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Agrammatic Comprehension of Relative Clauses

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Four hypotheses that attempt to account for the comprehension deficit in agrammatism are put to an empirical test. The interest in them is in that they all view the deficit as highly selective. The first, proposed by D. Caplan and C. Futter (1986, *Brain and Language*, 27, 117–134), argues that agrammatic patients cannot carry out normal syntactic analysis beyond the category label of each incoming lexical item and are reduced to the use of a cognitive strategy that commends assignment of thematic roles to noun phrases merely by their linear position in the string. A second, less radical hypothesis (Y. Grodzinsky, 1986a, *Brain and Language*, 27, 135–159), accounts for the deficit differently, by deleting a particular kind of syntactic object (trace) from the otherwise normal representation, and augmenting the resulting, underspecified representation by a strategy, whose use is quite restricted. A third account that is tested contends that agrammatic aphasics fail to comprehend perceptually complex constructions, where the metric for complexity is determined by results obtained from comprehension tests of normal listeners. The fourth account (M. F. Schwartz, M. C. Linebarger, E. M. Saffran, and D. S. Pate, 1987, *Language and Cognitive Processes*, 2, 85–113) argues that the thematic transparency of a construction (whether or not thematic roles are assigned directly to positions) is the best predictor of the manner by which agrammatics can handle it. An empirical test is thus constructed, both to extend the evidential basis concerning the comprehension skills of these patients and to distinguish between the accounts. Four types of relative clauses are presented to the patients, where embedding type (center vs. right) is one variable, and location of gap (subject vs. object position) is the other. The patients are tested in a sentence-picture matching paradigm. The finding, that is rather robust, is that gap location is the best predictor of agrammatic performance: the patients perform well above chance on both types of subject gap relatives, and at chance levels on object gaps. It is then shown that the Trace-Deletion Hypothesis (Grodzinsky, 1986a) is the only one among the accounts considered that is compatible with these data.

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INTRODUCTION

Getting at the right characterization of the comprehension abilities of agrammatic patients is important because it appears that this syndrome provides us with a linguistically selective impairment, through which we can get a glimpse at the inner workings of that piece of our cognitive system that is dedicated to linguistic analysis. Once the precise nature of the impairment is established, it will have implications for theories of normal language representation and use. For this reason, agrammatic comprehension has been a central target for research in the neuropsychology of language over the past decade or so. Although there could probably be more, the literature on agrammatism currently contains four hypotheses concerning the comprehension abilities of agrammatic patients. Fortunately, all four are stated explicitly enough so that they can be put to an empirical test. Some of them are conceptually preferable to others, as one would expect. Yet an empirical test is aways perceived as a more compelling argument and is thus worth carrying out.

In the following pages I will lay out the essentials of each account, derive predictions, and use them to motivate an experiment aimed at deciding between the competing accounts. But first, a brief historical review of the data and claims is in order.

I. PREVIOUS FINDINGS, PREVIOUS CLAIMS

Perhaps the most stable result concerning the comprehension abilities of agrammatic aphasic patients is their failure to understand certain types of relative clauses in a normal fashion, if all semantic and pragmatic cues are suppressed. This has first been demonstrated by Caramazza and Zurif (1976) and then replicated several times (e.g., Linebarger, Schwartz, & Saffran, 1983; Wulfeck, 1984). In fact, in some research centers, this has recently become one of the *criteria* to diagnose agrammatism in Broca's aphasia (e.g., Linebarger et al., 1983; Rosenberg, Zurif, Garrett, & Bradley, 1985).

What Caramazza and Zurif found was that in semantically "reversible" sentences, where all semantic cues had been removed (1), agrammatic comprehension abilities decreased dramatically, and the patients performed at chance level in a picture-matching task:

(1) The girl that the boy is pushing is tall.[1]

In (1), syntactic analysis is a necessary precondition for correct inter-

[1] Caramazza and Zurif actually tested a stronger hypothesis: that, in contrast to "reversible" sentences, semantically "nonreversible" sentences, such as, "The ball that the boy is kicking is red" are comprehended correctly by the patients. This claim has been criticized recently by Grodzinsky and Marek (1988), who argue that the experiment in question was not designed to test this part of the hypothesis.

pretation, as there are no cues to help a syntactically deficient comprehender bypass his impairment. Indeed, as Caramazza and Zurif demonstrated, their Broca's aphasics performed at chance level, reflecting, in these authors' view, their lack of syntactic skills in comprehension—the well-known "asyntactic comprehension." This landmark finding opened the way to a variety of experiments which were aimed at testing comprehension in agrammatic aphasia and has motivated several theoretical intepretations of the observed phenomena.

The body of data available today regarding agrammatic performance in comprehension tasks, quite clearly suggests that this interpretation is too strong. There have been several studies where it was found that even when presented with reversible sentences only, the patients' performance is not always poor, but rather, their success or failure in carrying out a task depends on the syntactic construction in question. So, for example, it has been found that on (semantically) reversible passives, agrammatic patients perform at chance level, but this is not the case for actives (Schwartz, Saffran, & Marin, 1980; Caplan & Futter, 1986; Grodzinsky, Finkelstein, Nicol, & Zurif, 1988; Grodzinsky & Pierce, 1987). It has also been demonstrated for other syntactic constructions that the impairment is differential, and not across the board.

At this point, there are two questions one might ask: First, given that the patients make distinctions between different sentential types, is there a natural way to explain their performance along some theoretical lines, to account for their successful attempts as well as for their failures in a unified fashion? A second question, intimately related to the first, is: Do all the agrammatic failures stem from the same disruption, or rather, can some be attributed to one source, the rest to another? Looking at alternative accounts should bring us closer to the answers.

2. ALTERNATIVE ACCOUNTS

This section examines four accounts of the comprehension failure in agrammatic aphasia. I will discuss each of them below, and then report an experiment which had been designed to distinguish between them empirically. It will be shown that the results of this experiment are consistent with only one of these accounts. Namely, that the pattern of impairment exhibited by agrammatic patients is very highly correlated with a particular syntactic distinction, indicating a specific type of impairment to their comprehension abilities in the syntactic domain. Let me, then, review these accounts, and their consequences for the case of relative clauses.

2.1. Linear Assignment

Caplan and Futter (1986) tested an agrammatic patient on a variety of sentential types and obtained a mixed finding in their study. Certain

structures presented no difficulty to their patient, while others did. Among those where their patient performed well, one finds reversible actives (2a), and subject clefts (3a); among those performed at chance level, are reversible passives (2b) and object clefts (3b).

(2) a. The monkey bumps the frog.
b. The monkey is bumped by the frog.

(3) a. It was the monkey who pushed the frog.
b. It was the frog who the monkey pushed.

There were many other structures in this experiment, but we will restrict ourselves to these for simplicity of interpretation.[2] On the basis of these findings, Caplan and Futter suggest that their patient had lost the ability to interpret sentences according to normal English grammar and was reduced to assignment of thematic roles (such as Agent of action, Theme, Source, and Goal) onto *linear* sequences of nouns and verbs, as opposed to hierarchical structures which are normally taken to be the syntactic domain of interpretative processes. On this account, then, the patient standardly employs a heuristic strategy, for lack of (the normally available) syntactic information, and the results of this strategy may sometimes overlap with the results of normal interpretive procedures (as is the case in the active sentences, for example), and sometimes not (as in passives). The findings are thus said to be explained by a small set of strategies that the patient employs, strategies that are explicitly stated by Caplan and Futter: "Assign the thematic roles of agent, theme, and goal to N_1, N_2, and N_3 in structures of the form N_1-V-N_2-N_3, where N_i does not already bear a thematic role" (p. 128).

2.2. *Trace-Deletion*

If an account like Caplan and Futter's were to be true, then agrammatic aphasia would be of very little interest to the student of normal linguistic processes. This is so because these authors deny the existence of any normal syntactic representation for the patient, beyond the category label identifying each lexical item. As it happens, this seems not to be the case. In an alternative proposal, also designed to explain apparent inconsistencies in the findings from agrammatic comprehension, I have made the claim that the patients are impaired syntactically, in that the syntactic representations they have available are incomplete. The analysis I have proposed is based on the observation that there is a common feature to all the constructions on which patients perform poorly, a feature uniformly absent from those constructions that pose no problem

[2] The other conditions involved two verbs and three nouns. As a consequence, there were too many possible ways to err. This makes the data uninterpretable at this point. See Grodzinsky (1986a, 1986b).

to the very same patients: from the point of view of the theory of syntax (as outlined in Chomsky, 1981, and related literature), the former are transformationally derived, while the latter are not (although later we will see that this distinction is insufficient and will have to be refined).

This analysis is proposed in Grodzinsky (1986a). Here, only its essentials will be reviewed briefly, with their implication to the case of relative clauses which were tested in the experiment reported here.

The proposal stems from the observation that agrammatics perform above chance in the comprehension of active sentences, and at chance on passives and object-gap relative clauses. The latter are derived by a transformation, which moves the object leftward and leaves an empty category, trace, behind, forming a chain between the two. This chain is crucial for the transmission of the thematic role to the subject of the passive. If the trace is deleted, this transmission is impossible, and the subject of the passive (or head of the relative clause) lacks a thematic role. This is when a nonlinguistic, cognitive strategy kicks in, assigning this NP a role by virtue of its serial position in the surface string, in this case, an agent role. So, in the passive case, there is an agent in subject position, and another one in the *by*-phrase, and hence the patient is forced to guessing.

This account holds for the Caramazza and Zurif (1976) finding, as well as Caplan and Futter's (1986). Consider an example from the former:

(4) The boy that the girl kissed was tall.

The structural description of this sentence involves a transformational derivation, as can be seen in Fig. 1.

Here, the analysis I have proposed above for agrammatism will give the sentence in Fig. 1 the structural description shown in Fig. 2.[3]

The representation now has two noun phrases preceding the verb. The second noun phrase (*the girl*) is the subject of the relative clause and is thus assigned Agenthood by the verb *kiss*. The first NP *The boy*, however, is in a nonthematic position, thus it is under the scope of the strategy. In addition, it is clause-initial, hence it is assigned the role of Agent. The result is, again, a thematic representation that contains two Agents: one that is assigned correctly, for structural reasons (*the girl*), another incorrectly, by the strategy (*the boy*). Chance performance is thus predicted. Similar considerations hold for cleft sentences (see Caplan & Futter, 1986, for results, and Grodzinsky, 1986a, for interpretation).

[3] Actually, the description here is not quite accurate. What it should really say is that the binding is between the trace (taken to be a variable here) and an operator in Comp. As the link is broken, the information is not available. See Grodzinsky (1986b) for elaboration.

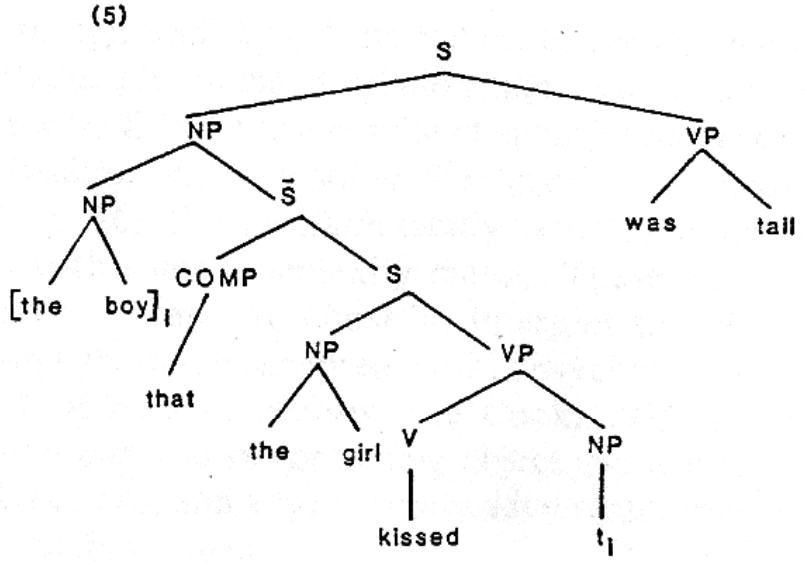

FIGURE 1

This presentation is brief and skips several steps in the reasoning. A full account is provided in Grodzinsky (1986a), and the reader is referred to that paper for further details. It should be emphasized here that special attention is given to the type of performance—responses at chance level vs. consistent errors. Note that the present account is an abstraction, and obviously, it does not make claims about "traces" being deleted from the patients' heads; all it offers is an abstract characterization of the nature of the syntactic representations in agrammatism. Another important feature of this characterization is that it is predicted over representations and not in terms of particular rule systems or principles of grammar. This has been done intentionally, here and elsewhere (see Grodzinsky, 1984a).

At this point we have two accounts for agrammatic performance, that have some common properties, yet are different from one another in

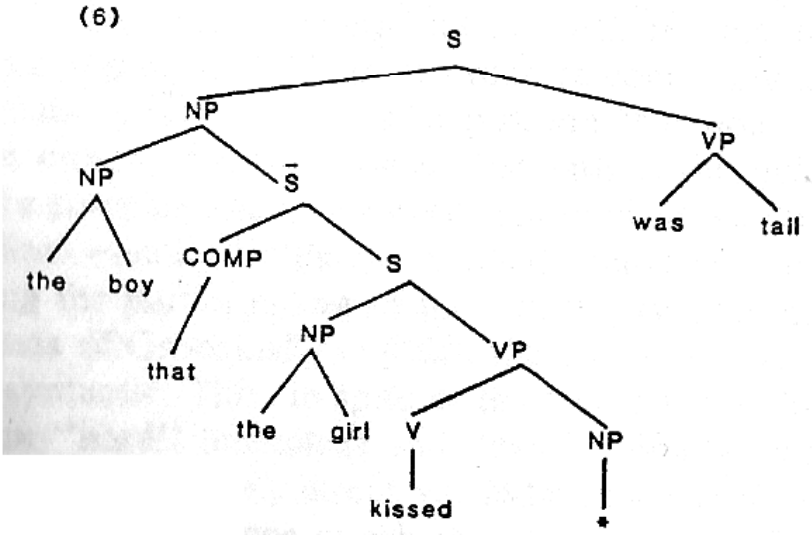

FIGURE 2

some important respects: Both assume some heuristic strategy to be a part of the interpretive process in agrammatic comprehension, yet Caplan and Futter's account claims that these heuristic processes are defined over linear sequences of category labels and that no structure building operations are carried out by the agrammatic patient. The Trace-Deletion Hypothesis, by contrast, assumes hierarchical (tree) structures which are incomplete (in that they are lacking traces and their indices at S-structure representation). There are other, conceptual differences between these two accounts, which I discuss elsewhere (Grodzinsky, 1986a).

The relevant difference between Caplan and Futter's account and mine in the present context is that the two differ sharply in prediction. Linear Assignment would predict that in the case of object-gap relative clauses above, as well as in passives, the patients will consistently *invert* the roles, (and consistently err) as it states that the first noun in the sequence is the highest valued candidate for Agenthood, and in both these constructions, this NP is the logical *object*, having been moved transformationally, and hence is linked to the thematic role of Theme. The Trace-Deletion Hypothesis, by contrast, predicts (the observed) chance performance in both cases.

2.3. Complexity

There is, however, yet another perfectly plausible alternative explanation for the observed findings. On this account, the generalization made by either of the previously discussed hypotheses is spurious, and the comprehension failures in passives and relatives ought to be attributed to different sources. In particular, the failure to understand the relative clauses is simply a result of the perceptual complexity of these structures and is unrelated to the other findings about comprehension failures in agrammatism. This account hinges on the well known ordering of syntactic constructions according to some complexity metric, where object-gap relative clauses of the center-embedded type are the most complex, in that empirically they have been found to be the most difficult to understand by normal speakers (see Miller & Chomsky, 1963; Fodor, Bever, & Garrett, 1974; Cook, 1975; Frauenfelder, Segui, & Mehler, 1980, and related references). An extension of this to agrammatism immediately comes to mind, namely, the claim that in this syndrome there is simply a decrease in the overall ability to deal with perceptually difficult construction types, and the finding is predicted.

This view is shared by several researchers, who interpret complexity in a variety of ways: Goodglass and Menn (1985), for instance, claim that "the comprehension of grammatical morphemes is involved in sentence comprehension only as a function of the cognitive difficulty of the relationship between lexical terms, which is signaled by the grammatical

morpheme" (p. 22), and thus, "the failure to comprehend morphologically and syntactically encoded relationships among nouns is the same phenomenon for both fluent and nonfluent aphasics and is due to cognitive problems in dealing with decoding the linguistic expression of those relationships" (p. 26). Such a claim tacitly assumes an order of difficulty in accordance with some complexity metric. These authors do not provide it, however. I therefore chose to interpret the claim in the most natural way—in light of the accepted view in psycholinguistics concerning the complexity of relative clauses (see Cook, 1975, for example), according to which a structure containing object gap is more complex than one with a subject gap, and a center embedded structure is more complex than a right branching one.

So, if we would like to make any of the above accounts more plausible, we must rule out this alternative, nonstructural explanation.

2.4. The Mapping Hypothesis

A fourth account has been proposed in a series of articles by Linebarger, Schwartz, Saffran, and their colleagues. These authors have made the claim that there is virtually no syntactic deficit in agrammatic aphasia and that the comprehension disorder that is observed can be explained as a failure to map syntactic structure onto semantic representations. The evidence they adduce for this position is based on a comparison between agrammatic performance in comprehension tasks, which is by and large "poor," and their surprisingly excellent performance in judging the acceptability of strings.

The most explicit formulation of their "Mapping Hypothesis" is given in Schwartz, Linebarger, Saffran, and Pate (1987). Examining the successes and failures of the patients in a judgment task, they identify a syntactico-semantic mapping failure, concluding that agrammatic performance is determined by complexity considerations of a particular type. On their view, complexity should be measured relative to the "thematic transparency" of a construction, that is, with respect to how direct thematic role assignment is. Thus, a structure containing a noun phrase in a nonthematic position, that is, a position that does not receive a thematic role directly by an assigner (but rather, through its link to a trace), is more complex and hence predicted to yield poorer performance than a structure where all NPs are in nonthematic positions. So, while acknowledging the partial nature of the deficit, just like the Trace-Deletion Hypothesis of Grodzinsky (1986a), they maintain that the right account is not syntactic. This, in spite of the fact that the distinction they make between "hard" (complex) and "easy" (simple) constructions is in fact a syntactic one (i.e., direct vs. indirect assignment of thematic role, which is a consequence of whether or not a transformational op-

eration had occurred). In this respect, the proposal here is similar to the Trace-Deletion Hypothesis. Namely, since what distinguishes "hard" from "easy" constructions is whether or not a given NP is in a thematic position, and since the notion "thematic position" is syntactic, and in fact, directly linked to transformational movement, what we get is a weaker version of the Trace-Deletion hypothesis: while this latter account predicts the level of performance on each construction type (that is, above-, below-, or at-chance), because it specifies the thematic role that is assigned to every NP in the sentence, the Mapping Hypothesis distinguishes only "hard" from "easy" cases, and is thus less precise.[4] For this reason, one would not expect there to be an interesting difference in prediction between the two accounts, and the Mapping Hypothesis will not be discussed any further below.[5]

These are the four available hypotheses, summarized briefly. Rather than dwell further on the merits and problems of each, I will now move on to empirical issues—to the experiment below. Before introducing the design of the experiment, one must consider cases where the hypotheses differ in prediction. This is done in the next section.

3. EXPERIMENTAL ISSUES

3.1. Constructions and Predictions

This experiment has been designed to distinguish between the hypotheses above (namely, "Linear Assignment," "Trace-Deletion," and

[4] Schwartz et al. (1987) dismiss the necessity for greater degree of precision in their Footnote 6, saying that there is great variability among patients, and further, that some patients even demonstrate different levels of performance in different testing sessions. It seems to me that the data at hand, if looked at carefully, fail to warrant such a conclusion. Actually, this kind of claim is quite puzzling, because if true, it means that we are dealing with a set of inconsistent phenomena, and thus NO theory can handle them.

[5] This, in fact, is true in the case of relative clauses only within a theory of transformations that does not admit vacuous movement (see Ross, 1967; Maling, McCloskey, Peters, & Zaenen, 1983; Chomsky, 1986, for differing positions). The issue, in brief, is whether or not the theory should permit movement that does not change the position of constituents relative to others—Should one accept transformations that do not move constituents across others? There are various arguments pro and con both positions, which are beyond the scope of the current discussion. What is important here are the consequences for the Mapping Hypothesis: within a theory that adopts vacuous movement, the operator in Comp for subject relatives is in a nontheta position, which are consequently predicted by the Mapping Hypothesis to be "hard," contrary to the prediction of the Trace-Deletion Hypothesis (see below). If, however, vacuous movement is disallowed, both hypotheses have similar predictions—that subject relatives be "easy." Yet in order to rid the discussion of this syntactic complication (which, in the final count, is irrelevant given the results obtained) I will ignore this issue from this point on.

"Complexity"). In order to do so, one must find crucial cases where they differ in prediction with respect to the performance of the agrammatic patients. Most crucially, and in sharp contrast to claims that have recently been made (e.g., Wulfeck, 1984; Berndt & Caramazza, 1980; Linebarger et al., 1983), the emphasis here will be on the structural properties of the stimulus materials coupled with the particular task, since only this way can one have a precise prediction for the performance. Neither tasks alone, nor structural descriptions are sufficient for that. The same structural deficit may well have different consequences for every modality (see Grodzinsky & Marek, 1988, for further discussion).

In this study, a task involving comprehension has been presented to the aphasic patients—sentence-picture matching (see Caramazza & Zurif, 1976; Schwartz et al., 1980), which involves choosing the picture that most appropriately fits the description given in a sentence. The choice is always made from several options, and clearly, the nature of the contrast between the various options is an important factor in the assessment of the agrammatic performance. I will return to this issue shortly, when discussing the stimulus items for this experiment.

Let me now present the relevant syntactic constructions, with their structural descriptions according to the theory of syntax I assume.

Consider the following sentences:

(7) a. The boy who is pushing the girl is tall.
b. The boy who the girl is pushing is tall.
c. Show me the boy who is pushing the girl.
d. Show me the boy who the girl is pushing.

While generally similar, there are some differences between these sentences that make them interesting for our present purposes. They represent four types of relative clauses: on the one hand, two are center embedded (*a*,*b*) and two are right branching (*c*,*d*); on the other, two are subject-gap relatives (*a*,*c*), namely, their head (the NP to which they are relativized) relates to the subject position, and the other two (*b*,*d*) are object-gap relatives. This is directly reflected in their S-structures, where a trace shares an index with the head of the relative, representing the relation between these two positions:

(8) a. [The boy]$_i$ [who [t_i is pushing the girl]] is tall.
b. [The boy]$_i$ [who [the girl is pushing t_i]] is tall.
c. Show me [the boy]$_i$ [who [t_i is pushing the girl]].
d. Show me [the boy]$_i$ [who [the girl is pushing t_i]].

We thus have a two by two table, that gives us four types.

What will each of the three hypotheses predict for agrammatic per-

formance on these constructions? Let me discuss each hypothesis in order.

3.1.1. Hypothesis I—Linear assignment. According to this hypothesis, the assignment of thematic roles is over linear sequences of nouns and verbs, and no hierarchical structures are involved. Consequently, no effect is expected to be observed for the type of embedding, only for the order of noun phrases around the verb. On this view, the first noun in the sequence of categories preceding the verb gets the role of Agent, and the second, Theme. Importantly, there can never be, under these assumptions, two NPs in a string that are associated with the same thematic role, which means that chance performance is never predicted. In the present case, the relatives and their heads in (7) will constitute the linear sequence, as shown in (9). I have listed there not only the forms for interpretation, but also the normal assignment of thematic roles, and the assignment predicted by this hypothesis:

(9)

Sequence	Normal interpretation	Linear strategy
a. NP V NP . . .	agent theme	agent theme
b. NP NP V . . .	theme agent	agent theme
c. . . . NP V NP	agent theme	agent theme
d. . . . NP NP V	theme agent	agent theme

So, according to this hypothesis, *a* and *c* (subject relatives) are expected to be performed normally, as the heuristic has the same consequences as the normal interpretive process, while in *b* and *d* (object relatives), the patients are expected to *consistently invert* the thematic roles, assigning agenthood to the head of the relative, which should actually function as Theme in the clause, being normally linked to a trace in object position (see (8)).

3.1.2. Hypothesis II—Trace deletion. Recall that this hypothesis states that S-structure representation in agrammatism does not contain traces and their associated indices; the assignment of thematic roles to noun phrases, on this account, is done normally when the NP at issue is in a thematic position (i.e., subjects and objects in actives, the NP following *by* in passives, objects of subject relatives and subjets of object relatives), and by the heuristic otherwise. Importantly, the type of embedding (i.e., center vs. right) is irrelevant, and hence is not expected to interact with the agrammatic deficit. So, in all the cases of (8) traces are said to be deleted. As a result, both object relatives (*b,d*) are predicted to yield chance-level performance, due to the interaction between the remaining

syntactic knowledge and the heuristic strategy. In the case of the subject relatives, however, it turns out that the patients are predicted to respond normally to the stimuli. There are two possible reasons for this: (1) If subject relatives are assumed to have a trace in subject position (i.e., string vacuous movement is allowed, see Footnote 5), then this trace will be deleted, and the heuristic assignment of thematic role will *overlap* with the normal one. That is, in both (8a) and (8c) the head of the relative (*the boy*) normally gets the thematic role of agent, being linked to a trace in subject position. In agrammatism this link will be absent from the representation, but the heuristic assigns these noun phrases the very same thematic role. On this account, the patients would give the correct answer for the wrong reasons. (2) If subject relatives are not assumed to contain a trace in subject position (assuming that no syntactic movement occurs in such cases), then no impairment is predicted in these cases, and performance should be perfect.

We can now see how the heuristic strategy, taken to be invoked by default for NPs without a grammatically based thematic role assignment, helps the patients at times, in that it fully compensates for the loss, yet at other times it works against them. In effect, the Trace-Deletion hypothesis predicts that in types *a* and *c*, the patients' performance would be apparently normal (although their structural *analysis* may be abnormal), while in cases *b* and *d* they are predicted to perform at chance level, due to a conflict between the normal part of their thematic role assignment, and the heuristic.

3.1.3. Hypothesis III—Complexity. This hypothesis is based on the claim that agrammatic patients are more likely to fail in a task that involves the comprehension of complex syntactic structures. That is, the more complex the construction (on some metric), the more likely it is that agrammatic patients would fail in comprehending it. Importantly, this hypothesis has one major shortcoming: coupled with a complexity metric it would predict which constructions are relatively *harder*, but it cannot predict the actual performance levels, as would the two previous ones.

At this stage, different claims about the nature of the breakdown in agrammatism have been reviewed, with the predictions that each has for performance on semantically reversible relative clauses. For easier reading, the sentence types are reiterated in (10), and the predictions summarized in (11):

(10) a. [The boy][who [t is pushing the girl]] is tall.
b. [The boy][who [the girl is pushing t]] is tall.
c. Show me [the boy][who [t is pushing the girl]].
d. Show me [the boy][who [the girl is pushing t]].

(11) Hypothesis	Prediction for each type			
	a	b	c	d
I Linear assignment	+	I	+	I
II Trace deletion	+	C	+	C
III Complexity	2	1	4	3

(+, normal performance; C, chance level; I, inversion of thematic roles; number, relative ordering of performance level).

We can now proceed to the experimental procedure itself.

The method of presentation has already been discussed above. What remains to be discussed is the important issue of the pictures from which the subject had to choose the correct response. Here one is concerned with the assignment of thematic roles in the relative clause, and the pictures were varied exactly in this respect. That is, for every sentence there was a set of three pictures: one depicting the correct thematic organization; another depicting inverse thematic organization (where Agent becomes Theme and vice versa); and a third, unrelated picture for control—just to make sure that when performing at chance level, the patient does so for the reasons mentioned above, and not because she/he does not understand the task and/or the content of the stimulus sentence.

A set of 40 auditorily presented sentences and visually presented pictures (see Appendix for the whole list) was thus given to the subjects. It consisted of 10 sentences of each of the four relative types in (11). Each sentence was semantically reversible, and made use of frequent, everyday English nouns and verbs. The pictures were clear and simple line drawings depicting one action and two characters—one Agent and one Theme (patient), both equiprobable to perform the action from a semantic and pragmatic point of view. Half the time, one figure was the Agent; in the other half, the situation was reversed, so that "learning" was not possible, given that the subject encountered every picture 4 times (once for each grammatical type).

The sentences were presented in a quasi-random order; that is, they were randomized, but with the constraint that two sentences with the same meaning must be at least 3 items apart from one another. Also, the sentences were mixed with sentences from another experiment. The subjects received all the test items in a single session.

The instructions were to match one picture to the sentence heard. They were repeated if necessary, with some demonstrations, and two practice items were allowed. Then the experiment began.

3.2. Subjects

Eight subjects were tested in this experiment. They were 4 agrammatic aphasics, and 4 normal controls, who were expected to perform without

any error on the test. Subjects were roughly matched for age, educational level, and socio-economic status. They were all paid volunteers, recruited through the Aphasia Research Center at the Boston VA Medical Center. Diagnosis of the patients was based on the BDAE (Goodglass & Kaplan, 1972), CT scan information, when available, and clinical workup. The details for the agrammatic subjects (3 males and 1 female) are summarized in Table 1. They all showed agrammatism both in their output, which was telegraphic, and in comprehension, as discerned on a number of informal clinical assessments. Their lesions (when known) involved broadly the area of the brain implicated in Mohr's (1976) discussion of Broca's aphasia.

3.3. Results

In Table 2 the raw data (proportion of errors) are given for each agrammatic subject, listed by condition. The results were given statistical treatment. First, a planned comparison was carried out in which subjects' performances in the two center embedded conditions (a,b) were summed and contrasted against the corresponding sums from the two right branching conditions (c,d). This contrast revealed no significant difference, $F < 1.0$. However, the comparison pitting the two subject relatives (a,c) versus the two object relatives (b,d) was statistically reliable, $F(1, 3) = 14.10$, $p < .05$. Thus, a hypothesis that does not group sentence types by gap position, but rather, in a way that is incompatible with this grouping, is rejected. Hypothesis III (Complexity) is one such case. Based on these two results we may conclude that Hypothesis III is incorrect. The results are consistent, rather, with both Hypotheses I and II.

Now, one would like to distinguish between the latter two hypotheses. The data show that in the conditions where the patients performed poorly, they performed at chance levels. Namely, a pairwise comparison between

TABLE 1

(12)	AGE	Handedness	Lesion site	Time post onset	Education
1. E.R.	50	right	No CT scan R hemiplegia	6 years	High school
2. L.D.	57	right	L fronto-parietal R hemiplegia	7 years	College
3. R.D.	68	right	No CT R hemiparesis	8 years	College
4. E.M.	67	right	L fronto-parietal R hemiplegia	7 years	8 years

TABLE 2

(13) Condition	Subject 1	2	3	4	$\bar{X}$
a. Center embedded subject relative	.2	.2	.2	.1	.175
b. Center embedded object relative	.4	.5	.8	.3	.5
c. Right branching subject relative	.1	.1	0	.1	.075
d. Right branching object relative	.4	.8	.5	.2	.475

the patients' performance on condition *b*—center embedded object relatives—and chance levels was far from significant in a two-tailed test [$t(3) << 1$], and the same was true of condition *d*—right branching object relatives [$t(3) < 1$]. On the other conditions, the patients' performance was well above chance: in *a*—center embedded subject relatives—the same test was highly significant [$t(3) = 13$, $p < .001$], and the same was true for condition *c*—right branching subject relatives [$t(3) = 17$, $p < .0004$].

These results are compatible with the predictions of Hypothesis II (Trace-Deletion), and run contrary to the prediction of Hypothesis I (Linear Assignment), according to which conditions *b* and *d* should yield consistent inversion of thematic roles, namely, *below* chance performance of the agrammatic patients.

The neurologically intact control subjects performed the task without any errors.

4. DISCUSSION AND SUMMARY

A careful look at the syntactic properties of the constructions tested in this experiment is now in order, to clarify the interpretation of the results. In (14) (shown in Fig. 3), the one structure tested by Caramazza and Zurif (1976)—center embedded object relative—is depicted (a reiteration of (5) above). Then, general properties of the sentences in the present study are discussed.

The sentence in Fig. 3 features the two properties that represent the variables tested here: type of embedding and location of gap in the relative clause. The former had two types: center embedding (15a) and right branching (15b) (shown in Fig. 4). In (15a) the relative clause (S_r) branches off the subject of the main clause (NP_{head} – the head of the relative), so that the embedding is in the middle of the main clause. In

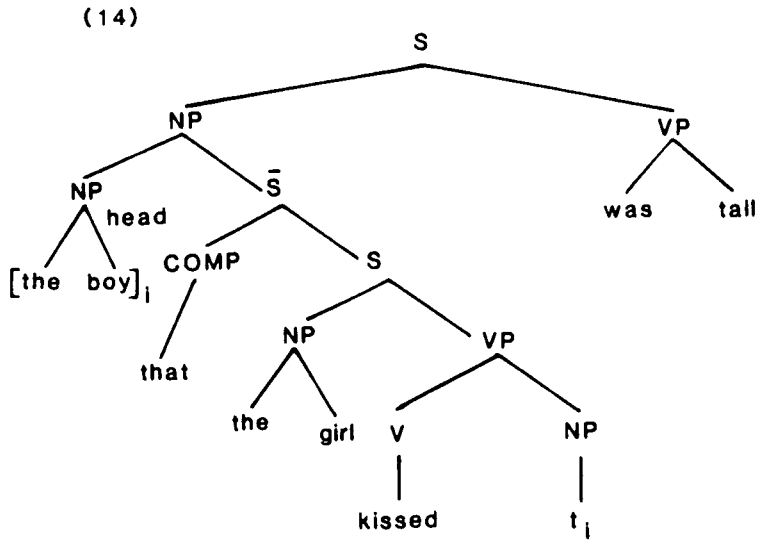

FIGURE 3

(15b), however, all the branching is to the right, because the head of the relative is the object of the main clause (see Fig. 4). The relativized NP in (15a) is the subject, resulting in a center embedded structure as in (14) (Fig. 3), whereas in (15b) we get a right-branching structure. This variation is a major contributor to the perceptual complexity of the sentences and is relevant to the Complexity Hypothesis (III) that was tested above.

The second variable is gap location. In (16) (see Fig. 5)—a right branching structure—the two types tested are demonstrated: (16a) contains a subject gap, represented by a trace (t), and (16b) has an object gap. The head of the relative clause, which is the NP carrying the index i, is associated with the empty category t which fills the gap. As Fig. 5 shows, in (16a) the gap is in subject, preverbal position in the relative clause (S_r), whereas in (16b) it is in object position. This contrast is relevant

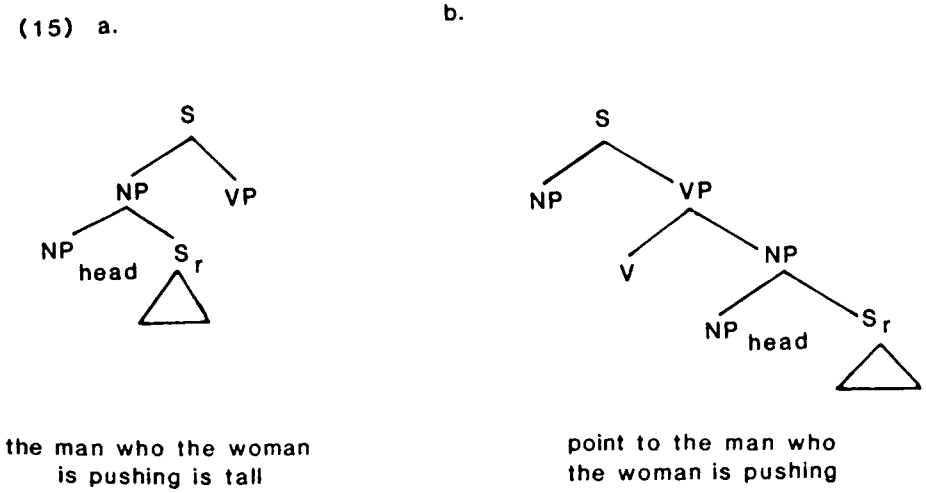

FIGURE 4

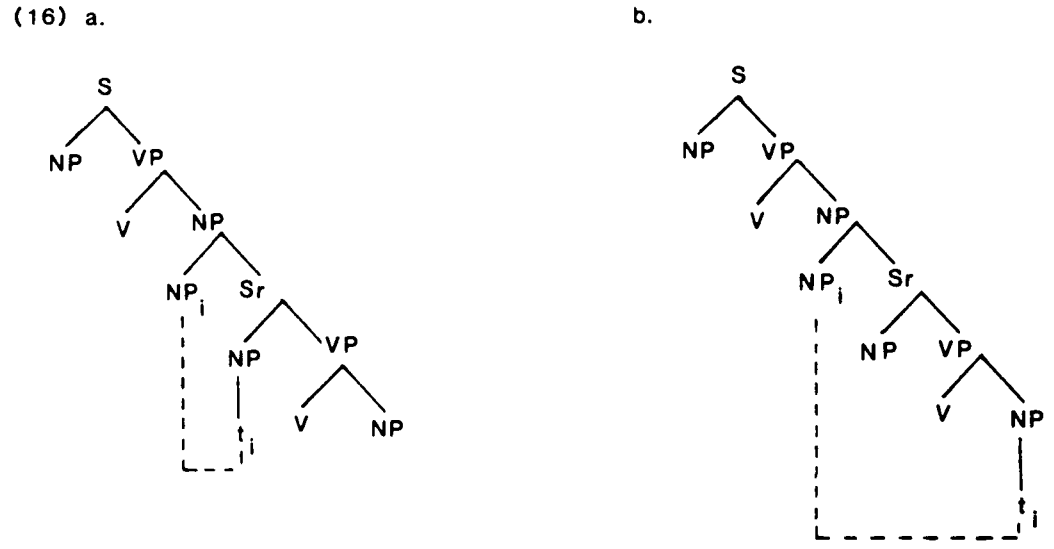

FIGURE 5

for the test of Hypotheses I and II (Linear Assignment and Trace-Deletion).

The results of the experiment (which, among other things, replicate Caramazza and Zurif's finding) are these: (1) The type of embedding does not interact with the agrammatic impairment. (2) The location of the gap determines the level of performance, such that on all object gap constructions performance is at chance level, and subject gaps are well above chance.

The hypotheses considered in the introductory part are of three different types: Hypothesis I—Linear Assignment—represents a nonlinguistic, heuristic-based approach to agrammatic comprehension in that it attempts to describe the observed comprehension pattern as following from general cognitive strategies rather than normal structural considerations. Hypothesis II—Trace-Deletion—adheres rather strictly to linguistic theory, and modifies it minimally to fit the agrammatic aberrant performance. Hypothesis III—Complexity—attempts to account for the performance by lowering the upper normal bound of the human perceptual ability to deal with input strings that are difficult to process.

The results serve as a means for ruling out Hypotheses I and III (Linear Assignment and Complexity). Linear Assignment (Caplan & Futter, 1986) predicts, correctly, that perceptual complexity would not hinder comprehension in agrammatism, and that subject-gap constructions would be performed above chance. It predicts incorrectly, however, that object-gap sentences would be performed below chance, namely, that the strategy the patients use would make them invert consistently the thematic roles in these cases. This hypothesis can thus be rejected.

Complexity predicts, incorrectly, that the type of embedding would correlate with agrammatic performance, which seems not to be the case.

Yet these results are consistent with Hypothesis II—Trace-Deletion. For this hypothesis, perceptual complexity is not a factor that interacts with the agrammatic limitation. Object gaps are predicted, correctly, to yield chance performance, in the manner described in the Introduction. Sentences containing gaps in subject position, however, are predicted to be performed above chance, under any construal of their syntactic status. If vacuous movement is disallowed (which is, briefly, a transformational operation that does not move constituents across others), then no traces appear in S-structure representations of these sentences, hence no deletion occurs, and the patients should have no problem with these structures. If, however, there is vacuous movement, then the trace in subject position is deleted, and the compensatory strategy assigns the NP that binds it the role of Agent, which happens to be the one it would normally receive (being linked to the subject of the relative clause). In this case, then, the strategy compensates correctly for the deficit, and the agrammatic patient performs normally, but for the wrong reasons. The data, then, are accounted for by the Trace-Deletion Hypothesis.

One may thus conclude that the extended data base for the grammatical description of the agrammatic limitation in comprehension strongly suggests that the performance patterns observed in agrammatism are not describable by nonlinguistic principles—be it heuristics or complexity considerations. Rather, it appears to be strongly linked to syntactic variables, and in particular, to transformational movement. This fact is a further step toward putting the theory of the normal function to a neuropsychological test (see Grodzinsky & Pierce, 1987, for one such demonstration). So, from a linguistic point of view the conclusion reached here is promising, because the aberrant performance patterns one discovers in aphasia may serve as a means of imposing neurologically based constraints on the theory of syntax.

APPENDIX

This appendix contains the stimulus materials used in the experiment. The sentences that were presented are listed by construction.

Subject embedded subject relatives:

1. The crow which is catching the cat is black.
2. The boy who is pushing the man is young.
3. The kid who is pulling the man is fat.
4. The woman who is photographing the girl is pretty.
5. The girls who are dragging the boys are pretty.
6. The doctor who is drawing the officer is young.
7. The soldier who is hitting the boy is tall.
8. The teacher who is grabbing the boy is strong.

9. The mother who is drying the girl is young.
10. The boy who is painting the man is young.

Center embedded object relatives:

1. The cat that the crow is catching is white.
2. The man that the boy is pushing is bald.
3. The kid that the man is pulling is fat.
4. The girl that the woman is photographing is tall.
5. The boys that the girls are dragging are tall.
6. The officer that the doctor is drawing is strong.
7. The boy that the soldier is hitting is tall.
8. The boy that the teacher is grabbing is short.
9. The girl that the mother is drying is little.
10. The man that the boy is painting is old.

Right branching subject relatives:

1. Point to the cat which is catching the crow.
2. Point to the man who is pushing the boy.
3. Point to the man who is pulling the kid.
4. Point to the girl who is photographing the woman.
5. Point to the boys who are dragging the girls.
6. Point to the officer who is drawing the doctor.
7. Point to the boy who is hitting the soldier.
8. Point to the boy who is grabbing the teacher.
9. Point to the girl who is drying the mother.
10. Point to the man who is painting the boy.

Right branching object relatives:

1. Point to the cat which the crow is catching.
2. Point to the boy who the man is pushing.
3. Point to the kid who the mother is pulling.
4. Point to the woman who the girl is photographing.
5. Point to the girls who the soldiers are dragging.
6. Point to the doctor who the officer is drawing.
7. Point to the soldier who the boy is hitting.
8. Point to the teacher who the boy is grabbing.
9. Point to the mother who the girl is drying.
10. Point to the boy who the man is painting.

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