

## Reception of Language in Broca's Aphasia

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This experiment tests between two competing hypotheses about the source of failures in comprehension by Broca-type aphasics with agrammatic production. These are characterised as (1) the hypothesis that these aphasic individuals have sustained a partial loss in syntactic knowledge, and (2) the hypothesis that, despite intact structural knowledge, they suffer from an inability to put that knowledge to use in comprehension tasks such as object manipulation and sentence-picture matching. To decide between the hypotheses, this study compared the speed and accuracy of Broca-type aphasics with a control group of normal subjects using an on-line grammaticality judgement task in which the anomaly involved closed-class vocabulary items. The results are in accord with the view that the source of agrammatic performance is not a loss of syntactic knowledge, as the responses of the aphasic group closely mirror those of the control group (e.g. word position effects were found for both groups). The results are interpreted, instead, as support for the alternative view that agrammatic aphasics have difficulties in processing syntactic knowledge.

### INTRODUCTION

Our concern in this research is with a pattern of symptoms that is characteristic of Broca's syndrome, the most notable feature of which is a marked

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reduction in fluency. The utterances of the persons we studied consist for the most part of short phrases, often haltingly and effortfully produced and with considerable constriction of vocabulary. It is untenable to suppose that these symptoms are the result purely of motor interference with the execution of fluent speech because the omission of words is selective. The utterances of our subjects typically consist of nouns and verbs with relatively few grammatical words such as particles, auxiliary verbs and prepositions. This telegraphic manner of speaking has often been called "agrammatic" (Isserlin, 1922; Pick, 1913), to underscore the selective nature of the omissions: The words that are omitted in the affected individual's productions are more often the grammatical (or "closed-class") words of the sentence (articles, prepositions, auxiliary verbs, etc.) than the content (or "open-class") words. Omission of these items results in sentences that are not well formed. Thus the concept of agrammatism carries with it the idea that at the core of Broca's syndrome is a disturbance in the structure of spoken language. Alternatively, these individuals might retain the critical structures but suffer from an inability to put the knowledge to use due to a limitation in processing. As a step toward developing a satisfactory understanding of the aphasias, we carried out an experiment to test between these competing hypotheses.

Originally, the concept of agrammatism was used to designate a disorder of speech output, but as a result of more recent developments in research on aphasia it is arguable that the deficit that underlies this condition is in fact more general, such that both production and comprehension are often impaired (Berndt & Caramazza, 1980; Bradley, Garrett, & Zurif, 1980; Caramazza & Zurif, 1976; Goodglass, Gleason, & Hyde, 1970; Heilman & Scholes, 1976; Parisi & Pizzamiglio, 1970; but see also Miceli, Mazzucchi, Menn, & Goodglass, 1983, for an indication that comprehension deficits are not always associated with agrammatic production). The comprehension impairments that are often part of the symptom picture in aphasia of the non-fluent type may escape notice because the aphasic individual usually appears to understand what the examiner says. Practical judgement and reasoning capacities are often remarkably intact, allowing the deficit in grammatical processing to remain hidden.

In a pioneering attempt to isolate the source of the language comprehension deficit associated with Broca's aphasia, Zurif, Caramazza, and Meyer-son (1972) applied a metalinguistic judgement procedure in which aphasic subjects were asked to indicate which words in a sentence belong together. These investigators concluded that Broca-type subjects failed to use syntactic categories in making their judgements, using other grouping strategies instead. In later research, Caramazza and Zurif (1976) tested comprehension of syntactically complex sentences containing relative clauses by means of a picture-matching task. It was found that patients diagnosed as

Broca's aphasics performed poorly on implausible sentences and sentences that were semantically reversible, such as (1):

1. The lion that the tiger is chasing is fat.

In the absence of context, the meaning of such sentences cannot be inferred by appeal to world knowledge. Together, the findings led the authors to propose that their Broca subjects were "asyntactic" in comprehension. They attributed the apparently intact comprehension displayed by these individuals in ordinary social communication to unimpaired "heuristic" strategies: The aphasic subject simply combines the meanings of the individual lexical items in a plausible way, thereby compensating for the loss of syntactic ("algorithmic") analysis. Caramazza and Zurif took a large step toward identifying the source of the comprehension disturbances in Broca's aphasia, but it remained an open question how these difficulties were related to the impairments in production.

A linguistic account which explicitly ties together the production and comprehension impairments was proposed by Bradley and her colleagues (Bradley, 1978; Bradley, Garrett, & Zurif, 1980). This proposal focused on the role that the closed-class morphology plays in models of normal language processing.<sup>1</sup> According to the Bradley et al. model, the closed-class portion of the lexicon can be accessed by two routes, but only one of these is ordinarily used in parsing sentences. In agrammatism, that route is selectively impaired, although agrammatic aphasics still retain closed-class items in their mental lexicon. This dual route hypothesis permits Bradley et al. to suppose that agrammatics have lost only the ability to use the closed-class vocabulary in constructing phrasal structure for sentences. But as a consequence of disruption to the mechanism that accesses this vocabulary, there is impairment of syntactic operations both in production and percep-

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<sup>1</sup>An alternative proposal by Kean (1977) argues that the core problem in agrammatism is in the phonological component. Kean supposed that components of the language apparatus are hierarchically organised, with a unidirectional flow of information between levels. Thus, a disturbance at a lower level in the system (i.e. the phonology) could masquerade as a breakdown at a higher level. In this way Kean attempted to explain the nature of the apparent "agrammatic" output associated with non-fluent aphasia. She maintained that the Broca's aphasic tends to reduce the structure of a sentence to the minimal string of elements which can be lexically construed as phonological words. This idea can be extended to account for both their production and comprehension impairments: The Broca's aphasic fails to produce or attend to suffixes and other elements which do not occur independently as phonological words—elements which are critical for subsequent syntactic and semantic analysis. Kean's is an elegant attempt to apply linguistic theory to explain a broad set of phenomena in aphasia. However, this viewpoint runs into the difficulty that Broca's aphasics are apparently sensitive to the meanings of many function words (e.g. Lukatela, Crain, & Shankweiler, 1988).

tion. The idea of double representation of closed-class words in the lexicon has been challenged on empirical grounds (see Gordon, 1983; Gordon & Caramazza, 1982). Though the notion of bifurcation of the lexicon may have to be abandoned, Bradley and her colleagues attempted to provide a compact explanation for the deficits that commonly co-occur in Broca-type aphasia: Both production and comprehension failures were seen as manifestations of impairment of some of the procedures for lexical retrieval.

It is worth noting that the proposal of Bradley et al. is consistent with the possibility that syntactic knowledge is retained in Broca-type aphasics who have comprehension difficulties. Difficulties would arise if the normal routes of access to stored linguistic knowledge were blocked. Alternatively, the source of the difficulty could be at some post-syntactic level. Data addressing this issue was obtained by Linebarger, Schwartz, and Saffran (1983a). Dissatisfied with the ambiguity in interpreting the results of commonly used tests of comprehension, these investigators asked whether Broca's aphasics are capable of constructing syntactic representations by having them judge the grammaticality of auditorily presented sentences. They found evidence of preserved sensitivity to transformational operations, subcategorisation of verbs, and at least partial sensitivity to the syntactic functions of some closed-class vocabulary items. Because the aphasic subjects studied by Linebarger et al. had been found to fail with regularity on sentence-picture matching and acting out tests, their success with grammaticality judgements came as a surprise to adherents of the asyntactic hypothesis. The findings seemed to fly in the face of previous research and theorising which had sought to establish that a phonological or syntactic deficit was responsible for the sentence processing difficulties of agrammatic aphasics. If the judgement task accurately reflects syntactic competence, then some component of language processing at a higher level than the syntax must be responsible for errors that these individuals make on standard measures of sentence comprehension.<sup>2</sup>

In view of the importance of the questions raised by the findings of Linebarger et al., the theory and methodology of comprehension testing in aphasia is deservedly undergoing thorough scrutiny (Caplan, 1985; Caramazza & Berndt, 1985; Kolk, van Grunsven, & Keyser, 1985). Predictably the conclusion that Broca's aphasics have retained syntactic competence

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<sup>2</sup>Linebarger et al. propose that the deficit resides in the mapping relation between the syntax and the semantics. They advance this "mapping hypothesis" to explain why their agrammatic subjects' performance on the grammaticality judgement task surpasses their performance on comprehension tasks like picture verification (see also Schwartz, Linebarger, & Saffran, 1985). This hypothesis is extended in Schwartz, Linebarger, Saffran, and Pate (1987), where the deficit is characterised as an inability to map syntactic functions on to appropriate thematic roles.

has not gone unchallenged (Caplan & Futter, 1986; Grodzinsky, 1986; Zurif & Grodzinsky, 1983). The debate hinges on the problem of inferring competence from various kinds of test data. In deciding how claims about the source of comprehension failures should be evaluated, we must ask which tasks give an accurate indication of where the problems lie. Although criteria for an adequate test are rarely specified, we suggest two. First, the task must allow one to draw inferences about a single level of processing. Comprehension tasks must be capable of teasing apart the individual contributing factors in order to pinpoint the source of the problem within the language apparatus. A second criterion requires the task to reflect the routine operations of the language understanding system. Let us see how existing comprehension tests measure up to these requirements, which we will call the *univocality* criterion and the criterion of *naturalness*.

These two criteria are often in competition, because we are trying to disentangle factors that are intertwined in ordinary spoken communication. For this reason, some commonly used methods for assessing comprehension fail to meet one or both criteria. For example, the method of sentence-picture matching seems to satisfy the criterion of naturalness, but it fails the criterion of univocality because it confounds syntactic and semantic processing. The method of object manipulation confounds a third factor with these two. In addition to carrying out a structural analysis of a test sentence, a subject must formulate a plan for demonstrating his understanding—see Hamburger and Crain (1984; 1987) for data and a discussion of the role of the planning stage in sentence comprehension. The univocality criterion will not be met in an object manipulation task whenever the plan associated with a sentence is as complex as either its syntactic or semantic structure, because failure to perform accurately in this circumstance cannot be unequivocally interpreted. This task also frequently fails the naturalness criterion, because subjects are asked to act out sentence meanings in the absence of prior context. This renders the task inappropriate for any construction that bears presuppositional content, because by their nature, presuppositions must be satisfied before an utterance is made (for a discussion of how the failure of researchers to satisfy presuppositions has masked children's knowledge of syntax, see Hamburger & Crain, 1982).

Let us now apply these criteria to the grammaticality judgement task used by Linebarger et al. (1983a). Consider first the criterion of univocality: The semantic and planning stages are largely circumvented in this task as the subject has only to indicate whether or not the test sentences are grammatical, but there may be sources of ambiguity inherent in this technique, too. Unless proper controls are built into the test sentences, there is no way of knowing which linguistic level of representation the subject is appealing to in making the judgement. When a sentence is made ungrammatical, even by the substitution of a single word, the sentence that

results may be semantically anomalous as well as syntactically deviant. Also, the substitution may alter the prosody, creating an anomaly which the subject could conceivably detect without performing a structural analysis at all. However, if the sentence meaning and prosody are adequately controlled, the grammatical judgement task would presumably meet the criterion of univocality.

The second criterion for evaluating comprehension tasks is naturalness: Does the grammaticality judgement task reflect normal sentence processing? In a reply to Linebarger et al. (1983a), Zurif and Grodzinsky (1983) challenge the grammaticality judgement task in assessing the syntactic knowledge of aphasics on the grounds of naturalness. They contend that "given the luxury of conscious reflection permitted by acceptability judgments, one might expect not to tap normal on-line processes". They go on to speculate that the judgement task employed by Linebarger et al. (1983a) would allow an agrammatic subject "to use processing routes other than those by which structural information is normally made available at the appropriate time for interpretation" (p. 208). Thus, in their view, success on this task could draw upon metalinguistic abilities that stand apart from the usual operations of the language understanding mechanism.

Resolution of the issue of naturalness hinges on what characteristics are imputed to the human sentence parsing mechanism. Various conceptions of how the parser works have been proposed, but many questions remain open. For example, no consensus exists concerning whether the parser operates in a serial or in a parallel manner (Frazier & Fodor, 1978; Gorrell, 1987), or whether its mode of operation is deterministic or non-deterministic (Fodor, 1985; Marcus, 1980). There is widespread agreement on one characteristic, however. As Zurif and Grodzinsky suggest, it is widely accepted that the operations of the parser are carried out "on line", allowing the rapid construction of syntactic and semantic structure as the input string is received.

While we know of no explicit definition of on-line processing, we consider three laboratory phenomena to indicate that the parser constructs a representation as the sentence unfolds. First, there is evidence from a variety of sources, including the present study, that decisions about both syntactic and semantic structure are made before the perceiver has heard all the words of a sentence (e.g. Crain & Steedman, 1985; Marslen-Wilson, 1975). Secondly, there is evidence that processing load increases as the distance increases between words that form discontinuous constituents, such as verb/particle constructions or agreement in number between a determiner and noun. Discontinuity is seen to tax working memory resources by postponing the closure of syntactic categories. Setting aside a constituent to await other elements with which it is to be associated is generally assumed to be costly of memory resources (e.g. Wanner &

Maratsos, 1978). This is consistent with the claim that the parser works most efficiently when it can form constituents locally, on a word by word basis.

Evidence of on-line processing is also provided by many detection experiments which find that the identification of a target segment—a specific phoneme, letter, or word—is faster as a sentence progresses. We call this the *word position effect*.<sup>3</sup> The word position effect probably reflects the normal on-line operation of the parsing mechanism. In the course of parsing, the perceptual processing system assigns structure to a sentence without waiting until all its words or constituents have arrived, allowing lower-level information to be rapidly segmented and shunted upward through the system. This enables the processor to work on several levels in parallel within a narrow “window” of only a few words (e.g. Frazier & Fodor, 1978; Marcus, 1980). Later items are detected faster because assignment of a structural analysis reduces the number of subsequent structural options that otherwise would be pursued. This, in turn, frees up computational resources needed for other processing tasks. Because information in verbal working memory can be stored only briefly before it decays (Baddeley & Hitch, 1974; Conrad, 1964), the availability of a mechanism for the rapid on-line integration of incoming information is essential for the interpretation of extended speech or text.

It is surprising, in view of the interest the question has generated, that the available data on comprehension in agrammatism leaves open the

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<sup>3</sup>An experiment by Foss (1969) presents an example of this phenomenon: It was found that response times are faster for detection of a target phoneme that comes late in a sentence, in comparison to one that comes early. It was Foss's view that this pattern required a structural explanation. Holmes and Forster (1970) reported the same pattern with a click-monitoring task, but they propose a different interpretation, attributing the longer reaction times for detecting early items to greater processing load at the early stages of sentence processing than at later stages. The inequality comes about putatively because at the beginning the subject is carrying out two tasks at the same time—making a decision about a target word and, in addition, processing the words that follow the target word. But if the detection of a target item is on line, then it is unclear why varying the position of the target word should affect processing time in any systematic way.

The interference account also predicts that there should be no difference between detection tasks that present grammatically structured material and those that present unstructured word strings. But just this difference has been reported repeatedly in the literature. Marslen-Wilson and Tyler (1980) and Marslen-Wilson (1984) demonstrated that the word position effect is obtained with syntactically organised material, but it does not occur with syntactically scrambled word strings. Moreover, Aaronson (1968) reported that for presentation rates appropriate to conversational speech, response time to detect a target segment does not decrease but actually increases with serial position in a list of unrelated words. These findings suggest that the word position effect occurs only with syntactically organised material. Taken together, they lend considerable support to Foss's view that the word position effect reflects the processing of structure.

question of how well agrammatics can process items in the closed-class vocabulary in tasks that tap normal (on-line) sentence parsing operations. The experiment of Linebarger et al. (1983a) was not designed to assess the on-line processing capabilities of their subjects. None the less, any attempt to dismiss the grammaticality judgement task on *a priori* grounds is unwarranted, as even *post hoc* judgements could in principle reflect structural analyses computed by the subject on line. The purpose of the present investigation was to study the question of whether agrammatic and normal speakers use implicit knowledge of closed-class words in the same way, both in computing syntactic structure for a given input string and in making on-line decisions about grammaticality. In designing the stimulus materials and procedure, we have been mindful of the criticisms raised by Zurif and Grodzinsky because much rides on the correct interpretation of Linebarger et al.'s (1983a) findings.

The present experiment satisfies the criterion of naturalness in so far as it was designed to reveal whether agrammatics assign syntactic structure on line. We developed a chronometric technique to test the speed and accuracy with which normal control subjects and aphasics can detect grammatical errors in sentences in which grammaticality turns on the use of a closed-class vocabulary item. The technique converts the ordinary grammaticality judgement task into one that taps on-line processing. It achieves this, first, by presenting each sentence only once at a normal conversational rate; secondly, by emphasising speed of decision, requiring a response as soon as the violation is detected, thus allowing little opportunity for reflection; and, thirdly, by controlling the location of the word that normal subjects would identify as the source of ungrammaticality of each test sentence.

The chief goal of this investigation was to discover whether the receptive language impairment commonly associated with "agrammatic" production results from impaired grammatical knowledge involving closed-class morphology or whether the impairment is caused by a processing difficulty. This question is framed against a backdrop of syntactic theory—as well as a current proposal concerning the nature of linguistic processing (e.g. the Modularity Hypothesis of Forster, 1979, and Fodor, 1983).<sup>4</sup> Within the

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<sup>4</sup>For proposals of this kind to pay dividends it must turn out that agrammatism represents an underlying unity, theoretically and empirically. From the standpoint of theory, the notion of agrammatism must be characterised within a viable model of language performance; that is, it should conform to natural seams in the language apparatus. It is clear from the work of Grodzinsky (1984b), Kean (1980; 1982) and Lapointe (1983) that the phenomenon associated with agrammatism, the incorrect use of the closed-class morphology, satisfies this criterion.

Badecker and Caramazza (1985) question the status of agrammatism as an empirical entity in view of significant variations in language performance among aphasic individuals so



framework of Government Binding theory (Chomsky, 1981), Grodzinsky (1984a) has proposed that the tendency of some aphasics to omit closed-class items in production, as well as their failures to interpret them correctly, is due to a selective impairment at the level of S-structure. On Grodzinsky's hypothesis, both the production and comprehension problems of agrammatic aphasics reflect impaired knowledge at this level of representation: What is lost in agrammatism is the lexical content normally present at the terminal nodes of closed-class vocabulary items in the construction of a representation at the level of S-structure.<sup>5</sup> Items belonging to *different* syntactic categories should be preserved, despite loss of sensitivity to distinctions *within* a category. So, for example, if an adverb were inserted in a sentence at a terminal node that requires a determiner, the agrammatic subject would detect this substitution, and would find the sentence anomalous. We will call this a between-class substitution. An example is given in (2):

2. \*The cabdriver forgot to bring the senator to *away* rally.

It follows from Grodzinsky's hypothesis, however, that a substitution *within* the same form class would not be noticed, even if this substitution leads to grammatical violations. A within-class substitution of this kind occurs in sentence (3). For sentences like this, agrammatic aphasics would simply have to guess whether the correct item was present under the auxiliary node, as in (4):

3. \*Peter *have* planning to see a new movie Saturday night.  
 4. Peter *was* planning to see a new movie Saturday night.

To test Grodzinsky's proposal, the ungrammatical sentences in the present study contained violations of lexical insertion both within and between classes. Because agrammatics cannot "look" under the lexical node in (3)

designated. This is not the place for a discussion of the issues raised in their critique (see Caplan, 1986). We would point out that although we do not accept their conclusion that the concept of agrammatism should be jettisoned, we share a concern with the problems for classification that are created by intersubject variation, and we concur that the practice of grouping data over subjects should never be undertaken lightly.

<sup>5</sup>The proposal was extended by Grodzinsky (1984b) to take account of cross-language differences in the manifestations of agrammatism. In marking syntactic distinctions, Grodzinsky predicts misselection of closed-class items within the same syntactic category, with the proviso that closed-class items will usually be omitted in a relatively uninflected language like English, but not in a morphologically complex language like Hebrew, where failure to inflect the stem properly could result in a nonword.

any more than than in (2), they might respond in the same way to both sentence types. On the other hand, a subject who is over-accepting would respond correctly (although for the wrong reasons) to sentences like (3), but not to sentences like (2), which contain a grammatical violation.

## METHOD

### Subjects

In the present study, our strategy was to compare the performance of normals with non-fluent aphasic subjects who had been selected using liberal criteria. We required only that the aphasics satisfy an operational definition of agrammatism by evincing significant limitations in production of closed-class vocabulary items.

Six normal subjects and six aphasic subjects participated in the experiment. All were native speakers of English with normal hearing. All were fully ambulatory and able to travel to the testing site. The characteristics of the aphasic subjects are summarised in Table 1. In each case, the aphasic symptoms were attributable to stroke which had occurred from 3 to 14 years prior to testing. Hospital records dating from the acute phase were scrutinised. The diagnostic work-up included CAT scan for all patients except LS. The clinical neurological examination revealed right hemiplegia in each case and the scan data indicated infarction in the territory of the middle cerebral artery, predominantly frontal, but with varying degrees of posterior extension into the Sylvian region. All the aphasic subjects had received diagnostic aphasia testing prior to the present study, including portions of the Boston Diagnostic Aphasia Examination. All were judged able to understand the task directions.

As may be seen from Table 1, each aphasic subject showed frequent omission of closed-class vocabulary items and a marked reduction in speech output. Their responses to the "cookie theft" picture are also agrammatic, in the sense that most of the sentences are not well formed. With regard to comprehension, however, the subjects showed less homogeneity. Only four of the six subjects showed significant impairment on comprehension of passive voice sentences. Two of the group comprehended both sets nearly without error, and one of these was perhaps the most severely affected of all the subjects in production.

The normal subjects were adult speakers of English who were matched approximately for age (mean 51 years) and education (mean 14 years) with the aphasic group. We will refer to them as the *reference group*.

TABLE 1  
Aphasic Subjects: Background Data

Subject	Age	Educa- tion	Aetiology	Comprehension			Production BDAE Cookie Theft Picture
				BDAE (Z Score)	Active (% Correct) <sup>b</sup>	Passive	
PJ <sup>a</sup>	47	12	L. frontal embolism (1979)	1.0	98	98	Mom is washing her ... dishes and her ... dishes. But I can't say it. Dishes going ... this way. I can't say it. Her ... dishes is uh ... fall and goes down there.
ME <sup>a</sup>	56	16	Infarct, L. mid- cerebral artery (1979)	0.6	98	98	Cookies dar, no I ... cookie jar. Tilts, tilts, stool. Wash dishes, I, no, she is ... washing dishes. She pour ... she ... she pour water. (Where?) She pour ... pour water floor ...
VS <sup>a</sup>	61	12	Infarct, L. mid- cerebral artery (1970)	0.7	88	60	Mother is washing the ... dishes ... The David and Kathy ... cookies. Fall on. The ... the ... water. The water is ... clump ... flowing. The chair is ... the boy is counter.
LS <sup>a</sup>	52	12	Occlusion, L. mid- cerebral artery (1974)	0.4	67	52	A mother ... a dish ... drying ... Plate ... a faucet ... running ... a boy, eating cookies ... eating the cookies ... girl.
AK	70	4	Infarct, L. mid- cerebral artery (1979)	0.7	79	42	Mother ... washing dishes. The boy ... falling. Eat ... s ... s ... coo ... kies. Girl cookie. Mother ... s ... s ... not look.
ED	68	12	Infarct, L. mid- cerebral artery (1980)	0.2	71	29	House ... kitchen ... woman clean dishes. The sink is full ... water ... spilling all ... over.

<sup>a</sup>ME and PJ also participated in Schwartz et al. (1987). VS and LS also participated in the study of Linebarger et al. (1983).

<sup>b</sup>These percentages are based on A', a non-parametric index of sensitivity. The materials consist of semantically reversible active and passive sentences (24 of each). Each was tested twice, once with a matching picture and once with a picture in which agent-patient roles were reversed. A' is theoretically equal to the proportion of correct responses attainable in a two-alternative forced-choice procedure.

## Materials

The stimulus set consisted of 112 sentences of 10 words each, half of which were ungrammatical. Forty of the ungrammatical sentences contain a single grammatical violation involving a closed-class item. These, together with their matched grammatical control sentences, are listed in the Appendix.<sup>6</sup> The grammatical violations were of four kinds—each involved a determiner, preposition, particle or verbal element. The four categories were equally represented. In each anomalous sentence, a word (or a bound morpheme) occurred which, in that context, made the sentence ungrammatical. We call this the *target*. For example, one type of violation involved agreement in number between a determiner and a noun, as in sentence (5). Here, the target “word” is the plural morpheme *s*:

5. The banker noticed that two customer< > deposited the checks late.  
Control: The sailor noticed that three shipmates left the dock early.

Detection of the ungrammaticality in (5) requires access to the grammatical feature (singular/plural) associated with the determiner and the affix of the noun. We will refer to the determiner (DET) in this case as the *licensing* word, because the recognition of its features is essential to detection of the anomaly, even though it is not itself the word that we expected people to alter to make the sentence grammatical (i.e. it is not the target word). In contrast, in violations involving particles (PART) such as (6), the licensing word is an open-class item, the verb “picking”, whereas the target is a closed-class item, the particle “on”:

6. Picking the birthday present *on* would be nice for Susan.  
Control: Picking an expensive gift out will be pleasant for George.

For half of the sentences the substituted item preserves category membership (e.g. an inappropriate preposition for an appropriate one); for half it does not (e.g. a preposition for a determiner). For every ungrammatical sentence there is included a grammatical (control) sentence matched in length and structure, as illustrated above. The serial position of the target word is also controlled, i.e. whether it occurs near the beginning (within the group consisting of words 1–3), middle (words 4–7), or near the end of the sentence (words 8–10). An additional factor is the proximity of the closed-class target item to the word which determines its appropriate-

<sup>6</sup>In addition, 32 simple conjoined-clause filler sentences were interspersed among the test items. These too consisted of equal numbers of grammatical and ungrammatical sentences.

ness (e.g. a determiner and a head noun). If the licensing word and the target word are adjacent, the proximity is CLOSE, as in (5); if separated by at least two intervening words, it is FAR, as in (6).

The test sentences were tape-recorded at normal conversational speed and the waveforms were digitised and stored. The test tape was prepared with the aid of a waveform editing program at Haskins Laboratories (WENDY). The procedure was as follows: For each ungrammatical sentence, a pitch pulse was placed in the non-speech channel to coincide with the onset of the word that caused the ungrammaticality (the *target* word). In order to accomplish this, the waveform for each target word was displayed with expansion of the time-scale such that the onset of voicing could be located reliably. A timing pulse was placed at that point in each of the ungrammatical sentences. This procedure allows us to discover if the subject is responding before hearing *all* the words in the sentence. The timing pulse triggered a response-time clock (accurate to 1 msec) which was stopped by a subject's key press. (For the grammatical control sentences, a pulse was placed at the onset of voicing of the initial word in the sentence. Because correct responses to grammatical sentences must always occur after the last word, no further use was made of response-time data for these sentences.)

Care was taken to exclude extraneous cues that might offer a spurious basis for judgement by permitting the subject to capitalise on a prosodic or semantic anomaly. Such extra-syntactic factors were controlled for as follows: First, the possibility of inadvertently creating ungrammatical test sentences with anomalous prosody, which might cue the correct response without syntactic processing, was minimised by recording and presenting each target only once, at a normal conversational rate, and by avoiding unnatural discontinuities that occur when tape splicing is used. Secondly, a trained speaker was employed in preparation of the stimulus tape. The speaker was instructed to read each ungrammatical sentence as though it contained a grammatically appropriate word in place of the anomalous word, thereby creating a sentence token that, though ungrammatical, conformed to normal prosodic contours. In order to avoid confounding syntactic analysis with sensitivity to semantic and pragmatic factors, the sentences were designed so that the meaning of the sentence was transparent and semantically plausible despite the presence of an anomalous word.

Another source of possible variability needs to be addressed. Each of the ungrammatical test sentences could be rendered grammatical by changing a single word, namely the word we designate as the target word. But, of course, each sentence could also be corrected in numerous other ways. For example, even the simple sentence *She were writing a letter* can be corrected as *She was writing a letter*, or *They were writing a letter*, and so on. Therefore,

one cannot assume without argument that subjects will always identify a particular word as the anomalous item. But just this assumption is critical for our analysis of on-line processing, for example, regarding the interpretation of the word-position effect.

A review of the relevant research indicates that people are remarkably consistent in the word they identify as anomalous in ungrammatical sentences like those we constructed for the present study (Crain & Fodor, 1987; Freedman & Forster, 1985). Returning to the example given above, this research leads us to expect that subjects would consistently correct the sentence to yield: *She was writing a letter*. Correcting the sentence in this way suggests that speakers of English typically pursue a strategy which, proceeding from the left, accepts as many words as can be incorporated into a single structural representation. A perceiver who is pursuing this strategy locates the anomaly on the last alternative possibility. This led us to expect a consensus among our subjects in how the anomalous test sentences would be construed.

We validated this expectation empirically by asking 20 undergraduate students to correct the anomaly in each test sentence, to discover whether or not they would correct each sentence by changing the target word and that word alone. The results of the correction task revealed that 93% of the responses were either alterations or deletions of the target word. By extension, we can suppose that the aphasic subjects and the reference group of the present experiment display a comparable degree of consistency and that their judgements reflect a common diagnosis of what is wrong with each of the anomalous sentences.

## Procedure

Subjects were tested individually in a sound-treated room. They indicated their responses to each test sentence by a key press. The response keys were labelled with cartoon faces—a smiling face to indicate a grammatical sentence, and a frowning face to indicate an ungrammatical one. The subjects' task was simply to press the appropriate key as rapidly as possible on hearing each test sentence. Subjects were instructed to press the frowning face key as soon as they detected an ungrammaticality, and not to wait until the end of the sentence. A practice session consisting of 12 sentences, with examples of each type, was used to ensure that each subject understood the task.

## Scheme of the Data Analysis

Statistical treatment of the measures of response time and accuracy for the ungrammatical (target) sentences was carried out to assess the between-

subjects factor of *group* (aphasic *vs* reference group) and the four within-subjects (structural) factors that were controlled in the test sentences. These are listed below:

(i) *Position*: the ordinal position of the critical closed-class word in the sentence, i.e. BEGINNING *vs* MIDDLE *vs* END.<sup>7</sup>

(ii) *Substitution type*: whether the substituted closed-class item preserves category membership, i.e. WITHIN- *vs* BETWEEN-class violations.

(iii) *Proximity*: the proximity of the closed-class item to the licensing word, i.e. CLOSE *vs* FAR.

(iv) *Category*: four categories of closed-class words are represented—determiners (DET), prepositions (PREP), particles (PART), and agreement in verbal items with their antecedents (AUX)

## RESULTS

Initially, the data from both the normal subjects and the aphasic subjects were combined, and parallel ANOVAs were carried out on the response-time and accuracy measures for the ungrammatical sentences. As one might anticipate, each structural variable had a significant effect on reaction time. Likewise, all but one had a significant effect on error rate (only *position* failed to reach significance). Considering first the response time measures, the results of the analysis for the combined data from both groups are as follows: *position* [ $F(2,22) = 21.79; P < 0.01$ ]; *proximity* [ $F(1,11) = 22.50; P < 0.01$ ]; *substitution type* [ $F(1,11) = 4.83; P < 0.05$ ]; and *category* [ $F(3,33) = 10.40; P < 0.01$ ]. With regard to errors, three of the four variables were again significant. The results are as follows: *position* [ $F(2,22) = 2.04; P < 0.15$ ]; *proximity* [ $F(1,11) = 9.18; P < 0.01$ ]; *substitution type* [ $F(1,11) = 8.27; P < 0.02$ ]; and *category* [ $F(3,33) = 2.81; P < 0.05$ ]. We consider the interpretation of these results presently when we discuss further analyses that test for differences between the subject groups.

Table 2 summarises the accuracy of responses by subject. The top half of the table gives the percentage correct for the ungrammatical sentences and

<sup>7</sup>An idiosyncrasy of the stimulus set should be noted. Because it is impossible to construct sentences in which the position of the closed-class item is at the beginning of the sentence and also distant from the licensing word, there is unavoidably an imbalance in the data set. We have dealt with this circumstance in the following way: when we wished to analyse the effect of position as a factor, we deleted the sentences where the value for proximity was FAR. When we wished to look at proximity, we deleted the sentences where the value for position was BEGINNING. Accordingly, analyses of variance were carried out using the between-subjects factor of *group*, and within-subjects factors of *position*, *substitution type*, *proximity*, and *category*.

TABLE 2  
 Percentage Correct by Sentence Type for Individual Subjects

<i>Subject</i>	<i>Overall</i>	<i>Within-class</i>	<i>Between-class</i>	<i>Control</i>
<i>Aphasic group</i>				
PJ	83	80	85	88
ME	90	79	100	96
VS	55	35	75	56
LS	75	60	90	83
AK	78	55	100	73
ED	68	60	75	79
Mean	75	61	88	80
<i>Reference group</i>				
BC	90	85	95	92
KB	100	100	100	100
CS	97	95	100	92
EW	100	100	100	100
TM	100	100	100	100
JM	97	100	95	96
Mean	97	97	98	97

their grammatical controls for the aphasic subjects; the corresponding data for the reference group are given in the bottom half. It may be seen that five of the six aphasic subjects performed with a higher level of accuracy on the grammatical control sentences (column 5) than on the sentences containing grammatical violations (column 2). The means were 80 and 75% correct, respectively, so the level of performance was roughly equivalent for both sets of sentences. In no subject was the discrepancy greater than 11%. In the absence of any marked tendency for the aphasic subjects to be over-accepting, further analyses are confined to the errors on the ungrammatical sentences. For the reference group, the mean performance level was 97% correct on both the ungrammatical sentences and grammatical control sentences.

In addition, Table 2 partitions scores on ungrammatical sentences in which the target word preserves or violates category membership—WITH-IN-class (column 3) vs BETWEEN-class (column 4). It should be noted that all six of the aphasic subjects and five of the six members of the reference group were more accurate in detecting between-class substitutions. The import of this result will be considered presently.

The major task of the data analysis was to test between the possibility that the aphasics' lower accuracy and longer response latencies reflect loss of syntactic structures or, alternatively, whether they point to a deficit in



linguistic processing. This question is examined by testing for interaction between the experimental variables and group. We reasoned that if the aphasic subjects have incurred a breakdown in the internal grammar that blocks full syntactic analysis of closed-class words, we could expect to find consistent between-group interactions on either or both of the dependent measures—response time and errors (where an error is failure to detect an ungrammatical sentence).

By contrast, the hypothesis that Broca's aphasics suffer from limitations in processing, but have preserved sensitivity to syntactic structure, would lead us to anticipate a different pattern of results, i.e. main effects for within-subject variables but no between-group interactions except those that arise as artifacts of measurement. Spurious interaction would result, for example, whenever the reference group reached a ceiling level of performance by responding with nearly perfect accuracy in making grammaticality judgements. Because the findings involving response time and accuracy parallel each other closely, we discuss both aspects of the results together, rather than allocating them to separate sections.

Figure 1 displays the performance of each group with respect to each of the four structural variables. We will refer to the panels in this figure in the order from upper-left to lower-right. The effects of ordinal *position* of the target word on response time and accuracy are shown in the pair of graphs at the top of the figure.<sup>8</sup> It is apparent that with respect to response time, performance increases with ordinal position for both the aphasic group [ $F(2,5) = 34.57$ ;  $P < 0.01$ ] and the reference group [ $F(2,5) = 7.47$ ;  $P < 0.04$ ]. As may be seen from inspection of the graph at the top left, both groups show slower responses to an anomalous target word at the beginning of a sentence than at the middle or end. The interaction of *group* and *position* is significant [ $F(2,20) = 10.88$ ;  $P < 0.01$ ], and so deserves further comment. The interaction occurred because the slope of the position effect is considerably steeper for the aphasic subjects than for the reference group, but the effect of position for both groups is in the same direction. With regard to accuracy, there was no significant effect of position for either group, as noted above.

The beneficial effect of increased *proximity* of the closed-class item to its licensing word was a significant factor in task performance for both groups, as shown in the second pair of graphs. It is apparent that there is a decrement in performance for the value FAR, both in speed and accuracy. This decrement is significant for response time, for the aphasic group [ $F(1,5) = 10.67$ ;  $P < 0.02$ ] as well as for the reference group [ $F(1,5) =$

<sup>8</sup>On the ungrammatical sentences, the mean response time was 2606 msec for the aphasic group and 1616 msec for the reference group. The difference was significant [ $F(1,10) = 15.62$ ;  $P < 0.01$ ].

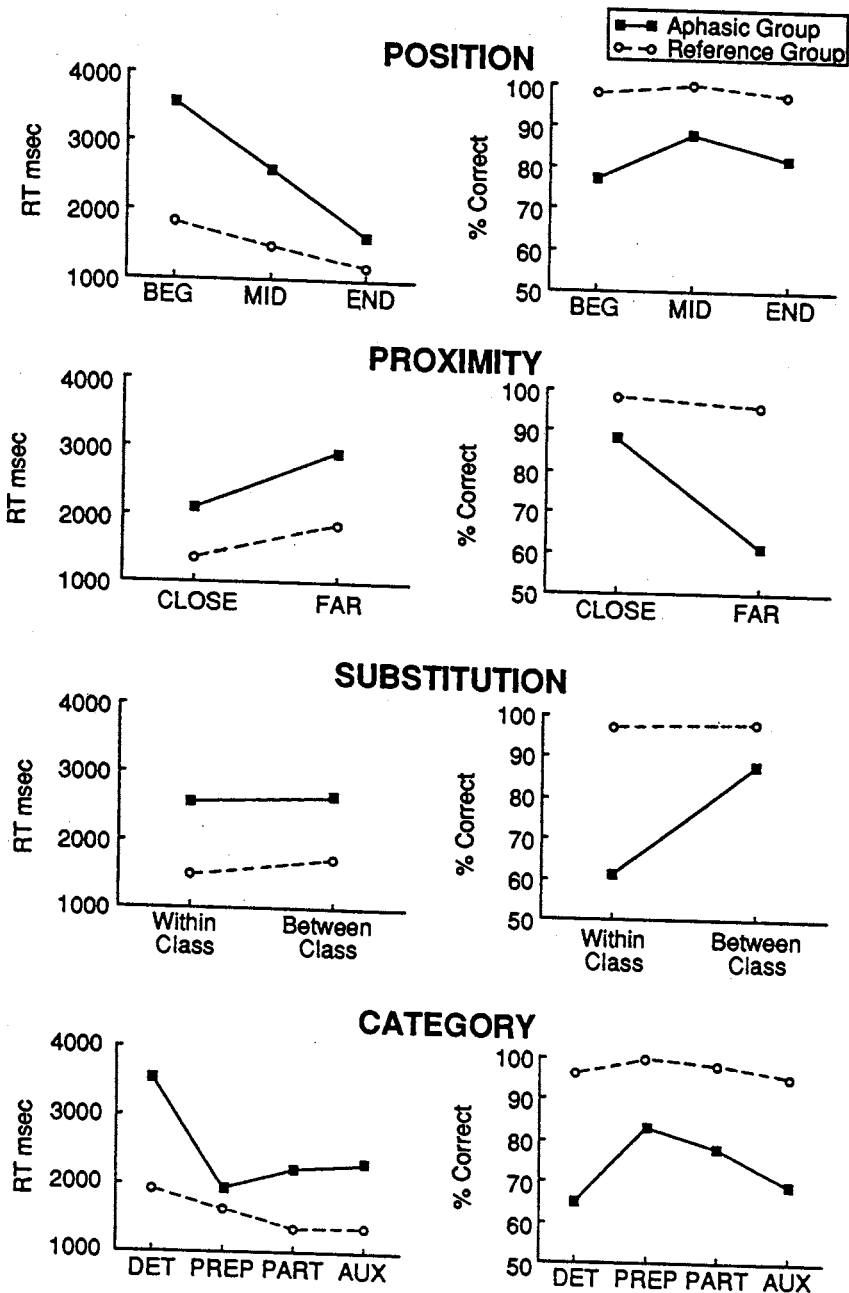


FIG. 1. Mean performance of the aphasic group and the reference group on reaction time and percent detection of ungrammatical sentences for each structural factor.

27.05;  $P < 0.01$ ]. It is noteworthy that there was no interaction with group ( $P < 0.3$ ). As for accuracy, the effect of proximity was also significant for the aphasic group [ $F(1,5) = 20.04$ ;  $P < 0.01$ ]. They responded correctly on 90% of the cases where the licensing word was CLOSE but only 63% when it was FAR, yielding a difference of 27%. For the reference group, the corresponding difference is only 2%, clearly not significant. Because the reference group was performing at ceiling in both conditions, an interaction arises [ $F(1,10) = 15.41$ ;  $P < 0.01$ ].

A comparison of the individual aphasic subjects' performances on the experimental materials reveals sufficient consistency to justify treating the aphasics as a group and reporting summary statistics on the grouped data, as presented in the foregoing paragraphs. Figure 2 shows the individual subject response times for *word position* and *proximity*, the two factors on which our argument for on-line processing rests. It is noteworthy that the effect of both variables is consistent across the individual subjects, despite fairly marked differences in overall level of performance. Each subject shows monotonically decreasing response times as a function of word position, and each shows faster response times for sentences in which the licensing word was close to the target word.

We have already noted differences in accuracy of responding by *substitution type*. As shown in Table 2, all of the aphasic subjects were more accurate in rejecting the between-class substitutions. The difference was significant for the aphasic group [ $F(1,5) = 27.25$ ;  $P < 0.01$ ], but not the reference group, presumably because the latter was performing at ceiling level on both types of substitutions. The reference group detected 98 and 97%, respectively, whereas the aphasics detected 61% of the within-class and 88% of the between-class substitutions. This led to a significant interaction by group [ $F(1,10) = 13.68$ ;  $P < 0.01$ ].

There was also an overall effect of *substitution type* on response time, but here the pattern was reversed. As shown in the third pair of graphs in Fig. 1, the between-class substitutions evoked longer response times for both groups. The effect of *substitution type* on response time proved to be a significant effect for the reference group [ $F(1,5) = 12.13$ ;  $P < 0.01$ ], but not for the aphasic group [ $F(1,5) = 0.49$ ;  $P < 0.5$ ], and there was no interaction of this factor with group. (See the Discussion for comments on the disparity in the findings for response time and accuracy.)

The effects on performance of syntactic *category* are shown in the pair of graphs at the bottom of Fig. 1. Recall that, within the set of test sentences, there were grammatically inappropriate substitutions among the four categories of closed-class words—prepositions, particles, verbal elements, and determiners. There is a significant effect across these categories on response time (but not on accuracy) for both the aphasic group [ $F(3,5) = 8.66$ ;  $P < 0.01$ ] and the reference group [ $F(3,5) = 13.81$ ;  $P < 0.01$ ]. The interaction

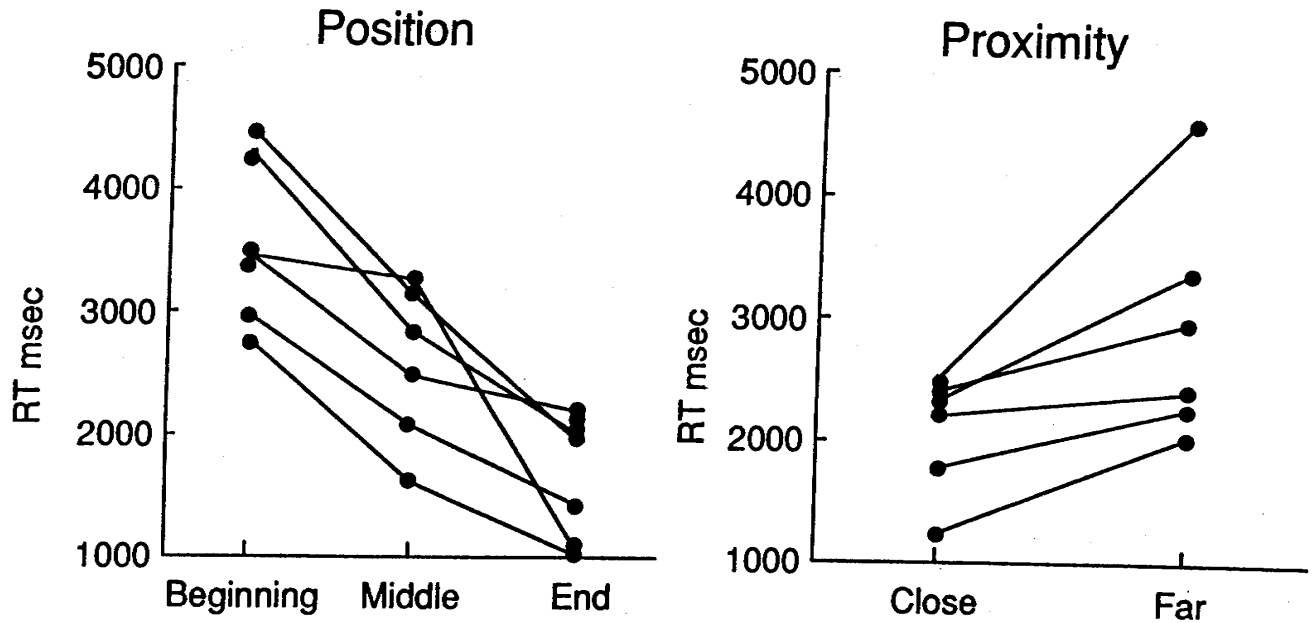


FIG. 2. Mean performance of individual aphasic subjects for Position and Proximity.

of *group* and *category* is significant also [ $F(3,30) = 5.63; P < 0.01$ ]. Further analysis shows that the interaction is due chiefly to one category, i.e. prepositions. The relatively better performance of the aphasic group on prepositions is consistent with the findings of others (e.g. Friederici, 1982; Grodzinsky, 1984b). With this category omitted from the analysis, the interaction disappears ( $P < 0.2$ ).

In summary, the results reveal both similarities and differences in the pattern of responses for aphasic subjects and the reference group. As for the similarities, we take the existence of the word position effect and the proximity effect in both groups to be a telling indication of on-line language processing. Differences between the groups are indicated by the consistently lower accuracy and longer response times of the aphasic subjects and by the occurrence of some interactions of the structural variables with group. In interpreting the interactions it was important to distinguish genuine interactions from spurious statistical effects that result from a problem in measurement arising, for example, when normal subjects approach a ceiling level of performance. In the following section we consider the implications of the findings for understanding the comprehension difficulties that may occur in cases of non-fluent aphasia and also the wider implications for the concept of agrammatism. We begin by examining the specific findings concerning sensitivity of the aphasic subjects to the closed-class vocabulary, using the reference group as a basis for comparison. Then we discuss how the findings fit within the larger framework of current theories of syntactic processing in aphasia.

## DISCUSSION

Applying the logic sketched in the Introduction, we looked for evidence of preserved on-line sentence processing by Broca-type aphasics, and we sought to delimit the locus within the language system of their comprehension difficulties. We assessed performance on the test sentences with respect to four structural variables—*position*, *proximity*, *substitution type*, and *category*. It is evident that the findings favour the hypothesis of preserved sensitivity to the syntactic functions of the closed-class vocabulary. This is indicated by critical similarities in response patterns for both accuracy and response latency for the aphasic group and the reference group on each factor. Thus the idea that the comprehension difficulties of the aphasic subjects are due to loss of structures is not supported. Instead, a deficit in processing is implicated. We now discuss the results in detail.

1. *Position*. Consider first the effect of the position of the anomalous word in the sentence. Both groups displayed the word position effect, showing a decrease in response time for later-occurring (in contrast to

earlier-occurring) anomalous words. In previous work on sentence processing in normals, this effect has been interpreted as a demonstration that language perceivers begin to construct a structural representation of a sentence almost from the outset. If this reasoning is correct, the appearance of the word position effect in the aphasic group constitutes evidence of preserved syntactic competence. The reference group was both faster and more accurate than the aphasic group, as expected, but both groups displayed the same trend.

The finding that the aphasics, like the normals, were consistently faster in detecting violations in later-arriving items calls into question a proposal by Caplan (1982) that agrammatics assign minimal structure to sentences above the lexical level. If we are correct in supposing that the word position effect is attributable to on-line construction of the syntactic structure, then these aphasic subjects must compute enough structure above the lexical level to enable the input string to be processed as a structured entity. It is apparent, then, that some Broca's aphasics are capable of using information about phrase structure above the lexical nodes as the basis for grammaticality decisions, as Linebarger et al. (1983a) claimed.

2. *Proximity.* Further evidence that the grammaticality judgement task involves on-line sentence processing is the beneficial effect of proximity of the licensing and the target words.<sup>9</sup> If a sentence is processed on line, the difficulty of relating two lexical items should increase with the distance between the items. It is presumably more difficult to relate two items if other items intervene than if they are adjacent because the grammatical features of the first item must be retained in working memory. On the other hand, if the sentence were being processed off line, its entire representation would be held in memory and no local effects of differences in proximity would be expected.

Proximity of the closed-class item to its licensing word was a significant factor in task performance for both subject groups. Each group performed significantly better for the grammatical anomalies in which the distance of the closed-class item to its licensing word was CLOSE. When there was greater distance between the licensing word and the target item, the aphasics, like the normal subjects, were slower to respond. It is noteworthy that the effect of proximity, like the effect of word position, was in the same direction for all the aphasic subjects. The finding that both groups

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<sup>9</sup>The present study does not address the issue of the precise characterisation of "distance". It may be that the amount of structure between the closed-class item and its licensing word is the relevant factor, or it may be the number of words, or amount of time. However distance comes to be defined, we will assume that our results are the effect of a single factor influencing the performance of both groups.

had more difficulty in the FAR condition is an indication that the more remote dependencies stress working memory. This, together with the effect obtained for ordinal position of the anomalous word, lends support to the conclusion that both groups processed the test materials on line.

3. *Substitution type.* A noteworthy feature of the design of this study permitted a comparison of the accuracy of detection of within-class and between-class substitutions. This comparison is of special interest in view of the recent theoretical claims of Grodzinsky (1984b; 1986) to which we have referred. Let us review the findings. First, we noted a main effect on response time for substitution type, with the between-class substitutions evoking longer response times, but no interaction of this factor with *group*. Both groups took longer to respond to between-class substitutions, although the effect did not reach significance for the aphasic group. Substitution type also had a significant effect on accuracy of responding, but the direction of the effect was reversed; the within-class substitutions, as expected, evoked a greater number of errors than the between-class substitutions. This difference was significant for the aphasic group, but not for the reference group, presumably because they were performing at ceiling level on both types of substitutions.

The disparity between the findings for response time and accuracy deserves comment, as it might appear paradoxical that within-class substitutions should evoke more errors, yet were more rapidly identified as incorrect. In our view both results are consistent with the other manifestations of on-line processing. To show this we must first explain why the between-class substitutions took longer; then we must explain why the within-class substitutions, though faster to detect, induced more errors.

In regard to the response time differences on between-class substitutions, we suggest that the reason an ungrammatical variant of an expected word (e.g. *were* instead of *was*) may be easier for the sentence parser to recover from than a totally inappropriate word is as follows: When an item cannot be fitted into the current parse of a sentence, the listener is jolted into a new attempt at structuring the available material. Attempts at restructuring are costly of time because there exists no correct alternative syntactic structure, but once the search has been exhausted, listeners would be accurate in rejecting the sentence.

In considering the response times for within-class substitutions, one must bear in mind that the analysis is based only on the data for sentences on which subjects gave the correct, negative response. Therefore, response times to the within-class substitutions reflect only those trials on which the subject was able to see that an illicit variant of an appropriate item had been substituted for it. Because the substitute was obviously inapt in these cases, no attempt at restructuring was made. On the other hand, the high rate of "misses" for within-class substitutions among the aphasic subjects

may reflect an automatic tendency to replace an illicit item with an appropriate one. Thus, the errors that occurred for within-class substitutions may simply represent a confusion between the item that was actually perceived and the spontaneously corrected item that subjects unconsciously replaced it with. Automatic correction of ungrammatical strings was a prominent phenomenon in a profoundly aphasic patient studied by Whitaker (1976). The operation of automatic correction may help to account for the relatively poor performance of aphasics in response to erroneous within-class substitutions. An account in these terms would not implicate the syntactic processor as the source of the problem. Instead, the problem would be seen as one of monitoring and suppressing information that the parser has automatically computed.

4. *Category.* The findings concerning accuracy of responses to variations in category also merit comment. Although the aphasic group was significantly less accurate on within-class than between-class substitutions, they performed above chance on two kinds of within-class substitutions: prepositions and particles. The response pattern is relevant to the proposal by Grodzinsky (1984a) and Zurif and Grodzinsky (1983), who maintain that in agrammatism the terminal nodes immediately dominated by the lexical nodes DET, AUX, INFL, COMP, etc. are left unspecified.<sup>10</sup> As Zurif and Grodzinsky (1983) point out, "violations of syntactic structure are permissible in agrammatism (that is, not noticed by the patient) only to the extent that they are either errors involving inflections, auxiliaries and determiners, at omissions of prepositions" (p. 210). Thus, agrammatic subjects should be unable to detect *any* within-class substitution but should remain sensitive to substitutions which fail to preserve category membership.<sup>11</sup> The fact

<sup>10</sup>An unexpected aspect of the ability to detect within-class substitutions is the detrimental effect on performance of the determiner substitutions. We do not have an adequate explanation of this effect. We do, however, consider it significant that the effect, whatever the cause, was evident for both groups. One might speculate that the increased response times result from the fact that the recognition of this type of error often depends upon a violation of number agreement between the determiner and its head noun. This type of error is often encountered in everyday contexts where the long latencies might reflect the time required to (unconsciously) correct this type of error (see Crain & Fodor, 1987).

<sup>11</sup>In a later paper, Grodzinsky (1984b) states the generalisation as follows: If a terminal element at S-structure is not lexically specified (see Chomsky, 1981), then it will be unspecified at this level in an agrammatic's representation. In a reply, Sproat (1986) presents theoretical reasons against characterising the agrammatic deficit as a structural deficit. He argues against the claim that in agrammatism traces are unspecified at S-structure. The argument has two parts. First, Sproat observes that the proposal entails that agrammatism involves the violation of a central tenet (the Projection Principle) of the linguistic framework in which Grodzinsky's hypothesis is placed (Government Binding Theory). Sproat then points to evidence from the study by Linebarger et al. (1983a) showing that, in fact, the Projection Principle is respected in the grammars of the aphasics they tested.



that the aphasic group responded with above-chance accuracy in response to particles (79% correct) and prepositions (83% correct) cannot easily be accommodated by the Zurif and Grodzinsky proposal.<sup>12</sup>

Also recalcitrant for their proposal is the finding that the aphasic group responded accurately to control sentences 80% of the time. As noted earlier, the Zurif and Grodzinsky proposal applies to the control sentences as well as to the ungrammatical target sentences—a subject who could not identify items beneath lexical nodes would err in the same, but opposite, proportion to each sentence type. For example, a subject who judged 80% of the control sentences to be correct should also have judged 80% of the ungrammatical sentences to be correct, using the same criteria. This would have resulted in only 20% accuracy for the ungrammatical items. The findings were inconsistent with this expectation, however. The aphasic subjects were 61% correct in responding to the target sentences. Recall, also, that the target sentences and their controls were identical in structure, except for the critical (anomalous) word, so that any differences in response rates must be attributed to the ungrammaticality of the test sentences.

Having considered the effects of each of the structural variables individually, we can now ask whether the findings form a coherent picture of the processing capabilities of the aphasic subjects. Earlier we discussed three indicators of on-line computation of structural representations—the word position effect, the proximity effect, and the detection of an anomaly before the sentence is complete. If the aphasic subjects are using closed-class vocabulary items in constructing a syntactic representation on line, we would expect them to exhibit each of these phenomena. We have presented evidence that demonstrates a word position effect and an effect of proximity. We found that aside from differences in overall level of performance, both the reaction-time and the accuracy data for each group are concordant (assuming that we are correct in attributing the interactions with subject group to ceiling performance by the normal subjects.) With regard to the remaining indicator of on-line processing, we note that 50% of the responses of the aphasic group were made before the arrival of the last word in the sentence in cases where the grammatical violation was near the beginning. Moreover, the post-sentential response times lagged an

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<sup>12</sup>To explain the disparity between the aphasic subjects' ability to detect between- and within-class substitutions, we would suggest an alternative to Zurif and Grodzinsky's (1983) proposal. Our proposal invokes the concept of degrees of acceptability (Chomsky, 1965). Because a substitution that violates category membership constitutes a more egregious violation, it has greater perceptual salience than a violation that preserves category membership. On this account, it is not surprising that the subjects in both groups were quite accurate in identifying the more salient between-class substitutions (3% errors for the reference group, 12% for the aphasic group).

average of only 182 msec after the end of the sentence, surely insufficient time for conscious reflection.<sup>13</sup>

Other data relevant to the issue of on-line processing by aphasics are presented in a recent case study by Tyler (1985). Like our aphasic subjects, the non-fluent aphasic studied by Tyler showed a word position effect in monitoring normal prose. However, this subject did not display an effect of word position for semantically anomalous prose. In this respect, Tyler's aphasic subject manifested an aberrant profile—in normal subjects a word position effect shows up in processing both standard text and semantically incoherent, but grammatically correct, sentences. Because the decrement in response time with advancing position is putatively due to the construction of a syntactic structure as the sentence proceeds, Tyler interprets the absence of a decrement in the anomalous prose condition as indicating the subject's inability to construct normal syntactic representations of sentences. This leads her to speculate that the word-position effect displayed by her subject in the standard prose condition might have resulted from an over-reliance on semantic/pragmatic information. It should be noted, though, that whatever ability underlies this subject's processing in the standard prose condition, it elicited the usual word position effect, rendering his performance indistinguishable from normal. Tyler offers the interpretation that her aphasic subject suffers from damage to two processors, resulting in deficient syntactic processing coupled with heightened sensitivity to semantics.

Another interpretation of the performance pattern displayed by this aphasic subject can be given—an interpretation that obviates the need to postulate opposing aberrant systems that conspire to make processing appear normal in ordinary circumstances. We raise the possibility that this subject's syntactic and semantic knowledge is intact. That is the simple conclusion to draw from the normal profile in the standard prose condition. But because the subject also has impaired processing capabilities, his ability to analyse language structure on line is weakened. As a consequence, the appearance of semantically incoherent word combinations may impose sufficient stress to disrupt syntactic processing. Put another way, our suggestion is that the syntactic processing capabilities of Tyler's subject are adequate under ordinary conditions, where both syntactic and

<sup>13</sup>These response times contrast sharply with post-sentential judgement tasks used to evaluate structural parsing preferences. For example, Frazier (1978) reports response times averaging over 1200 msec for the preferred reading of structural ambiguities. Although there are important differences between the stimulus materials in the present study and those used by Frazier, the differences in response times suffice to illustrate the point.

semantic cues converge on an appropriate analysis. But in adverse conditions syntactic processing may become derailed.

In our aphasic subjects, too, we would maintain that basic syntactic knowledge is intact. Moreover, the findings of the present research show clear indications that sentence processing routines that eventuate in grammaticality judgements are applied on line. This effectively answers the concerns expressed by Zurif and Grodzinsky (1983). Our results suggest, by extension, that the conclusion reached by Linebarger et al. (1983a) of preserved sensitivity to syntactic structure in Broca-type aphasics is not vitiated by the off-line character of their judgements task. The finding of a word position effect in the present study, which also used judgements of grammaticality, invites the inference that in the Linebarger study, too, these judgements reflect on-line decisions by the subjects.<sup>14</sup> Clearly, our aphasic subjects did not wait to apply syntactic processing routines until after all the words of a sentence had been encountered. If a subject were applying these routines in this way, the appearance of an effect of serial position would be mysterious. In short, there is evidence that Broca's aphasics are capable of on-line sentence processing, and that this processing is reflected in their grammaticality judgements.

Given our concern in this research with the issue of on-line processing in aphasia, the discussion inevitably sought to draw out the parallels in response pattern on the grammaticality judgements test between the aphasic subjects and the normal subjects. The value of this was to rule out a whole class of explanations of the nature of the basic deficit in agrammatic aphasia. What can we say, then, about the deficits which so definitely are displayed by the aphasic subjects? All of the non-fluent aphasics we have studied displayed major limitations in speech production that involve access to the closed-class vocabulary, confirming earlier indications of the critical importance of this portion of the lexicon for agrammatism. And, in four of the six subjects, these difficulties in speech production were accompanied by difficulties in comprehension, as evidenced by their performance on sentence-picture matching to passive-voice sentences. But, as

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<sup>14</sup>Like Linebarger, Schwartz, and Saffran (1983b), we find it implausible to suppose that the judgement task could permit syntactic structure to be computed by an alternative processing route. As these authors point out, this supposition amounts to the claim that there exists a separate, redundant sentence parser that is employed solely off line in certain tasks. It should also be mentioned that the Zurif and Grodzinsky proposal, which envisions such a delay between the arrival of an utterance and its structural analysis, entails unrealistic demands on working memory. That is, suppose that Broca's aphasics are unable to carry out on-line parsing. In order to judge grammaticality, then, they would be forced to accumulate and store a sentence as an unstructured aggregate of words that are subsequently fed into the special off-line parsing device. However, it seems to us that the verbal memory limitations of agrammatic aphasics would render them even less capable of such a feat than normal subjects.

we noted, there are inconsistencies in comprehension; two subjects performed almost without error on the test of passives. We cannot at present explain the apparent disparity between the results of studies using comprehension tasks, which present paradoxical findings concerning sparing and loss of syntactic knowledge, and studies using judgement tasks, which consistently demonstrate sparing. We might add that none of the current theories of agrammatism, the *Mapping Hypothesis* of Linebarger et al. (1983a; Schwartz, Linebarger, Saffran, & Pate, 1987), or Grodzinsky's *Trace Theory* (1986), can account for such discrepant individual patterns of response on language reception tasks in the face of consistent severe impairment in language production. The inconsistencies mean that a unitary account of agrammatism that cuts across both production and perception of language remains elusive. Future research would do well to focus on subjects who show these discrepancies, and to explore further the comprehension tasks which have led to inconsistent response patterns.

In summary, we conclude that the locus of the deficits in our aphasic subjects is in the processing system and not the system that represents grammatical knowledge. Were we to attempt to maintain that the findings reported for the aphasic group are the result of a loss of syntactic representations, we would be left without an explanation for the basically similar performance of the reference group. The proposal that the locus of the aphasics' deficit is in the processing system allows us to explain the parallels they showed with normal subjects as a reflection of spared syntactic competence. At the same time, the differences between the groups—longer response times and lower accuracy rates for the aphasic group—can be seen as reflections of the reduced processing capability that the aphasic subjects bring to the task of constructing a syntactic structure for an input string. We would predict, then, that if normal subjects were to perform a similar task under adverse listening conditions, e.g. time compressed speech (Chodorow, 1976) or the rapid serial visual presentation technique of Forster (1970), differences between the groups in response times and accuracy rates would narrow. We are currently investigating this possibility.

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## REFERENCES

- Aaronson, D. (1968). Temporal course of perception in an immediate recall task. *Journal of Experimental Psychology* 76, 129-140.
- Badecker, K. & Caramazza, A. (1985). On considerations of method and theory governing

- the use of clinical categories in neurolinguistics and cognitive neuropsychology: The case against agrammatism. *Cognition* 20, 97-125.
- Baddeley, A. D. & Hitch, G. B. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation*, Vol. 48. London and San Diego: Academic Press.
- Berndt, R. & Caramazza, A. (1980). A redefinition of Broca's aphasia: Implications for a neuropsychological model of language. *Applied Psycholinguistics* 1, 225-278.
- Bradley, D. (1978). *Computational distinctions of vocabulary type*. Unpublished Ph.D. dissertation, MIT.
- Bradley, D., Garrett, M., & Zurif, E. (1980). Syntactic deficits in Broca's aphasia. In D. Caplan (Ed.), *Biological studies of mental processes*. Cambridge, Mass.: MIT Press.
- Caplan, D. (1982). Syntactic competence in agrammatism: A lexical hypothesis. In M. Studdert-Kennedy (Ed.), *The neurobiology of language*. Cambridge, Mass.: MIT Press.
- Caplan, D. (1985). Syntactic and semantic structures in agrammatism. In M.-L. Kean (Ed.), *Agrammatism*. London and San Diego: Academic Press.
- Caplan, D. (1986). In defense of agrammatism. *Cognition* 24, 263-276.
- Caplan, D. & Futter, C. (1986). Assignment of thematic roles to nouns in sentence comprehension by an agrammatic patient. *Brain and Language* 27, 117-134.
- Caramazza, A. & Berndt, R. (1985). A multicomponent view of agrammatic Broca's aphasia. In M.-L. Kean (Ed.), *Agrammatism*. London and San Diego: Academic Press.
- Caramazza, A. & Zurif, E. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language* 3, 572-582.
- Chodorow, M. (1976). *Experimental studies of syntactic and lexical processes in language comprehension*. Ph.D. dissertation, MIT.
- Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, Mass.: MIT Press.
- Chomsky, N. (1981). *Lectures on government and binding*. Dordrecht: Foris Publications.
- Conrad, R. (1964). Acoustic confusions in immediate memory. *British Journal of Psychology* 3, 75-84.
- Crain, S. & Fodor, J. D. (1987). Sentence matching and overgeneration. *Cognition* 26, 123-169.
- Crain, S. & Steedman, M. (1985). On not being led up the garden path: The use of context by the psychological syntax processor. In D. Dowty, L. Karttunen, & A. Zwicky (Eds), *Natural language parsing*. Cambridge: Cambridge University Press.
- Fodor, J. A. (1983). *The modularity of mind*. Cambridge, Mass.: MIT Press.
- Fodor, J. D. (1985). Deterministic parsing and subadjacency. *Language and Cognitive Processes* 1, 3-42.
- Forster, K. (1970). Visual perception of rapidly presented word sequences of varying complexity. *Perception and Psychophysics* 8, 215-221.
- Forster, K. (1979). Levels of processing and the structure of the language processor. In W. Cooper and E. Walker (Eds), *Sentence processing: Studies presented to Merrill Garrett*. Hillsdale, N. J.: Lawrence Erlbaum Associates Inc.
- Foss, D. (1969). Decision processes during sentence comprehension: Effects of lexical item difficulty and position upon decision times. *Journal of Verbal Learning and Verbal Behavior* 8, 457-462.
- Frazier, L. (1978). *On comprehending sentences: Syntactic parsing strategies*. Ph.D. dissertation, University of Connecticut.
- Frazier, L. & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition* 6, 291-325.
- Freedman, S. & Forster, K. (1985). The psychological status of overgenerated sentences. *Cognition* 19, 101-131.
- Friederici, A. (1982). Syntactic and semantic processes in aphasic deficits: The availability of prepositions. *Brain and Language* 15, 249-258.

- Goodglass, H., Gleason, J. B., & Hyde, M. R. (1970). Some dimensions of auditory language comprehension in aphasia. *Journal of Speech and Hearing Research* 13, 595-606.
- Gordon, B. (1983). Lexical access and lexical decision: Mechanisms of frequency sensitivity. *Journal of Verbal Learning and Verbal Behavior* 22, 146-160.
- Gordon, B. & Caramazza, A. (1982). Lexical decision for open- and closed-class words: Failure to replicate differential sensitivity. *Brain and Language* 15, 143-160.
- Gorrell, P. (1987). *Studies of human syntactic processing: Ranked-parallel versus serial models*. Ph.D. dissertation, University of Connecticut.
- Grodzinsky, Y. (1984a). *Language deficits and linguistic theory*. Ph.D. dissertation, Brandeis University.
- Grodzinsky, Y. (1984b). The syntactic characterization of agrammatism. *Cognition* 16, 99-120.
- Grodzinsky, Y. (1986). Language deficits and the theory of syntax. *Brain and Language* 27, 135-159.
- Hamburger, H. & Crain, S. (1982). Relative acquisition. In S. Kuczaj (Ed.), *Language development*, Vol. 1: *Syntax and semantics*. Hillsdale, N.J.: Lawrence Erlbaum Associates Inc.
- Hamburger, H. & Crain, S. (1984). Acquisition of cognitive compiling. *Cognition* 17, 85-136.
- Hamburger, H. & Crain, S. (1987). Plans and semantics in human processing of language. *Cognitive Science* 11, 101-136.
- Heilman, K. & Scholes, R. (1976). The nature of comprehension in Broca's, conduction and Wernicke's aphasics. *Cortex* 12, 258-265.
- Holmes, V. & Forster, K. (1970). Detection of extraneous signals during sentence recognition. *Perception and Psychophysics* 7, 297-301.
- Isserlin, M. (1922). Ueber Agrammatismus. *Zeitschrift fuer die Gesamte Neurologie und Psychiatrie* 75, 332-416.
- Kean, M.-L. (1977). The linguistic interpretation of aphasic syndromes: Agrammatism in Broca's aphasia, an example. *Cognition* 5, 9-46.
- Kean, M.-L. (1980). Grammatical representations and descriptions of language processors. In D. Caplan (Ed.), *Biological studies of mental processes*. Cambridge, Mass.: MIT Press.
- Kean, M.-L. (1982). Three perspectives for the analysis of aphasic syndromes. In M. Arbib, D. Caplan, & J. Marshall (Eds), *Neural models of language processes*. New York: New York Press.
- Kolk, H., van Grunsven, M., & Keyser, A. (1985). On parallelism between production and comprehension in agrammatism. In M.-L. Kean (Ed.), *Agrammatism*. London and San Diego: Academic Press.
- Lapointe, S. (1983). Some issues in the linguistic description of agrammatism. *Cognition* 14, 1-39.
- Linebarger, M., Schwartz, M., & Saffran, E. M. (1983a). Sensitivity to grammatical structure in so-called agrammatic aphasia. *Cognition* 13, 361-392.
- Linebarger, M., Schwartz, M., & Saffran, E. M. (1983b). Syntactic processing in agrammatism: A reply to Zurif and Grodzinsky. *Cognition* 15, 215-225.
- Lukatela, K., Crain, S., & Shankweiler, D. (1988). Sensitivity to inflectional morphology in agrammatism: Investigation of a highly inflected language. *Brain and Language* 33, 1-15.
- Marcus, M. (1980). *A theory of syntactic recognition for natural language*. Cambridge, Mass.: MIT Press.
- Marslen-Wilson, W. (1975). Sentence perception as an interactive parallel process. *Science* 189, 226-228.
- Marslen-Wilson, W. (1984). Function and process in spoken word recognition. In H. Bouma & D. G. Bouwhuis (Eds), *Attention and performance X: Control of language process*. Hillsdale, N.J.: Lawrence Erlbaum Associates Inc.

- Marslen-Wilson, W. & Tyler, L. (1980). The temporal structure of spoken language understanding. *Cognition* 8, 1-72.
- Miceli, G., Mazzucchi, A., Menn, L., & Goodglass, H. (1983). Contrasting cases of Italian agrammatic aphasia without comprehension disorder. *Brain and Language*, 19, 65-97.
- Parisi, D. & Pizzamiglio, L. (1970). Syntactic comprehension in aphasia. *Cortex*, 6, 202-215.
- Pick, A. (1913). *Die agrammatische Spachstoerungen*. Berlin: Springer.
- Schwartz, M., Linebarger, M., & Saffran, E. M. (1985). The status of the syntactic deficit: The theory of agrammatism. In M.-L. Kean (Ed.), *Agrammatism*. London and San Diego: Academic Press.
- Schwartz, M., Linebarger, M., Saffran, E. M., & Pate, D. S. (1987). Syntactic transparency and sentence interpretation in aphasia. *Language and Cognitive Processes* 2, 85-113.
- Sproat, R. (1986). Competence, performance, and agrammatism: A reply to Grodzinsky. *Brain and Language* 27, 160-167.
- Tyler, L. (1985). Real-time comprehension processes in agrammatism: A case study. *Brain and Language* 26, 259-275.
- Wanner, E. & Maratsos, M. (1978). An ATN approach to comprehension. In M. Halle, J. Bresnan, & G. Miller (Eds), *Linguistic theory and psychological reality*. Cambridge, Mass.: MIT Press.
- Whitaker, H. (1976). A case study of the isolation of the language function. In H. Whitaker & H. A. Whitaker (Eds), *Studies in neurolinguistics*, Vol. 2. London and San Diego: Academic Press.
- Zurif, E. & Grodzinsky, Y. (1983). Grammatical sensitivity in agrammatism: A reply to Linebarger *et al.* *Cognition* 15, 207-213.
- Zurif, E., Caramazza, A., & Meyerson, R. (1972). Grammatical judgments of agrammatic aphasics. *Neuropsychologia* 10, 405-417.

## APPENDIX: EXPERIMENTAL SENTENCES CONTAINING GRAMMATICAL VIOLATIONS AND MATCHING GRAMMATICAL CONTROL SENTENCES

### AUX

#### *Within-class substitutions*

1. Roger wants the tusks that two large African elephants gives.  
Beth wants the wool that one big mountain sheep gives.
2. The baker told the helper that the bread were rising.  
The farmer told the stranger that a tornado was coming.
3. Peter have planning to see a new movie Saturday night.  
Mark is training to win the big race next week.
4. The Indian said that several bass was getting very large.  
The hunter said that one deer is getting awfully scared.
5. One of the sheep were sipping water from the trough.  
Two of the fish were eating worms off our hooks.

#### *Between-class substitutions*

1. One of the faculty the selling tickets for the dance.  
Four of the bison were chasing hunters across the field.

2. The mechanic told the driver that the fender *there* dented.  
The waiter told the diner that the pies were fresh.
3. The clerk said that six fish *here* getting quite hungry.  
The farmer said that two sheep were getting closely sheared.
4. Harry *that* attempting to reach the tall branch all day.  
George was going to visit his best friend on Sunday.
5. Paul wants the fillet that *on* tasty Alaskan salmon give.  
Tom wants the battle that many huge rainbow trout give.

## DET

*Within-class substitutions*

1. Several *man* begged to be allowed into the movie theatre.  
Several men begged to be admitted to the murder trial.
2. The realtor remembered to visit a newly listed country *houses*.  
The teacher remembered to bring two large clean glass jars.
3. The banker noticed that two *customer* deposited the checks late.  
The sailor noticed that three shipmates left the dock early.
4. Bill thinks many of the best *tool* disappeared last night.  
Terry thinks one of the worst players left this morning.
5. The astronaut forgot to bring the compass to a *spaceships*.  
The bellboy forgot to bring the luggage to the room.

*Between-class substitutions*

1. The cabdriver forgot to bring the senator to *away* rally.  
The paratrooper forgot to bring the map to the plane.
2. Sam thinks *out* of the old factories exploded after midnight.  
Harry thinks several of the new lambs arrived before lunch.
3. The carpenter noticed that *on* homeowner bought the wood yesterday.  
The lawyer noticed that one client paid the bill late.
4. Above *child* begged to be admitted to the football stadium.  
A youngster begged to be invited to the birthday party.
5. The old seamstress remembered to donate *what* ragged cotton dresses.  
The young salesman remembered to take a heavy wool jacket.

## PREP

*Within-class substitutions*

1. The machinist pointed to the lathe that Max fell *out*.  
\*The plumber pointed to the wrench that Allen fell over.
2. Out *up* the street an old truck was approaching noisily.  
Out of the window an engineer was waving his arm happily.
3. The janitor pointed to the broom that Phil swept *of*.  
\*The gardener pointed to the sprinkler that Larry tripped over.
4. The milkman was speaking *out* a man who needed advice.  
A policeman was talking to a woman who needed directions.
5. Of *the* overgrown snowy woods a rancher carried his saddle.  
Across the parched sandy desert a soldier was carrying his canteen.



*Between-class substitutions*

1. The mailman was looking *must* a dog that needed food.  
The fireman was shouting at a child who needed help.
2. Away *here* a goal a soccer coach was running wildly.  
Away from the plane a stunt pilot was walking jauntily.
3. The electrician pointed to the wire that Chunk fell *whar*.  
\*The plumber pointed to the wrench that Allen fell over.
4. Never *the* grassy rolling hills a family carried their picnic.  
Through the dense evergreen forest a lumberjack carried his axe.
5. The operator pointed to the switchboard that Barbara worked *where*.  
\*The gardener pointed to the sprinkler that Larry tripped over.

## PART

*Within-class substitutions*

1. The wife of the owner took the new hobby *down*.  
A friend of the manager took a big sign out.
2. The chef reheated the stew that the customer pushed *beside*.  
The programmer designed the game that the company brought out.
3. Picking the birthday present *on* would be nice for Susan.  
Picking an expensive gift out will be pleasant for George.
4. The good natured baker put *at* a white floppy hat.  
The well mannered butler put out a large grey cat.
5. Making *on* funny songs is difficult for choir directors.  
Making up long grocery lists is boring for busy housewives.

*Between-class substitutions*

1. Making *then* ghost stories is hard for young children.  
Making out bad checks is easy for clever criminals.
2. Picking a tasteful tie *the* could be simple for ministers.  
Picking a suitable prize can be fun for winners.
3. The pitcher delivered the ball that the batter swung *now*.  
The ranger relit the fire that the campers put out.
4. The child of the driver took a tiny truck *was*.  
The mother of the thief took the shiny jewel away.
5. The well attired banker put *is* a fine silk scarf.  
The well groomed barber put on a new white coat.

Note: Sentences preceded by \* serve as controls for more than one ungrammatical target sentence.