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Training and Generalized Production of *wh-* and NP-Movement Structures in Agrammatic Aphasia

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The present research examines production of "complex" sentences, which involve movement of noun phrases (NPs), in 2 agrammatic aphasic subjects. According to linguistic theory (Chomsky, 1991, 1993), such sentences are derived using one of two movement operations, either *wh-* or NP-movement, subsumed under the general rule "move alpha." In this experiment recovery of both *wh-* and NP-movement derived sentences was investigated using a treatment research paradigm. Subjects were sequentially trained to produce either *wh*-movement (i.e., *who* questions, object clefts) or NP-movement (i.e., passives, subject-raising structures) derived sentences. Throughout training, generalization to untrained sentences relying on both types of movement was tested. The influence of training on aspects of narrative discourse also was examined. Results showed generalization patterns constrained to type of movement: Training *wh*-movement structures resulted in generalized production of untrained *wh*-movement structures without influencing production of NP-movement structures. Similarly, training of NP-movement structures resulted in generalization only to other sentence types also relying on NP-movement. Aspects of sentence production in narrative contexts also was improved with treatment. These data indicate that movement to an argument (A) position as in NP-movement is distinct from movement to a non-argument (A-bar) position, required in *wh*-movement. The site where movement terminates in the s-structure of noncanonical sentences appears to influence sentence production. These findings show that linguistic properties of sentences influence sentence production breakdown and recovery in aphasia.

KEY WORDS: agrammatic aphasia, sentence production, treatment, generalization, neurolinguistics

This paper examines production of complex, noncanonical sentences in Broca's aphasic individuals with agrammatism. It is well documented that agrammatic subjects have difficulty comprehending such sentences in that they cannot match semantically reversible sentences such as passives or those with object relative clauses to pictures at above chance levels (Caramazza & Zurif, 1976; Hickok & Avrutin, 1995; Saffran, Schwartz, & Marin, 1980). It has been postulated that this comprehension difficulty is related to the linguistic nature of noncanonical sentences. According to one set of theories (i.e., The Principles and Parameters Approach, Chomsky, 1991, 1993), these sentences are derived using a syntactic operation called *move alpha* that involves a mapping of representations from an underlying or d-structure onto s-structure. Simply put, this operation involves moving certain sentence constituents (usually noun phrases [NPs]) from their canonical (Subject-Verb-Object [S-V-O]) position in the d-structure to noncanonical

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positions in the s-structure. Importantly, a *trace* (i.e., an abstract marker) is left behind in the position vacated by the moved NP and a *trace-antecedent chain* is created, coindexing the trace site with the moved NP. The trace-antecedent chain allows the thematic roles of moved sentence constituents (assigned at the d-structure level of representation) to be maintained in the s-structure of noncanonical sentences—a crucial aspect of sentence interpretation.

Broca's aphasic subjects with agrammatism may have some impairment in the realization of trace-antecedent chains, thereby rendering comprehension of these structures difficult. One description of the agrammatic deficit (Grodzinsky, 1986, 1990, 1995) maintains that traces are deleted from agrammatic subjects' syntactic representations and, thus, the thematic role associated with the trace-antecedent chain cannot be assigned. On another account, Mauner, Fromkin, and Cornell (1993) suggest that the traces are present, but that the coindexation relation between the trace and the antecedent is not realized so that the thematic role, once assigned to the trace, cannot be transferred. Regardless of which characterization is correct, research has shown that agrammatic aphasic subjects also exhibit disturbances in the formation or realization of trace-antecedent chains in online sentence processing experiments (e.g., Nicol & Swinney, 1989; Swinney & Zurif, 1995; Zurif, Swinney, Prather, Solomon, & Bushell, 1993).

Although the relations among sentence comprehension, processing, and production in agrammatic aphasia are unclear, these patients also have difficulty producing complex, noncanonical sentences. Agrammatic aphasic patients' sentence productions consist primarily of simple, canonical, S-V and S-V-O structures: They rarely produce grammatically correct sentences with moved sentence constituents even in late stages of recovery from aphasia (Christiansen, Goodglass, & Gallaher, 1993; Thompson et al., 1995). Nevertheless, we have shown that noncanonical sentence productions do improve with treatment. Importantly, recovery of sentence production appears to be limited to sentences that share similar linguistic properties. For example, we (Thompson, Shapiro, & Roberts, 1993; Thompson, Shapiro, Tait, Jacobs, & Schneider, 1996) showed that training *wh*-question production results in generalization only to *wh*-questions that are similar both in their underlying representation and in the specific movement operations required to derive their surface forms. Training *who* question forms, which involves movement of the direct object NP from an argument position that is properly governed by the verb, resulted in generalized production of *what* questions, which also involves movement from argument positions. However, this treatment did not influence *when* and *where* questions, formed by moving an adjunct from a position not properly governed by the verb. Similarly, training of *when* questions resulted in generalization to *where* questions, but not to *what* or to *who* questions. These constructions differ critically in the properties associated with the trace site created by *wh*-movement.

In another study (Thompson & Shapiro, 1994) we investigated aphasic subjects' ability to produce sentences that rely on different types of movement: either *wh*-movement or NP-movement derived sentences (see below for a description of these types of movement). Subjects were trained to produce sentences with *wh*-movement (i.e., either *who*-questions such as *Who did the woman follow* or object clefts such as *It was the man who the woman followed* and, during this training, generalized production of these *wh*-movement derived sentences and one NP-movement derived sentence type, passive sentences, was tested (e.g., *The man was followed by the woman*). Results showed that object-clefts generalized to *who*-questions, but not to passive sentences. This finding, once again, indicated that sentence production is influenced by the type of movement operations required to derive their s-structure.

The purpose of the present study was to extend our investigation of noncanonical sentences derived from both *wh*-movement and NP-movement. Specifically, we sought to replicate our 1994 findings, investigating the influence of training *wh*-movement structures on untrained *wh*-movement structures and on NP-movement structures. In addition, we examined the influence of training NP-movement structures (i.e., passive and subject-raising structures) on untrained NP-movement structures and on *wh*-movement structures. Because the two types of movement differ critically on theoretical grounds we postulated that training agrammatic aphasic subjects to produce sentences relying on one type of movement would influence untrained sentences also relying on that movement type, but that such training would not influence production of sentences relying on the alternate type of movement.

Before the details of this experiment are presented, we present a brief overview of "move alpha" and the distinction between *wh*- and NP-movement from Chomsky's Principles and Parameters theory (Chomsky, 1991, 1993), which was derived from Chomsky's earlier Government Binding theory (Chomsky, 1981). Also see Shapiro (1997) for a more complete discussion of these two types of movement as well as related subtheories.

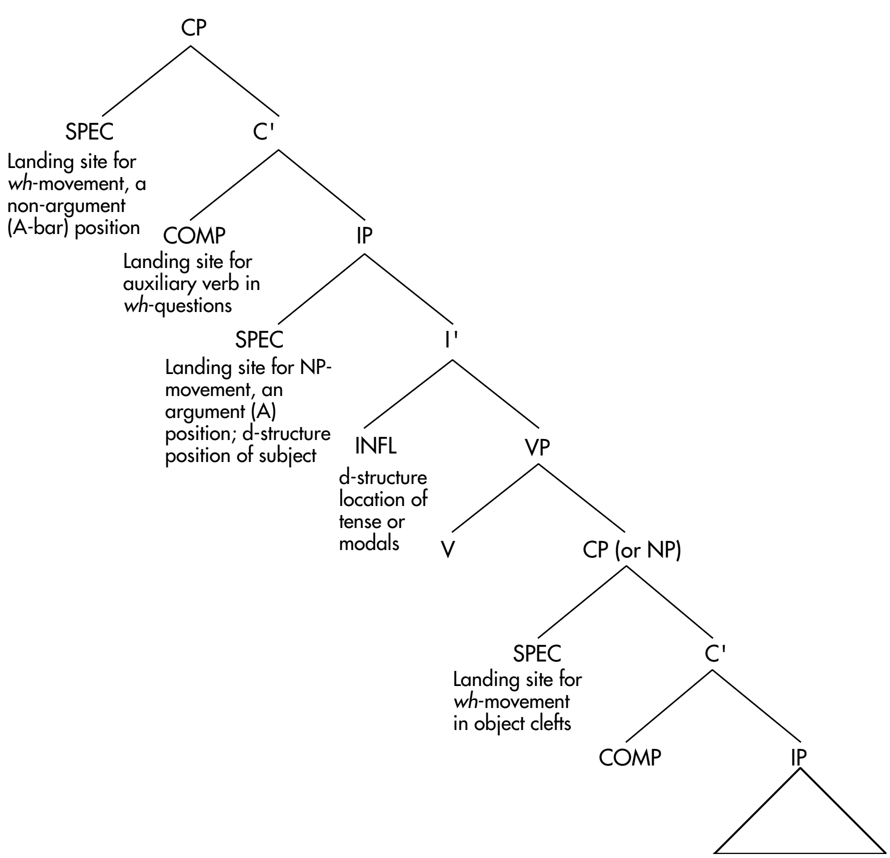
Wh *and NP-Movement*

According to linguistic theory there are at least two levels of representation for non-canonical sentences of the type that we are interested in here: the underlying or d-structure (akin to the basic S-V-O pattern in the

English language) and the s-structure (the structure derived once certain sentence constituents such as NPs are moved). The syntactic operation that moves NPs out of their canonical position is referred to as the transformation "move alpha." This general transformation replaces the large number of structure- and language-specific transformations that existed in earlier theoretical accounts of noncanonical sentences.

There are two major types of movement subsumed under the general transformation move alpha, *wh*-movement and NP-movement. Both *wh*- and NP-movement leave behind traces in positions (e.g., the direct object position) that are assigned theta-(thematic) roles by the verb (argument traces). The major difference between the two types of movement is related to the position (with reference to hierarchical tree structures) that the moved constituent takes once it is moved. The moved elements have different landing sites that have differing syntactic properties. In *wh*-movement, NPs are moved from argument positions (i.e., direct object position) to non-argument positions (i.e., Specifier of CP; [SPEC, CP]) that do not receive theta-role assignment directly by the verb. Thus, in this case an A-bar (non-argument) chain is formed. In NP-movement, an NP is moved from an argument position (e.g., the direct object position in passive sentences) to another argument position; the moved constituent terminates in subject position, Specifer of IP ([SPEC, IP]), forming an A-chain (argument chain). We adopted a notation introduced by Chomsky (1986). IP (Inflection Phrase) is equivalent to what was formerly denoted as S. CP (Complementizer Phrase) is equivalent to what was formerly S′. The different landing sites associated with *wh*- and NP-movement are shown in the tree diagram in Figure 1.

Figure 1. Diagram illustrating the major phrasal geometry of sentences and the relations among elements within a tree structure. Shown here are the local trees headed by CP (complementizer phrase, formerly S′), IP (inflectional phrase, formerly S), and VP (verb phrase). Going from the top down, the Specifier position of the COMP-headed local tree [SPEC, CP] is the landing site for movement in *wh*-questions. The head of CP, COMP, is a lexical category that can be filled, either at d-structure or through auxiliary verb movement (i.e., subject-auxiliary inversion) as in *wh*-questions. The next level down is the local tree headed by IP. Its Specifier position [SPEC, IP], the d-structure subject position, is the landing site of the moved sentence constituent in NP-movement. The local head, INFL, contains verb tense and agreement information.



Wh-*Movement Structures*

The *wh*-movement structures of interest in our experiment included *wh*-questions and object clefts. Consider, for example, the following sentences:

1. Who has the biker lifted? (*wh*-question)
2. It was the student who the biker lifted. (object cleft)

Indeed, on the face of it, these two sentences appear to be quite different. It turns out, however, that these two sentences are fundamentally similar in that they both rely on the syntactic operation *wh*-movement. The following examples show how *wh*-movement operates in the two sentence types below and identify some distinctions between them.

Wh-Questions

To illustrate the movement required to derive *wh*-questions as in (1) note again that noncanonical sentences are derived from an underlying- or d-structure as approximated in (3). The symbol ϕ is used here to indicate a movement site that is vacant at d-structure.

3. ϕ the biker lifted [who]

To form a *wh*-question, the *who*, which occupies a direct object argument position, is moved to the front of the sentence. Before movement occurs, thematic roles are assigned by the verb to all argument positions. The verb *lift*, for example, assigns its theta (thematic) role to *who*. Importantly, a trace (t) of that movement is left behind in the original position occupied by *who* and a chain is formed between the trace and the antecedent (i.e., the moved sentence constituent) of the trace. In this manner, the antecedent to the trace (in this case *who*) and the trace site (i.e., the direct object argument position) are co-indexed, forming a trace-antecedent chain as denoted in (4) using subscripting.

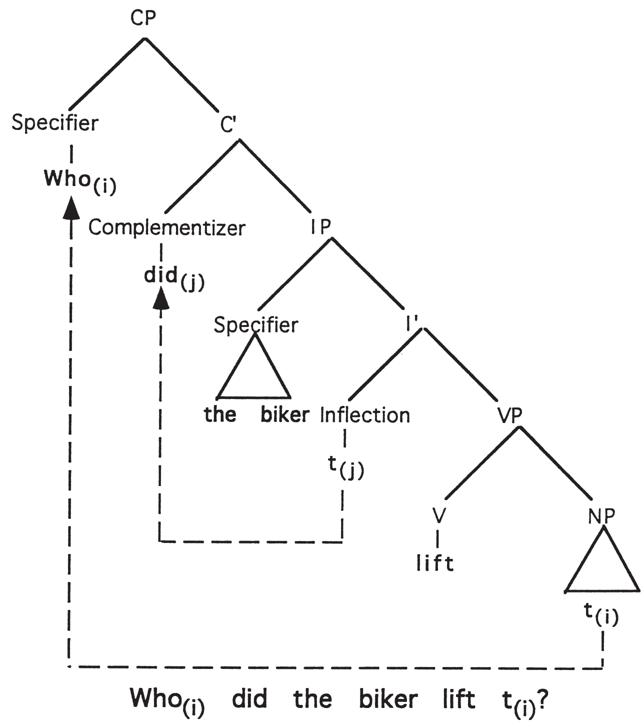
4. $[_{CP}$ who$_i$ $[_{C'}$ has $[_{IP}$ the biker lifted $_{trace\ i}$]]
   chain = [who$_{i,\ trace\ i}$]

The landing site for the *wh*-word (with reference to tree structures) is a non-argument position. Specifically, it lands in the Specifier position of CP, referred to as [SPEC, CP]. The landing site of *wh*-movement in *who*-questions is illustrated in Figure 2. The additional operation of subject-auxiliary verb inversion (verb movement) also is illustrated. The landing site for the auxiliary verb is COMP, the head position of CP.

Object Clefts

Now consider another construction that also involves *wh*-movement, the object cleft construction. As in *wh*-questions, movement occurs from direct object position—with *who* landing in the Specifier of CP [SPEC, CP]—and a chain is formed between the trace site and *who* as shown in (5).

Figure 2. Tree diagram illustrating *wh*-movement in *who*-questions.



5. It was the student [ϕ the biker lifted who]
   $[_{CP}$ It was the student $[_{CP}$ who $_i$ $[_{IP}$ the biker lifted $_{trace\ i}$]

It should be noted, however, that unlike *wh*-questions, object clefts involve movement within an embedded relative clause. In addition, in object clefts, a co-referential relation also holds between *the student*, NP head of the relative clause, and *who*. This referential relationship is illustrated below using the notational convention of superscripting:

6. It was the student^j $[_{CP}$ *who*^j_i $[_{IP}$ the biker lifted t1$_{i]}$.

To summarize, *wh*-questions and object clefts are formed through *wh*-movement operations. An NP is moved from a theta-marked (argument) position into a non-argument position [SPEC, CP]. In *wh*-questions this movement occurs in the matrix sentence, whereas movement in object clefts occurs within an embedded relative clause.

NP-Movement Structures

The NP-movement sentences of interest included passive and subject raising structures as in (7) and (8). Like our *wh*-movement structures, these NP-movement structures appear to be quite different on the surface. However, they are linguistically similar in an important way: both sentences rely on NP-movement.

7. The student was lifted by the biker.
8. The biker seems to have lifted the student.

Passives

As noted above, *wh*-movement involves movement from a (theta-marked) argument position to a non-argument position (i.e., the Specifier position of CP). NP-movement, however, involves movement from an argument position to another argument position, the Specifier position of IP ([SPEC, IP]). To illustrate the NP-movement involved in passive sentences, once again consider the d-structure approximated in (9).

9. ϕ was lifted the student by the biker.

To derive the passive, the direct object NP (i.e., *the student*) is moved and a trace of this movement is left behind (as in *wh*-movement). However, the landing site of the moved NP is the empty subject position ([SPEC, IP]) as in (10). Therefore, the trace is co-indexed with the moved sentence constituent that is now in the Specifier position of IP rather than with the Specifier position of CP as in *wh*-movement. The landing site ([SPEC, IP]) is shown in the tree diagram in Figure 3.

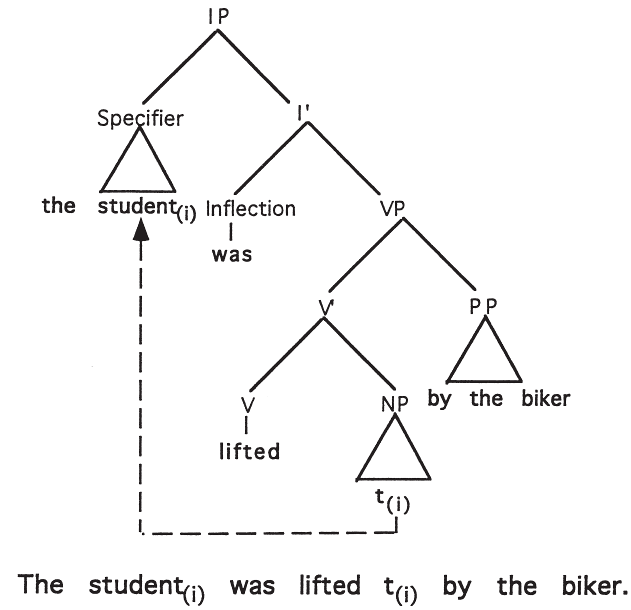
10. [$_{IP}$ The student$_i$ was lifted t$_i$ [by the biker]]

NP-movement in passive sentences occurs because passive verbs are prevented, by their passive morphology, from assigning Case to the object position. Case theory is a subtheory (Chomsky, 1981) that requires Case (e.g., nominative case, accusative case) to be assigned to every NP (Fabb, 1984). Case can be assigned only by certain syntactic elements called Case assigners, such as the verb (V), prepositions (P), or INFL (the abstract inflectional marker). Furthermore, because the subject position is vacant at d-structure, it is available as a landing site for an NP argument. Thus, because every NP must have Case, *the student*, in the above example, must move to the empty subject position. At this new position, it is assigned Case (from INFL) and it retains the thematic role (in this case Theme) that was assigned prior to movement. In full passives, as in (10), the role of Agent is assigned to *the biker*, through the preposition (*by*).

Subject Raising Structures

NP-movement is also involved in the derivation of what are called subject-raising constructions. In this type of sentence, movement is from the subject position of a sentential complement to subject position of the matrix sentence, as below in (11).

Figure 3. Tree diagram illustrating NP-movement in passive sentences.



11. ϕ seems [the biker to have lifted the student].

[$_{IP}$ The biker$_i$ seems [t$_i$ to have lifted the student]]

As in passive sentences, movement terminates with the moved constituent appearing in subject position. Skipping the details, movement occurs because: (a) the infinitive verb in the sentential complement clause cannot assign nominative Case to the subject position, and (b) a subject is required in the matrix sentence in all sentences in the English language. Raising verbs such as *seem* have no external argument in their representation; thus, their matrix subject position is vacant.

In this experiment, we examined the theoretical distinction between *wh*- and NP-movement and the importance of this distinction in agrammatic aphasic subjects' sentence production by looking for within-movement-type generalization. By training aphasic subjects to produce a *wh*-movement structure (e.g., object clefts), we expected to see generalization limited to the other *wh*-movement structure (i.e., *who*-questions). However, we predicted no generalization to the NP-movement structures. Similarly, by training one type of NP-movement (e.g. passives), we expected to see generalization limited to the other type of NP-movement tested (i.e., subject-raising), with no generalization to the *wh*-movement constructions.

In this experiment we used a single-subject experimental paradigm (Connell & Thompson, 1986; McReynolds & Kearns 1983; McReynolds & Thompson, 1986) to examine acquisition and generalization across sentence types. One sentence type was trained at a time, while the remaining ones were tested for generalization.

Throughout this training we also tested subjects' narrative production to assess the effect of training production of specific sentences on more general language production.

Method

Subjects

Two men, DM (Subject 1) and RP (Subject 2), with language production and comprehension patterns consistent with agrammatic aphasia served as the subjects. The aphasia, for both subjects, resulted from a single episode, left-hemisphere, thromboembolic stroke in the distribution of the middle cerebral artery (MCA). Lesions occupying the pars triangularis and opercular parts of the inferior frontal lobe were evident on CT scan for both subjects; however, Subject 2's lesion also extended posteriorly into the parietal area. At the time of the study, the subjects were 42- and 121-months post-onset of stroke, respectively. Both were native speakers of Standard American English. Subject 2 had completed 2 years of college and Subject 1 held an advanced degree in law. Premorbidly, Subject 1 was left-handed; Subject 2 was right-handed. Both subjects passed a pure-tone audiological screening at 40 dB HL at 500, 1000, and 2000 Hz.

Language Testing

Results of language tests administered prior to the study are shown in Table 1. Aphasia quotients (AQ) as derived from the Western Aphasia Battery (WAB; Kertesz, 1982) were 74 and 64.4, respectively. Auditory-verbal comprehension, although impaired, was superior to verbal expressive abilities. WAB comprehension subtest scores ranged from 9.0 to 7.3 with greater difficulty noted in comprehension of sequential commands than of yes/no questions or of single words. Fluency scores were 4.0 for both subjects, reflecting production of primarily short phrases and simple sentences. The 2 subjects had varying degrees of naming, repetition, and reading comprehension difficulties. However, both subjects demonstrated the ability to read short phrases and sentences aloud.

Table 1. Language testing data.

	Subject	
	DM (1)	RP (2)
Western Aphasia Battery (WAB)		
Fluency	4.0	4.0
Comprehension	9.0	7.3
Repetition	5.7	6.0
Naming	8.3	6.9
Reading	8.0	6.0
Aphasia Quotient (AQ)	74.0	64.43
Philadelphia Comprehension Battery for Aphasia (PCBA)		
Lexical comprehension	98%	100%
Sentence comprehension	78%	75%
Reversible	53%	63%
Lexical	100%	89%
Active/Subject relative	83%	80%
Passive/Object relative	65%	61%

Sentence comprehension was further tested using the Philadelphia Comprehension Battery for Aphasia (PCBA; Saffran, Schwartz, Linebarger, Martin, & Bochetto, 1989). This test contrasts: (a) lexical comprehension and sentence comprehension, (b) comprehension of semantically reversible and non-reversible sentences, and (c) comprehension of canonical and non-canonical sentences using a sentence-picture matching paradigm. Results indicated that lexical comprehension was superior to overall sentence comprehension and that semantically reversible sentences were clearly more difficult than non-reversible sentences. Comprehension of active sentences and subject relatives was superior to that of passives and object relative sentences. These findings were consistent with a diagnosis of asyntactic auditory comprehension.

Pre-Experimental Narrative Analysis

Narrative language samples were collected to establish lexical and morpho-syntactic patterns of production so that we might compare pre- and posttreatment language patterns. Samples were collected by asking subjects to tell the stories of *Cinderella* and *Little Red Riding Hood*. Books of each story, from which the printed words were deleted, were presented one at a time to assist the subjects in remembering the story. After each book was removed, subjects were instructed to retell the story. Narratives derived from both stories were combined to form a single sample. All samples were segmented into utterances (based on syntactic, prosodic, and semantic criteria) and entered into a computer for analysis. Samples then were analyzed using a method recently developed by Thompson et al. (1995). Sentences were coded for grammaticality, sentence type, and embeddings. All open class and closed class words were coded by class. Verbs were also coded by type and by argument structure. The complexity of verb morphology also was coded to derive a verb morphology index (VMI). Perseverative responses, starter phrases, and fillers were deleted from the analysis.

Results of this analysis revealed patterns of production consistent with a diagnosis of agrammatic aphasia;

both subjects produced primarily short utterances (MLU = 4.93 and 3.24, respectively) including few that were grammatical sentences (i.e., 26% of Subject 1's and 19% of Subject 2's sentences were grammatical). Most sentence productions were grammatically simple; they did not contain moved sentence constituents or embeddings. Simple sentences comprised 68% and 99% of the samples for the 2 subjects, respectively, whereas only 32% and 0.8% of their sentences were complex. The subjects' simple production was underscored by the mean number of embeddings produced, .404 and .005. Noun/verb ratios and open/closed class ratios indicated that the subjects produced more open class as compared to closed class words (2.05 and 2.52, respectively) and that of the open class words, subjects produced more nouns than verbs (noun:verb = 1.31 and 1.51 for the 2 subjects). See Table 2 for pretreatment narrative data as well as data for a non-brain-damaged comparison group (from Thompson et al., 1995).

Analysis of verb and verb argument structures showed that the subjects produced primarily two-place verbs (obligatory two-place verbs composed 11% of each subject's sample and optional two-place verbs composed an additional 21% and 56%, respectively). The subjects also produced a sizable proportion of complement verbs (52% and 17%, respectively). However, most of these verbs were produced with a direct object NP complement (in x, y form) rather than with a sentential complement (x, S′). Both subjects produced few three-place verbs (see Table 3).

It also is noteworthy that the subjects produced more one- and two-place verbs with correct argument structure as compared to three-place verbs, and they produced a number of copulas with correct arguments. Complement verbs were more often produced correctly with direct object NPs as compared with sentential complements. Overall, Subject 1 produced 43% of verbs with

Table 2. Narrative discourse data derived from analysis of pretreatment (pre), posttreatment (post) and follow-up samples.

	Subject 1 (DM)			Subject 2 (RP)			Normal subjects
	Pre	Post	Follow-Up	Pre	Post	Follow-Up	Mean (*SD*)
Total utterances	170	288	203	228	216	210	23.60 (7.09)
Total words	691	936	832	620	561	500	323.71 (113.57)
Sentence variables							
MLU	4.93	3.85	4.93	3.24	3.07	3.53	14.47 (2.20)
% Grammatical sentences	26%	36%	39%	19%	31%	30%	90% (8.0)
% Simple sentences	68%	54%	48%	99%	79%	77%	42% (16.9)
% Complex sentences	32%	46%	53%	0. 8%	21%	23%	58% (16.9)
Mean embeddings	.404	.418	.526	.005	.030	.032	1.03 (.23)
Lexical variables							
Nouns (total)	214	354	299	199	168	160	
% nouns	31%	38%	36%	32%	30%	32%	45% (5.0)
Verbs (total)	163	193	187	131	115	100	
% verbs	23%	21%	22%	21%	20%	20%	37% (4.0)
Noun:Verb	1.31	1.83	1.59	1.51	1.46	1.60	1.21 (.25)
Open class words (total)	465	679	582	444	403	345	
% open class	67%	73%	70%	72%	72%	69%	48% (2.0)
Closed class words (total)	226	257	250	176	158	160	
% closed class	33%	22%	30%	28%	28%	32%	53% (2.0)
Open class:Closed class	2.05	2.64	2.32	2.52	2.55	2.15	.91 (.08)
Verb morphology							
mean VMI*	2.12	1.98	2.12	1.80	1.51	1.57	2.62 (.08)
% correct VMI	71%	64%	62%	44%	46%	43%	100% (0.0)

Note. VMI = verb morphology index. A VMI is derived for each verb produced by assigning points. One point is assigned for the main verb and additional points are given for each grammatical element (e.g., one point is given for third person /s/, one point is given for an auxilliary verb, etc.). Normal subjects' data from Thompson et al. (1995).

Table 3. Verb and verb argument structure data derived from narrative discourse analysis of pretreatment (pre), posttreatment (post) and follow-up samples.

	Subject 1 (DM)			Subject 2 (RP)			Normal subjects
	Pre	Post	Follow-up	Pre	Post	Follow-up	Mean (*SD*)
Total verbs produced	163	193	187	131	115	100	57.14 (22.06)
Verbs produced by type							
Obligatory one-place (total)	1	6	14	7	11	9	
% OB1	0.6%	3%	7%	5%	10%	9%	10% (4.0)
% correct	100%	100%	83%	86%	82%	83%	100% (0.0)
Obligatory two-place (total)	18	9	19	14	12	15	
% OB2	11%	5%	10%	11%	10%	15%	17% (3.0)
% correct	44%	78%	78%	42%	66%	50%	99% (3.0)
Optional two-place (total)	34	33	32	73	59	43	
% OP2	21%	17%	17%	56%	51%	43%	16% (4.0)
% correct	35%	60%	67%	41%	61%	59%	97% (8.0)
Obligatory three-place (total)	2	0	2	0	3	5	
% OB3	1%	0%	1%	0%	3%	5%	3% (1.0)
% correct	0%	—	0%	—	67%	100%	100% (0.0)
Optional three-place (total)	12	10	17	8	6	5	
% OP3	7%	5%	9%	6%	5%	5%	13% (3.0)
% correct	33%	50%	50%	38%	33%	33%	98% (5.0)
Copula (total)	12	8	15	6	6	2	
% COP	7%	4%	8%	5%	5%	2%	12% (3.0)
% correct	92%	100%	86%	83%	67%	100%	100% (0.0)
Complement verbs (total)	84	127	88	23	18	14	
% COMP	52%	66%	47%	17%	16%	21%	30% (6.0)
% correct	40%	40%	41%	48%	78%	71%	99% (2.0)
Complement verbs: xy form (total)	49	53	33	22	16	12	
% xy	58%	42%	38%	96%	89%	86%	36% (17.0)
% correct	80%	56%	80%	50%	73%	58%	98% (6.0)
Complement verbs: xS′ form (total)	35	74	55	1	2	2	
% xS′	42%	58%	63%	4%	11%	14%	63% (18.0)
% correct	35%	28%	20%	0%	50%	100%	100% (0.0)
Verbs produced with correct verb							
Argument structure (total)	70	97	105	61	75	52	
% correct	43%	50%	56%	46%	65%	52%	99.12% (2.25)
Argument/Adjunct production							
Agent (x) (total)	153	201	84	130	125	67	
% correct x	78%	93%	91%	53%	72%	64%	99% (2.0)
Theme (y) (total)	113	141	64	63	71	36	
% correct y	79%	89%	88%	69%	89%	81%	100% (1.0)
Goal (z) (total)	3	4	1	3	8	3	
% correct z	33%	50%	0%	75%	63%	100%	95% (13.0)
Sentential complements (S′) (total)	44	76	26	1	3	2	
% correct S′	25.0%	29%	23%	0%	33%	100%	100% (1.0)
Predication phrase (p) (total)	35	49	26	14	17	4	
% correct p	94%	98%	100%	93%	82%	100%	99% (3.0)
Adjunct (j) (total)	11	14	6	10	15	7	
% correct j	45%	50%	33%	70%	53%	57%	95% (11.0)

Note. Normal subjects' data from Thompson et al. (1995).

correct argument structure; Subject 2 produced 46% of verbs with correct arguments. These data support the findings derived from our previous work in that our agrammatic subjects not only produced fewer verbs than age-matched normal subjects, but they also demonstrated a preference for producing primarily simple verbs that require accessing simple argument structure arrangements. Attempts to produce more complex verbs (i.e., those that take a greater variety of argument structure arrangements) resulted in either selection of the more simple form or in failure.

Experimental Stimuli

Using a set of 15 transitive verbs, 15 active sentences of the form NP-V-NP were developed. All sentences were semantically reversible and used animate nouns. Neither the nouns nor the verbs were more than two syllables in length. Mean frequency of occurrence for the verbs was 116 per million (range = 2 to 298) and mean frequency of occurrence for the nouns was 228 per million (range = 3 to 2110) (Frances & Kucera, 1982). For each sentence a picture stimulus was developed. A picture stimulus also was developed to represent the semantically reversible counterpart of each sentence. For example, one sentence stimulus was *The biker lifted the student*. For this sentence, one picture (the target) showed a biker lifting a student and the other (the foil) showed a student lifting a biker. All picture stimuli were artist drawn, black and white line, 8.5 x 5.5 inch drawings. To help overcome subjects' word retrieval difficulties, noun and verb labels were included on the pictures in large print (font = 18 point). One noun was placed in the upper right corner; the other noun was placed in the upper left hand corner of each picture. The verb was centered at the bottom of each (see Figure 4).

A list of sentence stimuli used in the study is presented in Appendix A. Using these sentence stimuli, as well as the picture stimuli, each of the sentence types of interest in the study was elicited using a sentence production priming task (see baseline procedures). For example, using the active sentence, *The biker lifted the student*, the following *wh*-question, object cleft, passive, and subject-raising sentences were elicited:

12. *Wh*-question—*Who has the biker lifted?*
13. Object cleft—*It was the student who the biker lifted*.
14. Passive—*The student was lifted by the biker*.
15. Subject-raising—The biker seems to have lifted the student.

For treatment purposes, an additional set of stimuli was developed. This set included individual sentence constituents contained within each training sentence (i.e., NPs and verbs) as well as grammatical elements required in the s-structure of target sentences types (e.g., *it*, *was*, *who*, *by*, *has*, *to have*). These sentence constituents and grammatical elements were written on 3.5 x 5 inch cards (font = 18).

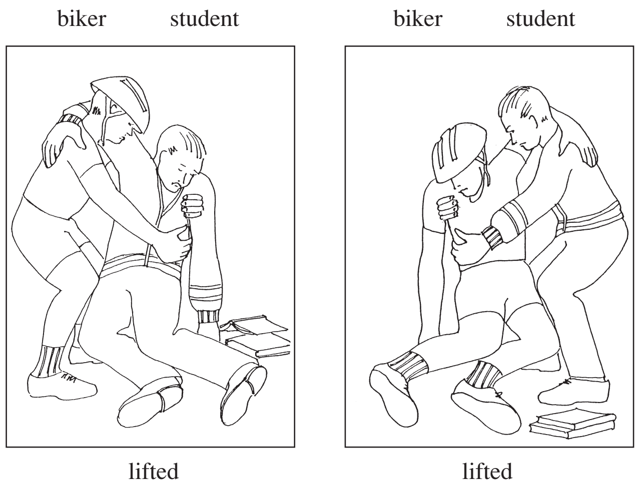
Experimental Design

A single subject multiple-baseline design across behaviors and subjects was used. As has been discussed elsewhere, single-subject experimental paradigms are particularly well suited for examining language generalization patterns in aphasic subjects (see Kearns, 1992; Kearns & Thompson, 1991; Thompson, 1992; Thompson & Kearns, 1991, for review). Prior to the application of treatment (during the baseline phase) production of all sentence types was tested using all experimental stimuli. One sentence type, relying on either NP or *wh*-movement, then was trained. Throughout this training, the remaining sentence types were tested for generalization. When generalization occurred across sentence types relying on the same movement process, treatment was applied to one of the other sentence types relying on the alternate movement process while generalization testing continued. Following baseline testing, Subject 1 was trained to produce one *wh*-movement structure: object cleft sentences. During this training, generalized production of *who* questions, which also rely on *wh*-movement, was tested. Additionally, subject-raising structures and passive sentences that rely on NP movement were tested. Next, subject-raising sentences, which require NP movement, were entered into training while generalization to untrained passive sentences (also relying on NP movement) was tested. The order of sentences trained was counterbalanced for Subject 2. He was first trained to produce passive sentences as generalized production of subject-raising structures (both relying on NP movement) was tested. Object cleft sentences and *who* questions were also tested for generalization and, finally, object cleft sentences were trained.

Baseline Procedures: Sentence Production Priming

Verbal production of the four sentence types was tested using a sentence production priming paradigm. This task entailed presentation of a pair of pictures (a target sentence and its semantically reversed foil) (see Figure 4). The examiner explained: "Here are two pictures. Both show a biker (pointing to the bikers) and both show a student (pointing to the students)." The target picture then was removed and, using the foil, a verbal model of one of the sentence types was provided for the subject. For example, to elicit an object cleft production, the examiner explained: "In this picture (pointing to the foil) *It was the student who the biker lifted*."

Figure 4. Semantically reversible picture stimulus pair used in the Sentence Production Priming Task.



The foil picture then was removed and the target picture was presented to the subject with the prompt: "In this picture _____?" Similar procedures were used to elicit the other types of sentences. Regardless of the sentence being elicited, each production trial began with the presentation of one pair of pictures and the identification of the nouns in each picture. Then the target picture was removed and the target sentence type was modeled using the foil picture. A 10-second response time was provided for production of each sentence. If a response did not occur within the allotted period, a new stimulus pair was presented and instructions to elicit another sentence type were provided. Feedback as to the accuracy of response was not given during baseline; however, intermittent encouragement was provided. All sessions were audiotaped for reliability purposes.

During each baseline session, the 15 picture pairs were presented four times each in random order (once for elicitation of each of the four sentence types), for a total of 60 sentence productions per baseline probe. Baseline sessions were approximately 2 hours long; subjects were given breaks during the period if needed. In keeping with the multiple baseline across subjects component of the experimental design, Subject 2 was held in baseline conditions for a longer period than Subject 1. Two complete baseline probes were completed for Subject 1; four baseline probes were completed for Subject 2.

All responses produced by the subjects during baseline testing were transcribed online by the examiner and an independent reliability observer situated behind a one-way mirror. Each response then was assigned a score from 0 to 8 to reflect salient characteristics of the response (see Appendix B). Grammatically correct productions of the correct target sentence (scores of 8) were considered correct. Responses scored as 7, those containing minor inflectional errors, omission of functional categories, or lexical substitutions, were also scored as correct. All other responses (scores of 0–6) were considered incorrect.

Treatment

Subjects were trained to produce each sentence type by taking them through a series of steps that emphasized the lexical and syntactic properties of the active declarative form of target sentences. In addition, movement operations required to form the s-structure representation of target *wh*- or NP-movement derived sentences were demonstrated. Using the active, declarative counterpart of target sentences, subjects were taught to: (a) point to the verb in each sentence and to the NPs representing the thematic roles of the verb (i.e., the verb argument structure), (b) move the proper sentence constituents to form the target sentence structure, and (c) produce the surface form of the targeted sentence type.

Each training trial began with a presentation of a stimulus picture pair and, as in baseline, the subject was given the opportunity to produce the target sentence type using the sentence production priming paradigm. If an incorrect response was produced (i.e., a response scored 0-6), the target picture was presented together with the sentence constituent stimulus cards representing the active form of the target sentence. For example, a sentence like (16) was presented (with each NP and the verb written on separate cards).

16. [the biker] [lifted] [the student] (active, declarative form)

Also on the table were the grammatical elements (in written form) needed to complete the target sentence type (e.g., *it was* and *who* cards for training object cleft productions). Using the active sentence, the examiner identified the verb while pointing to it (i.e., the examiner said: "The action in this picture is *lifted*. Someone lifted someone."). The examiner then identified the subject and object NPs and explained their roles in relation to the verb while adding the *who* card next to the object NP (i.e., the examiner explained: "The biker is the person doing the lifting and the student is the person being lifted. *Who* is added next to the student because he is the person who was lifted."). The examiner then moved the object NP and *who* cards to the sentence initial position while explaining: "We're going to make a new sentence about the biker and the student. To do this *the student* and *who* are moved to the beginning." The subject then was instructed to read or repeat the derived sentence. The *it was* card then was moved to the beginning of the sentence while the examiner explained that, "To make the new sentence complete, *It was* is added to the beginning." The subject then was instructed to read the new sentence. Finally, the sentence constituent cards were rearranged in their original order and the subject was instructed to move the cards to form the target sentence. Assistance was provided as needed. The foil picture stimulus then was re-presented and the sentence production priming procedure was repeated.

Subjects received treatment two times per week. During every session each of the training sentences was practiced at least one time and not more than two for a maximum of 30 training trials per session. Treatment for each sentence type was provided for a minimum of 14 training sessions and a maximum of 22. Subject 1 received a total of 42 treatment sessions (21 weeks); Subject 2 received 36 sessions (18 weeks).

Sentence Production Probes

Throughout treatment, the sentence production priming task, like the one presented during baseline, was administered to assess production of all sentence types. Sentence productions were tested prior to each training period in sets of 30 (a randomly selected half of the total 60 target sentences). In this manner, the complete set of 60 sentences was tested across two training periods. Responses to these probes, scored in the same way as in baseline, served as the primary dependent measure throughout the study and revealed emergent sentence production and generalization patterns. Generalized production to untrained sentence types was considered to have occurred when levels of performance changed by at least 40% over observed baseline levels. Percent change was calculated by subtracting mean percent correct production of each sentence type across all baseline sessions from the mean of the final two probes for each sentence type collected during a given treatment phase.

Four weeks following the completion of treatment, follow-up production probes were conducted. Once again the sentence production priming task was carried out to evaluate how well production levels reached in treatment phases were maintained when treatment was discontinued.

Narrative Discourse Probes

Narrative language samples were collected within one week following the completion of treatment (posttreatment) and at 4 weeks following treatment (follow-up). Elicitation and scoring procedures like those used in collecting pre-experimental narrative samples were followed.

Reliability

All responses produced in the sentence production priming task were scored, online, by both the primary examiner and by an independent observer situated behind a one-way mirror. Daily reliability checks were undertaken to ensure accurate scoring/coding of subjects' responses. Disagreements were discussed in order to improve scoring accuracy. Overall point-to-point agreement between the primary coder and the independent observer was greater than 95% across probe sessions.

All narrative samples were coded independently by two trained coders. Point-to-point agreement was calculated for all utterance, lexical, and morphological codes. Agreement between coders ranged from 78% to 93% across language variables with overall mean agreement at 82%.

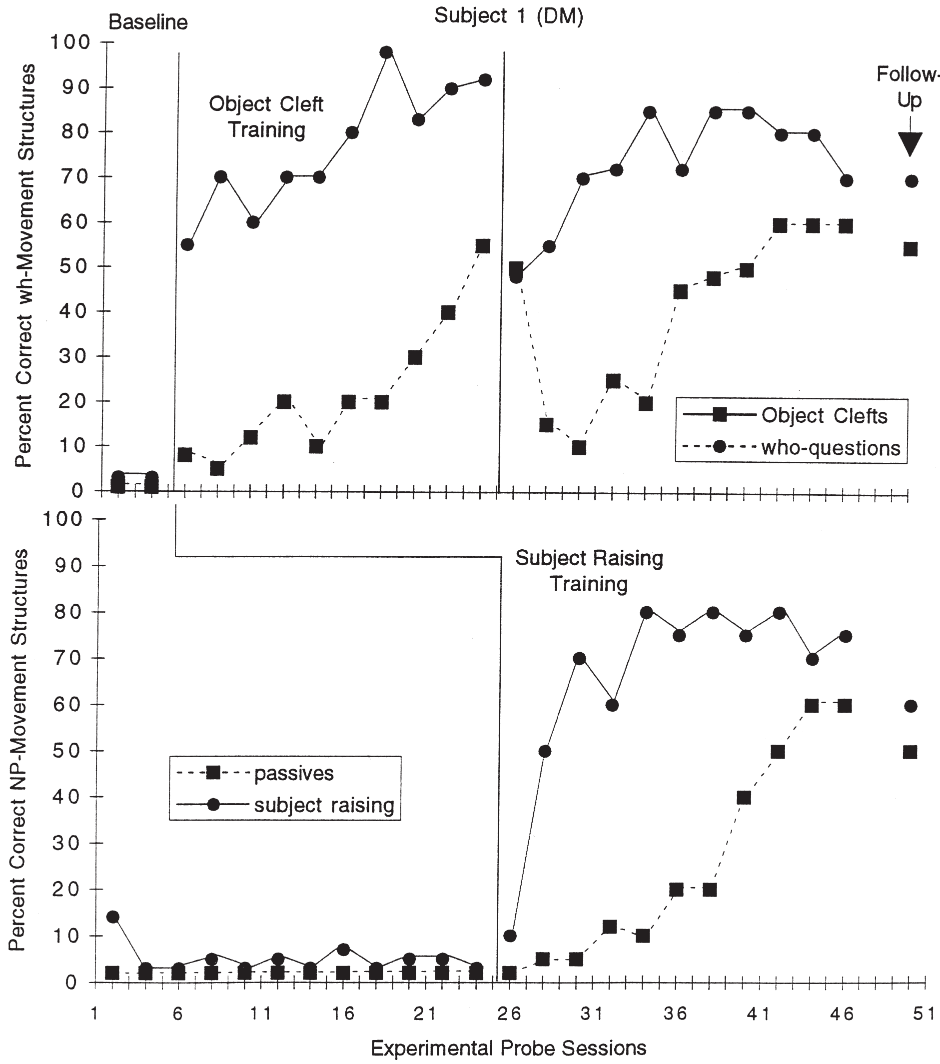
Results

Production of Trained Sentences

Data representing correct responses produced on sentence production priming probes for Subjects 1 and 2 are shown in Figures 5 and 6, respectively. These data indicated that, during the baseline phase, both subjects produced less than 12% of sentences correctly across types, with the exception of *who* questions for Subject 2. Subject 2's *who* question production ranged from 65% to 73% during the baseline phase and remained at a high level throughout passive and object cleft training phases. Therefore, *who* question data were excluded from subsequent training and analysis for this subject. During baseline, both subjects evinced errors of: (a) co-reference in which the wrong sentence constituent was moved or a gap was not established (score of 6), and (b) movement in which responses contained a similar, but incorrect, type of movement (score of 5 or 3). Many responses were simple, active sentences (scores of 1 or 0) or no response was produced.

Following baseline testing, successful acquisition of sentence types entered into treatment was noted for both subjects. The influence of training object cleft production was readily noted for Subject 1 during the object cleft training phase. Production of object clefts improved over baseline levels, ranging from 54% to 100% correct. Importantly, for internal validity purposes, object cleft training did not influence production of passive or subject-raising structures. Subsequent training of subject-raising structures similarly influenced correct production of this sentence type with correct production ranging from 10% to 80%. The data for Subject 2 showed a consistent pattern. Treatment focused on passive structures resulted in correct production ranging from 54% to 93% correct, while stable levels of performance were maintained for object cleft sentences. Treatment of object clefts subsequently resulted in object cleft production ranging from 4% to 88%.

Figure 5. Percent correct production of *wh-* and NP-Movement structures during the sentence production priming task across baseline and treatment phases of the study for Subject 1.



Generalization Across Sentence Types

wh-Movement to *wh*-Movement

Of key interest in this study was generalization across sentence types. In keeping with our hypotheses, the generalization data followed a linguistically predictable pattern. Notably, training Subject 1 to produce object clefts, which rely on *wh*-movement, influenced production of *who* questions, which also rely on *wh*-movement. Untrained *who* questions improved from 0% during baseline to a high of 48% during object cleft training. However, this training did not influence production of passive or subject-raising structures, both of which rely on NP-movement (see object cleft training phase in Figure 5). Generalization across *wh*-movement structures could not be analyzed for Subject 2 because *who* questions were produced at a high level prior to treatment.

NP-Movement to NP-Movement Structures

Generalization from trained NP-movement structures to untrained NP-movement structures was noted for both subjects. Specifically, for Subject 1, treatment of subject-raising structures resulted in improved production not only of subject-raising structures, but also of passive sentences. Untrained passive sentences improved from 5% correct to 60% correct during training of subject-raising structures (see subject-raising training phase in Figure 5). The data for Subject 2 replicated this effect in that passive sentence training resulted in improved production of subject-raising structures. Production of subject-raising structures, which were not trained, accelerated from 0% to 80% during passive training (see passive training phase data in Figure 6). Importantly, training NP movement structures (i.e.,

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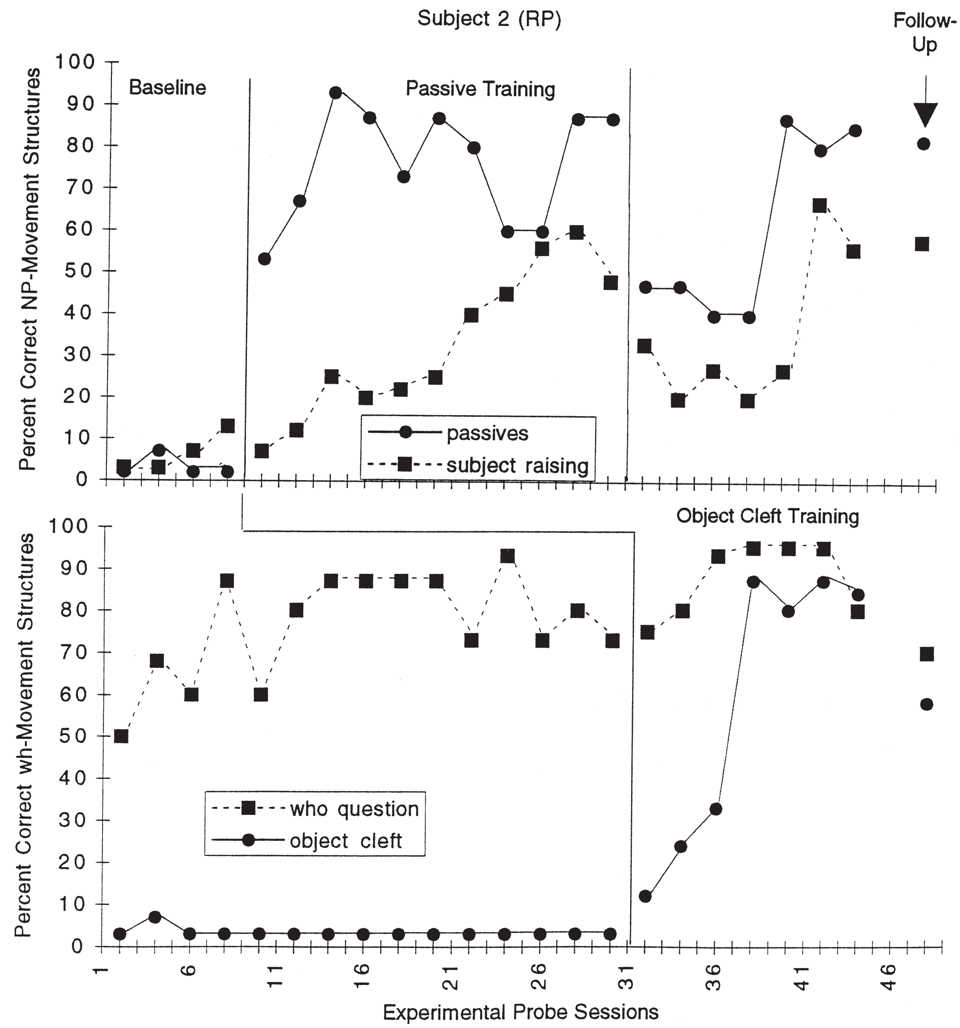
Figure 6. Percent correct production of *wh*- and NP-Movement structures during the sentence production priming task across baseline and treatment phases of the study for Subject 2.



passives) did not result in increased correct production of *wh*-movement structures (i.e., object clefts).

Effects of Treatment on Narrative Discourse

Results of pretreatment, posttreatment, and follow-up (4-weeks posttreatment) narrative discourse sampling and analysis are shown in Tables 2 and 3. Because similar findings were derived from the two pretreatment and posttreatment narrative samples collected, these narrative samples were collapsed to form one sample for each period.

The data presented in Table 2 indicate that, whereas MLU remained relatively stable across samples, the proportion of grammatically correct sentences increased for both subjects. At pretreatment, only 26% of Subject 1's sentences were grammatical, whereas in posttreatment and follow-up narratives, the proportions of grammatical sentences were 36% and 39%, respectively. Similarly, in pretreatment narratives, only 19% of Subject 2's sentence were grammatical, whereas at posttreatment and at follow-up, 31% and 30% were grammatical, respectively. Additionally, as noted in Table 2, the proportion of grammatically simple and complex sentences changed from pre- to posttreatment/follow-up. Although both subjects continued to produce more simple than complex sentences (with the exception of Subject 1's follow-up narrative), increases in the proportion of complex sentences were noted following treatment for both subjects. However, the mean number of embeddings was relatively stable across samples as was the proportion of nouns to verbs and open class to closed class words.

Table 3 indicates that both subjects also improved in the proportion of verbs produced with correct argument structure. Notably, this improvement was seen primarily with two-place verbs for both subjects. Prior to treatment, Subject 1 produced only 44% of obligatory two-place verbs with correct arguments, whereas in posttreatment and follow-up samples he produced 78% of these verbs with correct argument structure. Similarly, the argument structures produced for optional two-place verbs improved from 35% correct to 60% and 67% in posttreatment and follow-up samples, respectively. This improvement also was reflected in the proportion of Agents (x) and Themes (y) produced correctly across samples and in the total verbs produced with correct argument structure. On posttreatment and follow-up probes 50% and 56% of verbs, respectively, were produced with correct argument structure compared to only 43% on pretreatment probes.

Subject 2 showed the same pattern. Both obligatory and optional two-place verbs were produced with correct verb argument structure more often in posttreatment and follow-up narratives than in pretreatment narratives. Forty-two percent of obligatory two-place verbs were produced with correct argument structure in pretreatment narratives; in posttreatment and follow-up samples, 66% and 50% of these verbs were produced with correct arguments. Optional two-place verb productions also improved, increasing from 41% produced with correct arguments in pretreatment narratives to 61% and 59% produced correctly in posttreatment and follow-up samples, respectively. This subject also showed increases across narrative samples in the proportion of Agents and Themes produced correctly and in the proportion of total verbs produced with correct argument structure. Forty-six percent of all verbs were produced with correct arguments in pretreatment narratives, 65% were produced correctly at posttreatment, and 52% were produced correctly at follow-up.

Discussion

This experiment was undertaken for two reasons: (a) to establish the efficacy of our sentence production training program for agrammatic aphasic individuals, and (b) to investigate the relevance of linguistic theory to understanding language breakdown and recovery patterns in aphasia. We have shown in our previous work (Thompson et al., 1993; Thompson et al., 1996) that linguistic-specific treatment is efficacious for training sentence production in aphasia in that greater generalization across sentences has been observed with this treatment as compared to others (e.g., Helm-Estabrooks & Ramsberger, 1986; Schwartz, Saffran, Fink, Myers, & Martin, 1994; Wambaugh & Thompson, 1989). For example, Mapping Therapy (Schwartz et al., 1994), which focuses on training comprehension of thematic roles and how these roles map onto the syntactic structure of a sentence, has not resulted in generalized improvement of noncanonical sentence production. Like Mapping Therapy, our sentence production treatment trains subjects to establish and to improve knowledge and access to the thematic role information associated with given verbs. Our program also trains subjects to recognize the processes of constituent movement within a sentence and trace-antecedent chain formation. Therefore, the treatment is specifically applied to those noncanonical, semantically reversible structures that cause agrammatic subjects greatest difficulty. The present experimental findings once again show that our treatment improves noncanonical sentence production in agrammatic aphasic subjects and that generalization to untrained sentences with similar linguistic properties results from this treatment. Our findings, then, demonstrate the value of treatment that is based on analyses within linguistic theory.

Of further interest in our work is the extent to which treatment data can serve to validate various aspects of linguistic theory and to inform us as to the nature of sentence production breakdown and recovery in aphasia. In this regard, the generalization patterns that emerge when treatment is provided are of interest. In our previous work (Thompson et al., 1996), generalization patterns seen in recovery of sentence production reflected the properties of "move-alpha," the general transformational rule involved in the derivation of noncanonical sentences. Specifically, distinctions in the site from which movement originates influenced generalization; sentences with traces resulting from movement of arguments did not influence sentences with traces resulting from the movement of adjuncts and vice versa. However, generalization was observed to sentences with similar movement properties. The same was true in the present investigation. When sentences relying on *wh*-movement that involve movement to a non-argument (A-bar) position were trained, generalized production of untrained sentences was constrained to other sentences relying on *wh*-movement. This training did not influence production of NP-movement structures. Similarly, when NP-movement structures were trained (i.e., those that involve movement to an argument [A] position) generalization was constrained to other NP-movement structures. Thus, the theoretical distinction between *wh*- and NP-movement appears to influence recovery of sentence production.

The pattern of generalization seen between *wh*-movement structures warrants further discussion. Recall that Subject 1 was trained to produce object cleft sentences that resulted in generalization to *who*-questions. However, because Subject 2 produced *who* questions at a high level during baseline, we were unable to examine the opposite pattern of generalization, that from *who*-questions to object clefts. Based on our data from Subject 1 and based on our theoretical framework, we expected this generalization to occur. However, because the two structures are related to one another, we also expected similar performance on the two *wh*-movement structures, even in baseline. Therefore, further research investigating the relation between *wh*-movement structures is needed.

The error patterns noted throughout the study are also of theoretical interest. Initially, our subjects' sentences were produced with improper movement or they lacked evidence of a trace being created at the proper site. When treatment was applied, however, subjects readily learned to move the proper NP and traces resulting from this displacement were forthcoming. As noted above, the termination site of the moved NP influenced generalization. These data suggest that the production deficit seen in agrammatic aphasia reflects a deficit in establishing binding relations. It is of further interest to note that our subjects also showed errors concerned with functional categories (i.e., elements within the closed class such as prepositions and pronouns). For example, object cleft productions often were produced without the subject of the matrix clause, *it*, a non-referential "dummy" pronoun. This pattern persisted throughout the study in spite of improved production of the open class sentence constituents in their proper order. This finding indicates a dissociation between binding operations and functional categories in sentence production.

Consider now the data derived from analysis of our subjects' spontaneous discourse. Both subjects showed improvements in aspects of sentence production from pre- to posttreatment narrative samples. Although we did not see increases in production of the types of sentences that were entered into treatment, both subjects showed changes in narrative language that reflected aspects of the treatment provided. Specifically, the subjects showed increases in the proportion of grammatical sentences produced and in the proportion of complex as compared to simple sentences produced. Because production of complex, grammatical sentences was the focus of treatment, this finding was not surprising.

There also were increases in the proportion of two-place verbs produced with correct verb argument structure, the proportion of Agents and Themes produced correctly, and the total number of verbs produced with correct verb argument structure. Because treatment focused on: (a) production of sentences with two-place (Agent Theme) verbs, (b) the thematic properties of NPs around these verbs, and (c) the displacement (but retention of thematic roles) of these NPs, these changes also can be attributed to the treatment that was provided. These findings are consistent with Thompson et al., 1996, and indicate that specific aspects of sentence production that serve as the focus of treatment translate to improvements in narrative production.

Importantly, previous research (e.g., Thompson & McReynolds, 1986; Wambaugh & Thompson, 1989) has shown essentially no effect of sentence production treatment on spontaneous language production. We suggest that our spontaneous discourse effects are related to two possible variables: (a) the method of analysis of spontaneous discourse used, emphasizing the role of lexical properties in syntax, is perhaps more sensitive than that used in other studies, and (b) the treatment provided focused explicitly on the linguistic and psycholinguistic underpinnings that we hypothesized would influence sentence production.

Conclusions

The present data indicate that treatment improved sentence production in both of our subjects as demonstrated by the generalization patterns to untrained sentences and to narrative discourse. These findings have important clinical implications. Because of restrictions in health care for aphasic individuals, it is essential that clinicians provide treatment that will result in optimal generalization. When the linguistic underpinnings of the sentences selected for treatment and the treatment strategy applied are controlled, treatment appears to be efficacious. Therefore, linguistically based treatment may be used, with confidence, for training sentence production in individuals who have deficits like those seen in our subjects.

Our findings also are relevant to normal and agrammatic language production. Controlled analysis of sentence production patterns as they emerge throughout the course of treatment is a novel experimental paradigm for examining various types of lexical and syntactic relations. When patterns of recovery follow those predicted by linguistic theory, we take this as evidence that we have chosen the right course in developing our program.

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Appendix A. Active sentences used to elicit target noncanonical sentences.

1. The boy tickled the girl—active form of target sentence (pictured)
   The girl tickled the boy—active reversible foil (pictured)

Target noncanonical sentences:

(wh-question): Who has the boy tickled?
(object cleft): It was the girl who the boy tickled.
(passive): The girl was tickled by the boy.
(subject raising): The boy seems to have tickled the girl.

2. The skater hugged the coach.
3. The sailor pushed the soldier.
4. The sheriff kicked the convict.
5. The thief chased the artist.
6. The judge tripped the clerk.
7. The driver stopped the cop.
8. The skater passed the biker.
9. The guest watched the waiter.
10. The woman kissed the man.
11. The biker lifted the student.
12. The wife covered the husband.
13. The thief trapped the cop.
14. The farmer carried the hunter.
15. The girl shoved the boy.

Appendix B. Protocol used to score responses on the sentence production priming task. Sample responses for the target picture, *The girl tickled the boy.*

Score 8. Grammatically correct target sentence: [+movement][+gap][+morphology].

wh Who has the girl tickled?
oc It was the boy who the girl tickled.
pa The boy was tickled by the girl.
sr The girl seems to have tickled the boy.

Score 7. Correct target sentence containing verbal paraphasias (lexical substitutions) or verb inflection errors. In cases involving object clefts, the *who* may be omitted (e.g. *It was the boy the girl tickled*): [+movement][+gap][+/– morphology].

wh Who has the woman tickle?
oc It was the man who the girl tickle.
It was the boy the girl pushed.
pa The boy was tickle by girl.
sr The girl seems to tickled the boy.

Score 6. Incorrect target sentence containing movement and appropriate morphology but no gap: [+movement][–gap][+/–morphology].

wh Who has the girl tickled the boy?
oc It was the boy who the girl tickled the boy.
pa The boy was tickled the boy by the girl.

Score 5. Well- or ill-formed sentence of the same type (e.g. *wh*-question): [+(similar but not identical) movement][–appropriate gap][+morphology].

wh Who tickled the boy?
Who is the girl tickling the boy?
Who is the boy tickled by the girl?
oc What the girl tickled was the boy.
It was the girl who tickled the boy.
pa The boy seems to have been tickled.

Score 4. Well-formed sentence of a different type, showing the same type of movement as the target: [question/object cleft] or [passive/subject raising].

wh It was the boy who was tickled by the girl.
oc Who did the girl tickle?
pa I believe the girl to have tickled the boy.
sr The boy was tickled by the girl.

Score 3. Well-formed sentence of a different type, showing a different type of movement than the target.

wh The boy was tickled by the girl.
oc The boy was tickled by the girl.
pa It was the boy tickled by the girl.
sr The girl tried to tickle the boy.

Score 2. Ill-formed sentences with morphological enhancement.

wh The girl was tickle the boy.
Who was the girl by the boy tickled?
oc It was the girl tickle the boy.
It was the girl who the boy the girl tickled the boy.
pa It was the boy was the girl tickled.
sr The girl seems like boy.
The girl seems like boy tickled.

Score 1. Semantically appropriate active sentence.

wh The girl tickled the boy.
oc The girl tickled the boy.

Score 0. Repetition of foil sentence, semantically inappropriate active or sentence fragment.

wh The boy tickled the girl.
The girl the girl.
oc The boy tickled the girl.

NR. No response.

Note. wh = *who*-questions; oc = object clefts; pa = passives; sr = subject raising structures.