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Syntactic Processing in Agrammatic Aphasia by Speakers of a Slavic Language

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It is widely believed that agrammatic aphasics have lost the ability to assign complete syntactic representations. This view stems from indications that agrammatics often fail to comprehend complex syntactic structures, as for example, some types of relative clauses. The present study presents an alternative account. Comprehension by Serbo-Croatian-speaking agrammatic aphasics was tested on four types of relative clause structures and on conjoined clauses. The relative clauses varied in type of embedding (embedded vs. nonembedded) and in the location of the gap (subject position vs. object position). There were two control groups: Wernicke-type aphasics and normal subjects. The findings from a sentence-picture matching task indicated that agrammatic aphasics were able to process complex syntactic structures, as evidenced by their well-above chance performances. The success rate varied across different types of relative clauses, with object-gap relatives yielding more errors than subject-gap relatives in all groups. Each group showed the same pattern of errors: agrammatic subjects were distinguished from Wernicke subjects and normal subjects only in quantity of errors. These findings are incompatible with the view that the agrammatics are missing portions of the syntax. Instead, their comprehension deficits reflect varying degrees of processing impairment in the context of spared syntactic knowledge. © 1995 Academic Press, Inc.

EXPLAINING COMPREHENSION DIFFICULTIES IN AGRAMMATISM

The view that the "agrammatism" of Broca's aphasia represents a disorder involving loss of some structural component of the language apparatus has enjoyed considerable influence in the last two decades (Berndt & Caramazza, 1980; Schwartz, Saffran, & Marin, 1980; Zurif, 1984). The appeal to missing structural knowledge rested in part on the promise it seemed to hold for explaining parallel deficits in language pro-

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duction and comprehension. Just as agrammatic aphasics produce syntactically deficient speech largely as a result of a tendency to omit function words and to distort inflections, so, too, it might be supposed that they understand sentences by inferring meaning without recourse to normal syntactic operations, using non-syntactic, lexically based strategies instead. Several specific proposals have been offered, each seeking to ground the difficulties involving the closed-class vocabulary and the inflectional system on one or another level of linguistic representation: phonological (Kean, 1977), lexical (Bradley, Garrett, & Zurif, 1980), morphological (Lapointe, 1983), or syntactic (Caramazza & Zurif, 1976; Caplan & Futter, 1986; Grodzinsky, 1986, 1990; Hickok, Zurif, & Canseco-Gonzales, 1993; Mauner, Fromkin, & Cornell, 1993). Collectively, we call these proposals the Structural Deficit Hypothesis.

Whatever the plausibility of these proposals, there is mounting evidence that calls into question any form of the Structural Deficit Hypothesis. First, several case studies have reported patients who fail to show parallel deficits in production and perception. Some patients present agrammatic symptoms in production, but not in comprehension (Miceli, Mazucchi, Mann, & Goodglass, 1983). Additionally, there are reports of patients who show agrammatic symptoms in comprehension despite fluent production of well-formed sentences (Caramazza, Basili, Koller, & Berndt, 1981; Smith & Bates, 1987). These findings suggest that expressive and receptive agrammatism may represent different deficits, though they often occur together.

The finding that agrammatic aphasics retain the ability to make metalinguistic judgments of grammatical acceptability presents a further challenge to the Structural Deficit Hypothesis. Retained ability to detect syntactic violations has been demonstrated even in patients who were severely agrammatic in both production and comprehension (Linebarger, Schwartz, & Saffran, 1983). Preserved sensitivity to syntactic structure in doubly agrammatic patients cannot readily be explained by a syntactic account of agrammatism. Spared ability to judge the grammaticality of complex syntactic structures has been confirmed in additional studies of English-speaking agrammatics (Shankweiler, Crain, Gorrell, & Tuller, 1989; Wulfeck, 1988). Sensitivity to violations of the inflectional morphology has also been demonstrated in Italian, German, and Serbo-Croatian agrammatics (Lukatela, Crain, & Shankweiler, 1988; Kolk & van Grunsven, 1985; Bates, Friederici, & Wulfeck, 1987; Friederici, Wessels, Emmorey, & Bellugi, 1992).

Central to the Structural Deficit Hypothesis is the assumption that the comprehension deficit in agrammatism is syndrome-specific. This assumption, too, is challenged by findings with other language impaired populations and with normal subjects. For example, sentence comprehension in children with reading problems shows the same ordering of

difficulty across syntactic structures as is displayed by agrammatic aphasics (Smith, Macaruso, Shankweiler, & Crain, 1989). Moreover, normal adults working under time pressure have been found to conform to the same pattern (Milekic, 1993; Ni, 1988). Such consistencies that cut across diagnostic groups and normal subjects point to a common source of variation that would implicate a processing explanation, not a structural explanation.

Spurred by findings that are unfavorable to the Structural Deficit Hypothesis, an alternative has begun to crystallize. We call it the Processing Limitation Hypothesis.¹ This hypothesis appeals to the distinction between structural and processing components of the language apparatus. The structural components include the lexicon and the different levels of linguistic representation: phonology, syntax, and semantics. According to the Processing Limitation Hypothesis, impaired comprehension need not reflect loss of critical linguistic structures. Language processing involves not only the assignment of structural representations, it also requires a series of operations for storing and retrieving linguistic information and for coordinating the transfer of information between levels of linguistic representation. The Processing Limitation Hypothesis directs us to consider linguistic *processing* as a possible source of the comprehension deficits that are characteristic of aphasia.

In addition to giving direction to the quest for the source of sentence comprehension difficulties in agrammatism, the Structural Deficit Hypothesis and the Processing Limitation Hypothesis have implications for accounts of normal sentence processing. If an obtained pattern of preserved and impaired comprehension can be accounted for on the basis of the disruption of a particular component of syntactic representation postulated in one theory but not in others, then the data would provide support for that theory. However, if the pattern of performance can be accounted for on the basis of a limitation in processing capacity, then the data could not decide among linguistic theories, but would require a model of sentence processing that incorporates the appropriate processing components.

The intent of the present study was to compare a structural deficit versus a processing limitation account of syntactic comprehension difficulties in agrammatic aphasia. We proceed by examining a structure often implicated in agrammatism, *the relative clause*. We then present the rationale for a study of comprehension of relative clauses in agrammatic subjects who are speakers of the Slavic language, Serbo-Croatian. The highly

¹ The term "processing impairment" has been used differently by different authors. Tzeng, Chen, and Hung (1991) use the term much as we do to refer to an account of language breakdown based on deficits in the processes by which a preserved knowledge base is accessed and deployed.

inflected morphology of the Serbo-Croatian language is exploited to provide the appropriate experimental conditions for distinguishing between the two accounts and for testing specific proposals regarding difficulties in processing relative clauses.

Some initial comments about Serbo-Croatian are in order. The closed-class morphology, consisting of grammatical words and inflections, plays a somewhat different role in syntactic operations in a free word-order language, like Serbo-Croatian, than in a fixed word-order language, like English. In order to construct a grammatically correct sentence in Serbo-Croatian, words must match in gender, number, person, and noun case. This is accomplished by an appropriate suffix (an inflectional morpheme) added to the word root. In English, word order is used to indicate, for example, agent/object relations, both semantically and syntactically (e.g., "The girl pushed the boy"). Case is generally conveyed either by word order or by free-standing prepositions or pronouns in English. Case is conveyed by noun-inflections in Serbo-Croatian, however. In the absence of a consistent word order pattern, a Serbo-Croatian listener must rely on case markers and other agreement markers (subject-verb agreement, modifier-noun agreement, agreement between pronouns and their referents, etc.). Consequently, the English sentence from the example above can be translated into two Serbo-Croatian sentences having the same meaning but different word orders (e.g., "Devojčica_(nom) je gurnula dečka_(accus)" and "Dečka_(nom) je gurnula devojčica_(accus)"). The present study was designed to exploit this cross-language difference in the use of inflectional morphology to evaluate difficulties agrammatics experience in comprehending relative clauses. We proceed by examining relevant findings that have been reported in the literature.

Evidence from Studies with Relative Clauses

Among the earliest evidence of a specific sentence processing deficit in agrammatism is the finding by Caramazza and Zurif (1976) of difficulties in comprehension of semantically reversible relative clause sentences. It is presently well established that agrammatic aphasics often fail to understand correctly certain sentences with relative clauses if they are presented without the support of semantic content and/or pragmatic context. All types of relative clauses have not proven equally difficult, however. There appear to be selective difficulties on sentences with object-gap relatives, as compared to subject-gap relatives. For example, Caplan and Futter (1986) report such a pattern, based on a study of an agrammatic subject using an object manipulation test. Object-gap relatives contain a superficially empty noun phrase in object position (e.g., "The monkey that the rabbit grabbed _ shook the goat"). Caplan and Futter's subject performed more accurately with subject-gap relative

clauses, i.e., where the empty noun phrase is in subject position, (e.g., "The sheep that _ pushed the cat jumped over the cow"). The authors suggest that the subject had lost the ability to interpret sentences using the rules of normal English syntax. On their view, the subject attempted to map thematic roles (agent, patient, theme, etc.) directly to linear sequences of words. This strategy could sometimes result in the correct linguistic interpretation even for subjects who lacked the relevant grammatical knowledge. This would happen with structures that conform to the canonical word order of the language in question. Canonical word order provides the right results in sentences of English that contain subject-gap relative clauses. This strategy would lead to consistent misinterpretation of sentences that depart from canonical S-V-O form of English sentences, however. One example is object-gap relatives.

The distinction between object-gap and subject-gap relatives has received a specific structural interpretation by Grodzinsky (1986, 1989). Grodzinsky explains agrammatics' comprehension difficulties within the framework of Chomsky's theory of Generative Grammar known as Government and Binding theory. One aspect of this theory is the postulation of a "trace" whenever a constituent is moved by a transformational rule from one level of representation, D-structure, to another level, S-structure. What is missing in the representations of agrammatics, according to this view, is the trace left behind by the transformation. Therefore the affected individuals are unable to maintain the crucial grammatical link between the "trace" and the moved constituent. Although Grodzinsky discussed several structures that involve constituent movement, we are concerned here specifically with his discussion of relative clauses. One of the assumptions of Government and Binding theory is that traces are the bearers and transmitters of thematic roles. From this assumption it follows that the thematic role of a moved NP inside a relative clause will be unspecified in the absence of the trace. Accordingly, Grodzinsky proposes that agrammatics must resort to a default strategy for heuristically assigning thematic roles to disenfranchised NPs in relative clauses. In an SVO word-order language like English, the heuristic strategy assigns roles according to word order conventions: the initial NP would receive the role of agent. This strategy gives the right interpretation for sentences with subject-gap relatives such as, "The boy that kissed the girl is tall." In such a sentence, the transformation preserves the original NP order; therefore, comprehension is preserved in spite of loss of traces in the S-structure representations. However, in object-gap relatives, as a result of trace deletion, the S-structure representation has two NPs preceding the verb (e.g., "The boy that the girl kissed was tall"). Because there are two possible agent candidates, the assignment of thematic roles cannot be determined. Therefore, agrammatic patients should perform at chance in responding to object-gap relatives. According to Grodzinsky's

theory, then, agrammatics generate complete syntactic representations except in the case of constructions that involve movement transformations, such as relative clauses and verbal passives.

A test of this conceptualization of the comprehension deficit in agrammatism is presented by Grodzinsky (1989). In this study, agrammatic subjects were tested using a sentence-picture matching task for comprehension of four types of relative clauses (embedding vs. nonembedding and subject- vs. object-gap). The results are interpreted in favor of the trace deletion account. We question whether the results do constitute unequivocal support for this hypothesis, however. For one thing, Grodzinsky's analysis is based on averaging across sentence types. Each sentence type should be considered separately, in our view. By pooling the results of two types of subject-gap relatives and comparing them with two types of object-gap relatives, and by comparing two types of embedded structures with two types of nonembedded structures, one is liable to lose sight of relevant variability. In addition, there were marked individual differences among the subjects. For example, the performance of the four subjects varied from 20 to 80% error in response to nonembedded object relatives. These differences cannot be explained on Grodzinsky's account.

We have presented two structurally based accounts of agrammatic comprehension difficulties, indicating how each applies to sentences containing relative clauses. The accounts differ in their diagnosis of where within the structural apparatus the problem lies, but each assumes that critical syntactic information for the assignment of thematic roles is not available to agrammatics. We now consider how the two accounts might be differentiated empirically—Grodzinsky's specific trace deletion hypothesis and Caplan and Futter's more general syntactic simplification account—and how each, in turn, may be distinguished from the Processing Limitation Hypothesis.

Testing between the Two Hypotheses

Though differing in their assignment of the specific source of comprehension difficulty, each version of the Structural Deficit Hypothesis leads to specific predictions concerning the comprehension performance of an agrammatic subject. It is important to spell out the expectations in detail. (1) The affected individual would perform poorly on all sentences in which the correct interpretation depends on a full syntactic analysis that would bring into play the damaged component. Thus, if there is loss of syntactic knowledge there should be no significant variation across any sentence type that conforms to a specific syntactic pattern (this prediction would apply only if the putative syntactic loss was complete). If agrammatics construct incomplete syntactic representations, as on Grodzin-

sky's theory, they lack the means to determine the thematic role played by the moved NP. Therefore, they must apply a guessing strategy which should be reflected in chance performance on sentences with object-gap relatives. On the other hand, if agrammatics fail to construct hierarchical syntactic representations, but rely on simplified structures that are governed by word order, as Caplan and Futter supposed, then, similarly, they should consistently err in responding to object-gap relatives. (2) There should be no significant variability in performance level across patients on a given sentence type. If in order to understand a particular construction, it is necessary to apply the syntactic rule that is assumed to be missing (for example, a rule for assigning thematic roles in relative clauses), all agrammatic subjects would be expected to perform deficiently (i.e., at chance, if syntactic roles are randomly assigned, or below chance, if some specific non-syntactic strategy is used). (3) If the syntactic deficit is structural, one could expect it to be syndrome-specific. Thus, a given pattern of results would characterize agrammatism but not other syndromes which differ in the underlying deficit. Agrammatic patients would be forced to rely on non-syntactic comprehension strategies and to assign a syntactic structure that deviates from that assigned by the normal population, or by another aphasic group whose syntactic problems, if any, are not identified with those of Broca-type aphasics (for example, Wernicke-type aphasics). In consequence, the pattern of performance on any structures that tax the damaged component (for example, relative clauses) should be qualitatively different in agrammatic subjects than in other aphasics, or in normal subjects. (4) If a missing structure is part of Universal Grammar, agrammatics in any language would be expected to erroneously process the critical structures. Thus, if one tests the critical syntactic structure across different languages, agrammatics from a non-English-speaking population would be expected to fail in processing the missing structure just as their English-speaking counterparts.

The Processing Limitation Hypothesis makes different predictions about the comprehension difficulties associated with agrammatism. On this view, particular sentences place greater processing demands upon the language apparatus, and particular tasks further augment the difficulties imposed by these sentences. The processing limitations account makes specific predictions about the performance of agrammatic subjects. (1) Variability in performance levels across different sentence types is expected because processing difficulties are on a continuum. Agrammatic subjects are predicted to demonstrate more difficulty with syntactic structures that impose heavy demands on the processing system (e.g., object-gap relatives) as compared with structures that do not (e.g., subject-gap relatives). (2) Variability in performance levels across individuals on a given sentence type is expected, but each agrammatic subject should display the same rank order of sentence difficulty. The level of perfor-

mance should vary according to the severity of each individual's processing impairment. Thus, we would expect a continuous distribution of scores across subjects, but with a consistent ordering of sentence types. (3) The relative difficulty of each syntactic structure should be the same in both aphasic subjects and normal subjects; the sentences that are most difficult for normal subjects should also be most difficult for agrammatic aphasics. Although, the pattern of performance across different syntactic structures should be the same for agrammatic aphasics and normals, the level of performance may well differ. If difficulties in comprehension are caused by a processing limitation, then we would expect that when normal subjects are pressed (e.g., by artificially speeded speech or text) they would show the same pattern of performance as agrammatic aphasics. (4) Variability in performance across languages is expected because languages use different means to accomplish the same syntactic ends. These may vary in their costs to the processing system.

The present study was designed to take advantage of the manner in which inflectional morphology is used syntactically in a free word-order language, Serbo-Croatian. Four types of relative clauses varied in their place of attachment (embedded vs. nonembedded), and in the grammatical role of the missing NP inside the relative clause (subject- vs. object-gap). These sentence types are abbreviated as SS, SO, OO, and OS. The abbreviations use the first letter (S or O) to indicate the place of attachment (S = embedded, O = nonembedded). The second letter indicates the role of the missing NP (S = subject, O = object). In some relative clauses in Serbo-Croatian, as in subject-gap relatives (SS, OS) and non-embedded object-gap relatives (OO), the thematic role of an NP is determined by a noun-inflection marking the moved NP. Examples with underlined case-inflections are given in 1-3:

- (1) SS: Žena_(nom) koja_(nom) ljubi čoveka_(accus) drži kišobran _(nom, accus).
The lady who is kissing the man is holding an umbrella.
- (2) OS: Žena_(nom) ljubi čoveka_(accus) koji_(nom) drži kišobran _(nom, accus).
The lady is kissing the man who is holding an umbrella.
- (3) OO: Žena_(nom) ljubi čoveka_(accus) koga_(accus) štiti kišobran _(nom, accus).
The man is kissing the lady that the umbrella is covering.

Thus, in these sentence types the inflectional morphology aids in coindexation of the moved constituent and trace. However, in embedded object-gap relatives, as in (4), both NPs have the same nominative-case inflection and, therefore, thematic roles cannot be assigned by processing the noun-case inflection only.

- (4) SO: Čovek _(nom) koga _(accus) žena_(nom) ljubi drži kišobran _(nom, accus).
The man that the lady is kissing is holding an umbrella.

The relative pronoun of the relative clause is invariably marked by the thematically appropriate case inflection. Thus, although in SO sentences, the NPs cannot be thematically differentiated by processing only NP inflections, the thematic roles can nonetheless be differentiated by processing the relative pronoun-case inflection.

The fact that moved constituents are marked not only by traces but also by case inflections provides an additional cue for Serbo-Croatian users (which is unavailable to English users) when assessing thematic roles. It is this feature that enables us to test Grodzinsky's trace-deletion hypothesis. The trace-deletion account predicts that agrammatics will perform successfully on subject-gap relative clause sentences (OS, SS), but will be at chance on object-gap sentences (SO, OO). However, if, agrammatics have retained the inflectional morphology and are missing only traces of movement in their syntactic representations, as this hypothesis proposes, then Serbo-Croatian agrammatics are expected to have an advantage over English-speaking agrammatics because their preserved inflectional morphology would be sufficient for determining the thematic role. According to this account, therefore, Serbo-Croatian agrammatics are expected to perform at chance only on SO sentences but equally well on the other three types of relative clauses. Alternatively, if Serbo-Croatian agrammatics have intact inflectional morphology, their performance can be expected to be equally successful on all four types of relative clauses, since the relative pronoun in the SO sentences is marked by the thematically appropriate case inflection.

On the other hand, if Serbo-Croatian agrammatics are unable to make syntactic use of inflections, as an account of parsing deficiency resulting in incomplete, simplified syntactic representations would state, then noun and pronoun case inflections could not aid their comprehension of relative clauses. On this account Serbo-Croatian agrammatics are expected to err on all sentences that depart from canonical word order (SO, OO), systematically choosing the conjoined-clause interpretation instead. In consequence, Serbo-Croatian agrammatics should demonstrate a similar degree of difficulty as their English-speaking counterparts in comprehension of object-gap relatives.

In addition to testing agrammatics' ability to assign thematic roles in relative clauses we also asked whether they tend to simplify the syntactic structure of a relative clause. One possibility is that object-gap relative clauses might be treated as though they consisted of two conjoined clauses. This would be expected on the suggestion that agrammatics lose the ability to construct complete syntactic representations, regressing by default to simpler structures (e.g., Caplan & Futter, 1986). Thus, conjoined-clause sentences can be used to test the proposal that agrammatics fail in comprehension of relative clauses because they tend to simplify complex syntactic structures and employ heuristic, non-syntactic strate-

gies (e.g., a canonical word-order strategy) when interpreting some relative clauses. Studies previously cited have focused on testing for ability to assign correct agent/patient (thematic) relations. The present study offers the first test of the possibility that agrammatics tend to simplify the complex syntax of relative clauses in certain sentences by construing them as though they contained two conjoined clauses (CC). A conjoined clause simplification of, for example, an SO sentence (4) would be:

(5) CC: Čovek ljubi ženu i drži kišobran.

The man is kissing the woman and holding an umbrella.

A test of this possibility was made by requiring subjects to choose between two pictures, one of which depicted the conjoined-clause analysis and the other the relative clause analysis. This technique was used successfully in previous research examining comprehension of relative clauses by agrammatic aphasics (Zurif & Caramazza, 1976, Wulfeck, 1988; Grodzinsky, 1989).

The present study makes use of the forgoing features of the Serbo-Croatian language to investigate comprehension of relative clauses by Serbo-Croatian speaking agrammatics. The fact that inflectional morphology plays such an important role in Serbo-Croatian syntax makes it an ideal language to contrast with English for testing theoretical claims about the basis of comprehension deficiencies in agrammatism. The experiment was designed to distinguish between versions of the Structural Deficit Hypothesis as well as between either version and the Processing Limitation Hypothesis. The study therefore addressed the following questions:

1. Are there systematic variations in performance among agrammatic subjects across different types of reversible relative clauses and conjoined clauses. Do these variations form a graded continuum or are they all-or-none?

2. Are there cross-language differences in comprehension of relative clause sentences between agrammatic speakers of a highly inflected language (Serbo-Croatian) and a fixed word-order language (English)?

3. Are there systematic differences between subject groups? Will Broca-type aphasics, Wernicke-type aphasics, and normal subjects each show a distinctive pattern of errors? If a hierarchy of difficulty of sentence types is found, will it differ for the three subject groups, or will it be the same.

METHOD

Subjects

The aphasic subjects were seven non-fluent Broca-type aphasics (three females and four males) and five fluent Wernicke-type aphasics (one female and four males). All were outpatients of the Neurological Clinic or the Institute for Psychophysiology and Speech Pathol-

TABLE 1
Aphasic Subjects: Background Data

Aphasic subjects	Sex	Age	Educ.	Etiology	Lesion
Broca subjects					
S.P.	M	53	16	CVA (1981)	L inf. frontal at the depth of the ventricle
D.R.	M	62	16	CVA (1983)	Large subcortical Broca's area, L motor strip, parietal area, patchy Wernicke's area
V.P.	M	46	12	CVA (1986)	Cortical and subcortical Broca's area
D.T.	F	52	16	CVA (1984)	L basal ganglia and int. capsule
A.T.	M	46	10	CVA (1985)	L frontal, lower motor cortex
V.M.	F	44	14	CVA (1986)	L inf. fronto-temporal cortex
M.J.	F	47	10	CVA (1985)	L inf. frontal
Wernicke subjects					
M.C.	M	57	14	CVA (1983)	L subcortical tempo-parietal, supramarginal and angular gyri
A.B.	M	59	14	CVA (1985)	L fronto-parietal cortex and basal ganglia
V.V.	M	48	16	CVA (1987)	L fronto-parietal cortex
M.B.	M	59	16	CVA (1981)	L temporo-parietal cortex
D.D.	F	60	12	CVA (1980)	L temporo-parietal cortex

ogy, in Belgrade, Yugoslavia. All were native speakers of Serbo-Croatian. The age range was 44-62 for Broca-type aphasics and 48-60 for Wernicke-type aphasics. All subjects had at least a secondary education and all were right-handed. Further details are given in Table 1.

The control group comprised seven neurologically normal subjects (four females and three males), roughly matched to the aphasic group in age and years of education.

All patients were categorized according to a neurological examination, the results of a CT-scan, and the results of tests of language function based on the Serbo-Croatian version of the Boston Diagnostic Aphasia Examination (BDAE, Goodglass and Kaplan, 1972). The etiology in all cases was a single cerebrovascular accident confined to the left cerebral hemisphere. Time since onset of the symptoms varied from 6 months to 7 years. There was no history of drug abuse and no significant disabilities in vision or hearing among either the patients or the control subjects.

All Broca-type patients showed the characteristic nonfluent speech and all displayed some degree of agrammatism (see Table 2). Their sentences were short with impoverished syntactic structure, consisting mainly of nouns and verbs with frequent omission of free-standing functors and occasional substitution of bound morphemes. A common error was to use the nominative case, in place of the appropriate noun case. All Broca-type subjects had measurable losses in language comprehension when tested with the BDAE (results by individual subjects on the comprehension subtests of the BDAE are given in Appendix A).

The Wernicke-type aphasics had fluent speech with an apparently normal melodic line. Their sentences were rife with semantic and phonetic paraphasias and paragrammatically

inappropriate grammatical forms. Their comprehension was markedly impaired as measured with the BDAE (results by individual subjects on the comprehension subtests of the BDAE are given in Appendix A).

Materials

In designing semantically reversible sentences containing relative clause, steps were taken to minimize possible difficulties in pragmatic interpretation that these sentences might induce: (a) to this end only two animate noun phrases were allowed in each sentence (in contrast, for example to Caplan & Futter, 1986); (b) semantic relations among noun phrases were always plausible; (c) the third noun phrase in each test sentence was inanimate and conveyed descriptive information. The last restriction was imposed because findings with young children have shown that performance on an act-out task improved when the number of animate noun phrases in relative clause sentences was reduced from three to two (Goodluck & Tavakolian, 1982).

Experimental sentences. Four types of semantically reversible relative clause sentences were created and recorded on audiotape. The relative clauses varied in their place of attachment (embedded vs. nonembedded), and in the role of the missing noun phrase inside the relative clause (subject- vs. object-gap). See 1-4 above.

Control sentences. In addition to relative clause sentences, conjoined-clause (CC) sentences were included in the test materials. As noted, CC sentences have structures that are hypothesized to be syntactically less complex than relative clause sentences and are considered to be mastered earlier in development (Tavakolian, 1981). The CC sentences were derived from OS sentences. Each contained one empty noun phrase in the second clause, which is coreferential with the subject of the first clause, as illustrated below.

(6) CC: Žena drži kišobran i ljubi čoveka.

The lady is holding the umbrella and kissing the man.

Additional sentences were added as controls to ascertain that the subjects were attending to the entire sentence. These control sentences were of the same form as three of the sentence types (SS, OS, CC), but their respective foils differed. The picture foils for all sentence types are described later.

Picture materials. Given that the task is a forced choice among alternative pictures, the design and choice of picture materials is critical. Steps were taken to create pictures depicting possible nonreversible situations. The so-called "felicity conditions" (Hamburger & Crain, 1982) were met by providing a natural context for the relative clause. This was accomplished by depicting more than one character corresponding to the head NP. These felicity conditions were not met in the sentences used to test comprehension in previous studies of aphasia.

A two-choice picture task was adapted from materials constructed by Smith et al. (1989). Both picture choices depicted plausible events. Since a relation between two animate noun phrases was depicted in each picture, the location of agents (left or right side of the picture) was randomized within sentence sets. In half of the arrays, the correct picture was in the top position, and in the other half the correct picture was in the bottom position (sample test materials for an experimental sentence are displayed in Appendix B).

Picture foils. The conjoined-clause analysis was used as the picture-foil, that is, the correct interpretation of SO, OS, and OO sentences was contrasted with foils depicting the conjoined-clause analysis interpretation. This misanalysis was chosen for the reasons indicated above.

The following examples are descriptions of correct target pictures and the incorrect foils that were used for stimulus sentences.

- (7) SO:² The man that the lady is kissing is holding an umbrella.
 Target picture: a man holding an umbrella while a lady is kissing him.
 Foil picture: a man holding an umbrella and kissing a lady.
- (8) OS: The lady is kissing the man who is holding an umbrella.
 Target picture: a lady kissing a man while this man is holding an umbrella.
 Foil picture: a lady kissing a man and holding the umbrella.
- (9) OO:³ The man is kissing the lady that the umbrella is covering.
 Target picture: a man is kissing a lady while she is protected by an umbrella.
 Foil picture: a man is kissing a lady and he is protected by an umbrella.

For the SS sentences a conjoined-clause analysis would yield the same result as interpretation of the relative clause. Therefore, a foil depicting a main clause only interpretation was used for the SS sentences (10).

- (10) SS: The lady who is kissing the man is holding an umbrella.
 Target picture: a lady while holding an umbrella is kissing a man.
 Foil picture: a lady is holding an umbrella.

For the CC sentences, however, the foil depicted an erroneous minimum-distance principle interpretation (11).

- (11) Stimulus sentence (CC): The man is kissing the lady and holding an umbrella.
 Target picture: a man kissing a lady and holding the umbrella.
 Foil picture: a man kissing a lady and the lady holding an umbrella.

For the control SS and OS sentences a relative-clause only interpretation was depicted in the foil. Finally, a first-clause-only interpretation was used for the control CC sentences.

Test Design

The test contained 65 sentences: 10 sentences in each set (OO, SO, SS, OS, CC), plus 5 sentences in each set of foil-control sentences (SS, OS, CC). Two test orders were prepared, with the control sentences interspersed randomly. Practice trials consisting of four sentences and their picture sets were used to familiarize subjects with the procedure.

Procedure

When performing a sentence-picture matching task, the subject is asked to listen to each sentence and then to decide which picture, among simultaneously present alternatives, depicts the meaning of the sentence correctly. The dependent variable is error rate since performance on this task is not timed. Subjects were tested individually in a single, 1-hr session. Before each sentence was presented, the picture array was exposed. A practice session was administered to familiarize subjects with the materials and the procedure. Subjects were instructed to listen carefully to the entire sentence, to look carefully at both

² For the SO sentences there are two possible erroneous conjoined-clause analyses. One of these was the most commonly observed conjoined-clause response in studies with children (Tavakolian, 1981). Therefore this response type was selected to be the foil for this sentence type.

³ The OO sentences, like the SO, offer two conjoined-clause analyses. Again, young children choose one conjoined clause response more often than the other (Tavakolian, 1981) and that is why it was used as a foil.

pictures in the array, and then to point to the picture that matched the meaning of the sentence.

RESULTS

There is clear separation between the subject groups on overall accuracy. The Broca subjects averaged 22% errors, (range 10–34%), Wernicke subjects averaged 37% errors, (range 28–54%), and normal control subjects averaged 6% errors (range 2–10%). Thus the Wernicke subjects were more impaired in sentence-picture matching of relative clause sentences than Broca subjects or normals.

Since the task consisted of two-picture choices, chance performance would be 50%. We define chance performance conservatively: as an error rate between 40 and 60%. Error rates less than 40% were considered to be above chance, whereas error rates above 60% were considered to reflect systematic application of a nonlinguistic strategy.

Table 2 displays the mean number of errors by individual subjects. Although all subjects demonstrated better comprehension of subject-gap sentences than of object-gap sentences, there is much individual variability in error rates, with Wernicke subjects performing overall worse than Broca subjects. All Broca subjects exhibited overall above-chance ability to match the correct picture to the experimental sentence. On the SO sentences the Broca subjects manifested performance that ranged from

TABLE 2
Percentage of Errors on Each Sentence Type for Broca and Wernicke Subjects

Individual subjects	Sentence type					Mean
	OO	OS	SO	SS	CC	
Broca aphasics						
S.P.	40*	10	30	10	30	24
D.R.	30	30	60*	20	30	34
V.P.	10	10	30	20	20	18
D.T.	60*	40*	60*	0	0	32
A.T.	30	20	40*	10	10	22
V.M.	20	10	20	0	0	10
M.J.	10	20	30	0	10	15
Mean	29	20	40*	9	14	
Wernicke's aphasics						
M.D.	70	40*	60*	50*	50*	54*
A.B.	50*	50*	50*	10	50*	42*
V.V.	40*	30	60*	20	30	33
M.Dj.	50*	20	80	0	0	30
D.D.	40*	20	60*	10	10	28
Mean	50*	32	62*	18	28	

* Chance performance.

highly above chance (20% error) to chance (60% error). Four of the seven Broca subjects performed with an above chance success rate of this sentence type. However, subject D.T. performed at chance on all object-gap relatives (OO, SO), and, in addition, on some of the subject-gap sentences (OS). All five Wernicke aphasics performed at chance level on the SO sentences. Moreover, one subject (M.Dj.) chose the conjoined clause option very frequently (80% error). Another Wernicke subject (M.D.) performed at chance on all sentence types, and a third (A.B.) performed at chance on all sentence types except the SS sentences. The task was evidently too difficult for these latter subjects, so that they judged sentences in a random manner. For the OO sentences the mean error rate was smaller but there was high variability. The range of errors for Broca patients was 10–60% and for the Wernicke patients 40–70%. Only two Broca patients performed at chance, whereas all of the Wernicke patients did so. The pattern of performance within each aphasic group (with exception of two Wernicke patients who performed equally poorly on all sentence types) shows the same hierarchy of sentence difficulty.

Factorial analyses of variance were performed separately on the experimental and conjoined-clause control sentences, and on the foil-control sentences. Since there was no effect of test order on the accuracy score, the data from both orders were combined for analysis. The error scores were analyzed by an ANOVA which compared the factors of Group (Broca, Wernicke, Control) and Sentence type (OO, OS, SO, SS, CC). Both main effects were significant. The main effect of Group ($F(2, 16) = 26.35, p < .001$) indicates that there were differences between types of aphasia and the normal control group. The significant effect of Sentence type ($F(4, 64) = 21.83, p < .001$) indicates that all sentence types were not equally difficult. The interaction between Group and Sentence type was also significant ($F(8, 64) = 2.39, p < .02$). Its interpretation will be considered presently.

A post hoc Tukey test ($p = .01$) indicated that each subject group was significantly different from the others with the normal control group exhibiting the fewest errors and the Wernicke group exhibiting the most.

The rank order of difficulty for the sentence types was similar in both aphasic groups: The SO sentences were the most difficult. Three of the seven agrammatic subjects performed at chance level on these sentences, and four performed with above-chance success. The SO sentences were the most difficult for all the subjects including the control subjects, although the Sentence-type effect did not reach significance in this group because performance was at the ceiling level. A Post hoc Tukey test ($p = .01$) indicated that there were significantly more errors on SO sentences than on all others, with the exception of the OO type, from which they differed only at the $p = .05$ level. More errors occurred on the OO type than on either SS or CC sentences. The latter were not significantly

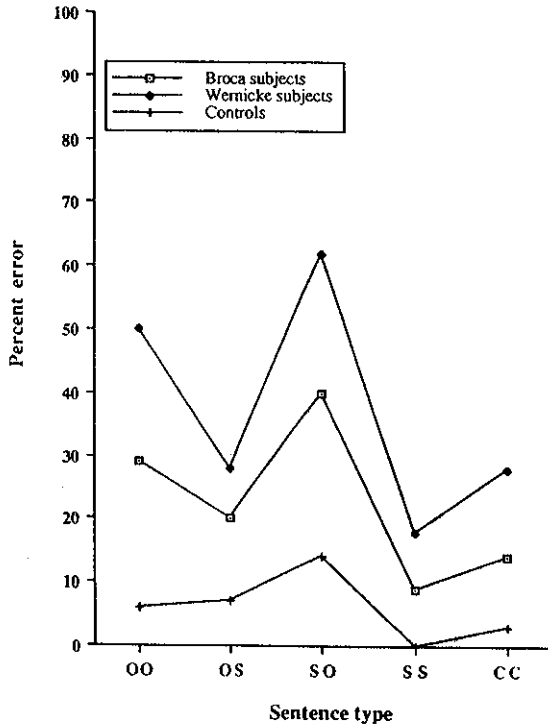


FIG. 1. Percentage of errors by sentence type.

different from each other. OS sentences gave rise to more errors than SS sentences but did not differ from OO or CC types. As was expected, the control CC sentences and the SS sentences were the easiest for all three groups of subjects.

The mean percent error per sentence type for the three groups of subjects is displayed in Fig. 1. The figure shows the same pattern of performance across sentence types in all three subject groups. When the Broca group and the Wernicke group were compared, there was a significant effect of aphasia type ($F(1, 11) = 9.19, p < .01$), but no aphasia-type by sentence-type interaction. The most difficult sentence type, the SO sentences, produced the only significant difference between aphasic groups ($p < .02$). Group differences on OO and OS sentence types were in the same direction, but failed to reach significance (each with $p < .09$). There was no significant difference between the two patient groups in the number of errors on control CC sentences and SS sentences.

Given the absence of interaction of type of aphasia and sentence type, we should ask why an interaction with subject group was obtained in the analysis that included all subjects. Figure 1 shows that few errors were

made by control subjects; for them, the plot of errors against sentence type is relatively flat. Thus, the presence of an interaction in the composite analysis is clearly attributable to the ceiling level performance of the control group.

Foil-control Sentences

On the foil-control sentences both aphasic groups performed at a high level of accuracy. Broca's aphasics averaged 4% errors (range 0–13%); Wernicke's aphasics averaged 7% errors (range 0–20%). The difference was not significant ($F(1, 10) = .46, p < .51$). The control group performed with 100% accuracy on these sentences.

DISCUSSION

Our purpose was to obtain evidence that could distinguish between the explanatory adequacy of two accounts of comprehension impairment in agrammatism. One explanation, the Structural Deficit Hypotheses, states that syntactic structures critical for sentence interpretation are lost or are unavailable. The other explanation appeals to a processing deficiency. To distinguish the two hypotheses we have studied one complex structure intensively, the relative clause. This structure is well suited also to our additional goal of bringing data from different languages bear on the problem.

This study is the first to present data from an inflected language on comprehension of a complete set of relative clause structures by Broca's and Wernicke's aphasics. The Structural Deficit Hypothesis predicts that agrammatics would fail to assign correct syntactic representations to relative clauses. If the requisite structures are lost, agrammatics would have no recourse but to apply nonsyntactic strategies. In the case of object-gap relatives, they might be expected, to assign thematic roles randomly (Grodzinsky, 1989) or to apply a canonical word-order strategy indiscriminately (Caplan & Futter, 1986). We therefore asked whether agrammatics do, in fact, lack the necessary syntactic structures to analyze object-gap relative clauses and, if so, whether they tend to simplify these structures by treating them as conjoined clauses. The first question was addressed by comparing the comprehension of relative clauses that differed in place of attachment (i.e., embedded and nonembedded relatives) and in the location of the gap (i.e., subject- and object-gap relatives). This was accomplished by exploiting particular features of the grammar of Serbo-Croatian, taking advantage of the fact that Serbo-Croatian marks thematic roles in relative clauses by case inflections. This characteristic enabled us to tease apart two possible sources of syntactic deficiency: syntactic simplification amounting to loss of hierarchic structure and deletion of the traces of movement. The second question was ad-

dressed by using conjoined-clause sentences as controls, a syntactic structure that could plausibly result from simplification of a relative clause. Accordingly, four types of reversible relative clauses and conjoined clauses provided the critical materials for testing between the two hypotheses.

Notably, the agrammatic aphasics found the different relative clause structures to be unequal in difficulty. Object-gap relatives yielded the highest error rates, in keeping with the earlier findings with English-speaking agrammatics (Caramazza & Zurif, 1976; Grodzinsky, 1989; Caplan & Futter, 1986) and in agreement with both Grodzinsky's and Caplan and Futter's predictions concerning the expected order of difficulty. If one were to draw conclusions about agrammatic subjects' competence only by taking average performance into account, one might be led to conclude that the subjects of the present study had lost a portion of their agrammatical knowledge and, consequently, were forced to rely on nonlinguistic strategies. However, the prediction of the Structural Deficit Hypothesis that agrammatics would perform at chance on object-gap sentences was not met, at least for a majority of subjects. Four out of seven of the agrammatic subjects performed well above chance on these structures. Thus, this result offers, at best, only partial support for the theoretical conceptions of Caplan and Futter and Grodzinsky.

It could be expected that trace deletion in object-gap relatives should impair Serbo-Croatian speaking subjects less than English-speaking subjects, since critical information about the subject/object distinction can be extracted from noun case inflections regardless of word order. But these subjects, like their English-speaking counterparts would be expected to be at chance on SO sentences if they lacked traces, even if they were able to rely on noun-phrase inflectional morphology. That is because, as we explained, these sentences have ambiguous inflectional markings because both noun phrases are marked for the nominative case. On the other hand, performance on OO sentences should not differ from subject-gap relatives because on these sentences the inflections indicate thematic roles unambiguously.⁴

However, although in all subjects object-gap relatives gave rise to significantly more errors than subject-gap relatives neither of these expectations based on Grodzinsky's hypothesis (1989) finds support in the data. Concerning the first prediction, although SO sentences were more diffi-

⁴ Grodzinsky's description of agrammatic *production* proposes a more inclusive deficit at the level of S-structure than the putative deficit underlying comprehension disorder (Grodzinsky, 1990). On this account nonlexical terminals are deleted, including case markers and other aspects of inflectional morphology as well as traces of movement. If this description of the agrammatic deficit were extended to comprehension, additional difficulties in interpretation of the inflectional morphology would be anticipated.

cult than OO sentences, performance was at chance only for three of the seven agrammatic subjects. One of those (D.T.) who performed at chance on SO sentences also performed at chance on OO and OS sentences, which indicates that this subject was not taking advantage of the inflectional morphology. Concerning the second prediction, the OO sentences were comprehended with more errors than the subject-gap sentences. Additionally, the comprehension difficulties in these agrammatics cannot be explained on the trace deletion account, since difficulties in comprehension were also present to a lesser degree on other structures (subject-gap relatives) which would be expected on the trace deletion account to be analyzed normally.⁵ On the other hand, diffuse difficulties are expected when there is a special limitation in processing. Only on the processing limitation account is it expected that the comprehension difficulties in agrammatics would be most severe on specific syntactic structures, but also present to a lesser degree with other structures.

The results of the present study lend no support to Caplan and Futter's (1986) conjecture that the syntactic apparatus of agrammatics has undergone simplification that would necessitate use of word-order strategy in the absence of syntactic parsing. On this proposal, agrammatics should choose the erroneous conjoined-clause interpretation on all relative clauses that fail to preserve canonical word order (OO, SO). That clearly did not happen. The possibilities for varying word order that are permitted by the grammar of Serbo-Croatian enabled us to hold word-order constant and to construct OS and OO sentences with the same sequencing of NPs and VPs. Keeping the same word order in OO and OS sentences would induce agrammatics to be incorrect on the OO sentences as often as they are correct on the OS sentences if they relied solely on a word-order strategy. Although, in fact, the agrammatics produced more errors on OO sentences than on OS sentences, their performance on OO sentences was above chance. They were successful in distinguishing different syntactic structures even though these structures had the same noun-verb sequences. Above-chance interpretation of the OO sentences is incompatible with the hypothesis that these agrammatics were using a linear word-order strategy.

A further test between the differing accounts of comprehension disorder in agrammatic aphasia was made by comparing the performances of agrammatic subjects with those of Wernicke's aphasics and with the neurologically-normal control group. The Processing-Limitation Hypoth-

⁵ A recent paper by Hickok, Zurif, and Canseco-Gonzales (1993) also reports that agrammatics can experience difficulties with subject relatives. In addition to their failure on object-gap relatives, Hickok et al.'s subjects showed a deficit in comprehension of matrix sentences in subject relatives. The latter finding, the authors note, is incompatible with the trace-deletion hypothesis as framed by Grodzinsky (1990).

esis predicts that the pattern of performance across sentence types should be consistent across subject groups. The present results showed that, in fact, both agrammatic Broca and Wernicke subjects experienced difficulties with interpretation of semantically reversible relative clauses. The significant group differences were differences of degree, not qualitative differences in pattern. Both types of aphasic subjects were similarly affected by the variations in syntactic structure that were introduced by inclusion of different types of relative clauses; the same rank order of difficulty among sentence types was found for each group with the object-relatives (SO, OO) being the more difficult structures. This order of difficulty was also observed in the normal control group. The agrammatic group performed better overall than the Wernicke group, creating the significant between-group interactions. Finally, a consistent pattern of performance across sentence types was observed in the individual subject data.

In this connection it is relevant to note that the ordering of difficulty on the four relative clause structures obtained in this study is consistent with that which has been found in several research studies that explored acquisition of relative clauses in young children (deVilliers et al. 1979; Tavakolian, 1981). In addition, this pattern has also been demonstrated in dyslexic children (Smith et al., 1989; Crain et al., 1990). These similarities are unlikely to be mere coincidences. The existence of parallel findings across such diverse groups fits with the failure of the present study to find evidence for a syndrome-specific comprehension deficit in agrammatism.⁶

Taken together, these findings give us reason to prefer an account on agrammatism that appeals to damaged processors in favor of an account that evokes loss of grammatical structures. The processing limitation account is to be preferred because it shows itself capable of tying together

⁶ The processing account gains further support from the finding that the performance gap between agrammatics and normal subjects can be eliminated when normal speakers are tested in a way that places them under a heavy processing load. Word-by-word reading, in which previous words disappear as new ones come into view, is a technique that was employed by Ni (1988) in studies of sentence processing in normal adult subjects. The task was to detect an anomalous word which occurred at the beginning, middle, or end of the test sentence. Comparing the results of Ni's study with the results obtained by Shankweiler et al. (1989) with agrammatic aphasics who were tested (in a listening test) with the same set of sentences, we find a similar pattern of latencies and errors across structures. The strong similarities between the normal subjects under pressure and the aphasics led Ni to infer that each group used syntactic mechanisms in the same way. The same conclusion was reached by Milekic (1993) in a comparison between performance patterns of Serbo-Croatian-speaking agrammatics and normals in a word-by-word reading test. Milekic's findings yield further evidence that sentence processing in normal subjects can be profoundly affected by variation in processing demands, and that the relative difficulty of different structures mirrors the pattern exhibited by agrammatic aphasics.

a wider variety of findings. An adequate theory of "agrammatic" comprehension would account for syntax-related variations in performance among agrammatics and for parallels across different populations.

It remains to give positive underpinnings to the proposal that the source of the comprehension deficit in aphasia is in processing limitations. The question becomes: What is the origin of the difficulties in sentence processing that cause comprehension failures? Elsewhere, we have developed a proposal that appeals to an extended version of Fodor's (1983) modularity hypothesis (Crain & Shankweiler, 1990). On this view, language processing is carried out in discrete stages, organized in a hierarchical, bottom-up fashion (Forster, 1979). Language comprehension involves a series of translations between levels of representation: phonological, syntactic and semantic. A processing limitation view of aphasics' comprehension difficulties assumes at least two distinct ways in which syntactic processing could be impaired. On one possibility, although syntactic knowledge is preserved, its access and utilization are restricted during the process of parsing in which syntactic structures are assigned to the incoming string of lexical categories. One consequence of impaired parsing capacity may be that agrammatics, contrary to normals, do not access syntactic information in an automatic fashion but via a slow and controlled process (Kolk & vanGrunsven, 1985; Friederici et al., 1992; Zurif et al., 1993). Under this assumption, although the input to the syntactic parser is normal, processing at the syntactic level is disrupted.⁷ On the other possibility (which we have discussed at length elsewhere, Crain et al., 1990), difficulties in processing syntax ultimately derive from deficient phonological input and memory processes. The phonology is especially vulnerable because it is the first level at which the input engages the language apparatus. Under this assumption, although syntactic processing per se is intact, the input to the parser is deficient, thus resulting in comprehension failure.

This notion is consistent with our findings concerning sentence comprehension in young children, normal adults, and the reading impaired, and we suggest a possible source of comprehension deficits in agrammatism that could also account for parallel findings in other populations. One resource limitation that young children, dyslexics, and aphasics may have in common concerns the processing of phonological input. The pro-

⁷ Recently, we have begun to use other paradigms to assess specific syntactic abilities in agrammatic subjects (Lukatela, Ocic, & Shankweiler, 1991). In an on-line study that used the syntactic priming paradigm, the same agrammatic subjects that participated in the present study demonstrated sensitivity to syntactic priming when case was primed by a preposition. These results, however, do not necessarily indicate intact on-line sentence processing ability given that priming was demonstrated within a "minimal" syntactic context; a test trial consisted of a sentence fragment.

cessing account can provide a basis for the observed parallels in syntactic comprehension performance. If the hypothesis is correct, then any group that suffers from a bottleneck in phonological processing, for any reason, should display limitations at sentence level.

In a subsequent study we obtained confirmation of phonological deficiencies in some of our agrammatic subjects. The capacity of phonological short-term memory was tested in the same Broca-type aphasics that participated in the present study (Lukatela & Shankweiler, 1990). The aphasic and control subjects were compared on verbal and nonverbal retention of rhyming and nonrhyming word strings, and nonsense drawings, testing in each case memory for serial order. The results indicated that these subjects had a material-specific deficit in short-term retention. They differed from the control group on word strings but not on nonsense drawings. The deficit was exacerbated when all the words were phonologically similar (rhyming). Arguably, a phonological processing deficiency of this nature could impair the working memory sufficiently to impede comprehension, at least for sentences that are likely to require reanalysis (McCarthy & Warrington, 1987). These findings, therefore, lend further substance to the speculations that our agrammatic subjects' comprehension difficulties may stem at least in part from deficiencies in phonological processing that curtail the efficient use of working memory in comprehension tasks.⁸

In sum, the comprehension difficulties encountered by the agrammatic aphasics are more consistent on several counts with a Processing Limitation Hypothesis than with a Syntactic Deficit Hypothesis involving trace deletion or failure to interpret grammatical inflections: (1) Comprehension accuracy for agrammatic speakers of Serbo-Croatian was overall above chance for all types of relative clauses. (2) Agrammatics' difficulties in comprehending these structures proved remarkably similar to those displayed by Wernicke's aphasics: the pattern of performance did not distinguish syndromes. (3) Comparisons from the literature based on dyslexic

⁸ The research literature presents a confusing picture of the relationship between sentence comprehension and working memory. Researchers have often noted that some aphasic patients with a severely restricted phonological short-term store are sometimes capable of sentence comprehension at a level far exceeding what would be expected on the basis of their span limitations (Martin & Feher, 1990; Caplan & Waters, 1990; McCarthy & Warrington, 1987). However, it is important to note that memory in these studies was assessed by measuring patients' span for unorganized material. In our theoretical model of working memory we have assumed that there are two components: a storage buffer and a mechanism whose primary task is to relay the results of lower-level analyses of linguistic input upward through the language apparatus (Shankweiler & Crain, 1986; Crain et al., 1990). In the studies cited above the patients may have suffered impairment of only one of the proposed memory components, the storage buffer, and have preserved a relay mechanism which maintained the ability to synchronize information flow.

children and normals tested under stressful conditions reveals an order of difficulty of relative clause structures consistent with that displayed by the aphasics. (4) Agrammatics can succeed in detecting syntactic violations of these and other sentence types with a high degree of accuracy,⁹ and they are sensitive to syntactic priming. (5) There is independent evidence of phonological impairments in the agrammatic subjects of this study.

⁹ The subjects of the present study were tested on another occasion for detection of syntactic violations in relative clause sentences that were structurally identical to those of the sentence picture matching study (Lukatela, Shankweiler, & Crain, 1988). Although the results of the grammaticality judgment test cannot be compared directly with those of the sentence picture matching test, it is instructive to note that performance on judgments was appreciably more accurate averaging 90.6% correct for subject-gap relatives and 85.5% for object-gap sentences.

APPENDIX A

Aphasic Subjects: Comprehension Data

Subjects	BDAE comprehension			Speech production: Description of "cookie theft" picture
	A (15)	B (12)	C (10)	
Broca				
S.P.	14	6	7	Kujna. Mama pere...ovaj tanjir. A ovaj decak i devojcica. Ova je voda pri..pri..E, voda je pr-li-la. Kitchen. Mama is washing...this plate. Boy and girl. This water...is li..li..Water is li-king.
D.R.	6	3	2	Seka...kolač...Majka...Čaše...Vodu Girl...cookie...Mother...Glasses..Water
V.P.	10	9	6	Mama...pe-re. Sestra i brat. Ne mogu da kazem. Vidi ovde... Mama...wa-shing. Sister and brother. I can not say. Look here....
D.T.	11	9	7	Uzimaju kolače. Bo..bori se da ne..Tu..mama..pere. Taking the cookies. Is try-trying not to... Here..mama..washing.
A.T.	10	11	9	Ovde žena pere sudove a klin-ci se igraju. Jedan pao sa sto-lice. To..pere sudove. Here a woman washing dishes, kids are playing. One is fallen from the chair. This.. washing dishes..
V.M.	15	10	10	Deca uzimaju kolače. Devojcica gleda. Dečak je pao. Majka pere a voda curi. Children are taking cookies. The girl is watching. The boy is fallen. Mother is washing and water is liking.

APPENDIX A—Continued

M.J.	13	10	9	Majka pere sudje. Deca se igraju. Uzi-maju keks. Stolica..stolica..seka i braca..Pašće sa stolice. Mother is washing dishes. Children are playing. They are taking cookies. The chair..chair..brother and sister..They are going to fall from the chair.
Wernicke M.C.	8	3	3	Majka radi, je bila je radila jedva za hranu, sa jedne strane to su radnici. A deca su uzela da jedu čokoladu. The mother is working, she was, she was working barely to support them, from one point this are workers. And children are eating the chocolate.
A.B.	2	0	0	Ovaj...dete je ustalo da pojede pekmez a ova žena je proslula vodu što je htela da pere pa je sve oprala. Well..the child stood up to eat the jelly and this woman has spilled the water, because she want to wash, she washed everything.
V.V.	6	1	1	Devojčica...ova stolica se valjda slomila. Ukrali su..ne mogu da se setim. Drugarica je donela kolače i sada deca krađu kolače. The girl...this chair, looks like it has broken. They are stealing..I can't say. The woman brought the cookies and the children are stealing cookies.
M.B.	4	0	0	Vidite ovde decu, devojčica, vidite ovaj stolnjak. Stolnjak nije u redu, a majka to ne vidi. U..kako se to zove. You see, here are children, the girl, you see this tablecloth. The tablecloth is not OK., and mother doesn't see that. Well, what's the name for this.
D.D.	5	3	4	Šta je ovo? Neka deca ovde su se popela,hoće da uzmu kolače. Žena pere..šta je ovo..tanjir. Ona stalno gleda kroz prozor. What's this? Some children have climbed here, they want to take cookies. The woman is washing..what is this..the plate. She is looking through the window.

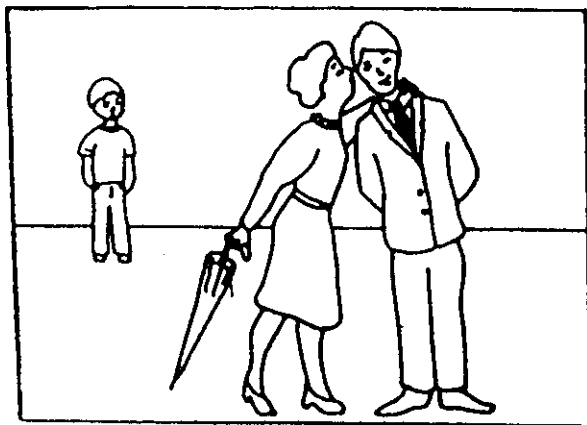
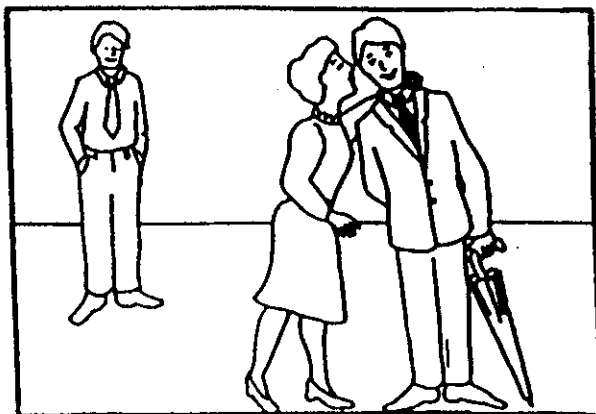
Note. A, Commands (max. score 15); B, Complex ideational materials (max. score 12); C, Reading sentences and paragraph (max score 10).

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APPENDIX B

Sample Picture Array for the Sentence–Picture Task



OS: The lady is kissing the man who is holding an umbrella.

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