

## Agrammatic Aphasic Subjects' Comprehension of Subject and Object Extracted *Wh* Questions

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This study attempted to replicate the unusual *wh* question comprehension pattern of Hickok and Avrutin's (1996) subjects who showed an expected subject/object extraction asymmetry for *which* NP questions, but not for *who* questions. We also examined comprehension of *what* and *which one* questions, which are similar to *who* and *which* NP questions, respectively, and we examined passivized *wh* questions in order to test predictions of Grodzinsky's (1995) restrictive theory of trace deletion, the Trace-Based Account (TBA). Results, using both a figurine manipulation task and a picture pointing task, showed that only one of four agrammatic (Broca's) aphasic subjects showed the pattern reported by Hickok and Avrutin and that this pattern extended to comprehension of *what* and *which one* questions. One of the subjects showed subject/object asymmetry for all *wh* questions tested, as would be predicted by the original trace deletion hypothesis (Grodzinsky, 1984), and two subjects showed neither pattern. None of our subjects demonstrated ability to comprehend passivized *wh* questions as predicted by the TBA. We discuss our findings in terms of the lack of homogeneity of *wh* question comprehension among individuals with agrammatic aphasia and we explore alternatives to the syntactic explanation for differences between *who* and *which* NP question comprehension advanced by Hickok and Avrutin. © 1999 Academic Press

Difficulty comprehending noncanonical sentences in English, such as passives, object relatives, and certain forms of *wh* questions, is a widely reported characteristic of agrammatic aphasia (Caplan & Futter, 1986; Grodzinsky, 1986; Sherman & Schweickert, 1989). According to syntactic theory, in par-

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ticular Government and Binding Theory (Chomsky, 1981, 1986), noncanonical sentences are derived through application of rules which involve movement of certain sentence constituents (usually noun phrases (NPs) from their original S-V-O position in the d-structure to a new position in the s-structure. When an NP is moved, a trace is left behind in its original position and a chain is formed consisting of the trace and the moved NP, such that the thematic role assigned by the verb is shared by both elements of the chain. Consider the following sentences with relative clauses:

1. The cop [who<sub>i</sub> t<sub>i</sub> is following the thief] is tall.
2. The cop [who<sub>i</sub> the thief is following t<sub>i</sub>] is tall.

In both sentences, there is a trace (t) in the relative clause; in (1) the trace (or gap) is in subject position and is assigned the thematic role of Agent by the verb. But in (2), the trace is in object position and is assigned the thematic role of Patient.

According to Grodzinsky's Trace Deletion Hypothesis (TDH; Grodzinsky, 1984, 1986) traces are deleted from agrammatic aphasic subjects' syntactic representations and, thus, the thematic role associated with the trace-antecedent chain is not assigned. The consequences of trace deletion with regard to interpretation of (1) and (2) are intuitive. If the trace is not established in (1), interpretation of the sentence will not be affected because subject extraction results in vacuous movement, whereas, if the trace is never associated with the moved NP in (2), interpretation of the sentence will be problematic. On Grodzinsky's account, aphasic individuals use a default interpretive strategy in order to interpret sentences, whereby the role of Agent is assigned to the first NP in the sentence. When there is a subject gap, this default assignment happens to be the correct one, but when there is an object gap, the representation contains two Agents, one assigned incorrectly by the default strategy and one assigned grammatically by the verb. With two possible Agents from which to choose, agrammatic comprehenders simply select one, rendering performance at chance level.

Hickok and Avrutin (1996) reported the results of an experiment in which two agrammatic aphasic subjects showed an interesting pattern in their comprehension of *who* questions and *which* NP questions. In their experiment, subject and object extractions of both *wh* question types as shown in (3) and (4) were tested.

Subject extracted.

- 3a. Who kicked the giraffe?
- 3b. Which elephant kicked the giraffe?

Object extracted.

- 4a. Who did the elephant kick?
- 4b. Which giraffe did the elephant kick?

Results showed the expected asymmetry in performance on *which* NP questions with subject extracted questions comprehended significantly better than object extracted ones. However, asymmetry was not noted on *who* questions. Performance was above chance for both subject and object extractions.

There are several distinctions between *which* phrases and *who* phrases that might account for the pattern noted by Hickok and Avrutin. First, according to Pesetsky (1987) *which* phrases are Discourse-linked (D-linked), requiring reference to previous discourse. For example, the *which* phrase *which giraffe* in (4b) above presupposes that one giraffe (from a set of giraffes), already mentioned in the discourse, was kicked. Conversely, *who* phrases are not D-linked as they do not require such reference. *Who* in question (4a), for example, does not refer to a certain element from a set. Thus, *who* phrases are considered nonreferential. Relatedly, Rizzi (1990) proposed that only NPs receiving referential theta roles (i.e., those that correspond directly to participants in an event) receive referential coindexing. When chains are formed involving these NPs, traces are licensed by binding and, therefore, *binding chains* (which allow for long distance movement) are formed. On the other hand, when nonreferential arguments (those that do not correspond to specific participants in an event) are moved, their traces are licensed by the stricter (more local) standard of government; thus, *government chains* are formed. Most importantly, Cinque (1990), based upon data drawn from Italian, extended Rizzi's proposal to *wh* phrases. *Which* NPs are referential and D-linked; thus they enter into binding chains. *Who* phrases are nonreferential and non-D-linked; thus they enter into government chains.

Hickok and Avrutin (1996) hypothesized that these distinctions between *who* and *which* NP questions might explain the comprehension patterns of their agrammatic subjects. They thereby proposed the Differential Chain Deficit Hypothesis, characterizing agrammatic comprehension as a deficit involving binding chains, in the face of relatively intact government chains. Their aphasic subjects showed difficulty with object extracted *which* NP questions, purportedly formed by binding chains (D-linked and referential), but not with object extracted *who* questions which are purportedly formed by government chains (non-D-linked and nonreferential).

One problem with this analysis, however, is that there may not be a clear distinction between these types of *wh* questions. Rizzi, for example, defined referentiality based on theta role type, e.g., the apparent grammatical difference in extractions involving arguments and adjuncts. On this account, both *who* and *which* NP questions involve the formation of binding chains, whereas other *wh* questions such as *how* and *why* involve the formation of government chains. Further, tests for referentiality proposed by Cinque (1990) are problematic to the extent that they fail to distinguish between *who* and *which* NP questions.

Another problem with Hickok and Avrutin's hypothesis concerns the comprehension of other sentence types in the pretest performance of their sub-

jects. Their subjects showed the characteristic pattern of comprehension difficulty seen in many agrammatic aphasic individuals: They had little difficulty comprehending subject-relatives and active sentences, but showed chance performance in comprehending object-relatives and passives. As pointed out by Grodzinsky (1995), in order for Hickok and Avrutin's hypothesis to be correct, the movement involved in passive sentences must result in a binding chain, yet it is not at all clear that this is the case. Grodzinsky thus concluded that the account proposed by Hickok and Avrutin cannot be correct.

Grodzinsky (1995), however, revised the Trace Deletion Hypothesis to account for the data presented by Hickok and Avrutin's two subjects, proposing the existence of a default strategy (R(eferential) strategy) which applies only to *referential* NPs (as in *which* NP questions), as opposed to nonreferential NPs (as in *who* questions). With this subtle restriction, the new trace-based account (TBA) could account for asymmetries in comprehension of active/passive pairs and the like, and it also correctly predicted the performance of Hickok and Avrutin's subjects. Faced with an object extracted *which* NP question (as in 4b), the R-strategy assigns the role of Agent to the first referential NP (*which giraffe*) and the verb correctly assigns the role of Agent to *the elephant*; thus, two Agents are assigned, the coin is tossed, and one is picked. Performance is at chance. For *who* questions (as in (4a)) the R-strategy does not apply, *the elephant* is properly assigned the role of Agent, and comprehension is above chance.

Grodzinsky (1995) points out that the restrictive TBA makes a surprising prediction for passives with quantified subjects (as in (7) below) vs. passives with referential subjects (as in (8)). Above chance comprehension of sentences like (7), but not (8) should be seen in agrammatic aphasic individuals. Grodzinsky cites data from Saddy to support this prediction. Consider the following:

7. *Every man* was photographed by a child.

8. *A man* was photographed by a child.

Saddy (1995) found that for agrammatic aphasic subjects sentences like (7) resulted in "[good] recognition of the thematic roles played by the actors, while [sentences such as (8)] resulted in . . . apparent lack of sensitivity to thematic roles" (p. 140).

The restrictive TBA makes a similar prediction for agrammatic aphasic comprehension of subject extracted *who* questions formed from passive sentences.

9. [CP *who*<sub>i</sub> [IP *t*<sub>i</sub> was followed *t*<sub>i</sub> by the elephant]]

Comprehension of sentences like (9) should be relatively spared as *who* is quantifier-like, nonreferential, and exempt from the R-strategy. Thus, the

Agent theta role is not assigned based on linear position in the sentence. Instead, it is correctly assigned to *the elephant* through the preposition *by*. Using other inferencing strategies, the remaining role of Patient is assigned to *who*. Thus, interpretation of subject extracted *who* questions formed from passives is expected to be above chance.

Next consider the object extracted passive *who* question below:

10. [CP  $who_j$  was [IP the elephant $_i$  followed  $t_i$  by  $t_j$ ]]

Once again, according to the restricted TBA *who* is not assigned the role of Agent normally because transmission of the Agent role from the trace (in the object of the preposition position) to *who* is disrupted. And, because *who* is nonreferential, the role of agent is not assigned by linear position in the sentence (i.e., the R-strategy does not apply). Thus, *the elephant* is assigned Agent, resulting in comprehension below chance.

We undertook the present study to replicate and extend the experiment reported by Hickok and Avrutin. Indeed, we found the unexpected comprehension pattern reported by Hickok and Avrutin to be intriguing not only because it did not coincide with the comprehension patterns noted with other subject and object extracted sentences, but also because a parsimonious explanation of the data is unavailable. Therefore, we queried whether the pattern reported by Hickok and Avrutin would extend to other individuals with agrammatic Broca's aphasia. Indeed, if this pattern prevailed across aphasic subjects, then further efforts toward explaining the data would be warranted.

In the present study we also tested comprehension of *what* and *which one* questions in order to examine whether or not the pattern noted by Hickok and Avrutin would extend to other types of *wh* questions. In addition, we examined comprehension of passivized *who* and *which NP* questions to test Grodzinsky's restrictive TBA for passives with quantified subjects. We reasoned that Hickok and Avrutin's observation should extend to other *wh* questions, i.e., we predicted that comprehension of *what* questions would correspond with that of *who* questions, and comprehension of *which one* questions would pattern with *which NP* questions. Further, we reasoned that if Grodzinsky's TBA is correct, passivized subject extracted *who* question comprehension should be above chance, while comprehension of passivized object extracted *who* questions should be below chance, while passivized *which NP* questions (either subject or object extracted) should be at chance.

Finally, we were interested in examining the effects of the stimulus condition used in testing *wh* question comprehension. Therefore, we used a figurine manipulation task like that used by Hickok and Avrutin, and, in addition, we examined *wh* question comprehension using picture stimuli. Hickok and Avrutin claimed that figurine manipulation is easier for the agrammatic patient than using pictures; however, they did not directly test differences in these conditions.

TABLE 1  
Subject Characteristics

Subject	Age	Gender	Lesion site	Years postonset	Education (years)
MD (1)	44	M	LF	4.0	19
CH (2)	43	M	LFP	4.6	14
DL (3)	29	M	LFP	2.9	16
FP (4)	68	F	LFTP	4.5	12

*Note.* CVA, cerebral vascular accident; LF, left frontal lobe; LFP, left frontoparietal lobe; LFTP, left fronto-temporoparietal lobe.

## METHOD

### *Subject*

Four monolingual, English speaking individuals, three males and one female, participated in the study. All but one subject (Subject 1 (MD)) were right-handed and all had a single lesion in the left hemisphere resulting from cerebral vascular accident (see Table 1).

### *Language Testing*

Subjects were evaluated using the *Western Aphasia Battery* (WAB; Kertesz, 1982). Results for all subjects showed behavioral profiles consistent with Broca's aphasia. Aphasia Quotients (AQs) ranged from 62.4 to 77.2 (see Table 2).

To derive a detailed profile of syntactic and morphological skills, narrative samples were obtained from all subjects. These were elicited using the procedure of Saffran, Berndt, and Schwartz (1989) whereby subjects retell a familiar fairytale (i.e., *Cinderella*, *Little Red Riding Hood*). These samples were coded and analyzed using the linguistic coding procedure of Thompson, Shapiro, Tait, Jacobs, Schneider, and Ballard (1995). This involved analyzing the presence and correctness of syntactic, morphological, and lexical elements of productions. This analysis further confirmed the diagnosis of Broca's aphasia as the subjects' spontaneous

TABLE 2  
Subject Characteristics Derived from Administration of Western Aphasia Battery (Kertesz, 1982)

Western Aphasia Battery	Subject			
	MD (1)	CH (2)	DL (3)	FP (4)
Aphasia quotient	62.4	77.2	72.2	68.0
Fluency	4.0	5.0	4.0	5.0
Comprehension	8.1	8.5	7.5	7.9
Repetition	5.2	8.6	8.4	5.9
Naming	6.9	7.5	7.2	7.2
Reading	8.3	8.2	8.4	7.6

TABLE 3  
Sentence Production Characteristics Derived from Linguistic Analysis  
of Narrative Samples

	Subject				Normal subjects [ <i>M</i> ( <i>SD</i> )]
	MD (1)	CH (2)	DL (3)	FP (4)	
Mean length of utterance (MLU)	4.93	6.79	4.50	7.44	13.87 (2.14)
Percentage of grammatical sentences	10.2	43.1	18.2	10.8	89.80 (8.08)
Simple sentences	56.8	71.6	81.8	59.5	42.5 (16.9)
Complex sentences	43.2	28.4	18.2	40.5	57.5 (16.9)
Mean embeddings	0.53	0.25	0.14	0.49	1.03 (0.23)
Percentage of verbs produced with correct arguments	50.6	64.8	39.3	60	98.55 (2.00)
Mean verb morphology index (VMI)	2.02	2.14	1.96	1.93	2.62 (0.08)
Percentage of correct verb morphology	61.8	75.5	65.4	62.5	99.48 (1.37)
Open:closed class ratio	2.29	1.86	1.66	1.73	0.91 (0.08)
Noun:verb ratio	1.65	1.62	2.07	1.77	1.21 (0.25)

*Note.* Data are from normal, non-brain-damaged subjects derived from Thompson et al. (1995). The verb morphology index (VMI) reflects the morphological complexity of the verb. One point is assigned for the main verb; additional bound or free-standing morphemes are assigned addition points.

productions were slow, effortful, and agrammatic. As shown in Table 3, all subjects produced a low percentage of grammatical sentences. Simple sentence structures, i.e., sentences with no embedded clausal structure or movement transformations, were produced more often than complex ones. All of the subjects produced more nouns than verbs and more open than closed class words. These results indicated overall production patterns consistent with agrammatic aphasia.

The Philadelphia Comprehension Battery for Aphasia (PCBA) (Saffran, Schwartz, Linebarger, Martin, & Bochetto, n.d.) also was administered in order to determine the sentence comprehension abilities of our subjects. All subjects demonstrated impaired sentence comprehension with intact lexical comprehension and grammaticality judgment. Subjects demonstrated more difficulty with items involving semantically reversible foils (i.e., reversible sentences) compared to lexical foils (i.e., lexical sentences) (see Table 4).

Because the PCBA uses only 5 exemplars of each syntactic structure for testing comprehension of reversible sentences, subjects' comprehension of active, passive, subject-relative, and object-relative sentences was further tested using a comprehension battery developed in the Aphasia Research Laboratory at Northwestern University, the Northwestern University sentence comprehension test. Items included 20 exemplars of each sentence type and only semantically reversible foils were presented. For example, subjects were shown a target picture (e.g., *The man was kissed by the woman*) and a semantically reversible foil (e.g., *The woman was kissed by the man*). A sentence stimulus was read aloud by the examiner and the subject pointed to the picture that corresponded to the sentence. This test was used to determine whether subjects showed an asyntactic comprehension pattern: above chance performance on canonical active and subject-relative structures, but at or below chance performance on

TABLE 4  
Sentence Comprehension Characteristics Derived from Language Testing

	Subject			
	MD (1)	CH (2)	DL (3)	FP (4)
Philadelphia Comprehension Battery for Aphasia (%)				
Lexical comprehension	100	100	100	100
Grammaticality judgment	93	90	87	93
Sentence comprehension				
Reversible sentences	53	43	63	67
Lexical sentences	100	97	97	100
NWU Sentence Comprehension Test (%)				
Active	90	80	90	80
Passive	65	50	65	50
Subject relative	80	90	90	70
Object relative	60	30	40	30

noncanonical passive and object-relative sentences. Results (shown in Table 4) revealed that all subjects had the required profile for inclusion in the experiment.

### Materials

Toy figurines, similar to those described by Hickok and Avrutin (1996), were used in the auditory sentence–figurine manipulation condition. Ten small and easily manipulable animals were used. Hickok and Avrutin used five verbs in their study with each verb appearing three times for each *wh* question structure. The present study used 10 two-place, transitive verbs. With the target nouns (animals) and verbs, a total of 120 questions were developed to comprise the experimental sentences. Target questions included 20 *who*, 20 *which* NP, 20 *what*, and 20 *which one* questions. For each question type, 10 were subject extracted and 10 were object extracted. Passivized question stimuli included 20 *who* questions and 20 *which* NP questions. Once again, 10 each were subject extracted and 10 were object extracted. All sentences were designed to be plausibly semantically reversible. All target questions are included in Appendix A. A total of 80, 8 by 10 in., black and white line drawings were prepared representing the scenarios for testing question comprehension in the auditory sentence–picture matching condition. Passive questions were only tested using figurine manipulation.

Prior to the experiment, lexical comprehension of all nouns and verbs used in the stimuli were tested to ensure that all subjects were familiar with the vocabulary. A forced choice task was employed to test comprehension using both figurines and pictures. All subjects obtained 100% accuracy on this task.

### Procedures

At the beginning of each experimental session, subjects received two practice trials using nonexperimental stimuli to orient them to the task. All subjects demonstrated understanding of task requirements after these two trials. In both practice and experimental trials, the subject was instructed to watch the figurines closely. The examiner then performed a simple scenario using three figurines. For example, one scenario depicted a horse following a giraffe which in turn was following another horse. Following the action, the subject was presented with a target question (e.g., *Which horse is the giraffe following?*). The noun phrase being questioned

always corresponded to the toy figurine of which there were two in the scenario. The subject responded to the question by pointing to one of the animals. One repetition of each stimulus sentence was provided if requested by the subject. Subjects were given a 10-s response time following each sentence/scenario presentation.

The stimulus presentation procedure used in the picture condition was identical. A single picture depicting the scenario was presented together with a question stimulus and the subject pointed to the appropriate animal corresponding to the question.

Testing for each subject was completed over three sessions during a 2-week period. The order of presentation of conditions was counterbalanced across sessions and subjects. The 80 question exemplars were presented in random order in both conditions. Passive questions were tested in the last session. These, too, were presented in random order, with active counterparts of some of the sentences included as fillers.

## RESULTS

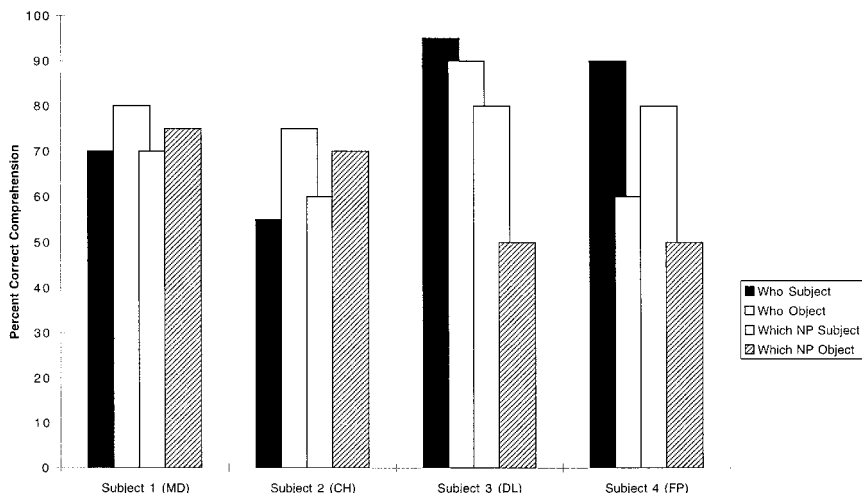
All analyses were carried out independently on each subject's data so that our findings could be directly compared with those of Hickok and Avrutin. Thus, we treat the subjects as four separate case studies. We used a paired samples, one-tailed *t* test, comparing each subject's performance to a hypothetical data set representing chance. We followed Hickok and Avrutin's method for calculation of chance; rather than 33% we used 50% because our subjects, like those of Hickok and Avrutin (1996), never responded by selecting the nonquestioned animal, even though there were three possible response choices for each query. For example, subjects *never* picked the giraffe for the question "Which horse followed the giraffe?" Instead, they picked one of the two horses.

### *Figurine Manipulation Compared to Picture Condition*

Results of the study showed identical patterns of performance in the figurine manipulation and picture conditions across subjects; accuracy levels were higher in the figurine manipulation condition for subject extracted questions. Using a 2 (stimulus type: figurine versus picture)  $\times$  2 (extraction site)  $\times$  4 (*wh* question type) multiple analysis of variance (MANOVA), no main effect for stimulus type was found ( $F(1) = 2.622$ ;  $p = .20$ ). However, a significant interaction existed between stimulus type and extraction site ( $F(1) = 147.00$ ;  $p = .001$ ), indicating better performance in the figurine condition than in the picture condition on subject extracted questions. Because of the noted similarity in performance across conditions, the data derived from the two conditions were combined for further analyses.

### *Who and Which NP Questions*

The data for *who* and *which* NP question comprehension are shown in Fig. 1. As can be seen, only one of our subjects (Subject 3 (DL)) matched the profile reported by Hickok and Avrutin, with a clear subject-object asymmetry for *which* NP questions, but not for *who* questions. Performance



**FIG. 1.** Percentage of correct *who* and *which* NP question comprehension in the figurine plus picture conditions.

on subject and object gap *who* questions was 95 and 90% correct, respectively, significantly above chance (subject *who*:  $t(19) = 3.94$ ,  $p = .0005$ ; object *who*:  $t(19) = 3.56$ ,  $p = .001$ ). Similarly, high performance was noted on subject gap *which* NP questions (80% correct), again above chance ( $t(19) = 2.85$ ,  $p = .005$ ); however, performance on object gap *which* NP questions was at chance (50% correct).

Subject 4 (FP) showed a subject–object asymmetry for both question types, with better performance on subject extracted questions (subject *who* = 90% correct; subject *which* NP = 80% correct) than on object extracted ones (object *who* = 60% correct; object *which* NP = 50% correct). Performance was significantly above chance for subject extracted questions of both types (subject *who*:  $t(19) = 3.56$ ,  $p = .001$ ; subject *which* NP:  $t(19) = 2.85$ ,  $p = .005$ ), but not for object extracted questions (object *who*:  $t(19) = 1.43$ ,  $p = .0815$ ).

Different performance patterns were noted for Subjects 1 and 2. Subject 1 (MD) exhibited above chance performance on all question types (subject *who*:  $t(19) = 2.18$ ,  $p = .021$ ; object *who*:  $t(19) = 2.85$ ,  $p = .005$ ; subject *which* NP:  $t(19) = 2.18$ ,  $p = .021$ , object *which* NP:  $t(19) = 2.52$ ,  $p = .011$ ). Subject 2 (CH) performed significantly above chance on object extracted *who* and *which* NP questions ( $t(19) = 2.52$ ,  $p = .011$ ;  $t(19) = 2.18$ ,  $p = .021$ , respectively), but not on subject extracted questions of either type (subject *who*:  $t(19) = 1.00$ ,  $p = .165$ ; subject *which* NP:  $t(19) = 1.43$ ,  $p = .0815$ ).

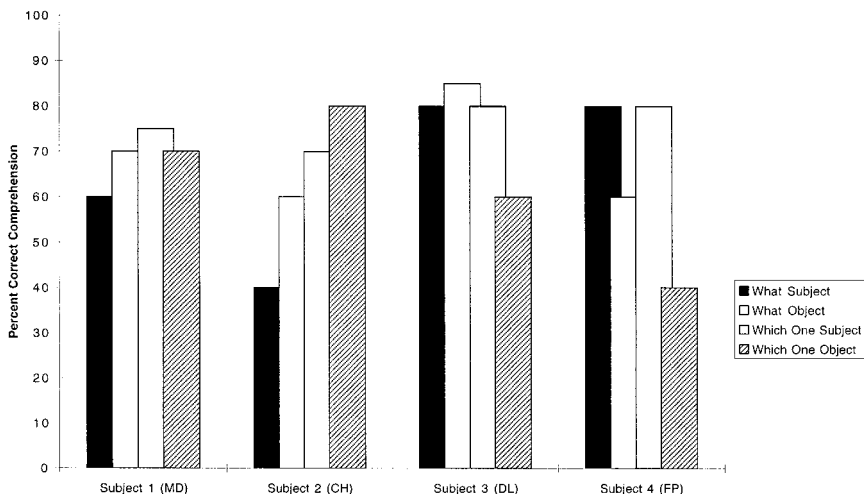


FIG. 2. Percentage of correct *what* and *which one* question comprehension in the figurine plus picture conditions.

### What and Which One Questions

In Fig. 2 we show composite performance for the subjects for *what* and *which one* questions, indicating performance patterns like those noted for *who* and *which* NP questions across subjects. Subject 3's (DL's) performance was significantly above chance for both subject and object gap *what* questions (80% correct,  $t(19) = 2.85$ ,  $p = .005$ , 85% correct,  $t(19) = 3.20$ ,  $p = .0025$ ), respectively) and for subject gap *which one* questions (80% correct,  $t(19) = 2.85$ ,  $p = .005$ ). Comprehension of object gap *which one* questions was not significantly above chance level (60% correct,  $t(19) = 1.43$ ,  $p = .0815$ ).

Subject 4 (FP) showed above chance performance on subject, but not object, gap questions of both types. Comprehension of subject extracted *what* questions was 80% correct, significantly above chance ( $t(19) = 2.85$ ,  $p = .005$ ), whereas comprehension of object extracted *what* questions was not (60% correct,  $t(19) = 1.43$ ,  $p = .0815$ ). For *which one* questions, subject gaps were 80% correct (above chance ( $t(19) = 2.85$ ,  $p = .005$ )); object gap questions were comprehended at 40% correct (below chance ( $t(19) = -1.45$ ,  $p = .0815$ )).

Subject 1 (MD) showed above chance performance on object (70% correct,  $t(19) = 2.18$ ,  $p = .021$ ), but not subject (60% correct,  $t(19) = 1.43$ ,  $p = .0815$ ), gap *what* questions, whereas, subject 2's (CH's) performance was not significantly above chance for either *what* question type (subject *what* (40% correct,  $t(19) = -1.45$ ,  $p = .0815$ ); object *what* (60% correct,  $t(19) = 1.43$ ,  $p = .0815$ )). Both subjects 1 (MD) and 2 (CH) showed above

TABLE 5  
 Percentage of Correct Comprehension of Passivized *Who* and *Which* NP Questions  
 (Figurine Manipulation)

Predictions:	Passive <i>who</i> questions		Passive <i>which</i> NP questions	
	Subject gap (above chance)	Object gap (below chance)	Subject gap (at chance)	Object gap (at chance)
MD (1)	50	50	70	60
CH (2)	50	40	80	40
DL (3)	60	80	70	70
FP (4)	80	60	70	70

*Note.* Predictions based on Grodzinsky's restrictive Trace-Based Account (1995).

chance performance on subject and object extracted *which one* conditions (MD: 75%,  $t(19) = 2.52$ ,  $p = .011$  for subjects; 70%,  $t(19) = 2.18$ ,  $p = .021$  for objects; CH: 70%,  $t(19) = 2.18$ ,  $p = .021$  for subjects; 80%,  $t(19) = 2.85$ ,  $p = .005$  for objects).

### *Comprehension of Passive Questions*

Recall that our subjects were pretested on comprehension of noncanonical sentences and showed an active-passive split, with above chance active sentence comprehension and at chance comprehension of passives. Recall further that Grodzinsky's (1995) restrictive Trace-Based Account predicted that comprehension of passivized *who* question comprehension would be above chance for those with subject, but not object, gaps.

Results of *who* and *which* NP passive sentence comprehension are shown in Table 5. These data indicated that none of the subjects performed as predicted by Grodzinsky. Above chance performance was noted for subject extracted *which* NP questions for Subject 2 (CH) (80%,  $t(9) = 1.96$ ,  $p = .042$ ), object extracted *who* questions for Subject 3 (DL) (80%,  $t(9) = 1.96$ ,  $p = .042$ ), and for subject extracted *who* questions for Subject 4 (FP) (80%,  $t(9) = 1.96$ ,  $p = .042$ ). All other passive questions were comprehended at chance levels.

## DISCUSSION

We undertook this study in an attempt to replicate the *who* versus *which* NP question comprehension pattern reported by Hickok and Avrutin (1996) and to examine *what* and *which one* question types. We also tested comprehension of *who* and *which* NP passive questions in order to examine predictions of Grodzinsky's restrictive TBA. Our findings showed that only one of four subjects (DL) demonstrated the question comprehension pattern

found by Hickok and Avrutin. One subject (FP) showed subject/object asymmetry for both *who* and *which NP* questions; one (CH) showed an object extraction advantage; and one subject (MD) showed little difference in comprehension of subject and object extracted sentences. Interestingly, performance on *what* questions largely patterned with performance on *who* questions, and performance on *which one* questions patterned with performance on *which NP* questions across subjects, as predicted. However, our data concerning passive *wh* question comprehension did not support the predictions of the restrictive TBA.

Our data also showed little difference in comprehension patterns using either picture stimuli or figurines. This finding was not surprising. In spite of the perhaps different processing demands inherent in figurine manipulation as compared to the picture condition, the same sentence parser is operating under both experimental conditions. Therefore, differences in performance patterns would not be expected.

The findings from this study indicate that, at best, there may be a subset of agrammatic aphasic subjects who show differences between *who* and *which NP* question comprehension. Given this characterization, the pattern must be explained. As pointed out above, the *wh* question comprehension data, as well as other data, do not support the postulate that binding chains, but not government chains, are implicated in aphasic comprehension deficit patterns. This explanation fails to account for established sentence comprehension patterns seen in aphasic subjects, i.e., passives are not clearly binding chains, yet they are comprehended poorly. Additionally, Hickok and Avrutin's syntactic theory is problematic in that the distinction proposed by Cinque (1990) based on data from Italian between *wh* movement forming government chains and *wh* movement forming binding chains has not been widely adopted within current syntactic theory.<sup>1</sup> Further, Hickok and Avrutin (1996) utilize Rizzi's (1990) referentiality theory to address *wh* expressions; however, Rizzi defined referentiality based on theta role type, i.e., the apparent grammatical difference in extractions involving arguments and adjuncts.

<sup>1</sup> See Chung (1994), who notes that the relationship of Cinque's account to the rest of syntactic theory is somewhat oblique, due largely to Cinque's appropriation of Rizzi's (1990) requirement that indices (i.e., subscripts<sub>i</sub>) be reserved for the expression of referential dependencies between arguments. Such a requirement would cause serious problems for the representation of coreference in variable anaphora. To cite Chung's example, bound variable pronominals can take both nonreferential and referential NPs as antecedents, as in (1) and (2) below. Rizzi, however, would restrict the use of coindexation to (2), suggesting an asymmetry which does not exist.

1. Who<sub>i</sub> loves his<sub>i</sub> wife?
2. Which man<sub>i</sub> loves his<sub>i</sub> wife?

See also Frampton (1991) for a discussion of this issue.

Finally, some tests for referentiality proposed by Cinque (1990) do not distinguish between the behavior of *who* and *which* NP questions.<sup>2</sup>

The role of referentiality in interpreting *wh* questions is also problematic given the experimental paradigms used in our experiment and in that of Hickok and Avrutin. Because *which* phrases are D-linked, requiring reference to previous discourse (Pesetsky, 1987), *which* NP questions, but not *who* questions, presuppose the existence of a set of people or animals, for example, from which one will be selected. Thus, in order to comprehend *which* NP questions both syntactic and contextual information is required. *Who* questions, on the other hand, do not normally require contextual information as the answer does not require picking something from a previously established set. However, the scenarios presented in our experiments testing the distinction between the two question types, indeed, provided reference for both *who* and *which* NP questions. Subjects were forced to answer both question types by picking from the set provided in the scenarios. Thus, correct interpretation of *both* question types required syntactic and contextual information. Indeed, Cinque suggests that *who* can be referential “under very special contextual conditions forcing some linking to previous discourse” (p. 16). Certainly, the contextual environment used in the experiments discussed herein is an example of such a condition. Cinque notes further that “the addition [to *who*] of a phrase like *the hell* or *on earth*, which expresses surprise or ignorance of the possible answers and is thus incompatible with the choice among elements isolated in the previous discourse, suffices to exclude . . . discourse linking” (p. 16). However, the use of such a construction in the laboratory condition is pragmatically infelicitous, as indicated by the symbol #:

11. #Who on earth kicked the elephant?

For our subject who showed Hickok and Avrutin’s comprehension profile, we suggest that an account based on the integration of syntactic and semantic

<sup>2</sup> For example, Cinque claims that only referential phrases can enter coreference relations and that only referential phrases show weak crossover effects; he uses the examples below to prove the latter point.

1. Her<sub>i</sub> mother introduced Maria<sub>i</sub> to a boy
2. \*Her<sub>i</sub> mother introduced every girl<sub>i</sub> to a boy  
[ = Cinque’s (26), (27a)]

While weak crossover indeed tests coreferentiality and the relationship between *Maria* and *her* in (1) is a clear example of coreferentiality, the use of *every girl* as an example of a nonreferential NP is problematic. *Every* is a quantifier which must bind a variable; this process is distinct from that of coreference. Application of the weak crossover test to *wh* phrases demonstrates that it fails to differentiate between *which* NP and *who* phrases, which both exhibit weak crossover effects.

3. \*His<sub>i</sub> coach wondered which athlete<sub>i</sub> would win the race
4. \*His<sub>i</sub> coach wondered who<sub>i</sub> would win the race

representations is less problematic. Because subject/object asymmetry, at least for *which* NP and *which one* questions, is part of the pattern, the syntactic representation must be considered in any equation. However, because *who* and *what* questions do not show this asymmetry, a complete explanation cannot be derived based on syntactic theory alone. We, therefore, suggest that semantic distinctions among *wh* questions be considered. Comprehension of object extracted *which* NP questions may have been difficult not only because the syntax is difficult, but also because *which* NP questions are semantically difficult. To illustrate, consider (12) and (13).

12. Who/What kicked the elephant?  
 $\exists x$ : (kick-elephant ( $x$ ))
13. Which giraffe kicked the elephant?  
 $\exists x$ : (giraffe ( $x$ ) & (kick-elephant ( $x$ )))

These examples show the computations required to solve the identity of the variable  $x$ . As can be seen, only one computation is required for the interpretation of *who* or *what* questions in (12); however, *which* NP questions (in (13)) require a conjoint computation. Therefore, it could be argued that *who* questions (as well as *what* questions) are semantically simpler to process than *which* NP questions.

Another possible explanation may be derived by consulting Chomsky's most recent theory, the Minimalist Program (Chomsky, 1993, 1995; Marantz, 1995). Here Chomsky distinguishes between *who* and *which* NP questions based on the type of movement involved. In the Minimalist Program, the definitions of minimal and maximal X-bar categories are reformed. It is proposed that nonbranching projections are minimal,  $X^0$  categories. Thus, *who* questions are considered minimal, akin to head, rather than phrasal movement. The difference in comprehension between *who* and *which* NP questions then reduces to the difference between head and phrasal movement. This explanation offers support for recent claims that head movement is intact in agrammatic aphasia (Hagiwara, 1995).

Before we go further in attempts to explain differences among *wh* question types additional data are needed not only derived from additional subjects in offline comprehension tasks, but also using other experimental paradigms. For example, experiments using online tasks such as those used by Zurif, Swinney, Prather, Solomon, and Bushell (1993) would be important in order to examine whether similar differences in processing of *wh* questions are seen. Additionally, experimental treatment paradigms examining emerging structures during recovery might shed light on the relations among *wh* questions (see Thompson & Shapiro, 1995).

## CONCLUSIONS

We were able to replicate Hickok and Avrutin's findings in only one of our four subjects who evinced language breakdown patterns, based on both

comprehension and production data, consistent with a diagnosis of agrammatic aphasia. Therefore, we conclude that, at best, Hickok and Avrutin's pattern of agrammatic comprehension may characterize a subset of individuals with agrammatic aphasia. Our subject whose performance replicated that of Hickok and Avrutin was not distinguishable in any systematic way from our other subjects in either comprehension pretest or production profiles. Additional research is needed to determine the pervasiveness of this pattern. Too, converging data derived from online processing experiments and well-controlled treatment research paradigms will more clearly delineate differences and similarities among certain *wh* question types.

The theoretical explanation for the *wh* question comprehension pattern offered by Hickok and Avrutin is problematic and, while a more parsimonious explanation may be one that appreciates both syntactic and semantic features of *wh* questions, we question the benefit of further attempts to explain this pattern until additional data supporting distinctions among *wh* questions are available. That is, it is possible that this pattern is an artifact, rather than a direct result, of the grammatical impairment giving rise to agrammatic Broca's aphasia. In this case, then, the nature of the data may detract from the ability to accede to a theoretical explanation. Indeed, a theoretical explanation of a fairly rare pattern, especially if it does not fit other empirical observations, may impede our progress toward understanding the nature of agrammatism.

#### APPENDIX A Stimulus Sentences for all Conditions

Question type	Subject extraction	Object extraction
<i>Who</i> questions	Who followed the giraffe? Who kicked the leopard? Who pulled the elephant? Who pushed the rhino? Who chased the hippo? Who led the horse? Who shoved the hippo?  Who bit the monkey? Who passed the leopard? Who harmed the lion?	Who did the horse follow? Who did the giraffe kick? Who did the lion pull? Who did the zebra push? Who did the tiger chase? Who did the elephant lead? Who did the monkey shove? Who did the rhino bite? Who did the zebra pass? Who did the tiger harm?
<i>Which</i> NP questions	Which horse followed the giraffe? Which giraffe kicked the leopard? Which lion pulled the elephant?	Which giraffe did the horse follow? Which leopard did the giraffe kick? Which elephant did the lion pull?

APPENDIX A—*Continued*

Question type	Subject extraction	Object extraction
	Which zebra pushed the rhino? Which tiger chased the hippo? Which elephant led the horse? Which monkey shoved the hippo? Which rhino bit the monkey? Which zebra passed the leopard? Which tiger harmed the lion?	Which rhino did the zebra push? Which hippo did the tiger chase? Which horse did the elephant lead? Which hippo did the monkey shove? Which monkey did the rhino bite? Which leopard did the zebra pass? Which lion did the tiger harm?
<i>What</i> questions	What followed the giraffe? What kicked the leopard? What pulled the elephant? What pushed the rhino? What chased the hippo? What led the horse? What shoved the hippo?  What bit the monkey? What passed the leopard? What harmed the lion?	What did the horse follow? What did the giraffe kick? What did the lion pull? What did the zebra push? What did the tiger chase? What did the elephant lead? What did the monkey shove? What did the rhino bite? What did the zebra pass? What did the tiger harm?
<i>Which one</i> questions	Which one followed the giraffe? Which one kicked the leopard? Which one pulled the elephant? Which one pushed the rhino? Which one chased the hippo? Which one led the horse?  Which one shoved the hippo? Which one bit the monkey?  Which one passed the leopard? Which one harmed the lion?	Which one did the horse follow? Which one did the giraffe kick? Which one did the lion pull? Which one did the zebra push? Which one did the tiger chase? Which one did the elephant lead? Which one did the monkey shove? Which one did the rhino bite? Which one did the zebra pass? Which one did the tiger harm?

APPENDIX A—*Continued*

Question type	Subject extraction	Object extraction
Passive <i>who</i> questions	Who was followed by the horse?	Who was the giraffe followed by?
	Who was kicked by the giraffe?	Who was the leopard kicked by?
	Who was pulled by the lion?	Who was the elephant pulled by?
	Who was pushed by the zebra?	Who was the rhino pushed by?
	Who was chased by the tiger?	Who was the hippo chased by?
	Who was led by the elephant?	Who was the horse led by?
	Who was shoved by the monkey?	Who was the hippo shoved by?
	Who was bit by the rhino?	Who was the monkey bit by?
	Who was passed by the zebra?	Who was the leopard passed by?
	Who was harmed by the tiger?	Who was the lion harmed by?
Passive <i>which</i> NP questions	Which giraffe was followed by the horse?	Which horse was the giraffe followed by?
	Which leopard was kicked by the giraffe?	Which giraffe was the leopard kicked by?
	Which elephant was pulled by the lion?	Which lion was the elephant pulled by?
	Which rhino was pushed by the zebra?	Which rhino was the zebra pushed by?
	Which hippo was chased by the tiger?	Which tiger was the hippo chased by?
	Which horse was led by the elephant?	Which elephant was the horse led by?
	Which hippo was shoved by the monkey?	Which monkey was the hippo shoved by?
	Which monkey was bit by the rhino?	Which rhino was the monkey bit by?
	Which leopard was passed by the zebra?	Which zebra was the leopard passed by?
	Which lion was harmed by the tiger?	Which tiger was the lion harmed by?

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