next section.

Strategies reconsidered: a caveat

The word "strategy" implies the use of a plan, a method to achieve a desired result. In the current context, however, the term is used to describe and/or explain patterns of response reflecting subjects' comprehension of sentences. To say that a subject or group of subjects employs a strategy, then, is to say that their responses demonstrate regularities that reflect their ability to impose order on linguistic input. This ability may reflect domain-specific constraints on the construction of linguistic representations and/or domain-general constraints, e.g., on the ability to form or utilize inductions over experience, such as regularities of word order. In subsequent discussion, the term "strategy" will bear the meaning which has been expressed here.

The research hypotheses

A large body of evidence has been accumulated to support the belief that agrammatism is attributable to a central, domain-specific syntactic deficit. Few studies have reported cross-modality studies performed on a single group of subjects; and those that have done so have supported the central deficit hypothesis (Caramazza, et. al., 1981; Friederici, et. al., 1982; Saffran, et. al., 1980; Schwartz, et. al., 1980; but see Linebarger, Schwartz and Saffran, in press). It was anticipated that the agrammatic subjects of this study would also yield results consistent with the central deficit hypothesis.

The following research hypotheses were advanced:

H1. If agrammatism is in fact domain-specific, then the character of this deficit should be unaltered by variation in task demands. The ability of agrammatic Broca's aphasics to correctly represent agent-action relationships in relative sentences was tested in two quite dissimilar comprehension tasks (to be described in the following section). It was hypothesized that their patterns of error across sentence types -- reflecting their syntactic processing deficits -- would be qualitatively equivalent across tasks.

H2. If the agrammatic deficit is to be considered syndrome-specific, and not the general result of damage to the dominant hemisphere, then the response patterns generated by Broca's aphasics should differ qualitatively from those of fluent aphasics. It was anticipated that such a distinction would be observed.

H3. It was further hypothesized that agrammatics, presumably incapable of normal grammatical analysis, employ a principled and predictable heuristic sentence processing strategy. It was predicted that the results of this study would provide evidence for the use of one such strategy.

METHOD

Subjects

The subjects who participated in this study were eight Broca's aphasics, six fluent aphasics and nine neurologically intact controls. All subjects were patients in the New York, Brooklyn or East Orange Veterans Administration Medical Centers. Each of the aphasics has a documented history of single left focal CVA, with no suspicion of bilateral involvement. Each was right-handed, premorbidly. The methods employed in the determination of lesion site varied from patient to patient, and consisted of combinations of all or some of the following: clinical neurological signs (e.g., hemiplegia, hemisensory deficit, reflexes), CT scans, and brain scans. Most of the controls were outpatient visitors to the otolaryngology clinic of the New York VA Medical Center, and had no history or suspicion of neurological disease. Background information pertaining to the aphasic subjects is summarized in Table 1.

Broca's aphasics

The eight Broca's aphasics ranged in age from 47 to 67 years, with a mean age of 54.13 years. In each case the site of lesion was within the distribution of the superior branch of the left middle cerebral artery (Mohr, 1976). The number of years of education completed ranged from 8 to 14, with a mean of 11.6. The duration of aphasic impairment ranged from 9 months to 12.5

years, with a mean of 4.56 years. Preselection criteria included: (a) Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972) profiles consistent with the diagnosis of Broca's aphasia, (b) z-scores of -.5 or better on the auditory comprehension subtests of the BDAE, (c) raw scores of 4 or better on the reading sentences and paragraphs subtest of the BDAE, and (d) nonfluent, agrammatic speech output. The severity of aphasic impairment was not a preselection criterion, but it was found that subjects with BDAE severity ratings as low as 2 were able to participate appropriately, while a patient at level 1 was unable to respond reliably. No very mildly impaired (level 5) Broca's aphasics were tested. Severity levels ranged from 2 to 4. Auditory comprehension z-scores ranged from -.1 to .8, with a mean of .464. Raw scores on the reading sentences and paragraphs subtest ranged from 5 to 8, with a mean of 6.25. Articulatory agility z-scores (BDAE) ranged from -2.1 to -.6, with a mean of -1.36 . The length of the longest uninterrupted phrase uttered in a speech sample ranged from 1 to 7, with a mean of 3.38. Ratings of availability of grammatical forms in spontaneous speech (BDAE) ranged from 1 (none available) to 5 (simple declaratives and occasional instances of more complex forms e.g., constructions involving modal verbs), with a mean rating of 2.94.

The validity of the use of contemporary classification schemes for making generalizations about the structure of language has recently come under serious scrutiny (e.g., Caramazza and Martin, in press; Schwartz, 1982). Schwartz (1982) has observed that despite the well-known clinical utility attendant upon identification of an aphasic with one or another of the major clinical syndromes, "it has become painfully clear that dividing patients along the lines of the classical aphasia syndromes does not make taxonomically relevant those generalizations about language organization that many of us strive to capture." She points out that the major aphasic syndromes are "polytypic" structures, defined by clusters of shared characteristics, of which no single one is necessary for identification with a particular syndrome. Thus, if the major clinical entity Broca's aphasia is viewed as a polytypic structure, one may not generalize a set of experimental findings to all Broca's aphasics. One should expect, to the contrary, to find Broca's aphasics who do not demonstrate this finding and, further, to find it in aphasics who would not be so classified on independent grounds. The recent experimental literature has offered several cases in point. Reports of two patients "presenting with agrammatic speech and what seems to be normal comprehension" are cited by Grodzinsky, Swinney and Zurif (in press). Caplan, Matthei and Gigley (1981), using an enactment paradigm, tested 11 clinically diagnosed Broca's aphasics' comprehension of gerundive constructions. Four of these subjects demonstrated the use of normal grammatical structures in their interpretation of trial sentences, six clearly failed to do so, and one produced a random response pattern. This result offers empirical reason to question the theoretical utility of syndrome-based groupings: here, a group of subjects who shared membership in a taxonomic category were separated out in the centrifuge of experimental study.

Heretofore, the terms 'Broca's aphasia' and 'agrammatism' have been used more or less interchangeably. With these recent examples in mind, it was of some interest to ask whether the Broca's aphasics participating in this study, who were selected on the basis of criteria which are common in clinical and experimental usage, would separate into discernible subgroups. Subjects' response patterns and other relevant data were examined for evidence of subdivision.

Fluent aphasics

The six fluent aphasics ranged in age from 33 to 71, with a mean of 54. In each case, a posterior site of lesion, either parietal or temporo-parietal, was established. Duration of aphasia varied from 1.5 months to ten years, with the mean just short of three years. The educational backgrounds of these patients varied widely, from completion of the 9th grade to the attainment of a Masters of Business Administration. The mean years of schooling for this group was 12.67. The preselection criteria for this group were (a) BDAE profiles consistent with the fluent aphasias (Wernicke's or anomic), and (b) the ability to read and understand at least four of the items of the BDAE reading sentences and paragraphs subtest. Severity of impairment was not a preselection criterion, but it was found that a fluent aphasic with a BDAE severity rating below 3 (able to discuss most everyday problems without much assistance) was unable to grasp the experimental task requirements. The severity levels of the participating fluent aphasics ranged from 3 to 5. These levels reflect relatively milder impairment in fluent patients when compared with the Broca's aphasics. This disparity was necessitated by the inability of more severely impaired fluent aphasics to complete the pretrial training (see below for details). It is believed that group differences in auditory and reading comprehension scores reflect this difference in overall severity. Auditory comprehension z-scores ranged from 0 to 1.0, with a mean score of 0.41. Raw scores on the reading subtest varied from 5 to 10, with the mean of 7.67. Articulatory agility z-scores ranged from 0 to 1.0, with a mean of 0.66. Phrase length varied from 5 to 11 words (mean = 8.33). There was no obvious limitation of the availability of grammatical forms.

Control subjects

The nine control subjects were otolanryngology or dermatology pa;tients of the New York Veterans Administration Medical Center. They were free of any indication of neurological disease. They ranged in age from 47 to 71 years, with a mean of 57.11. Their educational levels varied from completion of 9th grade to four years of college. The average number of grades completed was 12. These subjects were tested only to verify the claim that neurologically intact persons would perform more or less flawlessly on the experimental tasks. This was indeed the case: only three errors were recorded among the 1,440 responses generated by these subjects. There will be no further discussion of the normal controls.

Sentence materials

Two-clause relative sentences are well suited for this study, for the grammatical relations these structures express are altered by simple shifts in the ordering of major and/or minor lexical items. The stucture and labelling of the types of sentences employed in this study were discussed above. Examples of the experimental sentences follow.

(12) SS relative:
The man that bumped the woman fell down.

(13) SO relative:
The woman that the man bumped fell down.

(14) OS relative:
The man bumped the woman that fell down.

A conjoined sentence of the same length and containing the same set of major lexical elements served as a control structure:

(15) CO (conjoined):
The woman bumped the man and fell down.

Since these forms end with an intransitive verb, sentences of the OO-relative form, e.g.,

(16) The man bumped the woman that the girl watched.

cannot be used here. This restriction is motivated by the results of a pilot investigation which revealed that subjects who were unable to perform reliably with 3-NP sentences, such as (16), performed consistently with 2-NP forms. This finding re-iterates that of Goodluck and Tavakolian (1982), who reported that children respond more readily to 2-NP sentences than to 3-NP constructions.

The test sentences were generated from a closed list of two noun phrases, four transitive verbs and one compound intransitive verb. A closed set of stimuli was used to avoid semantic variability as a confounding factor. The noun phrases are:

the man
the woman

and the verbs are:

pushed
bumped
watched
greeted
fell down.

Five exemplars of each sentence type were constructed, with the number and position of NPs and verbs balanced across type. The order of sentence presentation was pseudorandomized: a computer-generated random list order was modified to ensure that no sentence type or transitive verb appeared twice in succession. The experimental sentences are listed, in order of presentation, in Appendix A.

The transitive verbs were originally chosen to test the hypothesis that verbs denoting proximal contact are in some way more readily incorporated into meaning structures than are verbs denoting physically more abstract actions. The enterprise was suggested by the work of Pastouriaux, Brownell and Zurif (1982), and by the choice of verbs employed in the work of Saffran and colleagues (Saffran, Schwartz and Marin, 1980; Scwartz, Saffran and Marin, 1980). It was intended to test the hypothesis by noting which verb(s) engendered the greater number of action-errors on the enactment task, to be described in the following section. As it happens, very few action errors were recorded; thus no analysis was possible.

Procedures

Testing conditions

Each subject was individually tested in a single session, which began with preliminary testing on portions of the BDAE (described above), followed in most cases with the taping of a spontaneous speech sample. In the interest of brevity, speech samples were not taken for patients having taped samples on file at the New York VA Speech Pathology Clinic. In addition, subjects underwent tests of verbal (and in some cases, nonverbal) short term memory. Patients who satisfied the preselection criteria were then trained in one of the experimental tasks and, having satisfied the training criteria (see below) were then subjected to the task. This was followed by training and testing in the second task. The details of training will be presented for each task separately. The order of administration of these tasks was counterbalanced across groups.

Short term memory tests

Digit span testing, both forward and backward, was included in the test battery. Testing proceeded at progressively difficult levels, and two failures at a given level ended the test sequence. The score was the highest number of successfully repeated digits. A number board was provided for sequential pointing, thus subjects were able to select a verbal or gestural response modality. About midway through testing, it was suggested that a measure of non-verbal memory be included. Consequently, the Knox Cube Test (Arthur Revision, 1947), was added to the battery in time to provide supplementary data for four Broca's aphasics and four fluent aphasics.

Experimental tasks

1. Auditory comprehension -- enactment task.

This task has been used successfully with aphasic subjects by Caplan, Matthei and Gigley (1981). It has also been employed extensively in the study of children's acquisition of grammar. At the start of each of the twenty trials on this task, a subject is confronted with two freestanding hand puppets -- one the likeness of a man, the other of a woman -- placed on the table and facing him. It has been suggested that sentences with restrictive clauses presuppose more than one instantiation per noun phrase, and that violation of this "felicity condition" might present problems in the interpretation of responses to such sentences (Hamburger and Crain, in press). Pilot testing indicated that the population of this study is unaffected by this factor, and consequently, only two dolls were presented. After each sentence was read aloud by the experimenter at a moderate rate and with normal inflection, the subject was required to act it out with the hand puppets. When performed in sequence, these enactments were readily accomplished by hemiplegic patients. A single repetition was provided on request or when responses were incomplete.

Subjects were trained to understand that each sentence depicts two actions: one figure performs one of four actions in relation to the other figure, and then one of them falls down. The instructions used to introduce this task were as follows:

> Here are two dolls: a man and a woman. I'll read a sentence to you and then your job is to show me what the sentence means, by doing the actions with the dolls. Let me show you what I mean. Here's a sentence:
> The man pushed the woman.
> (Experimenter demonstrates man pushing woman).
> How about some more? (E. Demonstrates greeted, bumped, watched).
> Now you show me:
> The man pushed the woman
> The woman greeted the man
> The man watched the woman
> The woman bumped the man
> The man fell down.
> Okay! Now let's do one that has two actions.
> The woman pushed the man and fell down.
> The man pushed the woman and fell down.
> Good. Now, the sentences I will read to you will have two actions. Remember, you have to show both actions. Ready? Let's begin.

In practice trials, each subject was required to demonstrate the ability to correctly act out each of the five actions and to keep track of all actor-recipient relationships. During the course of subject selection, all patients learned this task readily.

2. Sentence-fragment paraphrase judgment task.

At the start of each trial, the subject viewed a sentence printed in large type (IBM Orator) as the experimenter read it aloud at a moderate rate and with normal inflection. the card remained in the subject's view as six 2-element sentence fragments were presented in turn. Each element consisted of either an NP or a verb from the sentence in view. For example, in the SS relative sentence

(17) The man that pushed the woman fell down,

the fragments were:

THE MAN	PUSHED	(N1-V1)
THE MAN	THE WOMAN	(N1-N2)
THE MAN	FELL DOWN	(N1-V2)
PUSHED	THE WOMAN	(V1-N2)
PUSHED	FELL DOWN	(V1-V2)
THE WOMAN	FELL DOWN	(N2-V2)

From sentence to sentence, the order in which these fragments were presented was randomized by a computer program that generated the scoresheets. A sample scoresheet is included as Appendix A. As each fragment is presented, the subject's task was to decide whether the fragment did or did not paraphrase, or convey a part of the information expressed by the complete sentence. An affirmative or negative answer in any modality was acceptable. Note that the order of elements always conformed to their appearance in the parent sentence. This was done in order to discourage subjects from considering fragments without regard to the sentences from which they were derived. Thus, in the example given, only N1-V1, N1-V2 and N2-V2 decisions were analyzed; the other choices were treated as foils.

Training trials began with simple active declarative sentences used to demonstrate the task, and then employed semantically nonreversible conjoined and passive sentences, comparable in length to the experimental material. Subjects were trained to recognize the validity of "distant" noun-verb relationships (N1-V2) in conjoined and passive sentences. They were also trained to recognize that left-to-right concatenation of elements is not always appropriate. That is, they were shown that the N1-V1 pairing should be rejected in the context of passive sentences, and were warned that this is also true for some of the experimental sentences. The training instructions for this task were as follows:

> You will read some sentences. The sentences tell about something that happened. Here's an example:
> <u>The man washed the dishes.</u>
> I can take the words out of the sentence to make small phrases. Each one tells a little part of what happened (E shows fragments)
> THE MAN WASHED
> WASHED THE DISHES
> I can make one more little part, but it doesn't tell much about what happened:
> THE MAN THE DISHES
> Now I'll show you the sentence again and this time, I'll show you the phrases and it'll be your job to tell me if they tell a little part of what heppens in the sentence. (E. presents same sentence and fragments, reinforcing correct responses. The procedure is repeated for one or two

more simple declarative sentences. Then, larger, semantically nonreversible sentences are trained.

Now you will read some longer sentences. Each sentence tells about two things that happen. Here's an example:

The boy threw the rock and sat down.

What are the two things that happened? The boy threw a rock and the boy sat down. Look how I can take words out of the sentence to make small phrases. Each one tells one thing that happened: (E. shows fragments)

THE BOY SAT DOWN
THE BOY THREW
THREW THE ROCK

I can make more phrases, but they don't tell what happened:

THE BOY THE ROCK
THREW SAT DOWN
THE ROCK SAT DOWN

Now let's try it. I'll show you the whole sentence and then I'll show you some phrases. Your job is to tell me if the little phrase tells a part of what happens in the whole sentence. (Experimenter presents the phrases shown above, in random order. Errors are corrected and explained.) Now let's do another one (same procedure with another semantically nonreversible conjoined sentence.

Sometimes the 'little' words of a sentence make a big difference. Take this sentence: The box was carried by the man who burped. Who carried the box? (E. confirm correct answer). Yes: we know that because of the words was and by. So even if the man comes after the box in this sentence, we still know it was the man who did the carrying. Let's try the phrases (repeat as above, with corrections).

Subjects were accepted for the study when they demonstrated ability to complete three accurate series for each type of training sentence. A total of three potential patients, two fluent and one nonfluent, were unable to complete training for this task. One of the fluents could not be trained for behavioral reasons: he conducted a running monologue on his treatment at the hospital, his illness, etc., and he could not be focussed on the experimental material. The other fluent aphasic who was rejected was unable to comprehend the demands of the paraphrase task. This patient had received a BDAE severity rating of 2 (able to communicate with substantial assistance from the listener), while the fluents who were able to participate in this study had severity ratings of three or better. The scores for both men in other preselection measures were comparable with those of participating subjects. The lone nonfluent aphasic who was unable to complete training had been thought to have adequate comprehension despite a severe paucity of speech, which was limited to few single-word utterances. His auditory comprehension z-score was -.3, which was within the preselection guidelines but lower than that of any of the participating subjects.

Results

Tabulation of raw data

The subjects' individual responses are represented in Tables 2 to 6. Tables 2 and 3 show the subjects' affirmative responses to sentence fragments on the paraphrase task. For each sentence type, the two correct choices are marked by asterisks. Proportion scores are given for each fragment type. These reflect affirmative responses divided by number of occurences. Thus, on the paraphrase task (see Table 2), Broca's aphasics accepted the N1-V1 fragment 38 times in 40 occurrences within CO sentences, giving a proportion score of .95. As mentioned in the previous section, the ordering of lexical items in sentence fragments always conformed to the word order of the sentences from which they were derived. This constraint, which was imposed in order to discourage random guessing, precluded testing of N2-V1 fragments on CO, SS and OS sentences. Tables 4 and 5 represent the raw data from the enactment task. For each sentence type, the correct enactments are indicated by asterisks. Below these, individual subjects' choices and group accuracy proportions are listed.

Sequence of data analysis

Hypothesis 1 calls for an analysis of accuracy of response as a function of sentence type, compared across tasks.

A straightforward cross-task comparison was not possible, however, since the data for the two experimental tasks are not equivalent in form. The paraphrase task yields independent scores for each of three or four N-V fragments per sentence type, while the enactment task yields only two scores per sentence type. Accordingly, hypothesis 1 was tested in two separated analyses. First, a "whole-sentence" analysis collapsed all responses for a given sentence within a task into a single score (correct or incorrect). A correct whole-sentence score was obtained when all the raw scores for that sentence were correct. By this method the scores were rendered comparable across tasks, thus enabling the first analysis. Since data is inevitably lost in this sort of analysis, a score-weighting procedure was employed to enable the inclusion of each separate response in the second analysis. This weighting procedure is described below, and is followed by an analysis of weighted accuracy scores.

A consideration of hypothesis 3 follows the analyses of deficit patterns. Hypothesis 3 suggests that agrammatics might display a tendency to employ a particular heuristic sentence processing strategy. Persuant to this question, the responses of an "ideal user" of each of the four strategies discussed above were projected. Then, subjects' responses were compared with these predictions to derive proportional weighted strategy scores. These data were analyzed to test hypothesis 3. Finally, hypothesis 2 calls for intergroup comparisons. These were performed as part of each of the above analyses.

Analysis of "whole-sentence correct" responses

The whole-sentence correct data are given in Table 6. A groups by tasks by sentence type repeated measures analysis of variance was applied to these data. Both groups produced more fully correct responses on the enactment task (F [1,12] = 23.86 [p<.001]). There was a significant effect of sentence type as well (F [3,36] = 8.03 [p<.001]). Post-hoc testing (Tukey A, .05) showed that this resulted from significantly better performance on OS sentences than on SO and CO sentences. In addition, there was a significant groups by sentence type interaction (F [3,36] = 4.58 [p<.01]). This indicates that the Broca's and fluent aphasics did not respond to the four sentence types in the same way. In order to examine this interaction more closely, separate two-factor repeated measures analyses of variance were carried out for each group.

"Whole-sentence correct" analysis: Broca's aphasics

A task by sentence type repeated measures ANOVA was applied to the Broca's aphasics' data. A significant main effect of tasks indicated that enactment task scores were, on the whole, higher than paraphrase task scores (F [1,7] = 15.9 [p<01]). There was a significant main effect of sentence type (F [3,21] = 8.12 [p<.05]). A post-hoc test (Scheffe, .01) showed that on both tasks, the responses of these patients to OS-relatives were significantly more accurate than were responses to the three other sentence types. This pattern conforms to the minimal distance and adjacency strategies. Significant differences between SS, SO and CO sentence types did not emerge in this "whole-sentence" analysis. The task by sentence interaction was nonsignificant (F [3,21] = 1.66). This indicates that the performance of the Broca's aphasics was indeed parallel across tasks.

"Whole-sentence correct" analysis: Fluent aphasics

A similar two-factor repeated measures analysis of variance of the fluents' data showed that their enactment task scores were higher than paraphrase task scores (F [1,5] = 9.14 [p<.05]). A main effect of sentence type (F [3,15] = 4.14 [p<.05]) was due to consistently poorer accuracy for SO than for other sentence types (Tukey A, .05). This response pattern is consistent with all but one of the projected strategy patterns: the adjacency strategy predicts accurate responses to SO sentences. Again, the tasks by sentence type interaction was nonsignificant, indicating that performance was roughly parallel across tasks for this group as it was for Broca's aphasics.

The major findings of the foregoing analysis are: (1), each group responded to the four sentence types in patterns that are parallel across tasks; (2), Broca's and fluent aphasics produced different patterns of response to these stimuli; (3), Broca's aphasics performed most accurately in response to object-subject (OS) relatives, making no significant distinctions between SS, SO and CO sentence forms; and (4) fluent aphasics performed least accurately in response to subject-object (SO) relatives, making no clear distinction between SS, OS and CO sentence types.

This analysis is based on a tally of fully correct sentences: since each single correct sentence represents two scorable enactment responses or three to four scorable paraphrase responses, it is likely that a more finely detailed analysis -- one which takes each response into account -- would be more informative. This requires transformation of the data. The following section details this transformation procedure.

<u>Transformation of the data: weighted scores.</u>

The enactment task requires two forced choice decisions per sentence. This paradigm yields simple correct/incorrect proportion data. The paraphrase judgment task requires yes/no decisions, yielding four possible response categories per trial: correct affirmatives (hits), misses, correct rejections and incorrect affirmatives (false alarms). While these data may be converted into unbiased proportions by means of signal detection analysis (Pollack and Hsieh, 1969), not all of the paraphrase task data could be treated in this manner. In order to discourage subjects from responding without reference to the test sentences, the ordering of words in trial fragments never conflicted with the word order of their parent sentences. Thus, in SS, CO and OS sentences, the possibility of actor-action relationships between noun 2 and verb 1 was not tested. This permitted only correct/incorrect responses to N1-V1 fragments in these sentences, which are unsuitable for signal detection analysis. In order to permit meaningful and valid comparisons, the data from both tasks were transformed to weighted scores.

For the purposes of this analysis, correct responses are treated statistically as though they are the outcome of one of five strategies which might be applied to sentence comprehension by aphasics. (Note that this is not meant to imply that the writer views all syntactic processing as strategic.) The responses of an "ideal user" of each of the four strategies discussed earlier in this work were projected, along with correct responses, for each task. These projections are represented in Tables 7 and 8. Examination of these tables reveals that for most of the thematic relations expressed in the test sentences, more than one strategy may lead to a given response. To reduce the effect of these redundancies, each response was weighted according to the number of strategies to which it conformed. To illustrate: consider Table 7, which shows predictions and response weights for the paraphrase task. Observe that all five strategies predict affirmative responses to N1-V1(CO) fragments (i.e., noun 1-verb 1 fragments in CO sentences). Dividing one such response by the number of strategies it fits yields a score of 1/5. This value is then added to cumulative totals for each of the five strategies. Continuing the example, consider the N1-V2(CO) fragment. Table 7 shows that affirmative responses are predicted by three strategies, while negative responses are predicted by two. An affirmative answer is thus given a value of 1/3, and this value is summed to the totals of the three strategies predicting the response. A negative answer, predicted by two strategies, is given a value of 1/2, and this value is summed to the totals of those strategies. This procedure was applied to the enactment process, as well. Refer, now, to Table 8, which displays predictions and response weightings for the enactment task. This task required two enactments per sentence: one for each verb. Thus there were two independent scores per sentence. Let us again consider a concrete example. All five strategies predict that the actor associated with verb 1 in CO sentences will be noun 1. When this relationship is enacted, the response is apportioned among all the strategies it fits and thus the value 1/5 is summed to their totals. If the N2-V1 actor-action relationship is enacted, then nothing is added to the totals, for none of the strategies predict this response. With regard to verb 2 enactments: if a subject indicates that N1 is the actor then scores of 1/3 are added to the totals for the three strategies (correct, parallel function and first-NP) predicting the response; but if he designates N2 as the actor, then scores of 1/2 are added to the minimal distance and adjacency strategies. In this manner, each response received an unweighted value of 1, which was then apportioned among the strategies to which it conformed.

The total weighted scores assigned to each strategy were divided by the theoretically maximum scores for each, to derive "strategy proportion scores". Five such scores (one for each strategy) were developed for each subject on each task. These scores are listed in Table 9. The proportions were then subjected to arcsine transformations in order to make the data suitable for analysis of variance (Winer, 1971).

<u>Analysis of weighted accuracy scores</u>

This part of the analysis pertains to weighted correct proportion scores only. A groups by tasks by sentence type repeated measures analysis of variance was performed. There was a significant main effect of groups (F [1,12] = 5.1 [p<.05]), showing that the fluent subjects responded more accurately, overall, than did the Broca's aphasics., A significant main effect of tasks (F [1,12] = 13.83 [p<.005]) indicated that greater accuracy was achieved by the combined groups on the enactment task. A main effect of sentence type (F [3,36] = 7.51 [p<.001]) revealed that the four experimental sentence types were not treated alike. Overall, the right-branching OS-relative sentences elicited the most correct responses and SO-relatives engendered the most errors. A significant groups by sentence type interaction (F [3,36] = 5.12 [p<.01]) demonstrated that Broca's and fluents aphasics produced different patterns of response to the sentence types. This supports the hypothesis that the response patterns generated by Broca's aphasics are syndrome-specific and not a general result of brain damage. In order to examine this interaction more closely, separate two-factor repeated measures ANOVAS were carried out on each group's data.

Broca's aphasics' weighted accuracy scores

Figure 1a displays the response patterns of Broca's aphasics for the different sentence types. Analysis of variance reveals a significant effect of tasks (F [1,7] = 6.94 [p<.05]). Enactment scores are higher than paraphrase scores. A significant main effect of sentence type (F [3,21] = 9.67 [p<.001]) is due to the fact that OS-relative sentences elicit more correct responses than do the other sentence forms (Scheffe, .01). Note that this effect is highly significant despite considerable individual variation (see Tables 2 and 4; especially subjects B5 and B6). The question of individual variation is discussed at some length, below. The task by sentence type interaction is nonsignificant (F [3,21] = 2.88). This indicates that this group of Broca's aphasics display qualitatively parallel error patterns across tasks. If error patterns reflect sentence processing deficits, then this result supports the supposition that a syntactic deficit exerts a similar effect upon performance on both tasks.

Fluent aphasics: weighted accuracy scores

The data for this group are displayed graphically in Figure 1b. A significant main effect of tasks (F [1,5] = 7.67 [$p<.05$]) indicates that enactment task responses were generally more accurate than were paraphrase task responses. The main effect of sentence type was nonsignificant (F [3,15] = 3.07), as was the task by sentence type interaction (F [3,15] = 0.56).

Weighted accuracy scores: brief summary

First, the fluent aphasics of this study are generally more accurate than the Broca's aphasics. Although this would appear to contradict the general impression that comprehension is more intact among anterior-lesioned patients, it must be remembered that the fluent aphasics who participated in this study were generally less severely impaired than were the Broca's aphasics (please refer to Table 1 and to the discussion in the Methods section). Second, enactment task scores were higher than paraphrase task scores in each analysis. It is unclear whether this results from some real difference in task demands or from some artifact of the design. This finding will be discussed further, below. Third, the fact that fluent aphasics' accuracy scores were equivalent across sentence types indicates that their errors did not reflect particular difficulties with the variations of syntactic structure that distinguished the sentence types. It would appear, rather, that their errors may reflect lexical confusions among vocabulary items within the same form class, distributed more or less randomly among all sentence types. Finally, the Broca's aphasics' error patterns are nonrandom, and are consequently taken to reflect deficits in the processing of the structural elements that distinguish the sentence forms. The fact that these nonrandom patterns are qualitatively parallel across tasks suggests the presence, as hypothesized, of an *activity-independent* underlying syntactic deficit in this group of Broca's aphasics.

Given this conclusion, it is appropriate to test the hypothesis that agrammatic aphasics, as a group, employ a predictable sentence processing heuristic strategy. In the following section, an analysis of the full set of weighted strategy scores will be presented.

Analysis of weighted strategy scores

The five response patterns, for which predictions were projected and tested are:

1. correct grammatical analysis (CORR)
2. minimal distance strategy (MDS)
3. adjacency strategy (ADJ)
4. parallel function strategy (PFS)
5. first noun phrase strategy (FNP).

The first pattern (CORR) simply reflects instances in which responses are correct, and does not represent an heuristic strategy *per se*. The latter four are described and summarized in the review of the comprehension of relative sentences, above. Individual average weighted strategy scores are listed in Table 9.

A three-factor repeated measures analysis of variance revealed a significant main effect of tasks (F [1,12] = 29.98 [$p<.001$]), with groups and strategies pooled. There was a significant interaction of tasks by strategies (F [4,48] = 6.36 [$p<.001$]). There was, moreover, a significant groups by strategy interaction (F [4,48] = 7.93 [$p<.001$]), which again supports the notion of syndrome-specificity. The differences between groups were examined in greater detail by means of separate two-factor repeated measures ANOVAs, which are detailed below.

Broca's aphasics: analysis of weighted strategy scores

The data analyzed in this section are represented graphically in Figure 2a. The ANOVA yielded a main effect of tasks ($F[1,7] = 20.16$ [$p<.005$]). Again, enactment scores were higher than paraphrase scores. A significant main effect of strategy ($F[4,28] = 5.86$ [$p<.001$]) was found to result from the distinction between high minimal distance strategy scores and relatively low parallel function and first-NP scores (Tukey A, .05). A significant task by strategy interaction was found ($F[4,28] = 7.68$ [$p<.001$]). On the paraphrase judgment task, minimal distance scores were significantly higher than all others (Scheffe, .01), while there were no differences between strategies on the enactment task (Tukey A, .05).

A sentence by strategy analysis yielded similar results. In the paraphrase task, the main effects of strategy was highly significant ($F[4,28] = 11.65$ [$p<.001$]), as was the strategy by sentence interaction ($F[12,84] = 9.37$ [$p<.001$]). Post-hoc tests (Tukey A .05) show that for each sentence type, minimal distance scores were higher than those of strategies making different predictions. In the enactment task, in contrast, there were no significant differences between strategies.

The implication of these findings seems to be that while these subjects display the same syntactic deficit across tasks (recall that their task by sentence scores were parallel), their use of strategy is task-dependent.

Fluent aphasics: analysis of weighted strategy scores

The weighted strategy scores of the fluent aphasics are represented in Figure 2b. A tasks by strategy repeated measures ANOVA revealed that the main effect of tasks was nonsignificant (F [1,5] = 4.13). The main effect of strategies was significant (F [4,20] = 8.83 [p<.001]). Post-hoc testing shows that this effect is due to the fact that, with tasks pooled, minimal distance and adjacency scores are lower than correct scores (Scheffe, .01). Note that even at less stringent levels of testing, first-NP and parallel function scores are not distinguishable from correct scores (Tukey A, .05). The task by strategy interaction was nonsignificant (F [4,20] = 0.54).

Analysis of weighted strategy scores: brief summary

The foregoing may be summarized as follows. Just as with the processing deficits themselves, Broca's aphasics and fluent aphasics clearly differ with respect to strategies applied to sentence processing. Second, it is noteworthy that all the analyses show that enactment task scores are higher than paraphrase task scores. Although post-hoc tests fail to reveal significant differences, examination of Figures 2a and 2b shows that first-NP and, to a lesser degree, correct responses are higher in enactment than in paraphrase tasks. Perhaps the ephemeral nature of the auditory stimuli favored the use of the first-NP strategy in the enactment task. Since the correct response pattern is more redundant with first-NP than with minimal distance and adjacency patterns, the elevation of correct scores may be only a secondary effect. This explanation is clearly speculative, but as it seems to be the only one available at this time, it is tentatively accepted. Third, Broca's aphasics strongly favored the minimal distance strategy over all others; while fluent aphasics quite reliably rejected this strategy. The majority of responses produced by fluent subjects were correct, but the number of correct responses was not significantly different from the first-NP and/or parallel function strategy scores. Notice that the minimal distance strategy thematically relates adjacent noun-verb pairs, while the first-NP and parallel function strategies relate nonadjacent pairs. Fourth: although Broca's aphasics demonstrated qualitatively parallel deficits in sentence processing across tasks, they did not show uniformity of strategy preference across tasks. The use of strategies is, apparently, activity-dependent.

Individual variability:

In view of recent discussions of variablity within major taxonomic entities (e.g., Caramazza and Martin, in press; Schwartz, 1982) the individual strategy scores of the Broca's aphasics were examined. These are represented in Figure 3. It may readily be seen from these graphs that these patients are not a completely homogeneous group. Of the eight subjects, six produced marked minimal distance patterns on the paraphrase task. Among these six, there appear to be differences reflected in enactment task scores. Three subjects (B2, B4, B8) produced patterns that more or less parallel their paraphrase task scores, while another three (B1, B3, B7) show quite a different -- essentially random -- enactment pattern. The data for the two subgroups are displayed graphically in Figure 4. Hereafter, subjects B1, B3 and B7 will be referred to as Subgroup 1 and subjects B2, B4 and B8 will be designated Subgroup 2. The remaining two subjects, B5 and B6, although clinically identified as Broca's aphasics, yield patterns that correspond better with the fluent group (see Figure 5) than with the Broca's group. Their response patterns are not readily interpretable, and are assumed to reflect randomized responses.

Separate ANOVAS were performed on the data for subgroups 1 and 2. For subgroup 1, a highly significant task by strategy interaction was found ($F[4,8] = 9.29$ [$p<.005$]). On the paraphrase task, minimal distance scores, which could not be distinguished from adjacency scores, were significantly higher than were correct, parallel function and first-NP scores. There were no differences between strategies on the enactment task (Tukey A, .05).

The two-factor repeated measures ANOVA for subgroup 2 yielded an effect of tasks ($F[1,2] = 19.38$ [$p<.05$]), showing that the total enactment score was higher than the total paraphrase score. There was a highly significant main effect of strategy with tasks pooled (F [4,8] = 53.03 [p<.001]). At the .05 level of significance, the Tukey A test indicated a separation of strategies, in the order: minimal distance > adjacency > correct and parallel function > first-NP. A significant task by strategy interaction was also revealed (F [4,8] = 7.76 [p<.01]). For the paraphrase task, minimal distance scores were greater than the others (Scheffe [.05]). On the enactment task, minimal distance and adjacency scores were greater than the others (Tukey A, .05). If minimal distance and adjacency are considered to be equivalent strategies (see Discussion section), then the results for subgroup 2 are parallel across tasks.

It is possible that subjects who differ along the observed dimensions also differ in ways that were not apparent when they were first assigned group membership. Consequently, these patients' production and other ancillary data were examined for such differences. Biographical and ancillary data are displayed in Table 1. Looking across the table, there are no apparent discriminating features in the three Broca's subgroups on the following measures: digits forward, Knox cube scores, aphasia severity rating, articulation rating, phrase length, education level and lesion site. There is an apparent difference in age, such that all subjects but two are under 54 years old, while the two who are over 60 are in subgroup 2.

Observe, however, that the third member of subgroup 2 happens to be the youngest of the Broca's aphasics. More substantial differences arise between subgroups 1 and 2 on the following: Boston Diagnostic Aphasia Examination (BDAE) auditory comprehension and reading scores, and months post onset (subjects B5 and B6 range rather widely on these measures, and are undistinguishable from either of the other two subgroups).

Subgroup 1 achieved higher BDAE auditory comprehension scores than did subgroup 2. There was no overlap on this measure. On the Reading Sentences subtest of the BDAE, subjects B3 and B7 responded correctly to 8 of 10 sentences, while B2 and B8 read only 5. There was overlap on this measure, as B1 and B4 tied at 6 sentences. The most striking difference between subgroups was in the duration of aphasic impairment: subgroup 1 had been aphasic for an average of 67 months at the time of testing, while subgroup 2 were a mean 27 months post onset. Again, there was no overlap. Examination of the data for B5 and B6 indicates that the duration of aphasic impairment cannot alone account for the group differences: B5 had been aphasic for 150 months, while B6 had his CVA only 9 months prior to testing.

One can only speculate why those Broca's aphasics having the better auditory comprehension and greater duration of impairment (hence, the longer adjustment period) show greater variability on the enactment task. Perhaps these patients understand, because of their somewhat less severe comprehension deficit, because of their longer period of recovery and adjustment, or both, that the thematic relations expressed in sentences are not limited to adjacent lexical items (recall that minimal distance limits the representation of thematic relations in this way). Since understanding that one may be wrong is not equivalent to knowing what is correct, we may expect to observe more response variability in these patients, whose experience may have taught them the relative merits of guessing. One may speculate further, that this variability is more likely to be found when input is ephemeral, as in normal conversation and in the enactment task. When given the opportunity to consider and reconsider their answers, these subjects may be expected to show the true state of their ability to decode thematic relations.

On this last assumption, then, subgroups 1 and 2 really have the same upper bound on their grammatical capacity, and differ only in the ways in which they make use of it. By this reasoning, the eight Broca's aphasics split into two divisions only: the six of subgroups 1 and 2 and the two subjects (B5 and B6) who generated random strategy patterns.

A between-groups dissociation

The data indicate that, in the comprehension of relative sentences, differences between agrammatic and fluent aphasics may be captured by a characterization of their response biases vis-a-vis local versus phrase-spanning encodings of thematic relations. The relationships recognized by agrammatics are <u>local</u>: it seems that they accept a plausible N-V relationship as soon as their reading of the surface string allows it. They strongly tend to reject <u>distant</u> relationships. Consider now the paraphrase task performance of the six Broca's aphasics who produced consistent minimal distance patterns. They rejected distant (N1-V2) relationships -- 75% of which were correct -- at a rate of 88%, while at the same time they rejected only 7% of the local N2-V2 relationships (75% of which were incorrect). Both these rejection rates are highly significant ($p<.0001$, binomial test). No such dissociation was found among the fluents. They tended to accept noun - verb fragments regardless of their position in the sentence. Indeed, they may have accepted these fragments without any regard at all for the target sentences (although their behavior during testing indicated that they did attend to the sentences). These patients accepted N1-V2 and N2-V2 fragments at equivalent rates: 72% and 75%, respectively (both highly significant: $p<.0001$, binomial test).

Conclusions and General Discussion

The issue of domain-specificity

One of the major arguments supporting the central syntactic deficit hypothesis has been the modality-independence of the agrammatic deficit (Gardner, Denes and Zurif, 1975; Samuels and Benson, 1979; and see Berndt and Caramazza, 1980 for a review). This study sought to extend the modality-independence argument to activity-independence. A cross-task comparison of the performance of the Broca's aphasics studied here indicates that such extension is warranted.

The agrammatic deficit has been variously characterized. It is typically defined operationally in terms of the elements and structures that are implemented inaccurately or omitted altogether by agrammatic subjects. The present study used this operational approach to establish a pattern of agrammtic responses to three semantically reversible complex sentences containing relative clauses and a conjoined sentence of equal length. It was found that Broca's aphasics comprehended two forms of center-embedded sentence and the conjoined sentence forms relatively poorly, while the accuracy of their responses to right-branching sentences was high. Two separate analyses were employed. The first, a "whole-sentence" analysis, used the complete sentence as a unit: all responses pertaining to a given sentence had to be correct to achieve a single correct score. The weighted scores analysis used each separate response as a unit and is, accordingly, believed to be the more sensitive measure. In both analyses, the interaction of task with sentence type was nonsignificant. This indicates that the deficit pattern produced by this group of Broca's aphasics was qualitatively equivalent across two comprehension tasks with very different performance demands. These findings may be added to those recent studies which have reported cross-modality parallels not only within clinically defined groups, but within individual subjects (e.g., Caramazza, Berndt, Basili and Koller ,1981; Friederici, Schonle and Garrett, 1982). Here again is evidence for the existence of a central syntactic deficit which is domain-specific. The evidence for such a deficit -- and by inference, for a central, domain-specific syntactic processor in the normal language user -- continues to accumulate.

Syndrome-specificity

There is no question that anterior-lesioned aphasics display characteristics that are readily differentiated from those of posterior-lesioned aphasics, but it is also true that focal lesions in the left hemisphere can produce effects that are not syndrome-specific. Indeed, syntactic deficits have been reported in both anterior and posterior patients. For example, Gardner, Denes and Zurif (1975) found that both anterior and posterior-lesioned aphasics recognized semantic anomaly more readily than syntactic anomaly.

When the accuracy scores of the aphasic groups of this study were compared, their *patterns* of error were reliably different: in both the "whole-sentence" and weighted scores analyses, significant groups by sentence type interactions were obtained. The Broca's aphasics responded most correctly to object-subject relatives, and performed at roughly chance levels on the other three forms. In the whole-sentence analysis, the fluent aphasics performed at chance level on subject-object relatives, and at a slightly better level on the other three forms; but there were no distinctions between sentence types for this group in the weighted scores analysis. In subsequent sections, therefore, it may be confidently assumed that the agrammatic deficit under discussion is syndrome-specific.

Strategy preference

Given that the Broca's aphasics of this study demonstrate a syntactic deficit that is activity-independent and syndrome-specific, one may legitimately wonder whether their approaches to sentence processing, or strategies, are as consistent as their deficits. Do they consistently employ one or another strategy? Are such strategies as they may employ activity-independent, or does their use interact with task demands?

The data show that six of the eight Broca's aphasics strongly favor the minimal distance strategy on the paraphrase task, while two show no particular strategy preference on that task. Of these six, three produce roughly equivalent preference for minimal distance and adjacency patterns on the enactment task, while three others show no preference on this task. The two who yield random (no preference) patterns on the paraphrase task also yield random patterns on the enactment task. Indeed, substantial intertask variation is observed.

Consider the two experimental tasks. The sentence fragment paraphrase judgment task requires that a subject consider separately the possible meaning relationships in a stimulus sentence. On a given trial, the subject has before him the full stimulus sentence and a fragment consisting of a noun phrase and a verb. He is asked to decide whether that fragment expresses a part of the meaning expressed by the complete sentence, and he is given to understand that he has as much time as he needs to make his best judgment. Notice that it is on this task that we find consistency among six of the eight subjects. Now consider the enactment task. Here, the subject listens to an ephemeral string of words concerning two puppets placed before him. He is required to demonstrate with the puppets his understanding of the thematic relations expressed in the sentence. The choices are limited, but equally plausible. What is he to do when he is unsure? The input string, being acoustic, is gone. He cannot reconsider the stimulus, as in the paraphrase task. Instead of his considered judgment, he can offer only his best guess. The subject's response may follow the grammatical intuitions he displays on the paraphrase task, but if he lacks confidence in these intuitions, his response may be completely random, or may reflect some guessing strategy based on his post-onset experience. Perhaps it was the latter that produced the aberrant patterns observed for subjects B5 and B6. The available data are insufficient to provide an answer. Clearly, there may be many factors contributing to variability in on-line comprehension tasks. One factor that may have figured in the present findings is considered in the next paragraph.

It was noted earlier that the three highly consistent patients comprising subgroup 2 produced slightly different strategy patterns on the two tasks: their paraphrase task responses strongly reflected a minimal distance strategy pattern, while their enactment task responses were ambiguous between minimal distance and adjacency patterns. By the line of reasoning that follows, the two patterns may be viewed as equivalent.

According to Caplan (in press), agrammatics are hypothetically able to process the thematic information coded in the argument structures of individual lexical entries. This means that, among other things, they are able to assign nouns to verb arguments. Consider the sentences used in this study. Each of them contained one transitive and one intransitive verb. In three of the four sentence forms, the transitive verb was surrounded by nouns of equivalent animacy. In this condition, agrammatic subjects' paraphrase responses conformed to an SVO pattern. It is assumed here, as many have done, that order of appearance functions as a cue to the assignment of meaning relations when semantic or pragmatic disambiguation is absent. Some evidence to this effect has been reported (Blumstein, Statlender, Goodglass and Biber, 1979; Pastouriaux, Brownell and Zurif, 1982; Caplan, Matthei and Gigley, 1981). The data of this study also support this assumption. In the SO relative form, however, two animate nouns precede the transitive verb, thus neutralizing the effect of order. In this case, their assignment to the verb arguments might be randomized. Recall that the minimal distance strategy predicts that the noun immediately preceding the verb would be perceived as its subject, while adjacency predicts the first noun would be subject. The data are equivocal. Thus, when the canonical NVN ordering is violated, the assignment of thematic relations around verbs is disrupted, or randomized. To the extent that this may have occurred, responses will have been divided evenly between adjacency and minimal distance strategy patterns. Notice, however, that there was no minimal distance/adjacency ambiguity on the paraphrase task, for which the decay of acoustic information was not a factor. This suggests that the relatively high adjacency scores produced by some of the subjects of this study actually represent responses which would have been consistent with the minimal distance strategy, but for perturbation of the sort predicted by the interruption hypothesis of Slobin (1971). The use of heuristic sentence processing strategies, then, is not activity-independent. Again, there may be any number of factors contributing to variability in on-line comprehension tasks in which input is evanescent. In contrast, the consistency of agrammatics' responses to metalinguistic paradigms such as the paraphrase judgment task appears to take on added significance.

Within this framework, the hypothesis that agrammatics display a consistent response pattern in the comprehension of relative sentences is tentatively confirmed. The findings of this study suggest that the comprehension of sentences by agrammatic aphasics is constrained in such a way that only the most local, lexically coded meaning relationships are appreciated. The argument structure of a given verb is apparently filled with the nearest semantically appropriate noun or nouns; and thematic relationships signalled by phrasal or clausal structure are poorly recognized, if at all. Within this local constraint, the canonical word order pattern (SVO) appears to function as a default cue to the assignment of thematic roles around verbs.

Broca's aphasia, agrammatism and taxonomy

The Broca's aphasics who participated in this study offer qualified support for the arguments advanced by Caramazza and Martin (in press) and by Schwartz (1982), who maintained that the standard aphasia classifications fail to capture features of aphasic behavior that may be relevant to the organization of language. Schwartz asserted that the major aphasia syndromes are best viewed as "polytypic" structures, clusters of features which share the characteristic that none of them is essential to the larger classification. The Broca's aphasics who were studied in this work were selected on the basis of traditional clinical criteria, yet a degree of variability was encountered. Clearly, two of the eight so-called Broca's aphasics generated strategy score patterns that were indistinguishable from those of a group of fluent aphasics. As to the remaining six, they produced consistent strategy score patterns on the paraphrase judgment task, but again displayed significant variability in their responses to the enactment task. As mentioned earlier, this sort of variability is not unique (although reports to this effect are rare). Caplan, Matthei and Gigley (1981) reported a very similar finding. Had these subjects been tested only on the enactment task, information about their linguistic status would have been missed.

In view of the variability observed within the group of Broca's aphasics who participated in this study, it is appropriate to echo the warnings raised by Caramazza and Martin (in press) and Schwartz (1982) concerning syndrome-based group research. Those concerned with the nature of agrammatism will need to control task-related variables quite narrowly, selecting subjects on the basis of their agrammatic performance on some well-defined measure.

The effect of task demands upon on-line syntactic processing is poorly understood. It might be useful to carry out an extended study of a number of patients who demonstrate consistent performance on one or more metalinguistic tasks. Once baseline performances are established, then the effects of a series of carefully differentiated on-line tasks might be measured and correlated with biographical and nonlinguistic performance data.

There are obvious obstacles confronting the researcher who attempts to impose on-line (e.g., reaction time) tasks on aphasics, but recent successful applications (e.g., those of Bradley, et. al., 1980) are encouraging. Such an endeavor should serve to refine taxonomic distinctions , and may prove to be theoretically productive. It might be possible to replicate some of the experiments, carried out on normal subjects, that have been designed to isolate syntactic processes from other language processes. For example, variations of Forster's (1979) "same-different matching task," testing the independence of the effects of syntactic form and semantic plausibility, might be feasible. Aphasiologists have, if we are to believe Caramazza and Martin (in press), come close to exhausting the theoretical utility of the current aphasia classifications: it is at such times that "fishing expeditions" of this sort have been most useful.

Clinical implications

It is, more than ever, clear that the traditional formula for communicating with aphasics -- keep it short and simple -- is appropriate. If the data of this study are reliable, an agrammatic aphasic should be entirely capable of understanding simple N-V-N statements. To the limit of his/her ability to concatenate concepts, the agrammatic should be able to assimilate a string of such statements. Indeed, this is consistent with the findings of Goodglass, et. al., (1979) who reported that Broca's aphasics understood sentences like (18) better than they understood shorter, but more syntactically complex structures such as (19).

(18) The man was greeted by his wife and he was smoking a pipe.

(19) The man greeted by his wife was smoking a pipe.

The most important clinical implications of this study revolve around the need to clarify the parameters of aphasic symptomatology. It is clearly unwise to assume, for example, that a patient who presents with halting, labored speech and grossly adequate comprehension is incapable of syntactic analysis and might benefit from therapeutic efforts to re-establish syntactic skills. The data suggest that, even though such a patient might perform poorly on syntactically loaded tasks, his problem may not be agrammatism *per se*. On the other hand, patients who appear to be generally inconsistent in sentence comprehension may prove to be masking or compensating in some way for an agrammatic deficit. While standard clinical instruments such as the Porch Index of Communicative Ability (Porch, 1967) and the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972) are useful inasmuch as they are reliable indicators of change and level of severity, they provide inadequate descriptions, at best, of aphasic deficits. Hopefully, it will be possible to develop more effective rehabilitation techniques as a result of sharper characterization of aphasic impairment.

APPENDIX A: PARAPHRASE TASK SCORESHEET

1 CO 2 THE WOMAN GREETED THE MAN AND FELL DOWN

THE WOMAN THE MAN ....
GREETED THE MAN ....
THE MAN FELL DOWN ....
THE WOMAN GREETED ....
GREETED FELL DOWN ....
THE WOMAN FELL DOWN ....

2 SS 2 THE WOMAN THAT BUMPED THE MAN FELL DOWN

THE MAN FELL DOWN ....
THE WOMAN FELL DOWN ....
THE WOMAN THE MAN ....
BUMPED THE MAN ....
THE WOMAN BUMPED ....
BUMPED FELL DOWN ....

3 OS 3 THE WOMAN WATCHED THE MAN THAT FELL DOWN

THE WOMAN FELL DOWN ....
WATCHED THE MAN ....
THE WOMAN THE MAN ....
WATCHED FELL DOWN ....
THE MAN FELL DOWN ....
THE WOMAN WATCHED ....

4 CO 3 THE MAN PUSHED THE WOMAN AND FELL DOWN

PUSHED FELL DOWN ....
THE MAN THE WOMAN ....
THE MAN FELL DOWN ....
PUSHED THE WOMAN ....
THE WOMAN FELL DOWN ....
THE MAN PUSHED ....

5 SO 5 THE MAN THAT THE WOMAN WATCHED FELL DOWN

WATCHED FELL DOWN ....
THE MAN THE WOMAN ....
THE MAN WATCHED ....
THE WOMAN WATCHED ....
THE MAN FELL DOWN ....
THE WOMAN FELL DOWN ....

6 SS 5 THE WOMAN THAT GREETED THE MAN FELL DOWN

GREETED THE MAN ....
THE WOMAN FELL DOWN ....
THE WOMAN THE MAN ....
GREETED FELL DOWN ....
THE MAN FELL DOWN ....
THE WOMAN GREETED ....

7 OS 1 THE WOMAN PUSHED THE MAN THAT FELL DOWN

THE WOMAN THE MAN ....
PUSHED FELL DOWN ....
THE WOMAN PUSHED ....
THE MAN FELL DOWN ....
THE WOMAN FELL DOWN ....
PUSHED THE MAN ....

8 SO 3 THE WOMAN THAT THE MAN GREETED FELL DOWN

GREETED FELL DOWN ....
THE WOMAN FELL DOWN ....
THE MAN GREETED ....
THE MAN FELL DOWN ....
THE WOMAN THE MAN ....
THE WOMAN GREETED ....

9 CO 1 THE MAN BUMPED THE WOMAN AND FELL DOWN

THE MAN FELL DOWN ....
THE MAN THE WOMAN ....
THE MAN BUMPED ....
BUMPED THE WOMAN ....
THE WOMAN FELL DOWN ....
BUMPED FELL DOWN ....

10 SO 2 THE MAN THAT THE WOMAN PUSHED FELL DOWN

THE WOMAN FELL DOWN ....
PUSHED FELL DOWN ....
THE WOMAN PUSHED ....
THE MAN THE WOMAN ....
THE MAN FELL DOWN ....
THE MAN PUSHED ....

11 SS 1 THE MAN THAT GREETED THE WOMAN FELL DOWN

THE MAN THE WOMAN ....
THE MAN GREETED ....
GREETED FELL DOWN ....
THE WOMAN FELL DOWN ....
GREETED THE WOMAN ....
THE MAN FELL DOWN ....

12 OS 4 THE MAN BUMPED THE WOMAN THAT FELL DOWN

BUMPED FELL DOWN ....
THE MAN THE WOMAN ....
THE MAN FELL DOWN ....
BUMPED THE WOMAN ....
THE MAN BUMPED ....
THE WOMAN FELL DOWN ....

13 CO 4 THE WOMAN WATCHED THE MAN AND FELL DOWN

THE WOMAN FELL DOWN ....
THE MAN FELL DOWN ....
WATCHED THE MAN ....
THE WOMAN WATCHED ....
THE WOMAN THE MAN ....
WATCHED FELL DOWN ....

14 OS 2 THE MAN GREETED THE WOMAN THAT FELL DOWN

GREETED THE WOMAN ....
THE MAN THE WOMAN ....
THE MAN GREETED ....
GREETED FELL DOWN ....
THE MAN FELL DOWN ....
THE WOMAN FELL DOWN ....

15 SS 4 THE WOMAN THAT PUSHED THE MAN FELL DOWN

THE WOMAN THE MAN ....
THE WOMAN FELL DOWN ....
THE WOMAN PUSHED ....
PUSHED FELL DOWN ....
PUSHED THE MAN ....
THE MAN FELL DOWN ....

16 SO 1 THE WOMAN THAT THE MAN WATCHED FELL DOWN

THE MAN FELL DOWN ....
THE MAN WATCHED ....
THE WOMAN WATCHED ....
WATCHED FELL DOWN ....
THE WOMAN THE MAN ....
THE WOMAN FELL DOWN ....

17 CO 5 THE WOMAN BUMPED THE MAN AND FELL DOWN

THE MAN FELL DOWN ....
THE WOMAN BUMPED ....
THE WOMAN FELL DOWN ....
THE WOMAN THE MAN ....
BUMPED THE MAN ....
BUMPED FELL DOWN ....

18 OS 5 THE MAN PUSHED THE WOMAN THAT FELL DOWN

THE MAN FELL DOWN ....
PUSHED FELL DOWN ....
THE MAN THE WOMAN ....
THE WOMAN FELL DOWN ....
PUSHED THE WOMAN ....
THE MAN PUSHED ....

19 SS 3 THE MAN THAT WATCHED THE WOMAN FELL DOWN

THE MAN THE WOMAN ....
THE MAN WATCHED ....
THE WOMAN FELL DOWN ....
THE MAN FELL DOWN ....
WATCHED FELL DOWN ....
WATCHED THE WOMAN ....

20 SO 4 THE MAN THAT THE WOMAN BUMPED FELL DOWN

BUMPED FELL DOWN ....
THE MAN BUMPED ....
THE MAN FELL DOWN ....
THE WOMAN FELL DOWN ....
THE MAN THE WOMAN ....
THE WOMAN BUMPED ....

TABLE 1

PRODUCTION AND MISCELLANEOUS DATA

BROCA'S APHASICS

	B1	B2	B3	B4	B5	B6	B7	B8
Age	52	47	48	67	52	54	50	63
Educ (yrs)	10	12	14	13	12	8	12	12
Lesion site	FP	F	FP	FP	FP	FP	F	F
Months P. O.	75	36	45	36	150	9	81	9
Digits Fwd	5	8	3	4	4	5	5	5
Digits Bkwd	3	0	0	3	3	3	4	0
Knox Cubes		14				10	13	13
BDAE SCORES								
Severity	2	2	2	2	2	3	4	3
Aud. Comp.(z)	.75	-.10	.63	.25	.80	.25	.80	.33
Read. Sent.	6	5	8	6	7	5	8	5
Artic. Rating	1	4	4	4	2	2	3	1.5
Phrase Length	3	3	1	5	3	3	10	2
Grammat. Form	2	1.5	1	1.5	1	3	4	1.5

FLUENT APHASICS

	F1	F2	F3	F4	F5	F6
Age	60	44	61	33	55	71
Educ (yrs)	11	18	9	14	12	12
Lesion site	TP	TP	FP	TP	P	TP
Months P.O.	4	120	6	36	45	1.5
Digits Fwd	4	4	4	0	0	5
Digits Bkwd	3	3	3	0	0	3
Knox Cubes		10		8	11	8
BDAE SCORES						
Severity	3	4	3	5	4	4
Aud. Comp.	.33	0.0	0.0	1.0	.75	.40
Read. Sent.	6	6	6	10	9	5
Artic. Rating	6.5	6.0	5.0	6.5	7.0	5.0
Phrase Length	5	8	8	8	10	11
Grammat. Form	7	7	7	7	7	7

CONTROL SUBJECTS

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Age	64	71	47	47	54	63	59	55	54
Educ (yrs)	11	10	12	11	12	9	13	14	16
Digits Fwd	8	7	7	7	7	6	8	6	6
Digits Bkwd.	5	4	4	4	5	4	7	3	4

TABLE 2
INDIVIDUAL PRAPHRHRASE RESPONSES: BROCA'S APHASICS
("yes" responses only)

SENTENCE TYPE	SUBJ.	N1-V1	N2-V1	N1-V2	N2-V2
CO	correct	***		***	
	B1	5	-	1	5
	B2	5	-	1	5
	B3	4	-	1	5
	B4	5	-	0	4
	B5	5	-	4	2
	B6	4	-	3	3
	B7	5	-	1	4
	B8	5	-	1	4
proportion accepted		.95		.30	.73
SS	correct	***		***	
	B1	5	-	0	5
	B2	5	-	1	5
	B3	3	-	0	5
	B4	3	-	0	4
	B5	5	-	3	3
	B6	4	-	5	1
	B7	5	-	1	5
	B8	5	-	0	5
proportion accepted		.88		.25	.83
SO	correct		***	***	
	B1	4	1	0	4
	B2	0	5	0	5
	B3	3	5	2	4
	B4	1	4	0	4
	B5	0	5	1	5
	B6	5	2	3	2
	B7	1	5	3	4
	B8	1	5	0	5
proportion accepted		.38	.80	.23	.83
OS	correct	***			***
	B1	5	-	0	5
	B2	5	-	0	5
	B3	5	-	0	5
	B4	5	-	1	4
	B5	5	-	2	3
	B6	4	-	3	4
	B7	5	-	1	5
	B8	5	-	1	5
proportion accepted		.98		.20	.90

TABLE 3

INDIVIDUAL PARAPHRASE RESPONSES: FLUENT APHASICS
("yes" responses only)

SENTENCE TYPE	SUBJ.	N1-V1	N2-V1	N1-V2	N2-V2
CO	correct	***		***	
	F1	5	-	3	2
	F2	4	-	2	3
	F3	4	-	5	3
	F4	5	-	4	0
	F5	5	-	5	5
	F6	5	-	4	3
proportion accepted		.93		.77	.53
SS	correct	***		***	
	F1	4	-	5	3
	F2	5	-	4	3
	F3	5	-	5	2
	F4	5	-	5	1
	F5	5	-	5	5
	F6	4	-	4	1
proportion accepted		.93		.93	.50
SO	correct		***	***	
	F1	4	4	5	3
	F2	1	5	0	5
	F3	2	3	5	3
	F4	1	4	3	2
	F5	5	5	5	4
	F6	2	5	3	2
proportion accepted		.60	.87	.70	.63
OS	correct	***			***
	F1	4	-	4	4
	F2	5	-	1	4
	F3	4	-	5	1
	F4	5	-	0	5
	F5	5	-	5	5
	F6	5	-	0	4
proportion accepted		.93		.50	.77

TABLE 4

INDIVIDUAL ENACTMENT RESPONSES: BROCA'S APHASICS

SENTENCE TYPE	SUBJ.	TRANSITIVE VERB N1-V1-N2	N2-V1-N1	INTRANS. VERB N1-V2	N2-V2
CO	correct	***		***	
	B1	5	0	2	3
	B2	5	0	0	5
	B3	4	1	2	3
	B4	4	1	0	5
	B5	5	0	3	2
	B6	4	1	3	2
	B7	5	0	5	0
	B8	4	1	0	5
proportion correct		.90		.38	
SS	correct	***		***	
	B1	5	0	3	2
	B2	5	0	1	4
	B3	5	0	2	3
	B4	5	0	0	5
	B5	5	0	2	3
	B6	4	1	5	0
	B7	5	0	4	1
	B8	5	0	1	4
proportion correct		.98		.45	
SO	correct		***	***	
	B1	4	1	2	3
	B2	0	5	1	4
	B3	3	2	4	1
	B4	3	2	3	2
	B5	3	2	3	2
	B6	2	3	4	1
	B7	0	5	0	5
	B8	1	4	3	2
proportion correct		.60		.50	
OS	correct	***			***
	B1	5	0	3	2
	B2	5	0	0	5
	B3	4	1	0	5
	B4	4	1	1	4
	B5	5	0	5	0
	B6	4	1	1	4
	B7	5	0	0	5
	B8	5	0	0	5
proportion correct		.93		.75	

TABLE 5

INDIVIDUAL ENACTMENT RESPONSES: FLUENT APHASICS

SENTENCE TYPE	SUBJ.	TRANSITIVE VERB N1-V1-N2	TRANSITIVE VERB N2-V1-N1	INTRANS. VERB N1-V2	INTRANS. VERB N2-V2
CO	correct	***		***	
	F1	4	1	5	0
	F2	5	0	4	1
	F3	3	2	3	2
	F4	5	0	4	1
	F5	5	0	4	1
	F6	5	0	5	0
proportion correct		.90		.83	
SS	correct	***		***	
	F1	5	0	5	0
	F2	5	0	3	2
	F3	4	1	2	3
	F4	5	0	5	0
	F5	2	3	4	1
	F6	5	0	5	0
proportion correct		.87		.80	
SO	correct		***	***	
	F1	3	2	2	3
	F2	5	0	5	0
	F3	0	5	3	2
	F4	1	4	4	1
	F5	4	1	2	3
	F6	0	5	4	1
proportion correct		.57		.67	
OS	correct	***			***
	F1	4	1	3	2
	F2	5	0	2	3
	F3	4	1	2	3
	F4	5	0	0	5
	F5	4	1	0	5
	F6	5	0	0	5
proportion correct		.90		.77	

TABLE 6

"WHOLE-SENTENCE CORRECT" ANALYSIS:
SENTENCES FOR WHICH ALL RESPONSES WERE ACCURATE

Broca's aphasics: Paraphrase task

	B1	B2	B3	B4	B5	B6	B7	B8	Total
CO	0	0	0	0	3	1	1	0	5
SS	0	0	0	0	2	3	1	0	6
SO	0	0	0	0	0	0	0	0	0
OS	5	5	4	3	2	1	4	4	28
Total	5	5	4	3	7	5	6	4	

Broca's aphasics: Enactment task

	B1	B2	B3	B4	B5	B6	B7	B8	Total
CO	2	0	2	0	3	1	5	0	13
SS	3	1	2	0	2	4	4	1	17
SO	1	0	1	2	2	3	0	3	12
OS	2	5	4	4	0	4	5	4	28
Total	8	6	9	6	7	12	14	8	

Fluent aphasics: Paraphrase task

	F1	F2	F3	F4	F5	F6	Total
CO	2	2	2	4	0	2	12
SS	1	2	3	4	0	3	13
SO	0	0	0	3	0	1	4
OS	0	3	0	5	0	4	12
Total	3	7	5	16	0	10	

Fluent aphasics: Enactment task

	F1	F2	F3	F4	F5	F6	Total
CO	4	2	2	4	3	5	20
SS	5	2	2	5	2	5	21
SO	2	0	3	4	1	4	14
OS	1	2	2	5	3	5	18
Total	12	6	9	18	9	19	

TABLE 7

PARAPHRASE TASK:
STRATEGY PREDICTIONS AND RESPONSE WEIGHTING

Sent. type	Fragment	CORR.	MDS	ADJ	PFS	FNP	WEIGHT Y	WEIGHT N
	N1-V1	Y	Y	Y	Y	Y	1/5	0
CO	N1-V2	Y	N	N	Y	Y	1/3	1/2
	N2-V2	N	Y	Y	N	N	1/2	1/3
	N1-V1	Y	Y	Y	Y	Y	1/5	0
SS	N1-V2	Y	N	N	Y	Y	1/3	1/2
	N2-V2	N	Y	Y	N	N	1/2	1/3
	N1-V1	N	N	Y	N	Y	1/2	1/3
SO	N2-V1	Y	Y	N	Y	N	1/3	1/2
	N1-V2	Y	N	Y	N	Y	1/3	1/2
	N2-V2	N	Y	N	Y	N	1/2	1/3
	N1-V1	Y	Y	Y	Y	Y	1/5	0
OS	N1-V2	N	N	N	Y	Y	1/2	1/3
	N2-V2	Y	Y	Y	N	N	1/3	1/2

Y: Indicates "yes" response
N: Indicates "no" response

TABLE 8

ENACTMENT TASK:

STRATEGY PREDICTIONS AND RESPONSE WEIGHTING

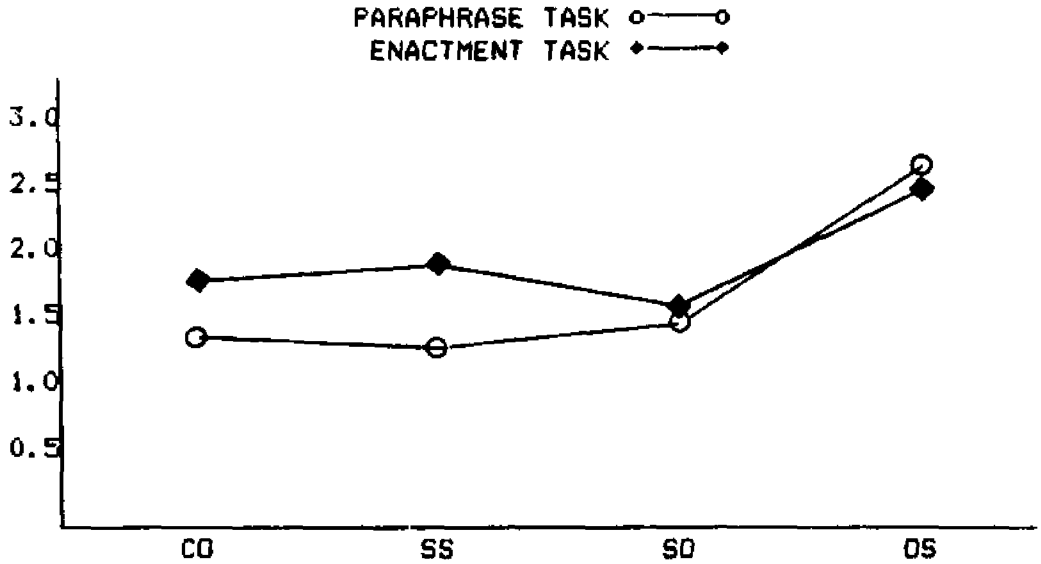
Sent. type	Fragment	CORR.	MDS	ADJ	PFS	FNP	WEIGHT (+)
CO	N1-V1-N2	+	+	+	+	+	1/5
	N2-V1-N1	-	-	-	-	-	0
	N1-V2	+	-	-	+	+	1/3
	N2-V2	-	+	+	-	-	1/2
SS	N1-V1-N2	+	+	+	+	+	1/5
	N2-V1-N1	-	-	-	-	-	0
	N1-V2	+	-	-	+	+	1/3
	N2-V2	-	+	+	-	-	1/2
SO	N1-V1-N2	-	-	+	-	+	1/2
	N2-V1-N1	+	+	-	+	-	1/3
	N1-V2	+	-	-	-	+	1/2
	N2-V2	-	+	+	+	-	1/3
OS	N1-V1-N2	+	+	+	+	+	1/5
	N2-V1-N1	-	-	-	-	-	0
	N1-V2	-	-	-	+	+	1/2
	N2-V2	+	+	+	-	-	1/3

+: Indicates enactment of indicated relationship

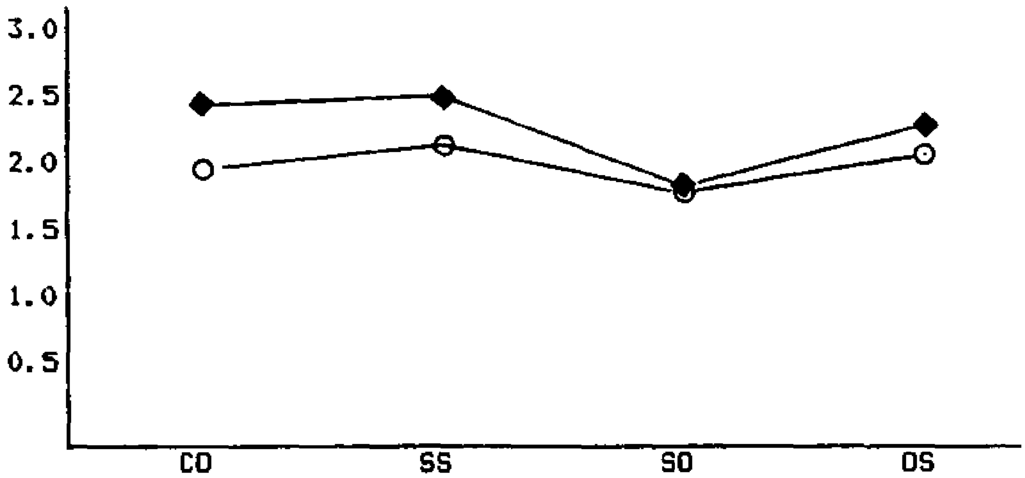
TABLE 9

WEIGHTED STRATEGY SCORES

SUBJ	PARAPHRASE TASK CORR	MDS	ADJ	PFS	FNP	ENACTMENT TASK CORR	MDS	ADJ	PFS	FNP
B1	.39	.85	.82	.37	.33	.52	.55	.70	.59	.70
B2	.54	.94	.60	.54	.17	.59	.94	.76	.52	.28
B3	.48	.85	.72	.37	.23	.68	.64	.66	.41	.54
B4	.45	.87	.63	.50	.24	.50	.79	.80	.36	.44
B5	.64	.68	.38	.73	.41	.56	.53	.55	.70	.73
B6	.58	.43	.53	.53	.64	.77	.47	.44	.57	.62
B7	.58	.83	.66	.46	.28	.74	.63	.53	.74	.47
B8	.46	.97	.67	.50	.17	.63	.84	.73	.42	.37
F1	.64	.44	.51	.55	.62	.66	.36	.34	.73	.64
F2	.60	.75	.44	.66	.33	.70	.40	.55	.56	.85
F3	.62	.36	.40	.68	.71	.68	.63	.47	.61	.47
F4	.86	.49	.42	.59	.52	.90	.53	.43	.63	.61
F5	.59	.54	.57	.54	.58	.62	.52	.60	.48	.54
F6	.77	.55	.48	.55	.48	.93	.49	.40	.66	.64

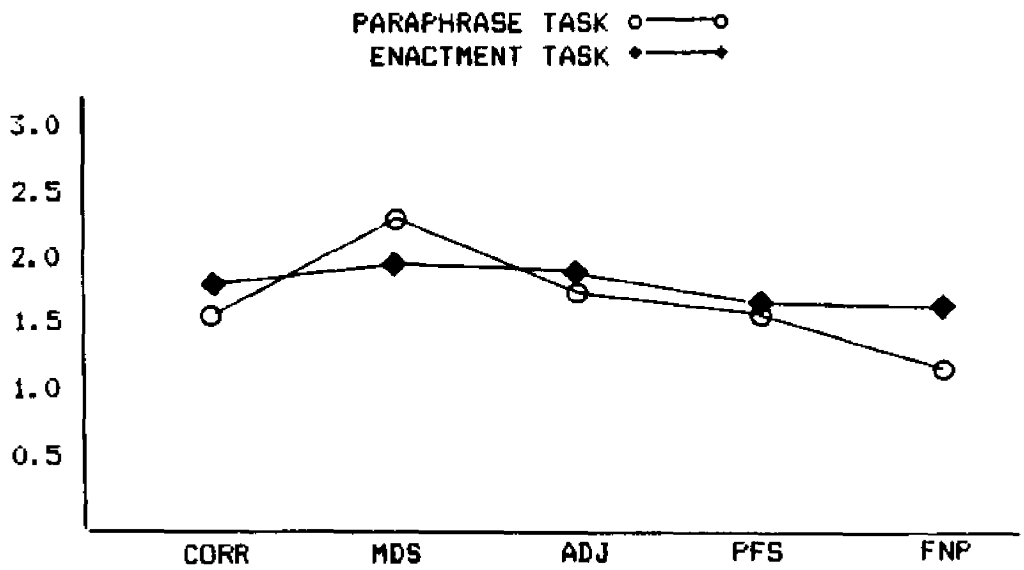


1a. PROPORTION CORRECT - BY SENTENCE TYPE (BROCA'S APHASICS)
(arcsine transformations of percentage scores)

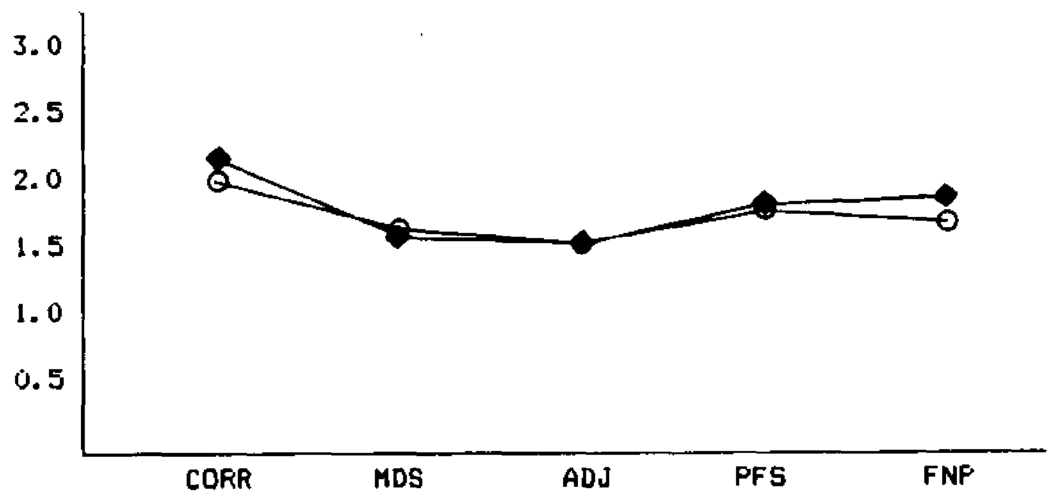


1b. PROPORTION CORRECT - BY SENTENCE TYPE (FLUENT APHASICS)
(arcsine transformations of percentage scores)

FIGURE 1

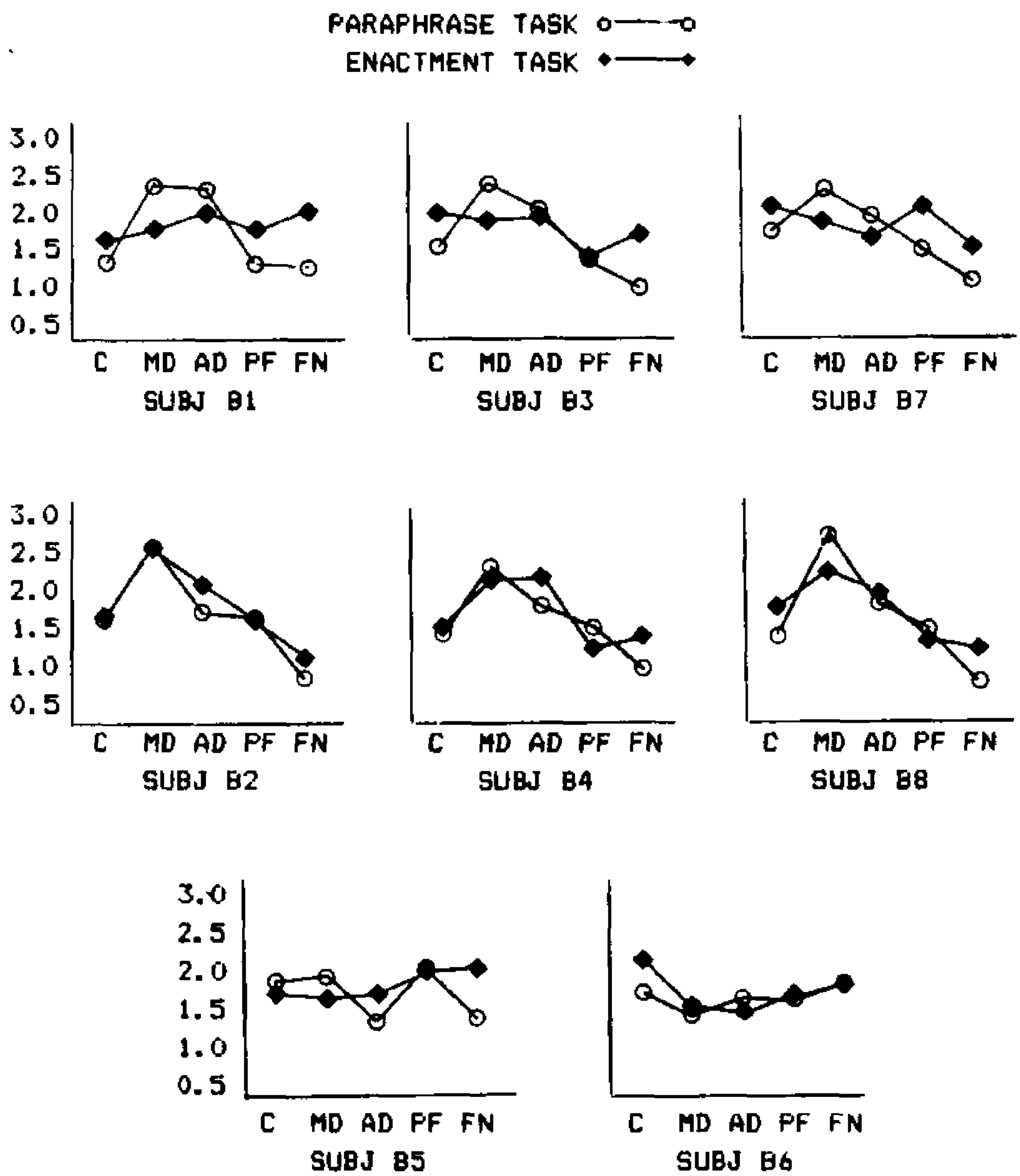


2a. STRATEGY SCORES (BROCA'S APHASICS)
(arcsine transformations of percentage scores)



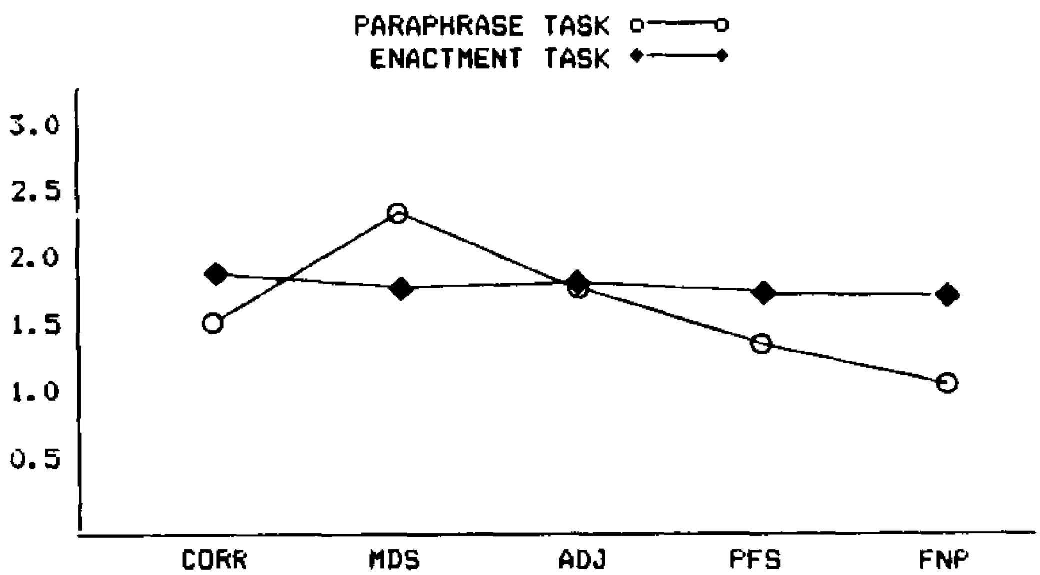
2b. STRATEGY SCORES (FLUENT APHASICS)
(arcsine transformations of percentage scores)

FIGURE 2

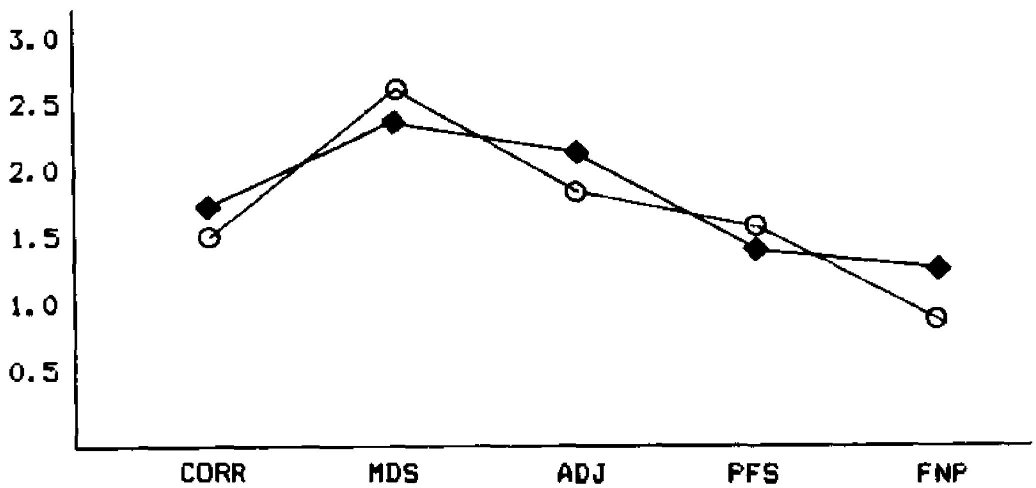


INDIVIDUAL STRATEGY SCORES (BROCA'S APHASICS)
(arcsine transformations of percentage scores)

FIGURE 3

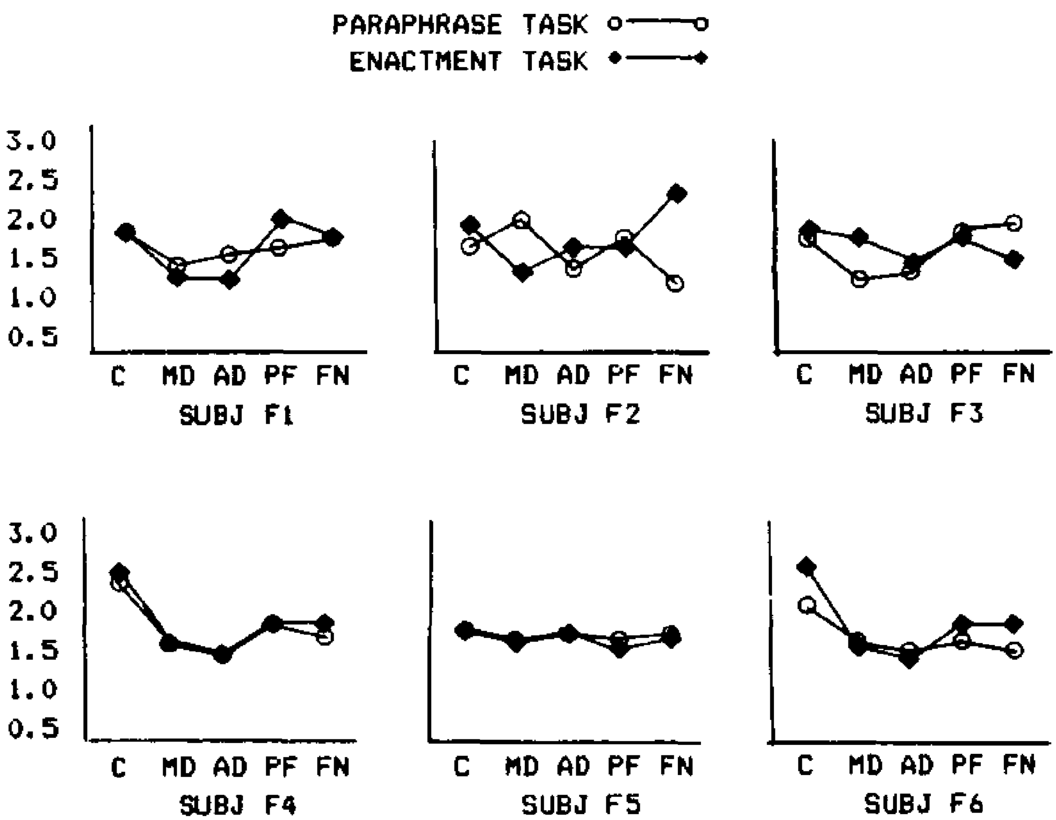


4a. STRATEGY SCORES (SUBGROUP 1)
(arcsine transformations of percentage scores)



4b. STRATEGY SCORES (SUBGROUP 2)
(arcsine transformations of percentage scores)

FIGURE 4



INDIVIDUAL STRATEGY SCORES (FLUENT APHASICS)
(arcsine transformations of percentage scores)

FIGURE 5

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