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Grammatism

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Findings from the literature on language development, dyslexia, and adult sentence processing provide a vehicle for comparing two models of the symptom complex associated with agrammatism. One model contends that agrammatism represents a deficit in linguistic structures. The other model maintains that the linguistic behavior associated with agrammatism is the result of a limitation in language processing. To adjudicate between the models, the present paper examines one linguistic construction, the restrictive relative clause. The results of experimental investigations across several subject populations reveal parallel patterns of linguistic behavior on this construction. The findings favor the processing limitation account of the linguistic difficulties experienced by agrammatic aphasics in comprehending sentences with a restrictive relative clause. © 2001 Academic Press

One of the central distinctions in psycholinguistic research is between the absence of a linguistic structure in a person's grammar versus that person's inability to access that structure due to limitations in processing capacity. This distinction figures prominently in research on language acquisition, and it has also become a central focus of studies of language breakdown. Although the distinction is intuitively clear, it is often difficult in practice to adjudicate between a structural deficit and a processing limitation. In the literature on aphasia, for example, the jury is still out on the source of the symptom complex associated with agrammatic aphasia. The purpose of this paper is to examine the comprehension difficulties of agrammatic aphasics on a single linguistic structure, the restrictive relative clause, to see whether the structural deficit hypothesis or the processing limitation hypothesis is more illuminating.

For over 20 years, researchers have ascribed many of the language-related difficulties experienced by agrammatic aphasics to a syntactic deficit. One early proposal was by Caramazza and Zurif (1976), who maintained that agrammatics suffer from a complete breakdown of syntax. More recently, Grodzinsky (1990) proposed that

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agrammatic aphasics have incurred a more circumscribed syntactic deficit. The proposal is as follows: Natural languages permit *displacement* operations in which an expression "moves" from one sentential position to another in the course of a derivation. When an expression moves, it leaves a trace behind at the site of origin. Traces left behind by movement operations are deleted in agrammatism, according to Grodzinsky. Therefore, interpretive principles that depend on traces are compromised. Because the interpretation of sentence structures involving movement, such as restrictive relative clauses, are not governed by linguistic principles in agrammatism, this population of individuals must rely on heuristic strategies to interpret sentences with relative clauses. The heuristic strategies sometimes yield interpretations that are equivalent to ones generated by linguistic principles, but this is the exception rather than the rule (Grodzinsky, 1989).

Another structural deficit account of agrammatism is offered by Friedman and Grodzinsky (1997), who adopt certain assumptions from the so-called Minimalist Program. On one version of the Minimalist Program, structure building is seen as a dynamic process in which higher projections are constructed on top of previously built projections (cf. Phillips (1996), who argues that structure building is top-down). Assuming that derivations are constructed in such a bottom-up fashion, structure building begins with the verb phrase (VP) projection and extends upward; additional phrasal projections are formed as new words are merged and incorporated into the derivation. The projection above the VP is an agreement phrase (AgrP), according to Friedman and Grodzinsky. Then, a negation phrase (NegP) is projected and, above that, a tense phrase (TP). Finally, the root of a completed derivation is built, the complementizer phrase (CP). On the Friedman and Grodzinsky account, different groups of agrammatic aphasics encounter difficulties at particular projections in the course of a derivation. One group of agrammatic aphasics is unable to project phrases above the VP. In a well-formed derivation, the verb originates within the VP, but it moves to the TP projection to receive inflectional morphology, such as present or past tense. Agrammatic aphasics who are unable to project a tense phrase (TP) will experience difficulties with verbal morphology.

Other predictions follow from the Friedman and Grodszinksy proposal. They maintain that if structure building is impaired at a lower level of projection, no higher-level projections can be built. Therefore, agrammatics who have a deficit in verbal morphology are expected to have concomitant problems in producing and comprehending sentences with complex syntactic structures, such as restrictive relative clauses. Because the landing site for movement in this construction is the CP, agrammatic aphasics who cannot construct phrasal projection above the VP will be unable to build the requisite derivation for this construction, and will be forced to rely on heuristic strategies for interpretation. The converse does not hold, however. It is possible for agrammatic aphasics to have a deficit in complex syntax, at the CP level, but sparing of lower-level phrasal projections, VP and TP, which are needed for verbal morphology. The Friedman and Grodzinsky model is an advance because it brings together (a) the difficulties of some agrammatics in verbal morphology, and (b) the difficulties that these (and possibly other) agrammatics experience in producing and comprehending sentences with complex syntax, including sentences with a relative clause. To the extent that the assumptions of the model are grounded in theory, this account of agrammatism moves beyond description, towards explanation.

There is a potential problem, however, for these recent versions of the structural deficit hypothesis. Performance by agrammatic aphasics is at chance levels on certain sentence structures, but their performance is at above-chance levels with other structures. This is where the heuristic strategies come into play, on the structural deficit account. When agrammatics are observed to perform at above-chance levels on a

certain complex sentence structures, the account is compelled to invoke a heuristic strategy to explain the data—aphasics are seen to produce the right responses for the wrong reasons. For instance, it is well documented that agrammatics perform at above-chance levels in comprehension measures of sentences with certain relative clause structures (e.g., subject-gap relatives, see below). According to the structural deficit hypothesis, this is because agrammatic aphasics interpret the sentences using a strategy based on the "canonical" word order of the language: Subject–Verb–Object order, for English. This explanation is viable only if the particular heuristic strategy that is invoked can be shown to be independently motivated, for example, if it can be shown that the same heuristic strategy is used by children in the course of language development. Unfortunately, independent support for the arsenal of heuristic strategies that are posited by the structural deficit hypothesis is suggestive at best. Since so much rests on this issue, we should ask whether the processing limitation account fares any better.

The alternative account supposes that agrammatic aphasics encounter difficulties in comprehending sentences with restrictive relative clauses of certain kinds and not others, because the resources of the performance system are stretched more for certain relative clause structures than for others. If this is correct, then the basic linguistic principles of relative clause formation may be spared in agrammatism, making the term "agrammatic" a misnomer. This is the position we have advocated in our recent work. On the processing limitation account, one expects to find clear evidence of sparing of the requisite linguistic projections, including the CP projection. In the final section, we return to this expectation. It is also expected that the pattern of linguistic behavior of agrammatic aphasics will mirror that of other populations with abnormal limitations in (linguistic) computational resources, such as young children, children with dyslexia, and Wernicke's aphasics. Another source of relevant comparisons stems from the advent of methodological techniques for measuring on-line processing difficulty experienced by normal adults. Although adults are not expected to show comprehension failures, on-line studies of sentence processing have revealed that certain structural properties of sentences exact a toll on processing resources. The processing limitation hypothesis expects agrammatic aphasics to experience difficulties in producing and comprehending the same structures that pose difficulties for normal adults in tasks that measure on-line sentence processing.

It should be understood that there is only an embryonic model of the language processing system, as compared to the theory of syntax within the Principles and Parameters framework, including its most recent incarnation, the Minimalist Program. Nevertheless, a processing limitation account of agrammatism can be advanced in certain cases. Relative clauses are a case in point. There is an extensive literature on the acquisition of relative clauses. There is also an extensive literature on how different kinds of relative clause structure are interpreted by normal adults in on-line sentence processing. Finally, there are extensive research findings from investigations of language processing by agrammatic aphasics. To assess the merits of the structural deficit hypothesis and the processing limitation hypothesis, we can look to the experimental findings from these literatures. First, however, some terminology is in order.

Relative clauses are subordinate (embedded) clauses that typically modify a noun phrase in the main clause of a sentence. Our concern is with four kinds of relative clauses. One is a relative clause that attaches to the noun phrase in the subject position; this is called a Subject relative. A relative clause that attaches to a noun phrase in object position is called an Object relative. In English, there is exactly one phonetically empty noun phrase (NP) inside every relative clause. This "gap" in the relative clause contains the trace of Wh-movement. By Wh-movement, a relative pronoun is moved from an argument (e.g., subject, object) position to a position in the CP projec-

tion. From that position it is co-indexed with the NP in the main clause that is being modified, as well as with the trace that is left behind. If the subject NP of a relative clause is phonetically empty, this is called a subject-gap relative clause; if the gap is in the position of the object NP, this is an object-gap relative clause. In examples (1)–(4), the first letter of the two-letter code refers to the NP that the relative clause attaches to in the main clause, and the second letter refers to the grammatical position (subject or object) of the gap inside the relative clause:

(1) SS: The doctor who _ cited the memo sued the hospital last week.
(2) SO: The doctor who the memo cited _ sued the hospital last week.
(3) OS: The hospital sued the doctor who _ cited the memo last week.
(4) OO: The hospital sued the doctor who the memo cited _ last week.

Now we will tour some of the relevant literatures on restrictive relative clauses, looking first at findings from investigations of child language. Three conclusions from the literature on child language are pertinent to the present discussion. One conclusion is that the linguistic principles needed for relative clause formation are not missing from the grammars of young children. When children are tested in contexts that are felicitous for the use of a relative clause, even children as young as 2 and 3 years old produce both subject-gap and object-gap relative clauses and interpret these structures in the same way that adults do. The second conclusion is that object-gap relative clauses are more difficult for young children to produce and comprehend than subject-gap relative clauses. In experiments designed to elicit different types of relative clauses, for example, children tended to produce subject-gap relatives with a full verbal passive, as in example (5), and not object-gap relatives, as in example (6). This suggests that object-gap relatives are more difficult for children to process:

(5) Point to the bufferfly that is _ getting flied over by the kangaroo.
(6) Point to the butterfly that the kangaroo is flying over _.

The third conclusion about the processing difficulty imposed by relative clauses is based on the nature of children's "errors" in comprehension experiments. When children find it difficult to comprehend sentences with relative clauses (e.g., in infelicitous contexts), their nonadult responses are indicative of a less complex structure, such as a conjoined clause structure. For example, children have been found to produce systematic nonadult responses to OS relatives such as example (7) when they are asked to "act-out" the meanings of sentences in a figure manipulation task. Children often respond to example (7) by having the dog push the sheep and then jump over the fence. This response makes sense if children analyze example (7) as containing two conjoined clauses, as if it had the structure in example (7a), as compared to the adult structure in example (7b)[1]:

(7) The dog pushed the sheep that jumped over the fence.
  (a) [The dog pushed the sheep] and [_ jumped over the fence]
  (b) The dog pushed [the sheep that _ jumped over the fence]

[1] The figure manipulation task does not satisfy the presuppositions of sentences, however, since there is no preceding conversational context. In sentence (7), there is a presupposition that the event mentioned in the relative clause took place before the event mentioned in the main clause (i.e., the jumping event precedes the pushing event). In ordinary conversational contexts, the conceptual order of information is satisfied, because the event depicted in the relative clause is established in the context before the sentence is uttered. By contrast, figure manipulation tasks force subjects to accommodate unsatisfied presuppositions. Children are apparently less able than adults to perform the necessary accommodations, which explains why they produce nonadult responses, despite knowledge of the relevant linguistic structure.

Another source of evidence concerning processing difficulties imposed by different types of relative clause structures comes from the sentence-processing literature. To investigate on-line processing difficulty, for example, we have conducted a series of experiments using time-sensitive recordings of eye movements during reading. One study (Ni, Shankweiker, & Crain, 1996) examined the four types of relative clause structures described in examples (1)–(4). Four stimulus lists were composed and presented to one of four groups of subjects. Each list contained five tokens of each version of a sentence-set (SS, SO, OS, OO), so no subject read more than one version of any particular set. Two measures were used to analyze the patterns of eye fixations during reading: (a) first pass reading times, and (b) incidence of regressive eye movements. For analysis of first pass reading times, the test sentences were divided into five regions: Region 1 was the subject NP; Region 2 was the relative clause in SS and SO sentences, and the main verb in the OS and OO sentences; Region 3 contained the main verb in SS and SO and the object NP in OS and OO; Region 4 contained the object NP in SS and SO and the relative clause in OS and OO; Region 5 was a terminating adverbial phrase, which was added to each sentence to ensure that "wrap-up" effects occurred after all of the critical regions. The main factors for analysis were PLACE of attachment (i.e., subject NP or object NP of the main clause), and TYPE of relative clause (i.e., subject-gap, object-gap).

Here are the main findings. As shown in Fig. 1, there was a significant main effect of TYPE ($F_1(1,31) = 40.59, p < .01$; $F_2(1,19) = 15.58, p < .01$), but not of PLACE ($p > .1$). Reading times for object-gap relative clauses (SO and OO) were significantly higher than for subject-gap relative clauses (SS and OS), regardless of whether the relative clause modified the subject NP or the object NP of the main clause. Regressive eye movements are a movement of the eye to material that was viewed previously. As Fig. 2 shows there was a significantly higher percentage of regressive eye movement for SO sentences (21.1%) than for SS sentences (13.5%): ($F_1(1,31) = 12.05, p < .01$, $F_2(1,19) = 5.26, p < .03$), and the same is true for OO sentences (20%) versus OS sentences (8.8%): ($F_1(1,31) = 22.24, p < .01$, $F_2(1,19) = 36.34$, $p < .01$).

The eye-movement patterns of normal adults during on-line processing of sentences containing relative clauses are consistent with other findings in the literature.

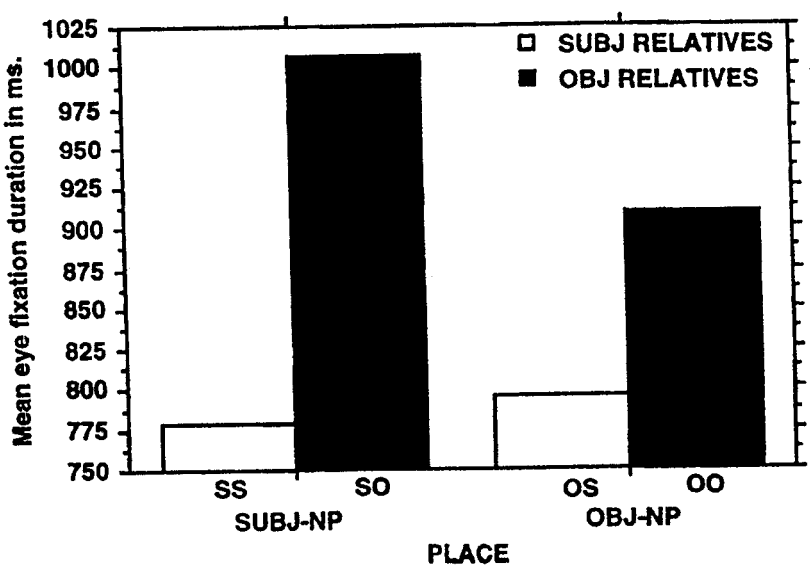

FIG. 1. First-pass reading times within the relative clause region (Ni et al., 1996).

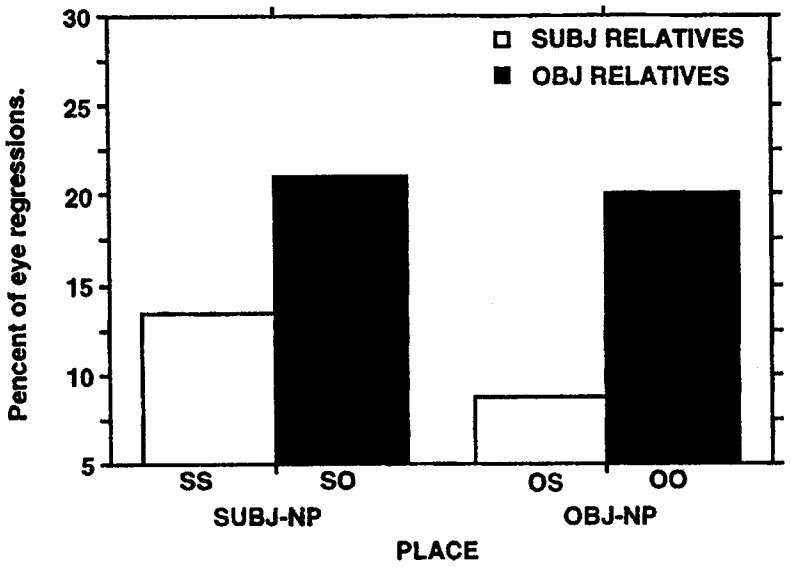

FIG. 2. Percentage of eye regressions from the relative clause (from data of Ni et al., 1996).

With regard to the locus of the difficulties, greater processing load is found with object-gap relatives as compared to subject-gap relatives, irrespective of differences in modality (print or speech), sentence structure, language, type of subject population, and experimental technique (e.g., Ford, 1983; Just & Carpenter, 1980; Hakuta, 1981; Holmes & O'Regan, 1981; MacWhinney & Pleh, 1988; Mecklinger, Schriefers, Steinhauer, & Friederici, 1995).

There are several possible explanations of the greater difficulty of object-gap relatives than subject-gap relatives. The key ingredient to processing load on most accounts is taken to be the distance between the gap and the NP in the main clause that bears the relative clause; we will refer to this NP as the "filler." Some researchers measure distance by counting the number of words that intervene between the filler and the gap; these researchers expect increased processing at the gap position. Another possibility is that processing difficulty arises due to the presence (hence, the number) of NPs that intervene between the filler and the gap, not the number of words. To investigate the issue, we performed a fine grained analysis of eye-fixations at three points in subject-gap relative (OS and SS combined) and object-gap relatives (OO and SO). In each case, Position 1 was the relative pronoun *who*. Position 2 was the VERB in a subject-gap relative, and the NP preceding the verb for an object-gap relative. Position 3 was the reverse: the VERB for an object-gap relative, and the NP for a subject-gap relative. An example of the linguistic content at each position is illustrated in example (8), and the mean first-pass reading times at each position are presented in Fig. 3:

(8)	Subject-relatives:	...who	cited	the memo...
		1	2	3
	Object-relatives:	...who	the memo	cited...
		1	2	3

Analysis of variance revealed significantly longer reading times for object-gap relatives (SO and OO) than for subject-gap relatives (SS and OS) ($F_1(1,31) = 10.62$, $p < .01$; $F_2(1,19) = 9.43$, $p < .01$). Further analysis showed that the NP in Position 2 was mainly reponsible for the differences in response latencies. This finding suggests that phrase length (in words) is not the critical factor; rather processing re-

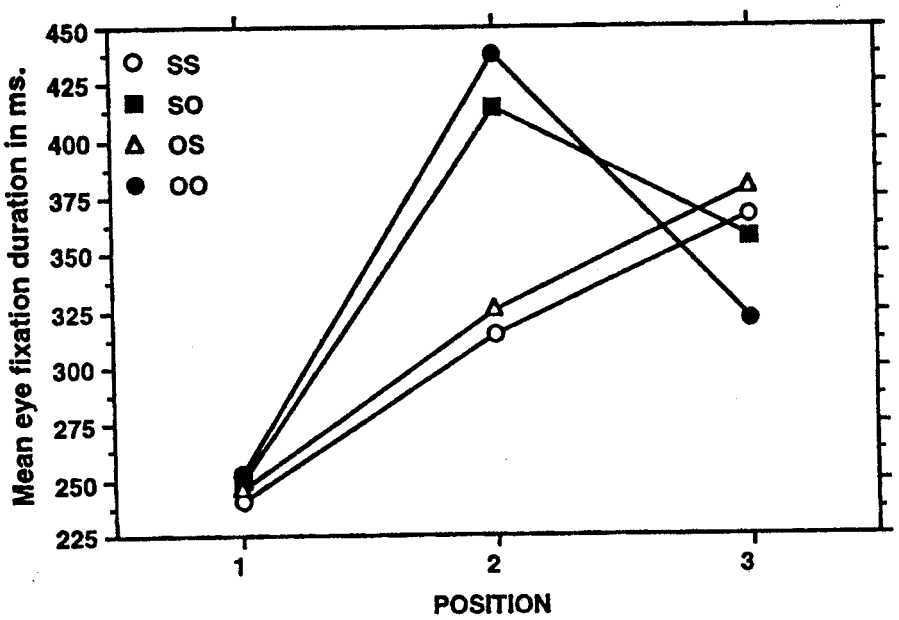

FIG. 3. First-pass reading times at each position in the relative clause (Ni et al., 1996).

sources are consumed in dealing with NPs that intervene between a filler and its associated gap.

So far we have seen that the findings of investigations of child language development and adult sentence processing lead to the conclusion that object-gap relative clauses impose greater demands than subject-gap relatives on the resources of the language processing system. This conclusion is important for adjudicating between the competing accounts of agrammatism. First, it is apparent that the processing limitation account can explain some of the same findings as the structural deficit account, namely the observation that agrammatic aphasics perform more poorly in comprehending object-gap relatives than subject-gap relatives. The difference in performance by agrammatics across sentence-types closely mirrors the pattern of results found in studies of child language development and adult sentence processing. Other findings provide further support for the processing limitation account. The account anticipates that the same pattern of linguistic performance will emerge in assessments of other aphasic syndromes and in other normal populations with abnormal limitations in computational resources, such as dyslexic children (who are known to suffer from deficiencies in verbal working memory). In recent research, we have investigated these predictions. It is now clear that the pattern of errors on relative clause sentences is not syndrome-specific, but seems to be more general. For example, Lukatela, Shankweiler, and Crain (1995) found that a pattern of difficulty that is supposed to characterize agrammatic aphasia was also displayed by subjects with Wernicke's aphasia, a syndrome often regarded as the very antithesis of agrammatic (Broca's) aphasia (e.g., Goodglass, 1993). The Lukatela et al. findings on sentence–picture matches for four versions of relative clause sentences, presented in spoken form, are shown in Fig. 4.

Although subjects with Wernicke-type aphasia made more errors overall than those with agrammatic (Broca-type) aphasia, the pattern was the same for both groups; fewer errors were incurred on subject-gap relatives than on the corresponding object-gap relatives (SS vs. SO and OS vs. OO), as expected on the processing limitation account. The same error pattern was also observed in studies of elementary school

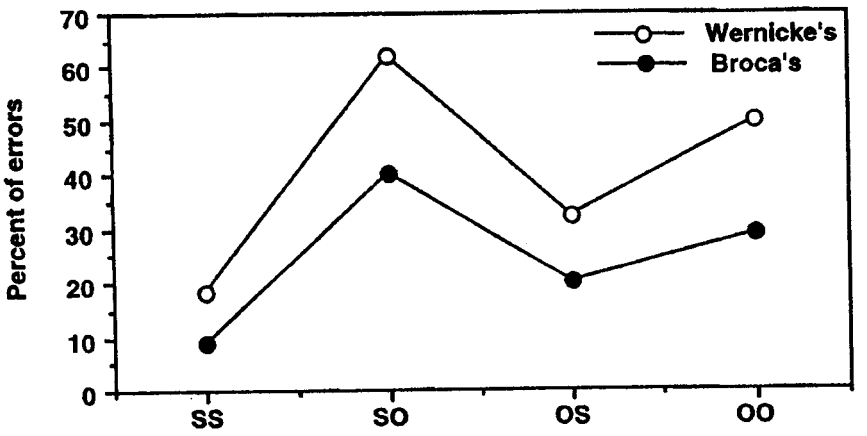

FIG. 4. Error pattern of the Serbo-Croatian-speaking aphasics on relative clause structures (Lukatela et al., 1995).

children at two levels of reading ability. The error data in Fig. 5 were obtained using a sentence–picture matching task in which the same sentence structures were presented in spoken form to the child subjects (Smith, Macaruso, Shankweiler, & Crain, 1989).

The remarkable convergence of performance profiles among normal adults, children who differ in reading ability, and aphasics representing two distinct syndromes challenges, on grounds of parsimony, any account that appeals to a specific structural deficit as the explanation for the comprehension difficulties associated with these structures. The findings of on-line processing by normal subjects, coupled with parallel findings from different populations, constitute unequivocal support for the processing limitation hypothesis, and against the structural deficit hypothesis. It is clear that the relatively greater difficulty with object-relatives in normal adults cannot be attributed to the absence of linguistic principles, because grammatical knowledge is intact in this population.

The remainder of the paper reports the findings of another technique for investigating linguistic competence, the elicited production task. Production data are particularly telling when the question is what is spared in agrammatism. Correct combinations of words do not come about by accident; even a single target utterance in an appropriate context is a compelling argument for competence with the relevant struc-

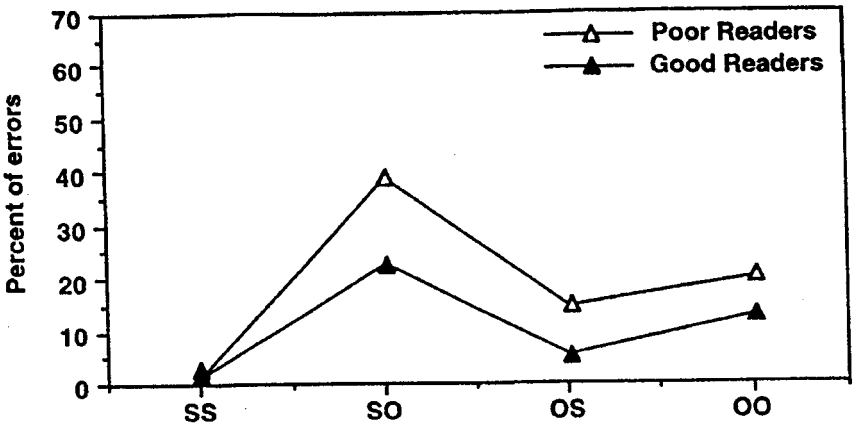

FIG. 5. Error patterns of school-age children on relative clause structures (Smith et al., 1989).

ture. Elicited production tasks are designed to evoke particular linguistic constructions. Structures are elicited by devising situations that are uniquely felicitous for them. The technique of elicited production is also useful because several examples of the same linguistic construction can be elicited from each subject. The design features of the elicited production tasks are described in detail in Crain and Thornton (1998).

In an ongoing study, we attempted to elicit relative clauses from two aphasic patients, HO and HW.[2] The productions of these patients include sentence-fragments with many of the hallmarks of relative clauses. Examples (9) and (10) illustrate the kinds of responses that are expected for the two kinds of relative clause structure. Beneath examples (9) and (10) are examples of utterances produced by HO and HW in the experiment. (See Ni, Shankweiler, Harris, & Fulbright 1997, for a preliminary report, including fMRI scan findings.)

(9) (a) The penny is under the bear (that is) _ holding a fish.
(b) The bear (that is) _ holding a fish is on top of the penny.

HO: *The bear which holding a fish sitting on the penny.*
The chicken with eating the bug is . . . uh . . . um . . . the penny is . . . under it.
The man holding b-boy is sitting on the penny.

HW: *The penny under the boy . . . uh . . . the . . .* [E: "man"] *man holding the boy.*
The penny under the rooster pecking the bug.

(10) (a) The penny is under the sheep that the frog is sitting on _.
(b) The sheep that the frog is sitting on _ is on the penny.
(c) The penny is under the sheep that _ has the frog on top of it.

HO: *The penny is under the sheep which _ has the frog on top of him.*
The penny under the fox who _ has the butterfly on him.
The penny is under the woman with a cat licking the woman.

HW: *The penny is under the sheep . . . riding . . . sheep*
The penny under the fox . . . tickling the . . . fox.
The penny . . . under the woman and the cat is by the woman side.

Despite the (characteristic) omissions and substitutions of closed-class morphological items, the productions of both HO and HW are noteworthy in several respects. Consider first the productions that they gave in response to situations that were designed to elicit a subject-gap relative clause, as in example (9). Both HO and HW were able to successfully convey the gist of the targeted sentences. In fact, some of their utterances differ from the targeted sentences simply by the omission of the copula. Moreover, HO produced a relative pronoun on one trial in this condition. This is unequivocal evidence of a CP projection. By contrast, HW produced only reduced relative clauses (i.e., without the optional *that is*).

We turn next to the trials on which the experimenter attempted to elicit object-gap relatives. Recall that young children often produced subject-gap relatives on such

[2] *HW:* BDAE percentile score of 70; average phrase length of 3.25 words. Infarct (encephalomalacia, gliosis, or both) involves pars opercula and pars triangularis of the inferior frontal gyrus (BA 44, 45); precentral gyrus BA 4, 6); postcentral gyrus, anterior aspect (BA 3, 1); supramarginal gyrus (BA 40); angular gyrus (BA 39); posterior aspect of superior temporal gyrus (BA 20; insula; subinsula regions; posterior limb of internal capsule and coronal radiata. *HO:* BDAE percentile score of 89; average phrase length of 3.25 words. Schemic damage largely in the form of encephalomalacia involves precentral gyrus (BA 4, 6); postcentral gyrus, anterior aspect (BA 3, 1); insula, posterior limb of internal capsule; and middle and posterior coronal radiata.

trials. HO followed suit, producing subject-gap relatives rather than object-gap relatives, as illustrated in example (10). Notice, however, that the structures used by HO preserved the word order of NPs as they appear in object-gap relatives and, again, HO produced relative pronouns, on two occasions. By contrast, HW had considerably more difficulty in producing coherent sentences on the object-gap trials. Presumably HW vacillated between object-gap and subject-gap structures. As a result, HW omitted NPs that should have appeared in the subject position of an object-gap relative clause. For example, the NP, *the frog,* was omitted in the utterance by HW corresponding to example (10). It is noteworthy also that HW successfully produced all of the relevant NPs when, instead of a relative clause structure, a conjoined clause structure was produced. This too parallels the observation from the literature on child language that young children often revert to a conjoined clause, rather than a relative clause, when they are experiencing difficulty with a task.

A final piece of data attests to knowledge of the structural properties of relative clauses, by HO and HW. On trials where the experimenter supplied most of the lexical material needed for constructing a relative clause, both HO and HW completed the experimenter's utterances with a transitive verb, but *without* a direct object NP. This is evidence that HW and HO knew that the completion of the experimenter's utterance required a filler/gap dependency, i.e., a restrictive relative clause. Here are examples:

(11) Experimenter: "The penny under the cow that the dog is . . ."
HW: *riding*
Experimenter: "The penny is under the cow that the dog . . . "
HO: *is riding*

To conclude, the processing limitation account of agrammatism has much to recommend it. It appears to explain more than the structural deficit account, at least when the focus is on sentences with a restrictive relative clause. The success of the processing limitation hypothesis depends on finding parallels in the linguistic behavior of agrammatic aphasics and other populations, including other subject populations with abnormal processing limitations, but also normal adults in studies of on-line sentence-processing difficulty. Such parallels are unexplained on the structural deficit hypothesis.

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