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Training *Wh*-Question Production in Agrammatic Aphasia: Analysis of Argument and Adjunct Movement

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The present research utilized aspects of the Principles and Parameters Approach (P&PA; Chomsky, 1991, 1993) in linguistic theory as well as findings from the psycholinguistic literature as a basis for examining sentence production in aphasic individuals. We examined the production of particular *wh*-movement constructions—*wh*-questions requiring movement of an argument noun phrase (i.e., *who* and *what* questions) and those which require adjunct movement (i.e., *when* and *where* questions). Using a single-subject experimental treatment paradigm, subjects were sequentially trained to produce these *wh*-questions and, throughout training, generalization to untrained *wh*-questions relying on similar *wh*-movement processes was tested. As well, the influence of training on aspects of narrative and conversational discourse was examined. Seven agrammatic aphasic subjects who evinced difficulty producing (and comprehending) ''complex'' sentences (e.g., passives, object relative clauses, *wh*-questions)—sentences that involve movement of noun phrases (NPs) out of their canonical positions, leaving behind a ''trace'' of that movement or ''gap''—participated in the study. Subjects were trained to produce *wh*-questions by taking them through a series of steps emphasizing the lexical and syntactic properties (e.g., thematic role assignment, movement processes, and proper selection of *wh*-morpheme) of declarative sentence counterparts of target sentences. Results revealed improved sentence production abilities in all subjects under study in both constrained sentence production and, importantly, in discourse tasks. The argument/adjunct distinction was observed in the sentence production recovery patterns noted in six of the seven subjects. Three of the subjects evinced correct argument movement across trained and untrained question structures when *wh*-questions

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relying on argument movement were trained; similarly, for these subjects, training structures relying of adjunct movement resulted in improved adjunct movement. Three of the remaining four subjects who required additional treatment to alleviate their *wh*-morpheme selection deficits, too showed covariance between argument and adjunct movement structures with each type of movement emerging across structures in temporal sequence. We discuss these data in terms of the operations necessary to produce *wh*-questions, the importance of considering linguistic and psycholinguistic data when designing treatment programs for language disordered patients, and the contribution that detailed recovery data can make both to understanding the nature of sentence production deficits and to issues regarding normal sentence production.

This paper describes an experiment designed to examine the efficacy of treatment for sentence production deficits in aphasic patients. Our purpose is to link linguistic and psycholinguistic issues with a proper treatment design so that generalization from trained to untrained structures can be assessed. We focus on a subset of aphasic patients (agrammatic Broca's patients) who show sentence production (and comprehension) deficits involving ''complex'' sentences—sentences where noun phrases (NP's) have been moved out of their canonical positions (e.g., *wh*-questions, passives, object relative clauses). We train subjects to recognize the nature of this movement, including the assignment of thematic roles and the selection of the proper *wh*-morpheme using a single-subject experimental design (e.g., Barlow & Hersen, 1984; Connell & Thompson, 1986). Through repeated measurement of both trained and untrained sentences throughout the course of training, the relation among the various sentence types used in our experiment is examined.

The present work represents an extension of our previous studies (e.g., Thompson, Shapiro, & Roberts, 1993) based on the notions that: (a) linguistic theories can and should be used to deduce how normal sentence processing operates, (b) aspects of normal sentence processing may serve a crucial role in determining what goes awry in the aphasias, and (c) perhaps the best way to approach treatment for aphasic deficits is to manipulate and control the lexical and syntactic properties that influence normal sentence processing and production.

Our work is akin to that of Grodzinsky (1990), who has used Chomsky's Government-Binding Theory (GB; Chomsky, 1981, 1986; van Riemsdijk & Williams, 1986; Haegeman, 1992) as a framework for discussing the sentence comprehension (and production) performance of agrammatic Broca's aphasic subjects (see also Hickok, Zurif, & Canseco-Gonzalez, 1993; Mauner, Fromkin, & Cornell, 1993). The main motivation for Grodzinsky's research has been the quest for a formal description of agrammatics' noted difficulty with the comprehension of sentences in which noun phrases (NPs) have been moved out of their canonical positions, leaving behind a ''trace'' or ''gap'' of that movement.

Like comprehension, production of sentences with moved constituents also poses a problem for the agrammatic aphasic patient. Agrammatic aphasic speakers are known to produce primarily simple, incomplete sentences (Bates, Friederici, Wulfeck, & Juarez, 1988; Gleason, Goodglass, Obler, Green, Hyde, & Weintraub, 1980; Saffran, Berndt, & Schwartz, 1989). That is, they use primarily SV and SVO structures in free speech (Christiansen, Goodglass, & Gallager, 1993), and in constrained production tasks they evince difficulty in producing sentence types in which the order of thematic roles is non-canonical (Caplan & Hanna, in press).

The present work examines production of non-canonical sentences—specifically, wh-questions. We use aspects of the Principles and Parameters Approach (P&PA; Chomsky, 1991, 1993) as well as findings from the psycholinguistic literature to set the framework for our approach. We select *wh*-questions because they appear less frequently in the speech of aphasic patients compared to normal speakers (Thompson & Doyle, 1991), and, importantly, P&PA is quite explict about how such constructions are derived (see below for a formal description of *wh*-movement). In addition, within the class of *wh*-questions, certain subsets of *wh*-constructions can be formed based on lexical-semantic as well as syntactic distinctions. For example, *what* and *where* questions—while appearing similar in their s-structure representation as both contain referential dependencies—are different when their underlying representations are considered. *What*-questions are derived by moving the direct object NP (i.e., an argument) from a position properly governed by the verb [NP, V'], whereas *where*-questions are formed by moving an adjunct from a position not properly governed by the verb [NP, VP] (see below for a review of the linguistic distinction between arguments and adjuncts).

Because our present approach seeks to facilitate generalization by both controlling linguistic properties known to underlie sentence formation and by training linguistic principles used across different sentence types, our findings may provide important data regarding the direction that sentence production treatment should take. Generalization is an essential component of any treatment program; indeed, without demonstrated generalization the efficacy of *any* treatment program must be questioned. If our hypotheses are correct concerning the need to consider the underlying representation of aberrantly produced sentences, then generalization across sentences relying on the same representational mechanisms but with different surface realizations should be expected. Furthermore, if learning and generalization patterns follow predictions gathered from linguistic theory, we might also be able to evaluate how well such theories can predict breakdown and recovery patterns in aphasia.

In order to discover important generalization patterns between and among language structures during the course of language recovery, careful study of individual subject's performance is necessary. Therefore, group research designs are largely contraindicated for analyses of this type. Instead, single-subject *experimental* paradigms (McReynolds, & Kearns, 1983; McReynolds, & Thompson, 1986) are more appropriate in that they not only allow inspection of individual subject's learning and generalization patterns, but also they control for the influence of extraneous variables on language performance throughout the experiment. That is, the intent of the designs is to establish internal validity or experimental control. Importantly, single-subject designs do not require the use of statistical analysis in order to determine the result of the experiment. Instead, subjects' performance on experimental probe tasks, administered throughout the course of the experiment, are plotted to allow direct examination of recovery over time. As has been discussed elsewhere, statistical analysis often is undesirable in work of the present nature because unique generalization patterns occurring across subjects may go unnoticed. In addition, statistical analysis may result in misleading findings, indicating that a particular treatment is effective when, in fact, it may have been so for only a few of the subjects included in the study (Caramazza, 1986; Kearns, 1992; Thompson, 1992). It is important to note here that these designs are unlike case study investigations of individual subjects. While case study investigations afford careful detailing of language performance across various language tasks in individuals subjects, they do not fulfill the requirements of experimental research.

Before we detail our current experiment, we begin with a brief review of representational issues; we follow with a discussion of sentence processing in both normal and disordered populations.

LINGUISTIC THEORY

We begin with a brief overview of one linguistic theory—the Principles and Parameters Approach (Chomsky, 1991; 1993). Here we consider some of P&PA's theoretical constructs, including the *lexicon, theta-theory, d-structure* and *s-structure,* the transformational rule *move-alpha, trace theory,* and the empty category principle (ECP).

The Lexicon and Theta-Theory

Our grammatical intuitions tell us that the verb *kiss,* for example, allows a noun phrase (NP) as its complement; that is, when we acquire a verb, we also acquire the knowledge that it can (and sometimes must) occur in particular structures:

1. Joelle kissed $[_{NP}$Zack]

Sentence (1) shows that the verb *kiss* occurs with a direct object NP. Such information is represented as part of the verb's entry in the lexicon, or mental dictionary. A partial lexical entry for *kiss* is shown in (2), where *kiss* is said to be subcategorized for an NP:

2. kiss: V [__NP]

There is more to lexical representations than that simplified in (2). Included also is a verb's *predicate-argument structure*. Argument structure characterizes the number of participants that go into the 'action' described by the verb. Arguments are typically NPs (though they can also be sentential clauses, prepositional phrases, or adjectival phrases) that fill *argument positions* (typically, subject, object, and indirect object positions). Arguments can be represented by variables. So, for example, in the sentence *Joelle kissed Zack*, the verb *kiss* takes a two-place argument structure with *Joelle* in the x-argument position and *Zack* in the y-argument position. Each argument of a verb is assigned a thematic role (e.g., Agent, Theme, Goal, Experiencer) and each verb selects sets of thematic roles (*thematic grids*) to assign. Like subcategorization, thematic properties are part of the verb's lexical representation. The verb *kiss*, for example, takes both an Agent and Theme in one thematic grid. Consider again (1), but with a description of the verb's thematic roles.

3. [$\text{Joelle}_{\text{AGENT}}$] kissed [$\text{Zack}_{\text{THEME}}$]

4. kiss: V—lexical category

   [__NP]—subcategorization

   (x, y)—argument structure

   (Agent Theme)—thematic grid

Sentence (3) shows that the verb *kiss* takes a two-place argument structure (an (x, y)), with the arguments assigned the roles of Agent and Theme, respectively. Sentence (4) is therefore a more fully specified lexical entry than (1), containing the verb's subcategorization frame, argument structure, and thematic grid.[1]

The lexical entry for *kiss* ensures the formation of grammatical sentences. Indeed, there is a formal principle—the *Projection Principle*—that states that the lexical properties of a word (i.e., a verb) must be observed in the syntax. Such a principle renders sentences like **Joelle kissed* or **Joelle kissed that the boy cried*[2] ungrammatical since the lexical properties in (4) require that *kiss* appear in sentences that contain a direct object NP assigned the role of Theme. Consider now sentences (5)–(8):

5. Joelle kissed Zack (active)

[1] We are simplifying the notion of lexical entry here. On some accounts thematic information is part of a more richly specified lexical-conceptual structure (LCS), containing primitives like CAUSE, PATH, GO, etc. (Jackendoff, 1990). Thus, thematic roles, on this account, are to be considered mnemonic devices that refer to an LCS representation.

[2] The asterisk (*) is used in linguistic notation to indicate an ungrammatical word string.

6. Who did Joelle kiss? (*wh*-question)

7. Zack was kissed by Joelle (passive)

8. It was Zack who Joelle kissed (object cleft)

Despite appearing in different grammatical positions, *Joelle* is the Agent and *Zack* (or *who* in (6)) is the Theme in each of these sentences. *Theta Theory* states that the verb assigns its associated thematic roles to particular grammatical positions at d-structure (an underlying form). A transitive verb like *kiss,* for example, has two thematic roles to assign, one associated with the subject position and one associated with the object position. This assignment is straight forward in (5); *kiss* assigns the role of Theme to the argument position occupied by *Zack* (and the VP assigns the role of Agent to *Joelle*). But (6)–(8) do not appear to have a direct object position occurring after *kiss* to which the role of Theme can be assigned, and thus, by the theory, (6)–(8) should be ungrammatical. Our intuitions, however, tell us that this cannot be so since (6)–(8) are indeed well formed. There must be some mechanism, then, allowing the assignment of thematic roles to NPs that have been moved out of their canonical argument positions. This mechanism is the *trace*.

Trace Theory and Thematic Role Assignment

The *Projection Principle* ensures proper thematic role assignment by requiring insertion of an abstract empty element or trace into the position from which a constituent has moved. The trace is linked (co-indexed) with the moved constituent to reflect the co-reference relation between the two positions. The thematic role is assigned by the verb to the trace in the original position. This thematic role is then inherited (via a theta-chain) by the co-indexed moved constituent. Details aside, consider sentence (6) *Who did Joelle kiss*?, with both its d- and s-structures and thematic role assignment for the direct object position. The d-structure representation for (6), shown in (9), captures the lexical properties of *kiss*. *Who* is in the direct object argument position and is assigned the Theme role by *kiss*:[3]

9. $[_{CP}[_{IP}$ Joelle kissed who]]

To derive s-structure, *who* is moved into the specifier position of CP, leaving behind a trace in the direct object argument position:

10. $[_{CP}$ Who_i $[_{C'}$ did $[_{IP}$ Joelle kiss t_i]]]

Who is co-indexed (represented by *i*) with the trace, forming a theta-chain.

[3] We adopt a notation introduced by Chomsky (1986). CP (Complementizer Phrase) is equivalent to S'; IP (Inflection Phrase) is equivalent to S.

The *wh*-element, therefore, receives its thematic role indirectly by way of the chain.

Sentences (7) and (8) receive a similar analysis, shown by the (partial) s-structures in (11) and (12):

11. $[_{IP}$ Zack$_i$ was kissed t$_i$ [by Joelle]]

12. It was Zack$_j$ $[_{CP}$ who$_{i,j}$ $[_{IP}$ Joelle kissed t$_i$]]

Skipping the details, in (11) the Theme role is assigned by the verb to the chain headed by the displaced argument *Zack* via the trace (t) in direct object position. In (12) the situation is similar to (10) with *wh*-movement of *who* from the direct object position; however, an additional coindexation relation holds between *Zack*, NP head of the relative clause, and the coreferential *wh*-item (i.e., *who*).

There are two major types of phrasal movement (subsumed under move-alpha): NP-movement and *wh*-movement. NP-movement occurs in the derivation of the passive (11) and NP-raising structures (e.g., *Zack seems to be sleeping*). NP-movement moves an NP from an argument position to another argument position, leaving behind an NP-trace. *Wh*-movement derives *wh*-questions, relative clauses, and relative clefts. Unlike NP-movement, *wh*-movement involves displacement of *wh*-phrases from argument or adjunct positions to non-argument positions (Specifier position in CP), leaving behind a *wh*-trace (e.g., (12)).

The Empty Category Principle and Proper Government

According to the Empty Category Principle (ECP) all traces must be properly governed. This type of government can take two forms. Traces in direct object position are directly governed by the verb, which assigns them case and a thematic role. This close relationship characterizes proper government in its simplest form. Traces not appearing as the direct object to a verb must be properly governed through antecedent government. This form of government is sensitive to the structural distance between a trace and its antecedent (e.g., the *wh*-word), and to the existence of any intervening maximal projections which might form barriers to antecedent government. Traces in adjunct position are subject to antecedent government, in contrast to traces in argument position, which are directly properly governed by the verb.

Arguments and Adjuncts

Implicit in this organization of lexical entries is the distinction between arguments and adjuncts. As we have shown, an argument is idiosyncratically selected by the verb, forms part of the verb's entry in the lexicon, is usually obligatorily present, and is covered by the Projection Principle. An argument is, thus, assigned its thematic role by the verb. An adjunct is not as rigidly selected by the verb, is never obligatorily present, and it is not covered by the Projection Principle. Consider the following sentences:

13. Keith mowed the lawn.

14. Keith napped on the sofa

In (13) the two-place predicate (the transitive verb *mow*) assigns two thematic roles to its arguments—agent to the NP *Keith*, and Theme to the NP *the lawn*. The one-place intransitive verb *nap* in (14) assigns only one thematic role—Agent/Experiencer to the NP *Keith*. The PP *on the sofa* is a locative adjunct; its ''meaning'' is not inherent in the verb's representation. Indeed, locative PP's like *in the office, in the garage,* etc. can occur fairly freely in any sentence. An argument of the verb is usualy obligatory, but can be optional under some circumstances. For example, in (13) the second argument of *mow* is optional; it can be omitted (as in *Keith mowed yesterday*), yet the verb carries it implicitly (one has to mow something). An argument can also be obligatory, as in *Keith hit the ball;* omitting the NP in this sentence will render it ungrammatical (**Keith hit*). The appearance of an adjunct, however, is optional (e.g., *Keith napped*). In the tree diagram shown in Fig. 1 below, illustrating (13), we see that the argument *the lawn* appears as a sister to the verb. That is, it is on the same phrasal level. In this type of structure, the verb directly theta-marks and assigns case to its direct object. If the object is extracted, leaving behind a trace in the original d-structure position, as in *wh*-question formation or passive, the trace is then properly governed by the verb itself, due to its position in the tree.

In the tree below illustrating (14) (see Fig. 2) we see that the adjunct PP is not sister to the verb, but appears outside of the projection of V (i.e., V') which immediately dominates the verb.

If we consider the structure of verb phrases in some more detail, we can see the difference between arguments and adjuncts clearly represented. The argument is sister to the verb; adjuncts enter the tree at higher or lower levels. Figure 3 illustrates the type of structure involved in cases where both an argument and adjunct are present. The hierarchical structure postulated is required by the data illustrating ordering regularities. Consider the following:

15. Keith mowed the lawn all afternoon.

16. *Keith mowed all afternoon the lawn.

17. Keith napped on the sofa all afternoon.

18. Keith napped all afternoon on the sofa.

Because the argument NP *the lawn* appears interior to the adjunct in the tree structure, the ordering of constituents in (16) is impossible—and thus ungrammatical.

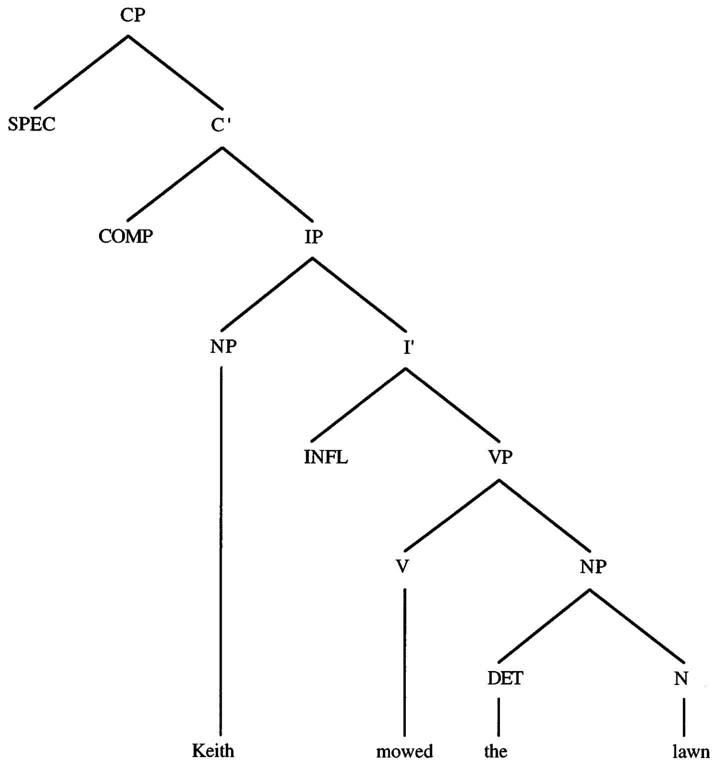

FIG. 1. Tree diagram illustrating the argument position.

The crucial consideration in argument versus adjunct movement is the proper binding of the traces. The tree structures in figs. 1–3 illustrate this distinction in binding (direct binding through theta/case government versus antecedent binding). While we have ample evidence that this representation is valid for normal sentence processing, we are still in the process of establishing its usefulness in descriptions of aphasic language. The results reported herein go some way towards this.

SENTENCE PROCESSING IN NORMAL AND NEUROLOGICALLY IMPAIRED POPULATIONS

Recent psycholinguistic work has shown that virtually all of these theoretical constructs have sentence processing implications. Consider the following examples from the psycholinguistic literature:

(1) A verb's argument structure and thematic representations affect the real-time processing of sentences. For example, the thematic representations of verbs appear to be accessed in the verb's temporal vicinity in normal listeners (e.g., Boland, 1991; Shapiro, Zurif, & Grimshaw, 1987, 1989; Sha-

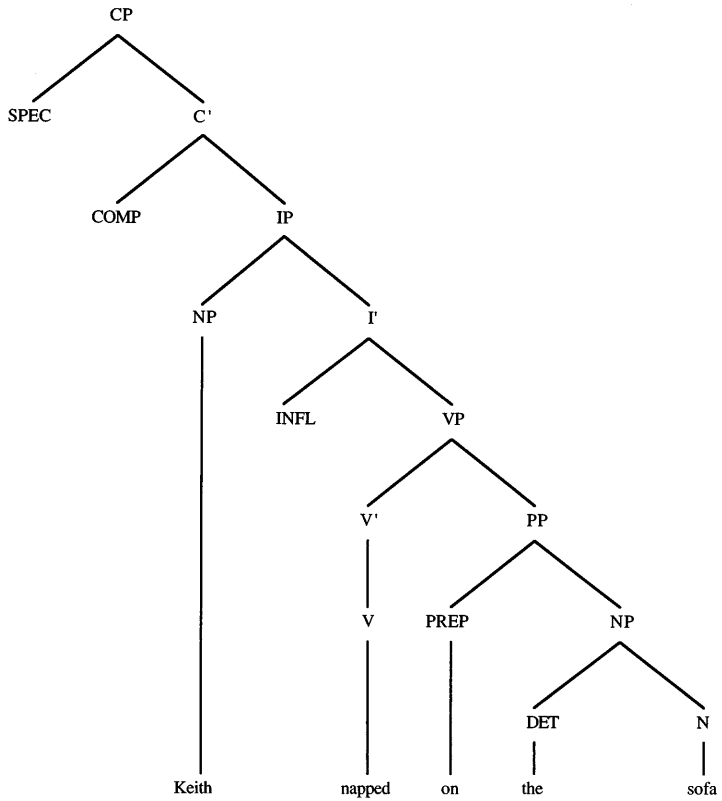

FIG. 2. Tree diagram illustrating an adjunct position.

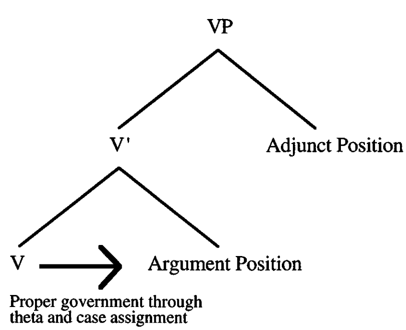

FIG. 3. The internal structure of the verb phrase (VP).

piro, Brookins, Gordon, & Nagel, 1991; Tanenhaus, Carlson, & Trueswell, 1989). That is, when the verb is encountered and accessed during the temporal unfolding of a sentence, so too are its thematic properties, setting up possible paths the parser may need to subsequently entertain in interpreting the sentence. Further, it has been shown that after the verb's lexical properties are made available to the system, the most preferred complement is used as the first analysis the parser attempts. If the structure of the sentence coincides with the preferred analysis, parsing ensues unabated. But if the structure of the sentence is incongruent with the preferred lexical property, the sentence must be re-analyzed (Shaprio, Nagel, & Levine, 1993). This work involves the use of a cross-modal lexical priming (CMLP) paradigm in which subjects listen to sentences over headphones and at specific points during the temporal unfolding of the sentence a visual lexical decision probe—a word or a nonword—is presented on a computer monitor. Subjects are instructed to listen to the sentence for meaning and to indicate—by pressing a button—as rapidly and as accurately as possible whether or not the probe is a word or a nonword. Reaction times (RTs) are recorded in these experiments as a measure of processing load.

(2) When the head of an adjunct prepositional phrase (e.g., ***in*** *the house*) is encountered during the temporal unfolding of a sentence, processing load is increased relative to the head of an argument prepositional phrase (e.g., ***to*** *the house*) (Shapiro et al., 1993). That is, again using the CMLP paradigm, normal subjects exhibit greater RTs when adjuncts as compared to arguments are encountered (Trueswell, Tanenhaus, & Kello, in press).

(3) There is a large body of evidence suggesting that the antecedent to a trace (the moved NP, for example) is reaccessed in the immediate temporal vicinity of the trace—well after the moved constituent has occurred in the sentence (e.g., Nicol, in press; Swinney & Osterhaut, 1990). For example, in the sentence *Which priest*$_i$ *did the parishioner ask #t*$_i$ *to give a blessing for her friend Mary*?, the moved NP—*Which priest*—is reaccessed at the lexically unfilled direct object position occupied by the trace (as evidenced by faster RTs to words that are semantically related to *priest* than to *parishioner* at the probe site (#)) (Nagel & Shapiro, 1994).

(4) It also appears that *wh*- and NP-movement each may have their own processing routines: that is, more ''work'' needs is required to attach an antecedent to a *wh*-trace than to an NP-trace as a *wh*-trace and its antecedent are separated by clausal boundaries (e.g., Berwick & Weinberg, 1984). Consider, for example, the simplified structures in (19) and (20):

19. [$_{IP}$ The boy$_i$ was hit t$_i$ by the girl] (NP-movement structure: passive)

20. [$_{CP}$ It was the boy [$_{CP}$ who$_i$ [$_{IP}$ the girl hit t$_i$]]] (*wh*-movement structure: object cleft)

Note that there is a greater distance between the trace and its antecedent in (20) as compared to (19). That is, no IP node (clausal boundary) intervenes between the trace and its antecedent in the passive (19), whereas in the object cleft (20), *who* has moved out of IP into the Specifier position of CP.

Evidence also points to the importance of these theoretical constructs for an explanation of impaired language performance. Consider the following examples from the neurolinguistic literature:

(1) Agrammatic Broca's aphasic subjects, unlike Wernicke's aphasic patients, show normal access to the thematic properties of verbs (Shapiro & Levine, 1990; Shapiro, Gordon, Hack, & Killackey, 1993). Nevertheless, Broca's aphasic patients have difficulty properly assigning thematic roles to arguments that have been moved out of their canonical positions (Caplan & Futter, 1986; Grodzinsky, 1990; Schwartz, Linebarger, Saffran, & Pate, 1987).

(2) Agrammatic Broca's aphasic patients may not show normal co-referencing between elements in sentences with moved sentence constituents. For example, Zurif, Swinney, Prather, Solomon, and Bushell (1993) reported that their Broca's aphasic patients did not show the normal pattern of co-reference between the head of the relative clause (i.e., *the professor*) and *who* in subject-relative constructions such as *The gymnast loved the professor from the northwestern city who complained about the bad coffee*.

(3) The distinction between NP- and *wh*-movement (and their derived sentence types) shows up in aphasic performance (Caplan & Hildebrandt, 1988) and in the sentence production performance of both amnesic patients and their controls (Shapiro, McNamara, Zurif, Lanzoni, & Cermak, 1992), as does the argument/adjunct distinction.

(4) Finally, reports in the cognitive neuropsychology literature concerned with description of the production deficit noted in Broca's aphasic patients with agrammatism have shown not only that these aphasics use shorter and less complex sentences than do normals, but also that they produce fewer verbs than normal or aphasic subjects of other types (Miceli, Silveri, Villa, & Caramazza, 1984; Saffran et al., 1989; Zingeser, & Berndt, 1990). Additionally, we (Thompson, Shapiro, Schneider, & Tait, 1994) found in a recent analysis of the production patterns of aphasic subjects that agrammatic subjects do not use the full range of argument structures available given a particular verb. That is, we found that the aphasic speakers produced significantly more one- and two-place verbs than normal speakers and, conversely, that normal speakers produced more three-place and complement verbs than aphasics. Also, for more complex verbs, the aphasic speakers used them in their ''simplest'' form more frequently than normal speakers—either with fewer arguments or without sentential clauses. This restriction, we surmise, is not due to any simple length or ''economy of effort'' consideration, but is due to a complex mixture of verb and sentence variables that affects the computational complexity of producing sentences. We suggest that this limi-

tation may partially explain the short utterance length that is prevalent in agrammatic aphasia.

These psycholinguistic and neurolinguistic facts argue for a principled account of grammatical representations when investigating normal and disordered sentence processing and, subsequently, when designing treatment programs. For example, lexical entries at least for open-class items seem to be available at d-structure for some, if not all, Broca's aphasic subjects; the problem for these patients lies either in the derivation of s-structure representations (e.g., traces—see Grodzinsky, 1990) or in the sentence processing routines computing these representations (see, for example, Prather, Shapiro, Zurif, & Swinney, 1992; Zurif et al., 1993). On the production side, it appears that verbs are compromised relative to nouns, and even when used, the lexical entries for verbs are not fully accessible. In the following experiment we exploit these strengths and weaknesses; we also consider the representational similarities and differences underlying the surface realizations of sentences that are the focus of our study—similarities and differences that can only be explained by reference to linguistic theory.

TREATMENT OF SENTENCE PRODUCTION IN AGRAMMATIC APHASIA

Several approaches to training sentence level deficits in agrammatic aphasic individuals have been advanced in the aphasia literature—some of which focus directly on sentence production (e.g., Helm-Estabrooks & Ramsberger, 1986; Loverso, Prescott, & Selinger, 1986; Thompson, & McReynolds, 1986; Wambaugh & Thompson, 1989) and others which focus on aspects of sentence comprehension, testing sentence production as an outcome of training (e.g., Byng, 1988; Jones, 1986; Schwartz, Saffran, Fink, Myers, & Martin, 1994). Results of this work have indicated successful outcomes of both types of treatment in that subjects entered into these studies have improved in their ability to produce trained sentences; however, less impressive findings have been reported with regard to generalization across sentence types. That is, little or no generalization from trained to untrained sentences has resulted from treatment application. For example, production treatments focused on instruction and practice in producing sentences that are notably difficult for aphasic subjects to produce have failed to demonstrate improved production of sentences other than those trained (see, for example, Thompson & McReynolds, 1986). Further, even when more cognitively based treatments have been applied—for example, Mapping Therapy which exploits the thematic roles of sentence NPs and ''mapping'' of semantics onto the syntax—improvement has been constrained largely to the types of sentences entered into treatment. For example, Schwartz et al. (1994) trained thematic role comprehension in canonical (S-V-O) sentences with action verbs and various ''padding'' (additions of modifying words and phrases to the subject and/or object NP) using their Mapping Therapy approach and found improved canonical sentence comprehension (and production), yet little improvement on non-canonical sentences (i.e., passives, object relatives, and subject relatives).

We suggest that the lack of noteworthy generalization in the aforementioned studies may be related to the nature of the sentences entered into treatment and to the treatment strategy itself. From our discussion of the linguistic and psycholinguistic underpinnings of normal and disordered language, we propose that treatment for sentence production deficits in aphasia consider the lexical and syntactic properties of sentences in both (a) selection of treatment variables and (b) selection of sentences for treatment and for generalization analysis. That is, agrammatic Broca's aphasic subjects appear to have normal access to verbs and thematic information; however, they do not always assign these normally nor do they use them fully in their sentence productions. Further, these patients do not appear to process trace-antecedent relations normally in sentences with moved constituents—and it is likely that such binding relations are also not established in production. So, we suggest that treatment for sentence production should begin with tasks concerned with establishing and improving knowledge and access to the thematic role information around the verbs that **are** reliably produced.[4] Next, the operations involved in establishing trace-antecedent relations in complex sentences should be exploited. Finally, when we consider the linguistic underpinnings of such complex sentences, it turns out that some sentences can be entered into treatment while others having the same linguistic underpinnings but different surface forms can be reserved for generalization testing. Careful study of sentence production patterns emerging when such treatment is applied, then, can potentially yield information not only concerning the most efficacious ways to approach sentence production treatment, but also concerning the processes involved in sentence production.

Consider two previous studies. Wambaugh and Thompson (1989) examined the effects of training *wh*-question production in four agrammatic aphasic subjects. Using a multiple baseline design across behaviors and subjects (Connell & Thompson, 1986), *what* and *where* questions were trained, while generalization within and across structures was examined. Results indicated that, although generalization within structures occurred (i.e., from *what*-constructions to untrained *what*-constructions), generalization across structures

[4] We note that ''Mapping Therapy'' (Jones, 1986; Byng, 1988; Schwartz et al., 1994) focuses also on the thematic roles of sentence NPs. Our approach, however, departs from theirs in that we require production (vs. strictly comprehension) of the verb and its arguments as well as adjuncts contained in target sentences. Additionally, we exploit the movement operations involved in creating grammatically correct noncanonical sentences and emphasize how thematic roles are retained in the s-structure of complex sentences in which NPs have been moved out of their canonical positions.

(i.e., from *what*- to *where*-constructions) was not forthcoming. In keeping with our theoretical framework, we surmised that this lack of generalization across *wh*-questions that are roughly analogous in their s-structure representation could have resulted because of the difference in argument structures for the two *wh*-question types. Consider, for example, the following sentence trained by Wambaugh and Thompson (1989):

21. What is he cooking?

22. Where is he sleeping?

Importantly, the verbs *cook* and *sleep* have different lexical properties. *Cook* is a two-place transitive verb allowing a direct object NP and an Agent, Theme thematic grid; whereas, *sleep* is a pure intransitive verb—not taking a direct object NP. Here the focus of the *wh*-question is, in fact, a locative adjunct. To appreciate the structural distinction between these two verb types, consider the following:

23. He is $[_{VP}[_{V'}$ cooking the dinner]]

24. He is $[_{VP}[_{V'}$ sleeping] in the bed]]

As discussed above, the direct object in (23)—*the dinner*—occurs as sister to the lexical head of VP; that is, it is directly theta-marked and properly governed by the verb. However, in (24), the locative—*in the bed*—occurs as sister to V' in an adjunction structure and is, thus, outside of the V' containing the head verb. Therefore, in *what*-questions derived from argument (object NP) movement, a theta-chain consisting of a trace in the object NP position and its co-indexed antecedent (the *wh*-word) is established and the trace is properly governed by the verb. A similar chain is established in *where*-questions, but the trace is crucially not properly governed by the verb, but is only antecedent-governed by the *wh*-word.

We theorized that the lack of generalization from *what*- to *where*-questions was related to the distinction between argument and adjunct movement. We further conjectured that, if this postulate were correct, *wh*-questions that are alike not only in s-structure, but also in their underlying linguistic representation (i.e., verbs with similar argument structures/thematic grids) would be better candidates for generalization. For example, we predicted generalization from *what*- to *who*-questions that are identical in both argument structure and in phrase structure; both constructions require verbs that take a direct object NP.

In a follow up study, we (Thompson, Shapiro, & Roberts, 1993) investigated this possibility and reported the results of training two agrammatic aphasic subjects to produce *what*- and *who*-questions. Consider the following:

25. Zack is helping $[_{NP}$ a friend$_{THEME}]$

26. Zack is fixing [$_{NP}$ the toy$_{THEME}$]

In (25) and (26) both the verbs *help* and *fix* take a direct object NP. To derive a *wh*-question, the direct object NP (which received the role of Theme in the d-structure) is replaced by a trace co-indexed with a *wh*-morpheme in the sentence initial position [SPEC, CP] as in (27) and (28):

27. [Who]$_i$ is Zack helping [t]$_i$

28. [What]$_i$ is Zack fixing [t]$_i$

In our experiment we used sentences like those in (25) and (26) to train *who* and *what*-questions like those in (27) and (28). We do not claim that declarative sentences like (25) and (26) are, in fact, the d-structure or underlying form for the derived wh-questions in (27) and (28); they simply contain the same thematic properties and thus can be used to help train such notions. In addition, we used sentences with ditransitive or dative verbs like *give* embedded in NP^V^NP^PP sentences (as in (29)) to train *who* and *what*-questions (as in (30)).

29. The man is giving money to the boy.

30. What$_i$ is the man giving t$_i$ to the boy?

Results of the study indicated, as predicted, that training of selected exemplars of *who*-questions resulted not only in improved production of both trained and untrained *who*-questions, but also of untrained *what*-questions for one of the two subjects. Interestingly, both subjects showed generalization from more to less ‘‘complex’’ structures. That is, when sentences like (29) were utilized to derive sentences like (30), generalized production of sentences like those in (27) and (28) was noted without direct treatment of these structures.

The purpose of the present study was to further examine the relation between *wh*-movement structures which require movement of the argument NP and those which require movement of an adjunct. Specifically, we asked the following question: Is there a distinction between these separate movement operations—both of which utilize wh-movement—in sentence production? As noted above, arguments of the verb and adjuncts affect on-line sentence processing in different ways—i.e., increased processing time is required for adjuncts as compared to arguments when they are aurally encountered in the temporal unfolding of sentences. We asked then if this distinction is also present in agrammatic aphasic subjects’ sentence production patterns. To answer this question, subjects were taught to produce either *who* or *what* questions—both of which require similar movement of the argument NP (direct object)—or *when* and *where* questions—each of which require adjunct movement—and generalization within and across these four *wh*-

questions was tested. We conjectured that generalization might be constrained to structures relying on similar movement patterns because of the inherent difference between verb arguments and adjuncts.

Crucially, we also were interested in detecting any wider effects of our training program on the discourse production patterns of our subjects. To answer this question, both narrative and conversational discourse samples were collected prior to and upon completion of the study. These samples were linguistically analyzed to determine any changes in their lexical and/or morpho-syntactic nature.

METHOD

Subjects

Seven aphasic individuals presenting with language production (and comprehension) patterns consistent with agrammatism served as subjects. All subjects (age 39–79; five males and 2 females) evinced aphasia secondary to a single left-hemisphere neurological insult and were between 19 and 198 months post onset of infarction when the study was initiated. Five of the subject's aphasia resulted from thromboembolic CVA in the distribution of the left middle cerebral artery (MCA); subject 4 suffered a left MCA ruptured aneurysm in the temporal parietal region; and subject 7's aphasia resulted from excision of a left frontal mass. All subjects were native English speakers (subject 3 was also fluent in German), premorbidly right-handed (with the exception of Subject 1), and had completed high school. Five of the eight subjects had completed at least some years of college and one held an advanced degree (subject 1). All subjects passed a pure-tone audiological screening at 40 dB HL at 500, 1,000, and 2,000 Hz in at least one ear.

Language Testing

A series of language tests were administered to all subjects with results as shown in Table 1. Aphasia quotients (AQ) as derived from the *Western Aphasia Battery* (WAB; [Kertesz, 1982]) ranged from 62 to 85. Auditory–verbal comprehension, while impaired, was superior to verbal expressive abilities; WAB comprehension subtest scores ranged from 8.0 to 10.0 with greater difficulty noted in comprehension of sequential commands than yes/no questions or auditory word recognition. Fluency scores were 4.0 or 5.0, reflecting production of primarily short phrases and simple sentences. Subjects presented with varying degrees of naming, repetition, and reading comprehension difficulties. However, all subjects demonstrated ability to orally read short phrases and sentences.

Sentence comprehension was further tested using the *Philadelphia Comprehension Battery for Aphasia* (Saffran, Schwartz, Linebarger, Martin, & Bochetto, unpublished).[5] This test contrasts lexical comprehension with sentence comprehension, comprehension of semantically reversible and non-reversible sentences, and 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 (lexical) sentences. Good comprehension

[5] The PCBA is an unpublished test developed primarily for research by Saffran and colleagues. It was selected for use in this study because there are no available published tests to the authors' knowledge that address comprehension of the sentence types of interest in this study.

TABLE 1
Preexperimental Aphasia Language Testing Data

Subject	1 MD	2 FP	3 JG	4 TE	5 GG	6 PR	7 SW
Western aphasia battery							
Aphasia quotient	62	68	78	64	85	66	78
Fluency	4	5	5	4	5	5	5
Comprehension	8	8	9	8	10	8	10
Repetition	5	6	8	6	10	8	9
Naming	7	7	7	7	9	7	8
Reading	8	7	7	4	8	7	9
Philadelphia comprehension battery for aphasia (% correct)							
Lexical comprehension	100	98	95	100	100	98	100
Sentence comprehension	82	68	75	90	95	72	85
Reversible	63	47	53	80	90	43	70
Lexical	100	100	97	100	100	100	100
Active	95	80	80	95	100	90	90
Subject relative	85	70	75	80	100	70	90
Passive/object relative	60	65	70	70	70	65	50

(i.e., 70–100% correct) of canonical sentences (i.e., actives and subject relatives) was evident, with comprehension of more complex sentences in which NPs are moved out of their canonical position (i.e., passives and object relatives) ranging from 50–70% correct.

Preexperimental Discourse Analysis

To delineate both lexical and morpho-syntactic aspects of production, discourse samples were collected in both narrative and conversational conditions on two separate occasions and analyzed using the coding system developed by Thompson et al. (1994). Both narrative and conversational samples were collected in order to obtain a large and varied sample of language production abilities. Narrative samples were obtained by asking subjects to tell the story of *Cinderella* using the method delineated by Saffran et al. (1989). A picture book, from which the printed words were deleted, was provided to assist subjects in remembering the story. After the book was removed, subjects were instructed to retell the story. Conversational samples were obtained by asking each subject and a familiar conversational partner to first view and then to discuss a TV news segment. All language samples were segmented into utterances based on syntactic, prosodic, and semantic criteria, coded, and entered into a computer for analysis. Perseverative responses, starter phrases, fillers, and repairs occurring in the discourse were deleted from the analysis. Results of this analysis are shown in Tables 2 and 3.

From Table 2 it can be seen that the agrammatic subjects produced primarily short utterances (MLU ranged from 2.7 to 5.8) containing few grammatical sentences (i.e., ranging from 6 to 51%).[6] Most sentence productions were grammatically simple—that is, sentences had no moved sentence constituents or embeddings. Between 67 and 98% of the agrammatic subjects'

[6] The proportion of grammatical sentences was based on total utterances, i.e., the number grammatical sentences/total utterances.

TABLE 2
Preexperimental Lexical and Morpho-syntactic Data Derived from Narrative and Conversational Discourse Samples (n = 2 of Each Sample Type per Subject)

Subject	1 MD	2 FP	3 JG	4 TE	5 GG	6 PR	7 SW	Normal subjects
Total utterances coded	223	184	132	230	105	257	150	370
MLU	3.2	5.8	3.8	2.7	3.3	3.1	3.9	12.64
Proportion (%) of grammatical sentences	18	23	07	06	51	09	37	78
Simple sentences	74	67	88	98	78	95	68	43
Complex sentences	26	33	12	02	22	05	32	57
Mean embeddings	.24	.41	.10	.02	.28	.02	.70	1.10
Noun/verb	1.03	1.76	1.46	2.09	1.06	2.82	1.09	.98
Open class/closed class	3.0	2.0	1.8	2.6	1.5	2.0	1.2	.91
Number of Wh-morphemes	08	10	00	08	02	01	02	10

Note. Normal data obtained from a sample of five age matched normal control subjects (Thompson et al., 1994).

sentence productions were simple as compared to 43% of normals, and only 2 to 33% of their sentences were complex sentences compared with 57% of normal productions. The agrammatics' simple production was also underscored by the mean number of embeddings produced, ranging from only .02 to .70, which was low compared to normal subjects' mean embeddings of 1.10. Noun/verb ratio and open/closed class ratios indicated that the subjects produced more open class as compared to closed class words; notably, within the open class, subjects produced more nouns than verbs (noun : verb = 1.03 to 2.82; our normal subjects' noun : verb = .98).

Analysis of verb and verb argument structures produced by the subjects also was revealing. (See Appendix A for a detailing of verb and verb-argument coding.) As shown in Table 3, the agrammatic subjects produced primarily obligatory one- and two-place verbs (between 41 and 52% of their verbs were of these types). Between 5 and 20% of their productions were optional two-place verbs and between 0 and 6% were optional or obligatory three-place verbs. Some subjects also produced a sizable proportion of complement verbs (between 5 and 37%), however, few of these verbs were produced with sentential complements—most were produced in x, y (phrasal complement) form. Similar proportions of verb types were produced by the normals, however, they produced more three-place verbs and more complement verbs in x, S' form (i.e., with a sentential complement) than did the experimental subjects.

Further, as shown in Table 3, subjects produced more one and two-place verbs with correct argument structure as compared to the other verb types, and they produced a sizable number of copulas with correct arguments (between 33 and 100%). Complement verbs were more often produced correctly in x, y (phrasal complement) form as compared to x, S' form and three-place verbs were often produced incorrectly. This pattern was repeated in the production of individual arguments and adjuncts. Agents, Themes, and predication phrases were the sentence constituents most often produced correctly in our subjects' discourse, with few, if any, third arguments (e.g., goals) or sentential complements produced correctly. It is also important to note that adjuncts were produced correctly in less than 50% of attempts across subjects. These data indicate that our agrammatic subjects not only produced few verbs, but also that they demonstrated a preference for producing primarily simple verbs that require accessing simple argument structure arrangements. Further, attempts to produce more complex verbs (i.e., those that can take a greater variety of argument structure arrangements) resulted either in selection of the more simple (x, y) form or in failure.

TABLE 3
Preexperimental Verb and Verb Argument Structure Data Derived from Narrative and Conversational Discourse Samples (n = 2 of Each Sample Type per Subject)

Subject	1 MD	2 FP	3 JG	4 TE	5 GG	6 PR	7 SW	Normal subjects
Total number of verbs produced	366	354	209	255	152	162	240	940
Proportion of verbs produced by type								
Obligatory one-place	18	28	09	12	22	41	23	09
Obligatory two-place	23	23	37	30	30	10	18	15
Obligatory One- and Two-Place	41	51	46	42	52	51	41	24
Obligatory three-place	02	01	01	00	00	00	02	03
Optional two-place	12	05	16	20	14	20	08	14
Optional three-place	01	01	06	01	00	00	00	10
Complement	37	32	12	05	19	10	32	32
x, y	76	61	64	100	67	100	72	54
x, S'	24	39	36	00	33	00	28	46
Copula	07	10	19	33	15	19	17	17
Proportion (%) of verbs produced by type with correct argument structure								
Obligatory one-place	62	71	100	77	100	33	77	100
Obligatory two-place	52	54	58	14	100	43	100	98
Obligatory three-place	00	25	00	—[a]	—	—	00	90
Optional two-place	45	33	69	57	100	34	89	98
Optional three-place	00	33	33	00	—	—	—	97
Complement	46	34	33	00	86	50	77	97
x, y	59	71	66	00	100	60	100	92
x, S'	21	34	66	00	00	00	80	97
Copula	85	53	61	100	100	33	61	97
Total (%) verbs produced with correct argument structure	52	51	59	61	84	39	82	97
Proportion (%) of correctly produced arguments and adjuncts								
Agent (x)	69	65	82	36	99	36	97	98
Theme (y)	64	74	81	30	96	54	95	98
Goal (z)	00	25	25	—	—	—	12	93
Sentential complement (S')	23	14	25	00	16	17	24	98
Predication phrase (P)	88	79	63	100	83	53	67	96
Adjunct (J)	25	49	25	39	49	28	23	94

Note. Normal data obtained from a sample of five age matched normal control subjects (Thompson et al., 1994).

[a] Cells containing (—) indicate instances in which the proportion of correct production of that variable could not be computed because it was not produced in the corpus (0%); e.g., subject 4 produced 0% obligatory three-place verbs in the samples derived and, therefore, the proportion of correct production of ob3 verbs could not be computed.

TABLE 4
Verbs Used in Experimental Sentence Stimuli

Training sentences		Generalization sentences	
Pushing	Kicking	Pushing	Hitting
Chasing	Helping	Kicking	Carrying
Following	Attacking	Chasing	Hugging
Kissing	Protecting	Following	Grabbing
Lifting	Touching	Protecting	Pulling

Experimental Stimuli

Using a set of 20 optionally transitive verbs, 80 active sentence stimuli (NP^V^NP^PP) were developed to depict the active sentence counterparts of the four question constructions (i.e., *who, what, when,* and *where*) under investigation (n = 20 for each). Ten exemplars for each of the *wh*-questions were utilized for training and the remaining 10 were reserved for analysis of generalization within the trained form. The training stimuli for each *wh*-form contained the same 10 optionally transitive verbs (see Table 4); five of these verbs as well as an additional five untrained verbs (also optionally transitive) were included in the untrained stimuli across *wh*-forms. All sentence stimuli were formed using animate nouns with a frequency of occurrence greater than 25 per million (Frances & Kucera, 1982). Subjects' comprehension of all verbs, nouns, and prepositions utilized in the sentence stimuli—tested individually using an auditory word-picture matching task prior to the study—was 100%. See Appendix B for a listing of sentence stimuli utilized in the study.

Sample sentence stimuli utilized for eliciting *who, what, when,* and *where* questions, respectively, are shown in (31)–(34).

31. The soldier is pushing the woman in the street.

32. The boy is kicking the cow in the barn.

33. The student is helping the doctor during the evening.

34. The guard is protecting the clerk at the store.

These declarative sentences contain the same lexical information (and, crucially, have the same thematic role assignments) as our target *wh*-questions ((35)–(38)). Recall that *who*- and *what*-questions are formed by movement of the object NP to [SPEC, CP] (argument movement) as in (35) and (36), and *where*- and *when*-questions are formulated by adjunct movement as in (37) and (38).

35. Who_i is the soldier pushing t_i in the street?

36. What_i is the boy kicking t_i in the barn?

37. When_i is the student helping the doctor t_i?

38. Where_i is the guard protecting the clerk t_i?

The 80 active sentence stimuli were displayed in large print (font = 18 points) on cards (2 × 10 in.). Written stimuli were utilized (a) to control the lexical content of target sentences, (b) to offset subjects' word retrieval difficulty, and (c) to decrease subjects' need to rely solely on auditory input during *wh*-question elicitation and training (see below for details). An additional set of stimuli was developed for treatment purposes; this set included individual sentence constituents contained within each training sentence stimulus (i.e., NPs, auxiliary verbs with

-ing inflection, and PPs) printed on separate cards (3 × 5 in.). Additional cards on which the single words *who, what, where,* and *when* were printed, and a question mark card also were utilized.

A 2-min videotape was developed to familiarize subjects with the nature of expected responses—i.e., that subjects would be expected to produce several different *wh*-question types. The tape consisted of the experimenter eliciting each of the four questions on two separate trials from a non-brain-damaged adult using sentence stimuli that were identical in syntactic form, but differed semantically from the experimental stimuli.

Design

A single-subject multiple-baseline design across behaviors (Connell, & Thompson, 1986) was utilized to examine generalization across *wh*-questions. As treatment was extended to one structure, for example *who*-questions that rely on movement of the argument to [SPEC, CP], generalization to *what*-questions that also rely on argument movement was tested. As well, generalization to structures requiring adjunct movement (i.e., *where*- and *when*-questions) was examined. The emergent sentence production patterns provided information regarding the organization of sentence production operations within and across subjects.

Prior to application of treatment—during the baseline phase—production of all *wh*-questions was examined using all experimental stimuli. *Wh*-question production then was trained using selected exemplars of one *wh*-question type, with the order of *wh*-questions entered into treatment counterbalanced across subjects. During this training all *wh*-question types, as well as untrained exemplars of the trained form, were tested for generalization. When (and if) generalization occurred across *wh*-question types relying on the same movement process, treatment was applied to one of the *wh*-question forms relying on the alternate *wh*-movement process and generalization testing continued. For example, following baseline testing, subject 1 was trained to produce *when*-questions which rely on adjunct movement. During this training generalized production of *where*-questions which also rely on adjunct movement was tested. Additionally, both *what*-questions and *who*-questions which rely on argument movement were tested. Next, *what*-questions which rely on argument movement were entered into training while generalization to untrained *who*-questions (also relying on argument movement) was tested. The complete experimental design is shown in Table 5.

TABLE 5
Order of wh-Questions Trained across Subjects Using the Multiple Baseline Design across Behaviors

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7
First trained structure	When	Who	What	Where	When	What	Who
	Where	What[a]	Who	When[b]	Where	Where	What
Generalization tested to	What	When	Where	Who	Who	Who	When
	Who	Where	What	What	What	When	Where
Second trained structure	What	When	Where	Wh-morpheme			
Generalization tested to	Who	Where	When	Discrimination-production training			

[a] Treatment was applied to *what*-questions for a short time following *who*-question training for subject 2 because generalization to this structure did not occur during *who*-question training.

[b] Treatment of *when*-questions was provided for a few sessions following *where*-question training for subject 4 as generalization did not occur to *when* structures during *where* training. Because *when*-question treatment did not result in elimination of *wh*-morpheme selection errors, *wh*-morpheme discrimination-production treatment was applied.

Semantic Pretraining

Prior to testing the sentence productions of interest, each subject underwent semantic pretraining to ensure comprehension of the *wh*-morphemes under investigation. *Wh*-word cards were placed on the table and the subject was instructed to ''point to the word'' for person (*who*), thing (*what*), time (*when*), or place (*where*) in random order. If subjects were unable to perform this task accurately, the examiner trained the appropriate semantic relations by pairing the *wh*-word cards with its verbal meaning. All subjects demonstrated ability to perform this task with 100% accuracy prior to baseline testing (20 correct out of 20 trials—5 for each *wh*-word—without feedback). All sessions were conducted in a quiet treatment room with only the examiner and the subject present.

Baseline

Prior to treatment, each subject's verbal production of the four *wh*-questions was tested using the 80 experimental stimuli. All sessions were audiotaped for reliability purposes. At the beginning of each baseline session, the videotape providing a model of expected responses was played for the subject to view. Subjects then were given the following verbal instructions: ''Now I want you to try to produce *wh*-questions like the ones on the video tape. I will show you a sentence; we will read it together; and then I want you to try to produce a *wh*-question.'' No practice trials were provided. The 80 experimental stimulus sentences were then presented individually in random order for the subjects to read aloud. If subjects experienced difficulty reading the sentence it was read aloud by the examiner for the subject to repeat, or the examiner and the subject read the sentence simultaneously. (Subjects seldom required assistance with reading as all subjects demonstrated ability to orally read short sentences pre-experimentally.) With the full sentence in view, together with the *who, what, when,* and *where* cards placed above the sentence in random order, the examiner instructed the subject to formulate a question about the sentence using specific instructions for eliciting each of the question types. Using, for example, the stimulus sentence in (31) above (*The soldier is pushing the woman in the street*), a *who*-question was elicited with the following instruction: ''You want to know **the person** the soldier is pushing, so you ask?'' The word ''person'' was emphasized, rising inflection was used, and the question mark card was placed above the sentence. To elicit *what*-questions using the stimulus sentence in (32) above (*The boy is kicking the cow in the barn*), the examiner instructed: ''You want to know **the thing** the boy is kicking, so you ask?'' This time, the word 'thing' was emphasized. To elicit *when*- and *where*-questions, the same procedure was used except that subjects were instructed to ask about **the time** or **the place,** respectively. A 10-sec response time was provided following each stimulus presentation. If a response did not occur within the allotted 10-sec period, a new stimulus was presented and instructions to ask another *wh*-question were provided. Feedback as to the accuracy of response was not given during baseline, however, intermittent encouragement was provided.

All 80 sentence stimuli were presented during each baseline session—which were approximately 2 hr in length. During this 2-hr period, subjects were given frequent rest periods. The number of baseline sessions administered prior to application of treatment varied in a manner consistent with the multiple baseline design across subjects. Subjects 4, 6, and 7 were tested on two separate occasions; responses to the 80 stimuli were tested for subjects 1, 2, and 5 on three separate occasions, and subject 3 participated in four separate baseline testing sessions. This aspect of the design was included for experimental control in the event that generalization occurred across all *wh*-questions following training of only one question type. All subject responses occurring during baseline testing were transcribed on-line by both the examiner and an independent reliability observer situated behind a one-way mirror. Lexical, sublexical, and syntactic aspects of each response were analyzed and codes reflecting these dimensions were assigned (see Appendix C).

Treatment

Argument/adjunct movement treatment. Subjects were trained to produce target *wh*-question forms by taking them through a series of steps that emphasized the lexical and syntactic properties of the declarative sentence form as well as the *wh*-movement required to derive the surface realization of target *wh*-questions. Specifically, subjects were taught (a) to recognize the verb, verb argument structure, and thematic roles of NPs contained in sentences in their declarative form; (b) to move the proper sentence constituent (i.e., either argument or adjunct) and replace it with the proper *wh*-morpheme; and (c) to produce the surface form of targeted *wh*-questions (see Appendix D).

Training periods were provided for subjects two times per week. During each training period each of the 10 sentences designated for treatment was presented for training (using the training protocol relevant to the *wh*-question being trained) one time each for a total of 10 training trials per session. Treatment for each *wh*-question form was extended for at least 20 training periods (over 10 weeks) and not more than 35 (17.5 weeks), unless subjects evinced acquisition of trained question forms *and* generalization to untrained *wh*-question forms, requiring movement of the same *wh*-phrase, in fewer training periods (see constrained *wh*-question production probes below).

Wh-morpheme discrimination/production training. For some subjects, training focused specifically on *wh*-morpheme discrimination and production was introduced at various points throughout the study. Despite their demonstrated proficiency in the semantic pre-training phase of the experiment, these subjects' production patterns indicated *wh*-morpheme production errors. These subjects demonstrated ability to select and move the proper sentence constituents to formulate the various *wh*-questions (i.e., subjects acquired the ability to correctly select and order all sentence constituents during training), however, they continued to produce, randomly, any one of the *wh*-morphemes under study. This treatment involved a re-introduction of semantic pre-training, together with additional comprehension and production tasks with *wh*-words and their referential equivalents (see Appendix E).

Production Probes

Constrained wh-question production probes. Throughout treatment, sentence production probes like those presented in baseline were administered to assess production of both trained and untrained *wh*-questions. Probes were presented prior to each training period in sets of 40 stimuli (a randomly selected half of the total 80 experimental stimuli). In this manner, the complete set of 80 sentences was tested across two training periods. Responses to these probes, coded in the same manner as in baseline, served as the primary dependent measure throughout the study and revealed emergent sentence production patterns across subjects. Generalized production to untrained *wh*-question forms was considered to have occurred when levels of performance changed by at least 50% over observed baseline levels. The percent change was calculated by comparing mean percent correct production of each *wh*-question type across all baseline sessions to the mean of the final two probes for each *wh*-question collected during a given treatment phase.

Post-treatment probes. Sentence production was again assessed between 4 and 6 weeks following completion of the study. Elicitation and analysis procedures were identical to those used previously. Two narrative and two conversational discourse samples were collected at the completion of the study—after all *wh*-question types had been trained (or after generalization to all *wh*-question types had been observed). Data collection and analysis procedures were identical to those used for pre-experimental discourse samples.

Reliability

All responses produced during constrained sentence production probes were scored, online, by both the primary examiner and by an independent observer situated behind a one-way mirror. Daily scoring reliability checks were undertaken to ensure accurate interpretation 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 90% across probe sessions.

Narrative and conversational discourse data also were coded independently by three trained coders. Point-to-point agreement between coders was greater than 87% across all language variables.

RESULTS

Constrained Sentence Production

The data derived from constrained sentence production probes during baseline and treatment phases of the study for subjects 1–3 are depicted in Figs. 4–6, respectively. The data for subjects 4–7 are shown in Figs. 7, 9, 11, and 13. Shown in these figures are the percent of *wh*-question responses produced in grammatically correct form during these probe sessions. Results indicated that experimental training resulted in improved production of *wh*-questions—following stable baselines—as they were entered into training across subjects, regardless of the order in which they were trained. Additionally, training resulted in generalization to untrained sentences of trained forms for all *wh*-questions for all subjects.

When generalization across *wh*-question forms was examined, however, two patterns of emergent sentence production across the subjects were noted. Three of the seven subjects (subjects 1, 2, and 3) demonstrated generalization patterns largely as predicted by our initial hypothesis. When treatment was applied to *wh*-questions requiring argument movement (i.e., direct object; either *who* or *what* questions), generalized production of untrained *wh*-questions was restricted to those also relying on argument movement. Similarly, when treatment was applied to *wh*-questions requiring adjunct movement (i.e., *where* or *when* questions), generalization occurred to untrained *wh*-questions relying on adjunct movement. Importantly, argument movement did not generalize to adjunct movement constructions, and vice versa. Examination of sentence production error patterns for these subjects (see Table 6) revealed that, in early phases of treatment, these subjects evinced primary difficulty with selection and/or movement of the proper sentence constituent (i.e., errors of co-referencing) to derive the proper question form. For example, these subjects produced responses such as: ''Who_i is the soldier pushing the woman t_i?'' for the target: ''Who_i is the soldier pushing t_i into the street?'' or ''Where_i is the soldier pushing t_i into the street?'' for the target: ''Where_i is the soldier pushing the woman t_i?'' In addition to these errors, subjects 2 and 3 also produced a large number of *wh*-morpheme selection errors (e.g., ''*What* is the soldier pushing into the street?'' instead of ''*Who* is the soldier pushing into the street?''); subject 1 showed few *wh*-morpheme selection errors during baseline testing. It is interesting to note that upon completion of argument/adjunct movement treatment, subjects 2 and 3 con-

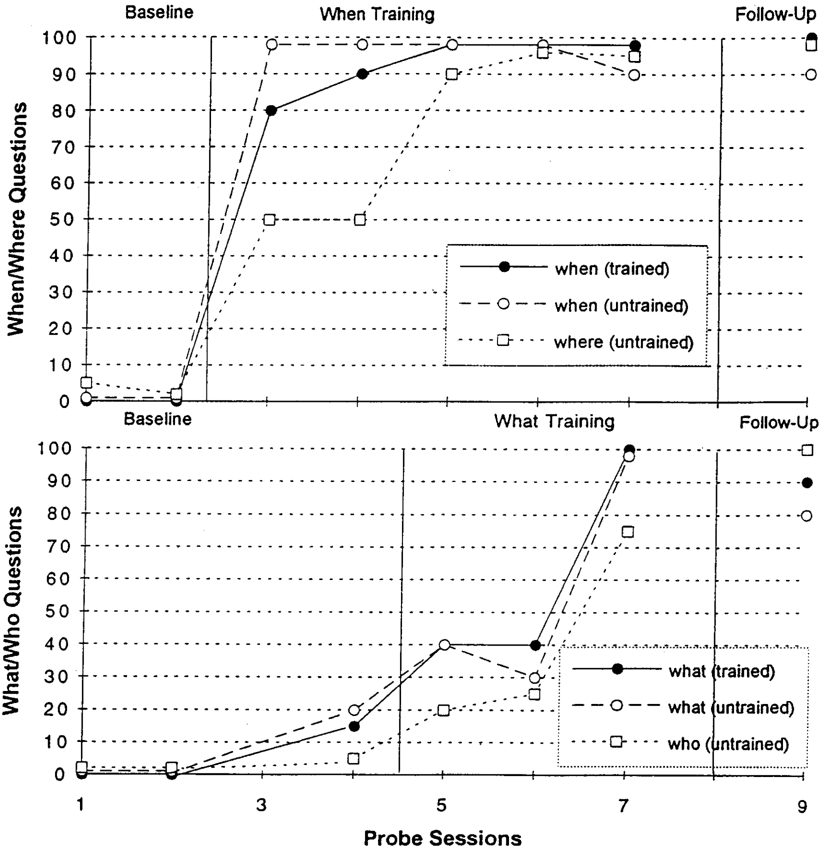

FIG. 4. Percentage of grammatically correct productions of *when, where, what,* and *who* questions during baseline and experimental training phases of the study for subject 1 (MD). These data indicate that adjunct movement training of *when* questions resulted in generalized production of *where* questions—both of which rely on adjunct movement—however, this training had little if any effect on production of *what* and *who* questions—both of which rely on argument movement. When argument movement treatment was applied to *what* questions, generalization occurred to *who* questions.

tinued to produce wh-morpheme selection errors (20%) even though errors of co-reference were largely eliminated.

A somewhat different pattern of sentence production acquisition was noted in the other four subjects. While argument/adjunct movement treatment resulted in improved production of trained *wh*-question forms as well as a decrease in errors of co-referencing in untrained questions forms, these subjects' *wh*-morpheme selection errors precluded correct *wh*-question production. Therefore, additional *wh*-morpheme discrimination/production training was required which resulted in correct production of *all wh*-question con-

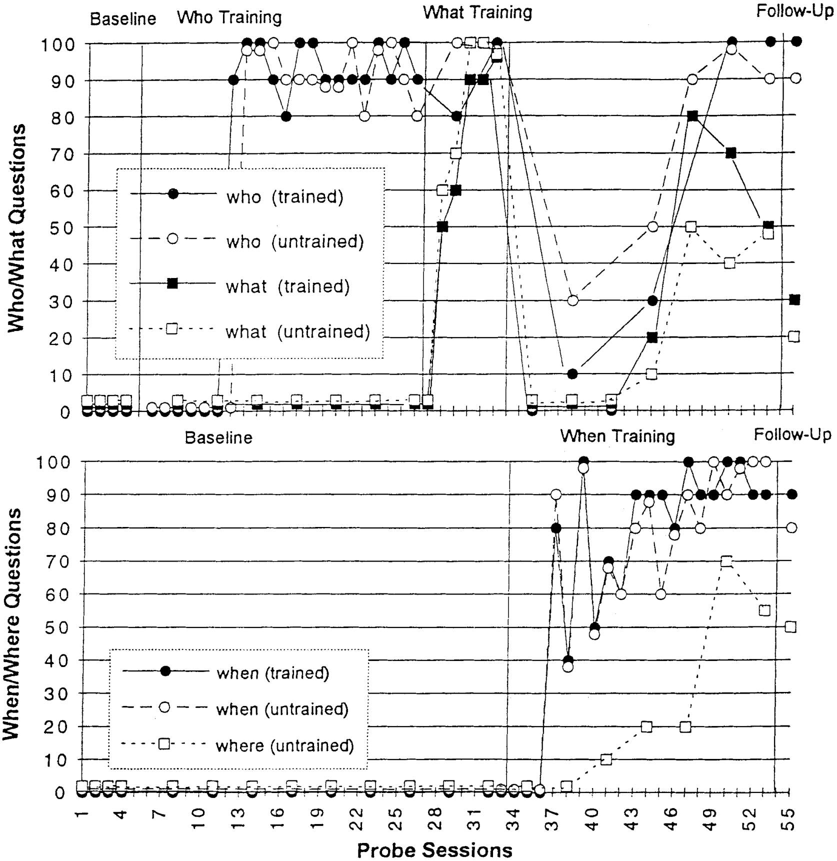

FIG. 5. Percentage of grammatically correct productions of *who, what, when,* and *where* questions during baseline and experimental training phases of the study for subject 2 (FP). These data indicate that argument movement training of *who* questions resulted in no change in production of *what, when,* or *where* question productions; when treatment was extend to *what* questions, rapid acquisition of *what* occurred. Subsequently, when adjunct treatment was applied to *when* question productions, generalization occurred to *where* questions—both of which rely on adjunct movement.

structions. For example, subject 4 (see Fig. 7) was first trained to produce *where*-questions using adjunct movement training, which resulted in successful production of *where*-questions. In addition, this training successfully eliminated errors of co-reference that were evident during baseline testing (see Table 6: *wh*-sel/co-ref errors during baseline as compared to pre *wh*-discrimination/production training), immediately for *when* questions (also requiring adjunct movement) and a few training sessions later for *what* and *who* questions (requiring argument movement; see Fig. 8). However, this training did not influence *wh*-morpheme selection as this subject continued to

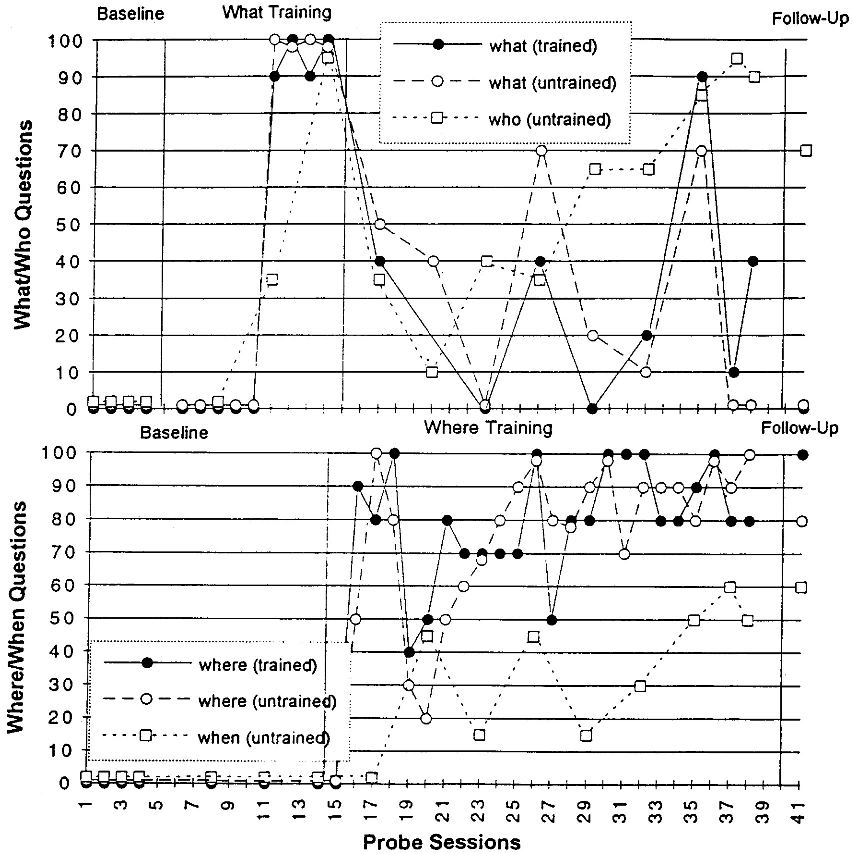

FIG. 6. Percent grammatically correct productions of *what, who, when,* and *where* questions during baseline and experimental training phases of the study for subject 3 (JG). These data indicate that when argument treatment ensued for *what* question production, generalized production of *who* questions occurred—which also rely on argument movement. This training had no effect on *where* or *when* question productions—both of which rely on adjunct movement. Subsequent application of adjunct movement treatment to *where* questions, resulted in generalized production to *when* questions.

display a large number of *wh*-morpheme selection errors throughout adjunct movement training. The subject continued to consistently misselect the *wh*-word—producing any one of the four *wh*-morphemes at random. Therefore, *wh*-morpheme discrimination/production training was provided, which resulted in correct production of all *wh*-questions as shown in Fig. 7.

As depicted in Figures 9, 11, and 13, the remaining subjects (subjects 5, 6, and 7, respectively) performed in a manner similar to that of subject 4. That is, application of argument/adjunct movement training resulted in correct production of only the *wh*-question form being trained; prevalent

TABLE 6
Wh-Question Production Errors (Percentage Errors by Type) Occurring during Constrained Sentence Production Probes on Baseline and Final Treatment Probes for All Subjects

Phase/subject	Error type (percent occurrence)							
	wh-sl/co-ref	*wh*-sl/mvt	*wh*-sl	co-ref	mvt	s/aux	lex	Correct
Baseline (pre-argument/adjunct movement treatment)								
Subject 1 (MD)	2	0	0	90	0	2	0	6
Subject 2 (FP)	30	0	22	48	0	0	0	0
Subject 3 (JG)	20	0	15	40	20	5	0	0
Subject 4 (TE)	98	0	0	0	0	2	0	0
Subject 5 (GG)	40	0	32	2	0	0	0	26
Subject 6 (PR)	40	2	41	17	0	0	0	0
Subject 7 (SW)	50	0	10	40	0	0	0	0
Pre *wh*-discrimination production treatment								
Subject 4 (TE)	0	0	70	8	0	0	0	22
Subject 5 (GG)	8	0	39	2	0	0	0	51
Subject 6 (PR)	8	0	60	7	0	0	0	25
Subject 7 (SW)	0	0	70	2	0	0	0	28
Final treatment probe								
Subject 1 (MD)	0	0	0	5	0	2	0	93
Subject 2 (FP)	0	0	20	0	0	2	0	78
Subject 3 (JG)	3	0	20	5	0	0	0	72
Subject 4 (TE)	0	0	5	0	0	0	0	95
Subject 5 (GG)	0	0	4	5	0	0	0	91
Subject 6 (PR)	0	0	3	5	0	0	0	92
Subject 7 (SW)	0	0	0	3	0	0	0	97

Note. Error patterns noted prior to implementation of *wh*-morpheme discrimination/production treatment also are shown for subjects who received this treatment (subjects 4–7). The proportion of grammatically correct responses produced on each of these probes is also indicated. *Wh*-sl/co-ref, *wh*-morpheme selection error plus co-referencing error; *wh*-sl/mvt, *wh*-morpheme selection error plus movement error; *wh*-sl, *wh*-morpheme selection error; co-ref, co-referencing error; mvt, movement error; s/aux, subject-auxiliary verb inversion error; lex, lexical error (see Appendix C).

wh-morpheme selection errors precluded correct production of the other *wh*-question constructions (see Table 6). However, when *wh*-morpheme discrimination/production training was applied, correct production of all question forms resulted. It is of interest, however, to note that for these subjects, like subject 4, argument/adjunct training successfully eliminated errors of co-reference (see Figs. 10, 12, and 14) and resulted in a concomitant increase in correct argument/adjunct movement patterns. Further, covariance between argument movement structures and between adjunct movement structures was noted for subjects 5 and 6. That is, subject 5 produced *who* questions at a high level during baseline and also displayed correct argument movement for *what* questions during baseline testing, although *wh*-morpheme selection errors prevented his correct production of *what* questions. Interestingly, however, this subject did not show correct adjunct movement during the baseline for either *when* or for *where* questions. When adjunct movement treatment was applied to *when* questions, correct adjunct move-

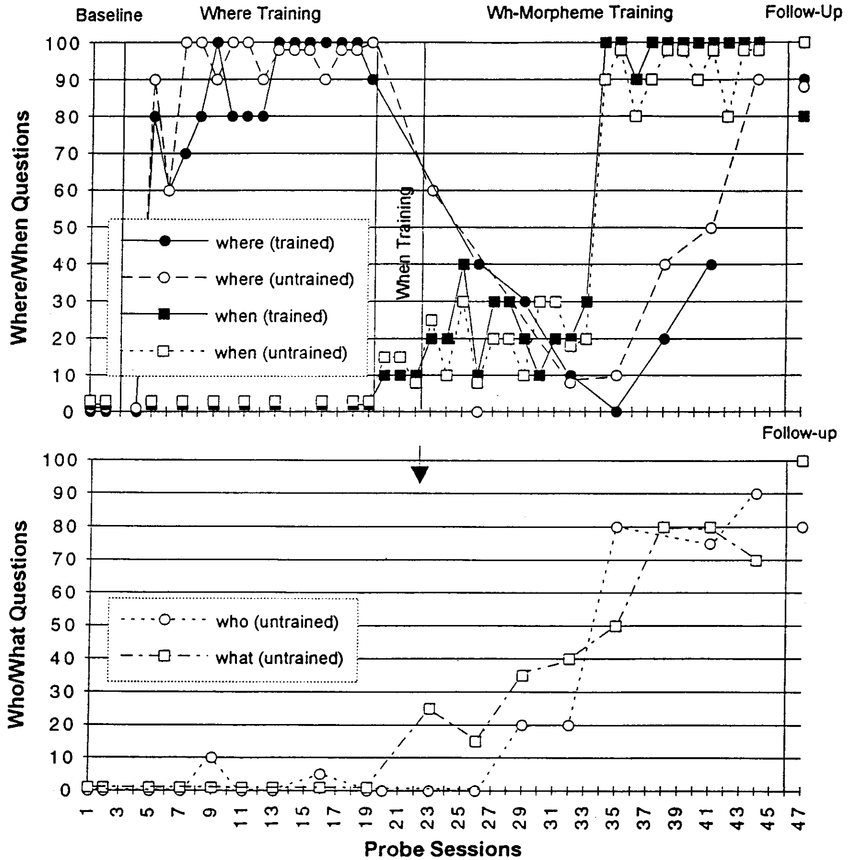

FIG. 7. Percentage of grammatically correct productions of *where, when, who,* and *what* questions during baseline and experimental training phases of the study for subject 4 (TE). These data indicate that adjunct movement treatment applied to *where* resulted in improved *where*-question production, but this training did not influence correct production of the remaining *wh*-questions. Adjunct movement training applied to *when* questions was unsuccessful due to prevalent *wh*-morpheme selection errors. Generalization across all *wh*-question forms occurred when *wh*-morpheme discrimination/production training was initiated. (Arrow indicates session in which *wh*-morpheme treatment was begun.)

ment was forthcoming for both *when* and for untrained *where* questions productions (see Fig. 10).

Figure 12 shows a similar covariance between argument movement structures and between adjunct movement structures for subject 6. Baseline data again showed few instances of correct movement in *wh*-question production attempts with a high number of co-referencing errors noted for all *wh*-question responses (see as well Table 6). When argument movement treatment was applied to *what* questions, correct movement was initially seen on *what*

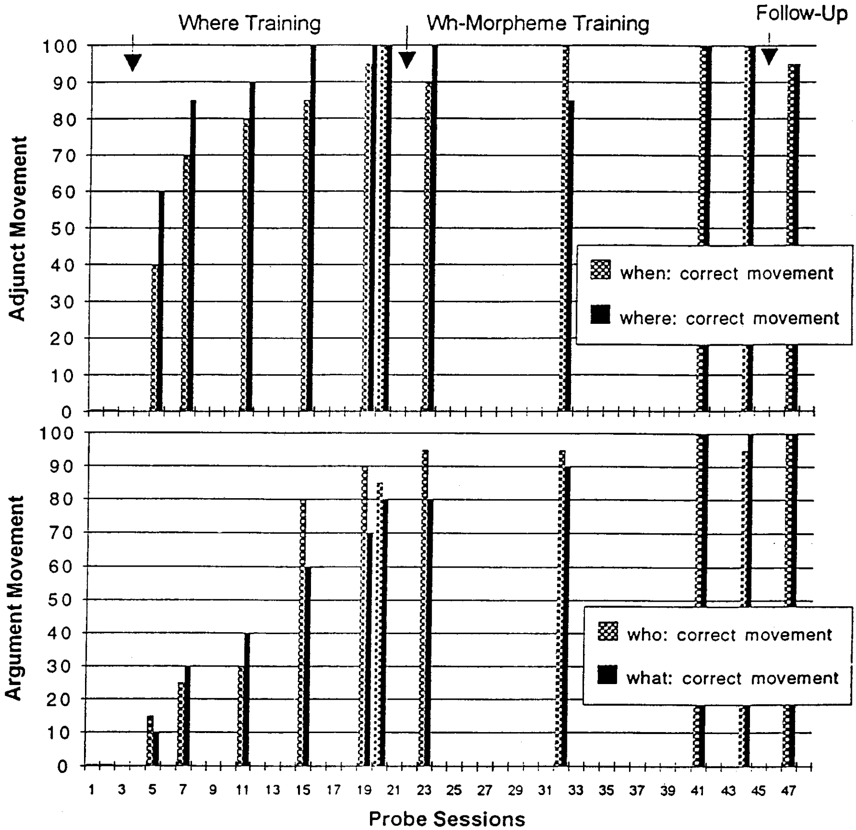

FIG. 8. Percent correct adjunct and argument movement noted in production of *where, when, what,* and *who* questions on experimental probes during baseline and experimental phases of the study for subject 4. Note that adjunct movement training applied to *where* questions resulted in correct movement for both *where* and *when* questions. Subsequently, argument movement, too, was improved, with a correct adjunct movement seen on both *who* and *what* questions.

and *who* questions (requiring argument movement). Some four treatment sessions later, adjunct movement also began to emerge. A clear and distinct pattern of argument and adjunct movement was not noted for subject 7 as both types of movement emerged when argument movement was applied to *who* questions (see Fig. 14).

Discourse Effects

The effects of training our aphasic subjects to produce *wh*-questions also was noted in discourse production patterns. Pre- versus post-testing production patterns are shown in Tables 7 and 9 for individual subjects across se-

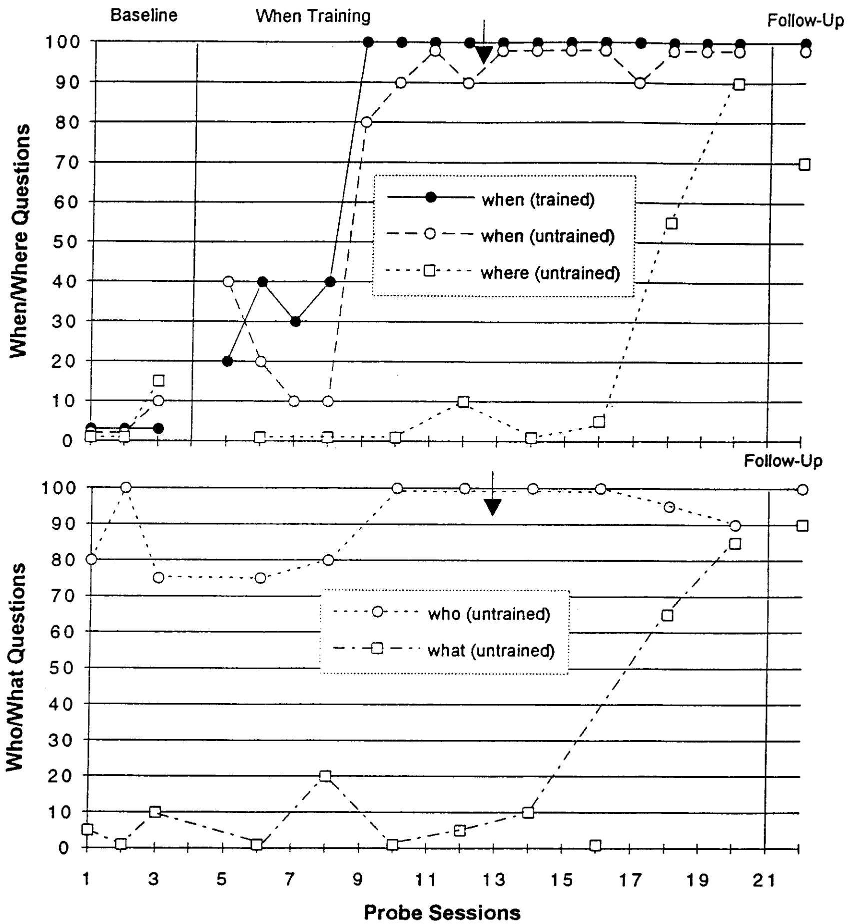

FIG. 9. Percentage of grammatically correct productions of *when, where, who,* and *what* questions during baseline and experimental training phases of the study for subject 5 (GG). These data indicate that adjunct movement treatment applied to *when* resulted in improved *when*-question production, but no generalization to the remaining *wh*-questions. Note that *who* questions were produced correctly at a high level prior to initiation of treatment. Generalization across all *wh*-question forms occurred when *wh*-morpheme discrimination/production training was initiated, indicated by the arrow on each graph.

lected language variables. Tables 8 and 10 show the results of statistical analyses of these data using t-tests for matched pairs to compare pre- versus post-treatment means. As noted in Table 8, statistically significant changes in the proportion of simple and complex sentences produced prior to and following treatment was evident, although no notable changes in the proportion of grammatical sentences was seen. These changes reflect a decrease in simple sentence productions and a concomitant increase in complex sentence

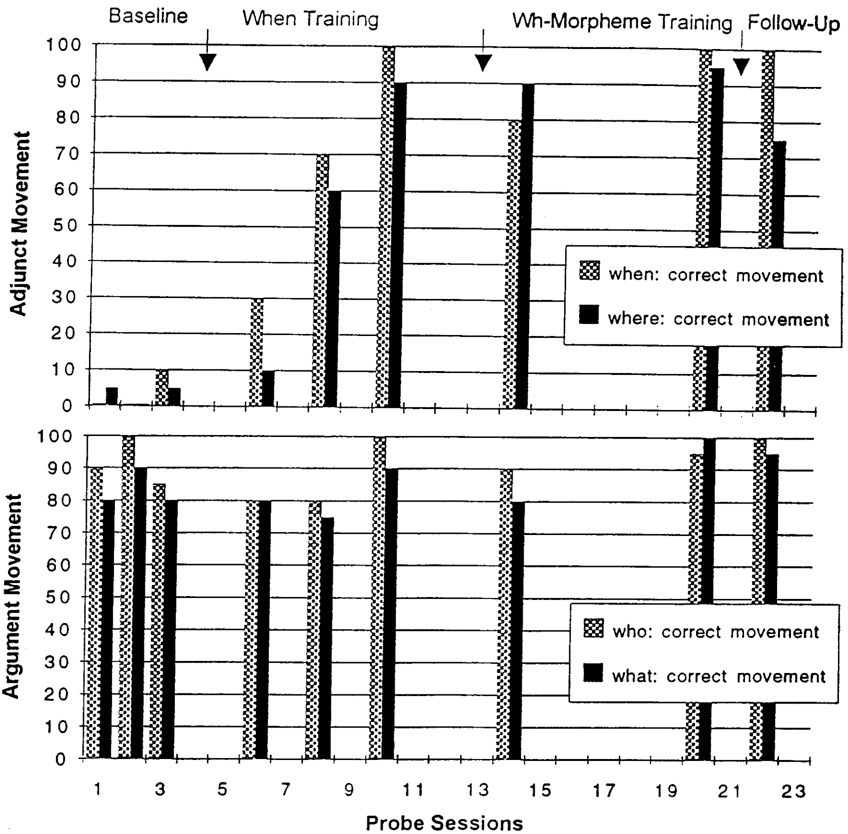

FIG. 10. Percentage of correct adjunct (*when* and *where*) and argument (*what* and *who*) movement noted in production of *wh*-questions on experimental probe task during baseline and experimental phases of the study for subject 5. Note that during baseline, correct argument movement was noted for both *who* and *what* questions, even though he only was able to produce *who* questions grammatically. Adjunct movement treatment applied to train *when* questions resulted in a concomitant increase in correct adjunct movement for both *when* and for *where* questions.

productions. That is, 67 to 98% (mean = 81.14; *SD* = 12.63) of utterances produced in pre-treatment samples were simple sentences as compared to 43 to 90% (mean = 67.31; *SD* = 17.40) of utterances produced in post-treatment samples, whereas 2 to 33% (mean = 18.86; *SD* = 12.63) of utterances produced in pre-treatment samples were considered complex sentences, as compared to 10 to 56% (mean = 32.59; *SD* = 17.17) of utterances produced in post-treatment samples. Four of the subjects also showed increases in MLU on post-treatment discourse samples as compared to pre-treatment samples (i.e., subjects 2, 4, 5, and 7); however, this increase was not statistically significant across subjects. Slight, but also not statistically

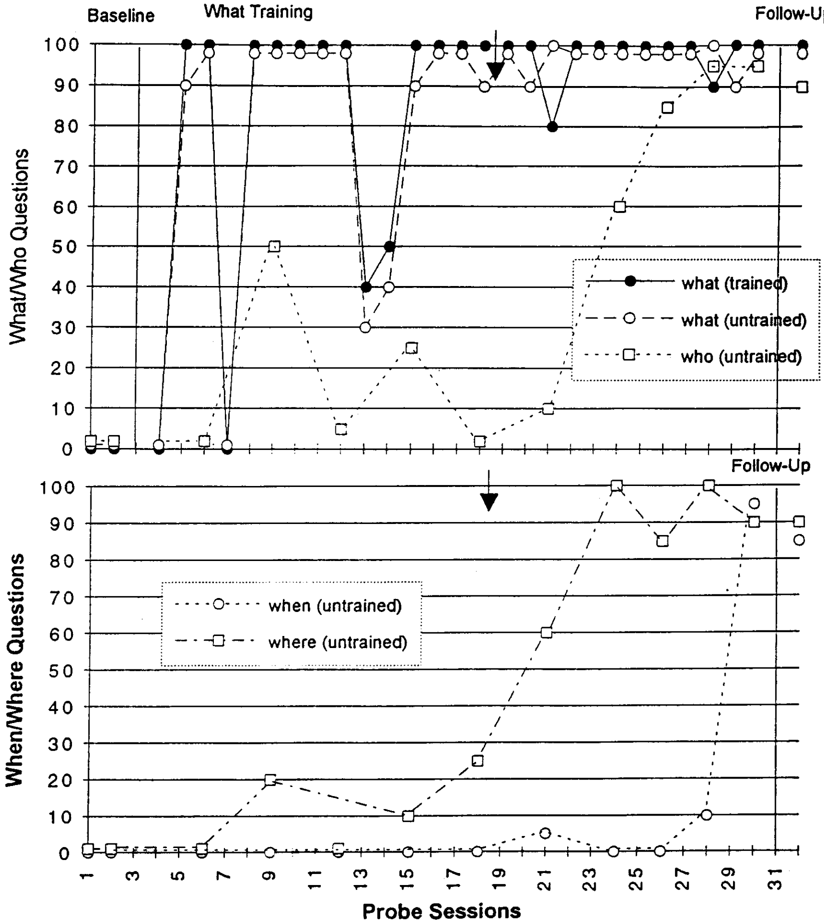

FIG. 11. Percentage of grammatically correct productions of *what, who, when,* and *where* questions during baseline and experimental training phases of the study for subject 6 (PR). These data indicate that argument movement treatment applied to *what* resulted in improved *what*-question production, but no generalization to the remaining *wh*-questions was observed. Generalization across all *wh*-question forms occurred when *wh*-morpheme discrimination/production training was initiated, indicated by arrows in the graphs.

significant, increases in the mean embeddings per utterance were noted for some subjects (i.e., subjects 2, 3, and 5), although their mean embeddings remained well below that of normal subjects.

Examination of the lexical categories in the corpus indicated no discernible change in open class/closed class ratio. However, four of the subjects showed decreases in noun/verb ratio, indicating an increase in the proportionate number of verbs as compared to nouns produced in discourse samples following treatment (i.e., subjects 2, 4, 6, and 7). This change in noun : verb

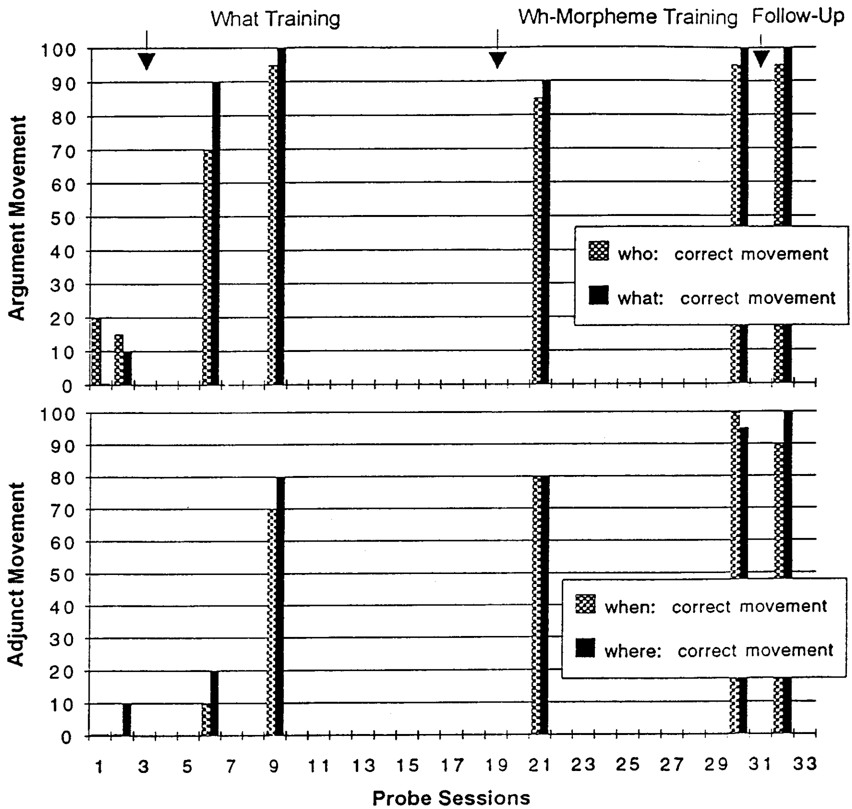

FIG. 12. Percentage of correct argument and adjunct movement noted during production of *wh*-questions on experimental probe task for subject 6. Note that argument treatment applied to train *what* questions resulted in an increase in correct argument movement for both *what* and *who* questions. Subsequently, correct adjunct movement emerged for both *where* and *when* questions.

ratio, however, was not statistically significant across subjects. Nevertheless, changes in verb production were also reflected in the verb and verb argument structure analysis (see Table 9). Our subjects showed a decrease in usage of obligatory one- and two-place verbs (between 41% and 52% in pre-treatment samples as compared to between 31 and 41% in post-treatment samples). Additionally, four of the seven subjects showed increases in proportionate use of complement verbs (i.e., subjects 1, 2, 3, and 7), together with a statistically significant shift from greater production of these verbs in x, y (phrasal complement) form to proportionally greater numbers of these verbs produced with sentential complements (see Table 10).

It is also of interest to note that all of the subjects showed statistically significant increases in the proportion of verbs produced with correct verb

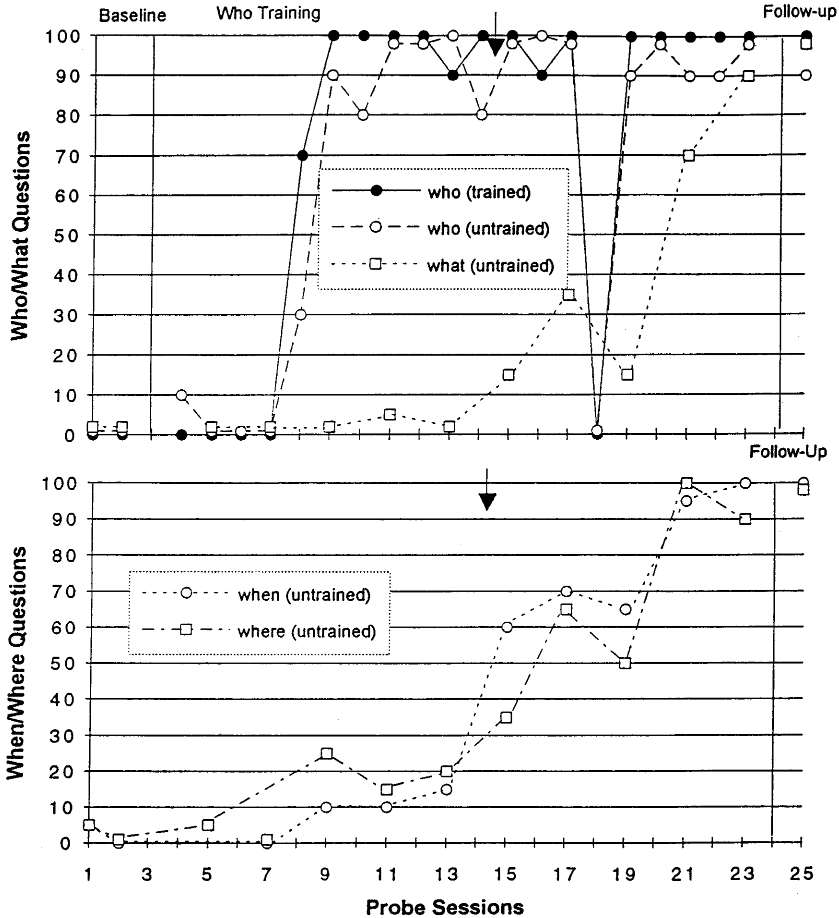

FIG. 13. Percentage of grammatically correct productions of *who, what, when,* and *where* questions during baseline and experimental training phases of the study for subject 7 (SW). These data indicate that argument movement treatment applied to *who* resulted in improved *who*-question production, but no generalization to the remaining *wh*-question forms was seen. Generalization across all *wh*-question occurred with provision of *wh*-morpheme discrimination/production training. (Arrows indicate session in which *wh*-morpheme treatment was initiated.)

argument structure. As shown in Tables 9 and 10, between 39 and 84% (mean = 61.14%; *SD* = 16.53) of verbs produced in pre-treatment samples were produced with correct verb argument structure as compared to post-treatment samples in which between 49 and 98% (mean = 68.14%; *SD* = 18.73) of verbs were produced with correct verb argument structure. This change in performance was largely due to significant increases in correct production of one- and two-place structures (i.e., obligatory and optional

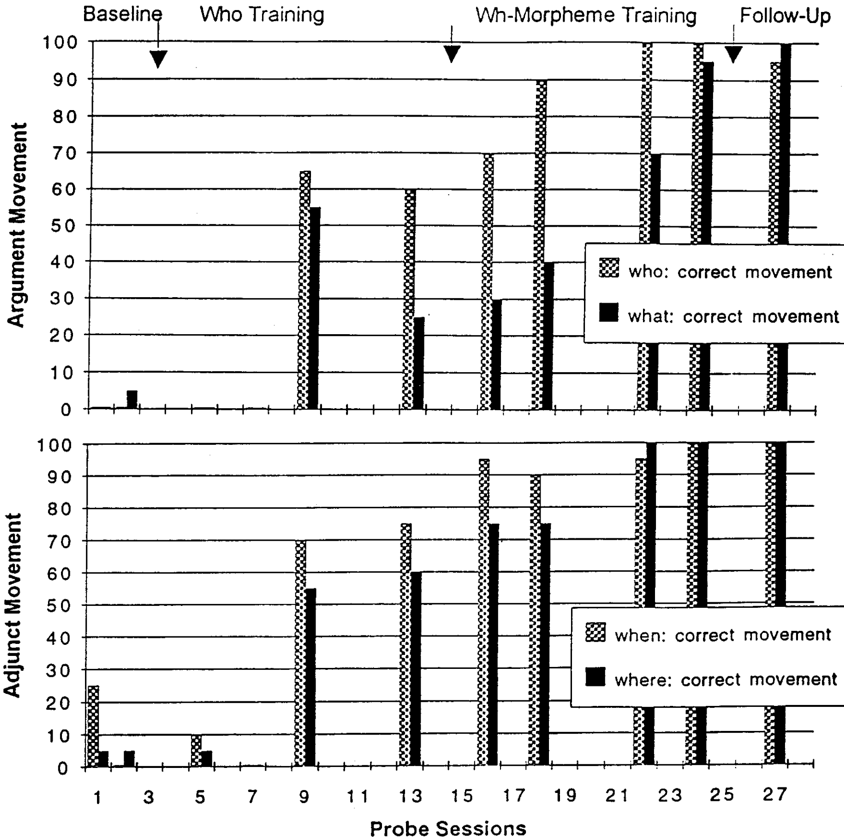

FIG. 14. Percentage of correct argument and adjunct movement occurring on *wh*-question production probes during baseline and experimental phases of the study for subject 7. Note that argument movement treatment applied to train *who* question productions resulted in an increase in correct argument and adjunct movement.

two-place verbs as well as complement verbs produced with direct object NPs). This change in production patterns was also revealed in analysis of the individual arguments produced across samples. As noted in Table 9, all subjects showed increases in correct usage of both x (Agents) and y (Themes), resulting in statistically significant effects (see Table 10). Additionally, some subjects showed better usage of the third argument (i.e., z—goal) (although few three-place verbs were produced by our subjects and, therefore, this change was not statistically significant), and six of the seven subjects (i.e., all except subject 3) showed increases in the proportion of sentential complements produced correctly, resulting in a statistically significant difference between pre- and post-treatment samples. It is of further interest to note that a statistically significant change in the proportion of

TABLE 7
Narrative and Conversational Discourse Data Derived from Analysis of Pre- vs. Post-treatment Samples

	Aphasic subjects														
	1 (MD)		2 (FP)		3 (JG)		4 (TE)		5 (GG)		6 (PR)		7 (SW)		
Language variables	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Normal subjects
Total utterances coded	233	306	184	172	132	152	230	175	105	116	257	175	150	117	170
MLU	3.20	3.00	5.80	6.10	3.80	3.80	2.70	3.20	3.30	5.40	3.1	3.1	3.9	4.9	12.64
Proportion (%) grammatical sentences	18	18	23	21	07	13	06	04	49	55	09	06	37	38	78
Simple sentences	74	65	67	55	88	81	98	82	78	55	95	90	68	43	43
Complex sentences	26	35	33	45	12	19	02	18	22	45	05	10	32	56	57
Mean embeddings	.24	.21	.41	.50	.10	.14	.02	.02	.28	.72	.02	.04	.70	.67	1.10
Noun/verb	1.03	1.19	1.76	.76	1.46	1.80	2.09	1.75	1.06	1.13	2.82	1.94	1.09	.78	.98
Open class/closed class	3.00	3.30	2.00	1.20	1.80	1.70	2.60	2.00	1.50	1.30	2.00	2.20	1.20	1.43	.91

Note. Normal data obtained from a sample of five age matched normal control subjects (Thompson et al., 1994).

TABLE 8
Statistical Analysis (*t* Tests for Matched Pairs) Comparing Pre- vs. Post-treatment Narrative and Conversational Discourse Data

	Mean (*SD*)			
Language variable	Pre	Post	*T* Score	Probability
MLU	3.69 (1.02)	4.21 (1.25)	−1.749	0.131
Proporation of grammatical sentences	21.29 (16.42)	22.14 (18.36)	−0.603	0.569
Simple sentences	81.14 (12.63)	67.31 (17.40)	4.702	0.003*
Complex sentences	18.86 (12.63)	32.59 (17.17)	−4.796	0.003*
Mean embeddings	0.25 (0.24)	0.33 (0.30)	−1.207	0.273
Noun/verb ratio	1.62 (0.66)	1.34 (0.49)	1.442	0.199
Open class/closed class ratio	2.01 (0.62)	1.88 (0.73)	0.857	0.424

* Significance at $p < .05$.

adjuncts (J) produced correctly also was noted. Production of adjuncts ranged from 23 to 50% (mean = 34.14; *SD* = 11.72) prior to treatment and from 20 to 100% (mean = 62.57%; *SD* = 32.29) in post-treatment samples. These data indicated that following treatment our subjects produced proportionately more verbs across discourse samples and, while retaining a preference for producing primarily simple verbs (i.e., one- and two-place verbs), they more often produced these verbs, as well as other more complex verbs, with correct verb argument structure.

DISCUSSION

Generalization Patterns

The present data indicate that our treatment approach was successful in that all subjects improved their *wh*-question productions as shown by generalization to untrained sentences. Thus, these data support our previous work investigating the treatment of sentence production deficits in aphasic individuals (Shapiro & Thompson, 1994; Thompson & Shapiro, 1994; Thompson, Shapiro, & Roberts, 1993). When the linguistic underpinnings of (a) the language deficits exhibited by aphasic individuals, (b) the sentences selected for treatment, and (c) the treatment strategy applied are considered, treatment appears to be efficacious. When linguistic underpinnings are not considered, generalization effects are considerably diminished—or are absent, resulting in little or no discernible improvement in sentence production beyond the kind of constructions that were trained (cf. Wambaugh & Thompson, 1989; Doyle, Goldstein, & Bourgeois, 1987).

There is, of course, more to this story than this simple conclusion would indicate. Consider that when the emergent generalization patterns occurring across subjects were examined, we found two somewhat different patterns.

TABLE 9
Verb and Verb Argument Structure Data Derived from Pre- and Post-treatment Narrative and Conversational Discourse Samples (n = 2 of Each Type per Subject)

Language variables	Subject														
	1 (MD)		2 (FP)		3 (JG)		4 (TE)		5 (GG)		6 (PR)		7 (SW)		Normal subjects
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Proportion of verbs produced by type															
Obligatory one-place	18	13	28	19	09	12	12	16	22	09	41	23	23	14	09
Obligatory two-place	23	14	23	22	37	26	30	15	30	25	10	15	18	27	15
Obligatory one- and two-place	41	27	51	41	46	38	32	31	52	34	51	38	41	41	24
Obligatory three-place	02	00	01	01	01	00	00	00	00	00	00	00	02	02	03
Optional two-place	12	08	05	03	16	19	20	35	14	18	20	19	08	17	14
Optional three-place	01	00	01	01	06	08	01	00	00	04	00	02	00	02	10
Complement	37	42	32	45	12	17	05	00	19	14	10	14	32	36	32
x, y	76	45	61	50	64	56	100	00	67	50	100	58	52	38	64
x, S'	24	55	39	50	36	44	00	00	33	50	00	42	48	62	36
Copula	07	22	10	10	19	18	33	37	15	29	19	27	17	19	17

Proportion (%) of verbs produced by type with correct argument structure															
Obligatory one-place	62	68	71	71	100	100	77	57	100	100	33	79	77	100	100
Obligatory two-place	52	59	54	49	58	70	14	40	100	100	43	00	100	88	98
Obligatory three-place	00	—[a]	25	00	00	—	—	—	—	—	—	—	00	67	90
Optional two-place	45	50	33	50	69	66	57	57	100	100	34	60	89	80	98
Optional three-place	00	—	33	25	33	80	00	—	—	75	—	100	—	50	97
Complement	46	42	34	44	33	30	00	—	86	100	50	36	77	89	97
x, y	59	61	71	77	66	75	00	—	100	100	60	66	100	100	92
x, S'	21	32	34	28	66	00	00	—	00	100	00	75	80	91	97
Copula	85	87	53	90	61	90	100	100	100	100	33	45	61	84	97
Total (%) verbs produced with correct argument structure	52	59	51	55	59	71	61	56	84	98	39	49	82	89	97
Proportion (%) of correctly produced arguments and adjuncts															
Agent (x)	69	78	65	76	82	87	36	66	99	100	36	71	97	97	98
Theme (y)	64	72	74	81	81	84	30	50	96	100	54	62	95	96	98
Goal (z)	00	50	75	100	25	25	—	—	—	25	—	25	12	58	93
Sentential complement (S')	23	29	14	46	25	06	00	25	16	75	17	63	24	96	98
Predication phrase (P)	88	87	79	97	63	100	100	75	83	96	53	66	67	67	96
Adjunct (J)	25	20	49	83	25	65	39	75	50	100	28	45	23	70	94

Note. Normal data obtained from a sample of five age matched normal control subjects (Thompson et al., 1994).

[a] Cells containing (—) indicate instances in which the proportion of correct production of that variable could not be computed because it was not produced in the corpus (0%).

TABLE 10
Statistical Analysis of Verb and Verb Argument Structure Data Derived from Narrative and Conversational Discourse Samples Collect at Pre- vs. Post-treatment

Language variables	Mean (*SD*)		*T* Score	Probability
	Pre	Post		
Proportion of verbs produced by type				
Obligatory and optional one and two place	19.95 (2.55)	17.51 (3.42)	1.853	0.113
Obligatory and optional three place	1.07 (1.21)	1.43 (1.40)	−0.826	0.441
Complement	21.00 (12.65)	24.00 (17.00)	−1.260	0.254
x, y	74.29 (18.96)	49.50 (7.31)	3.799	0.013*
x, S'	25.71 (18.96)	50.50 (7.31)	−3.799	0.013*
Copula	17.14 (8.33)	23.14 (8.75)	−2.440	0.050*
Proportion (%) of verbs produced by type with correct argument structure				
Obligatory and Optional one and two place	65.14 (23.25)	68.76 (20.60)	−2.860	0.029*
Complement	46.57 (28.88)	56.83 (29.79)	−0.548	0.607
x, y	65.14 (33.60)	79.83 (16.68)	−2.531	0.052*
x, S'	28.71 (33.12)	54.33 (40.00)	−0.859	0.430
Copula	70.43 (25.31)	85.14 (18.73)	−2.575	0.042*
Total (%) verbs produced with correct argument structure	61.14 (16.53)	68.14 (18.73)	−2.953	0.026*
Proportion (%) of correctly produced arguments and adjuncts				
Agent (x)	69.14 (25.97)	82.14 (12.93)	−2.463	0.049*
Theme (y)	70.57 (23.55)	77.86 (17.93)	−3.104	0.021*
Goal (z)	28.00 (32.95)	47.17 (29.63)	−2.636	0.078
Sentential complement (S')	17.00 (8.64)	48.57 (31.39)	−2.675	0.037*
Predication phrase (P)	76.14 (16.11)	84.00 (14.56)	−1.080	0.322
Adjunct (J)	34.14 (11.72)	62.57 (32.29)	−2.907	0.027*

Note. The proportion of three-place verbs produced with correct argument structure was not statistically analyzed due to the low frequency of use of these verbs.

* $p < .05$.

First, for three of our agrammatic Broca's aphasic patients, when treatment was applied to *wh*-questions requiring argument movement (e.g., *who* or *what* questions), generalized production of untrained *wh*-questions was restricted to those also relying on argument movement. Similarly, when treatment was applied to *wh*-questions requiring movement of the adjunct phrase (e.g., *when* or *where* questions), generalization occurred to untrained *wh*-questions relying on the same adjunct movement. Importantly, argument movement constructions did not generalize to adjunct movement constructions, and vice versa. These data, then, indicate that the argument/adjunct distinction found in both the theoretical linguistic and psycholinguistic literature extends to the cross-generalization patterns exhibited by our aphasic patients.

A second, unexpected, pattern was observed in our remaining aphasic subjects—a pattern that was revealed only by carefully examining the production patterns (including error patterns) occurring across experimental phases that is required when using single-subject experimental manipulations. Namely, four of our agrammatic subjects evinced persistent *wh*-morpheme selection errors that precluded their correct production of *wh*-questions other than those trained. While these subjects readily acquired production of trained *wh*-questions, they appeared to misselect (more so than did the first three subjects) among the four *wh*-morphemes (*who, what, when,* and *where*) when producing *wh*-questions. Therefore, *wh*-morpheme discrimination/production training was applied which resulted in generalization across *all wh*-question constructions. Interestingly, these subjects—like the first three—also showed errors concerned with argument/adjunct movement processes during the baseline phases of the study and argument/adjunct movement treatment successfully eliminated these error patterns. Additionally, movement treatment resulted in generalization across *wh*-questions relying on similar movement operations for three of these subjects. That is, when adjunct movement was trained, adjunct movement structures emerged simultaneously, as did argument movement structures at a later point in recovery. Similarly, when argument movement was trained, correct argument movement was seen emerging in both trained and untrained questions relying on argument movement; and later correct adjunct movement also emerged. However, during this training, correct *wh*-movement was masked by their deficit in *wh*-morpheme selection.

The observed generalization across different types of movement (e.g., from argument to adjunct movement) noted in these subjects deserves some comment. Although this generalization was delayed in three of the four subjects—that is, for example, generalization from argument movement to adjunct movement occurred only after generalization across argument movement structures was noted—the case could be made that these movement operations are not different. We suggest that because argument movement and adjunct movement are in essence subsets of the more general operation of *wh*-movement, this generalization pattern was not surprising. The lack of such generalization in the first three subjects could be attributed to their more severe co-referencing deficit as noted in their error patterns; the other four subjects showed more mild co-referencing deficits and, therefore, these errors were more readily eliminated. The elimination of these mild co-referencing errors led, then, to emergence of more general *wh*-movement operations.

These sentence production recovery patterns suggest that (at least) two operations must be completed for successful *wh*-question production to take place: movement of the proper sentence constituent and control of sub-lexical features of the *wh*-morpheme (i.e., *wh*-morpheme selection for ± human, etc.). So far as the latter is concerned, we note that the *wh*-morpheme is a *functional category* (i.e., not determined by the features ±N, ±V)—a type of category that is particularly compromised in the speech of at least some agrammatic patients (Saffran et al., 1989). Grodzinsky (1990) has suggested that the sentence production deficit in agrammatism can be described in terms of the representations referring to such categories; specifically, functional categories appear to be filled lexically in a random fashion. Our data suggesting random selection of *wh*-morphemes during *wh*-question production support this hypothesis.

Our findings highlight the importance of using linguistic constructs to guide investigations in aphasia. Clearly, the Principles and Parameters Approach (Chomsky, 1991, 1993) used here assisted in our learning that sentence production deficits in agrammatism are not homogeneous. Some subjects had difficulty establishing the binding relations between the trace and its proper antecedent in production, while others presented a substantial problem with sublexical selection. By applying experimental manipulations to each of these noted deficits, we find concomitant changes in production patterns that can be explained along linguistic lines.

The observed dissociation between *wh*-movement operations and selection of the *wh*-morpheme suggests that two distinct operations underlie *wh*-question production. This observation also suggests that separate treatment approaches for alleviating *wh*-question production deficits in aphasic individuals may be warranted. Treatment of *wh*-question productions as well as other sentence types requires careful analysis of *how* and in *what ways* the sentence processing/production system has been affected with brain damage. Indeed, the more we learn about the lingusitic and psycholinguistic underpinnings of sentence production and, of course, comprehension—and the deficits subsequent to brain damage—the more detailed we can be about the design of treatment.

Discourse Patterns

Consider now the data from our analysis of the spontaneous discourse of our patients, which suggest that the benefits that our patients received from treatment extended beyond the clinical setting. Most subjects not only produced proportionately more verbs in post-treatment samples as compared to pre-treatment samples, they also produced more verbs with correct argument-structure—particularly two-place verbs and complement verbs in their x, y (phrasal complement) form. Additionally, our subjects produced more adjuncts in post-treatment samples as compared to pre-treatment samples. We also observed on post-treatment relative to pre-treatment a greater proportion of complex sentences for all subjects, more embedded clauses per utterance (for some subjects), and an increase in production of sentential complements. Finally, subjects on post-treatment also used a greater number of *wh*-clauses (e.g., ''Cinderella . . . who went the ball beautiful . . . rags now'') and that-clauses (e.g., ''Cinderella . . . knows that this shoe is . . . the one'').

Because treatment was focused on (a) the thematic properties of phrases (phrases that are eventually displaced), (b) the movement of phrases, and (c) the argument/adjunct distinction, it follows that an increased number of verbs produced with their correct thematic properties, an increased number of correctly produced arguments and adjuncts, and an increased number of complex sentences (defined as those involving either moved sentence constituents or embedded clause structures) would be observed in post-treatment samples. Also, the noted increase in use of *wh*- and that-clauses in post-treatment might be a consequence of that part of our treatment which emphasized complementizers—that is, greater access to complementizers in general may have been forthcoming with improved access to *wh*-morphemes. 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 attribute the changes noted in this study in spontaneous discourse to two possible variables: (a) the method of grammatical analysis of spontaneous discourse we have developed—emphasizing the role of lexical properties in syntax—was perhaps more sensitive than that used in other studies, and (b) the treatment provided here was focused explicitly on the lingusitic and psycholinguistic underpinnings that we hypothesized would influence production of sentences. Indeed the present observation that sentence production treatment influenced lexical and syntactic properties that apply to sentence production in general attests to the efficacy of this treatment approach. If such improvements had not been forthcoming as a result of our intervention, the efficacy of this approach to treatment could be questioned. As we have pointed out previously, it is the **generalization of treatment effects** that indicates the efficacy of treatment.

Conclusions

Our findings attest to the contribution that detailed recovery data can make both to understanding the nature of sentence production deficits, and to issues regarding normal sentence production. We have shown that our program—though successful in its treatment application—can also be considered a novel experimental paradigm for examining various types of lexical and syntactic relations. We find our results compelling in terms of the use of treatment research paradigms—i.e., single-subject experimental designs—for investigating theoretical issues relevant to both normal and agrammatic language. Because agrammatism appears to be a linguistically selective impairment, studying the relations between and among structures through controlled analysis of generalization patterns provides information relative to the nature of the disorder and to the ‘‘usability’’ of the linguistic constructs upon which our analyses are based.

APPENDIX A

Verb and Verb Argument/Adjunct Codes Used in Discourse Analysis

Obligatory one-place verbs (ob1), intransitive verbs, requiring an external argument only—(Agent [x]).
e.g., the verb work. *[The men]$_{Agent(x)}$ work$_{(ob1)}$.*

Obligatory two-place verbs (ob2), transitive verbs, requiring two arguments (and external Agent, [x] and a Theme/Patient [y] or a Theme/Patient [y] and a Predication Phrase [P]—Noun Phrase, Prepositional Phrase, or Adjectival Phrase) (x, y; y, P).
e.g., the verb fix. *[Zack]$_{Agent(x)}$ fixed$_{(ob2)}$ [the radio]$_{Theme(y)}$.*
e.g., the verb look. *That$_{Theme(y)}$ looks$_{(ob2)}$ [good]$_{Adjectival\ Phrase\ (P)}$.*

Obligatory three-place verbs (ob3), requiring three arguments (an external Agent [x], Theme/Patient [y], Goal [z]). Includes both alternating and non-alternating datives (x, y, z; x, z, y).
e.g., the verb give. *[Joelle]$_{Agent(x)}$ gave$_{(ob3)}$ [the ball]$_{Theme\ (y)}$ [to Zack]$_{Goal(z)}$.*
[Joelle]$_{Agent(x)}$ gave$_{(ob3)}$ [Zack]$_{Goal(z)}$ [the ball]$_{Theme(y)}$.

Optional two-place verbs (op2), also known as optional transitives, must take an Agent [x], but the Theme [y] is optional. Therefore, they may take two possible argument structure arrangements (x) and (x, y).
e.g., the verb eat. *[He]$_{Agent(x)}$ eats$_{(op2)}$.*
e.g., the verb read. *[John]$_{Agent(x)}$ read$_{(op2)}$ [the sign]$_{Theme(y)}$.*

Optional three-place verbs (op3), must take an external argument and a Theme, but the Goal is optional, therefore, three argument structure arrangements are possible (x, y), (x, y, z) and (x, z, y). Includes both alternating and non-alternating datives.
e.g., the verb send. *[John]$_{Agent(x)}$ sent$_{(op3)}$ [the paper]$_{Theme(y)}$.*
[John]$_{Agent(x)}$ sent$_{(op3)}$ [the paper]$_{Theme(y)}$ [to Joan]$_{Goal(z)}$.
[John]$_{Agent(x)}$ sent$_{(op3)}$ [Joan]$_{Goal(z)}$ [the paper]$_{Theme(y)}$.

Complement verbs (c), may be produced with three argument structure arrangements, requiring an external argument (x) and (a) a Theme (y) (x, y), or (b) a sentential complement [S'] such as a wh-clause, that-clause, or an infinitive clause (x, S'), or (c) a predication phrase [P] (x, P).
e.g., the verb accept.
[Zack]$_{Agent(x)}$ accepted$_{(c)}$ [the money]$_{Theme(y)}$.
[Zack]$_{Agent(x)}$ accepted$_{(c)}$ [that the money was for a good cause]$_{Sentential\ Complement(S')}$
e.g., the verb feel. *[Zack]$_{Agent(x)}$ felt$_{(c)[tired](P)}$*

Copula verbs (cop), a form of be, serving as the matrix verb in sentence structure, takes a Theme (y) and a predication phrase (noun phrase, prepositional phrase, or adjectival phrase) [P], (y, P).
e.g., the verb is. *[John]$_{Agent(x)}$ is$_{(cop)}$ [a boy]$_{[P]}$*

Argument, Adjunct Codes

x Agent
y Theme
z Goal

S' Sentential Complement
P Predication Phrase (NP, PP, AP)
J Adjunct (optional to the verb structure)

APPENDIX B

Sentence Stimuli

I. *Who* sentence stimuli

A. Sentences designated for training

1. The soldier is pushing the woman in the street.
2. The girl is kicking the man at the park.
3. The father is chasing the child in the afternoon.
4. The clerk is helping the doctor in the store.
5. The teacher is following the student during the summer.
6. The thief is attacking the guard during the night.
7. The husband is kissing the wife in the morning.
8. The policeman is protecting the woman during the day.
9. The coach is lifting the boy in the gym.
10. The nurse is touching the baby in the hospital.

B. Sentences designated for generalization testing

1. The woman is following the clerk during the day.
2. The man is pushing the boy in the afternoon.
3. The child is kicking the girl by the gym.
4. The student is chasing the policeman during the night.
5. The guard is protecting the soldier during the night.
6. The father is hitting the teacher at the school.
7. The doctor is carrying the nurse into the hospital.
8. The baby is hugging the father in the morning.
9. The boy is grabbing the mother in the park.
10. The cook is pulling the waiter into the kitchen.

II. *What* sentence stimuli

A. Sentences designated for training

1. The trainer is pushing the tiger at the zoo.
2. The boy is chasing the dog in the park.
3. The baby is touching the bird at the store.
4. The child is kicking the cow in the barn.
5. The teacher is kissing the kitten at the school.
6. The policeman is protecting the dog during the night.
7. The girl is following the rabbit in the park.
8. The woman is attacking the snake in the woods.
9. The man is helping the horse into the stall.
10. The farmer is lifting the pony in the winter.

B. Sentences designated for generalization testing

1. The man is attacking the tiger during the night.
2. The guard is touching the lion at the zoo.
3. The girl is kissing the kitten in the garage.
4. The farmer is helping the cow during the day.
5. The man is pulling the pony in the winter.
6. The child is lifting the dog into the car.
7. The trainer is hugging the snake at the zoo.
8. The policeman is grabbing the cat in the street.
9. The boy is carrying the rabbit in the house.
10. The hunter is hitting the deer in the woods.

III. *When* sentence stimuli

A. Sentences designated for training

1. The boy is pushing the girl in the morning.
2. The child is kicking the pony in the evening.
3. The monkey is chasing the bird in the afternoon.
4. The student is helping the doctor during the evening.
5. The policeman is following the thief during the night.
6. The teacher is attacking the student in the morning.
7. The mother is kissing the baby in the morning.
8. The soldier is protecting the dog during the night.
9. The nurse is lifting the man during the day.
10. The woman is touching the snake in the afternoon.

B. Sentences designated for generalization testing

1. The cow is chasing the calf in the afternoon.
2. The husband is kissing the wife in the morning.
3. The boy is pulling the pony during the afternoon.
4. The snake is attacking the bird in the day.
5. The policeman is protecting the woman during the night.
6. The baby is hugging the father in the morning.
7. The boy is pulling the donkey in the summer.
8. The woman is grabbing the dog in the night.
9. The man is hitting the thief during the night.
10. The groom is carrying the bride in the spring.

IV. *Where* sentence stimuli

A. Sentences designated for training

1. The boy is following the dog into the woods.
2. The coach is pushing the man in the gym.
3. The child is kicking the pony by the barn.
4. The student is chasing the kitten in the street.
5. The guard is protecting the clerk at the store.
6. The tiger is attacking the lion at the zoo.
7. The doctor is touching the child at clinic.

8. The woman is kissing the child in the kitchen.
9. The boy is lifting the monkey at the circus.
10. The nurse is helping the soldier at the hospital.

B. Sentences designated for generalization testing

1. The thief is pushing the guard in the street.
2. The father is touching the bird in the store.
3. The donkey is kicking the pig in the barn.
4. The man is helping the woman in the park.
5. The husband is lifting the wife into the car.
6. The boy is pulling the dog by the woods.
7. The soldier is hitting the man on the dock.
8. The doctor is carrying the soldier into the hospital.
9. The baby is hugging the girl in the clinic.
10. The fisherman is grabbing the turtle in the water.

APPENDIX C

Analysis of Wh-Question Responses Produced on Constrained Production Probe

Grammatically correct (gc). *Wh*-morpheme is produced, together with correctly ordered sentence constituents, represented by correct lexical items (e.g., Who is the soldier pushing into the street?).

Lexical error (lex). Grammatically correct *wh*-question in which the correct *wh*-morpheme is produced, together with correctly ordered sentence constituents, however, lexical selection errors may be evident (e.g., Who is the soldier *shoving* into the street? or Who is the *man* pushing into the street? instead of: Who is the *soldier pushing* into the street?).

Subject-auxiliary verb inversion error (s/aux). Correct *wh*-morpheme produced with correctly selected and ordered sentence constituents, however, subject auxiliary verb inversion is not performed (e.g., Who the soldier *is pushing* into the street? instead of: Who *is* the soldier *pushing* into the street?).

Movement error (mvt). Correct *wh*-morpheme produced in place of the proper sentence constituent to be moved, however, no movement is established. That is, the *wh*-morpheme is not moved to the sentence initial position, leaving behind a trace of its movement (e.g., The soldier is pushing *who* into the street? instead of Who_i is the soldier $trace_i$ pushing into the street?)

Co-referencing error (co-ref). Correct *wh*-morpheme produced, but improper co-reference established between *wh*-morpheme and moved NP (i.e., trace is not established for the proper NP) (e.g., *Who* is the soldier pushing *the woman?* instead of Who_i is the soldier $trace_i$ pushing into the street?).

Wh-morpheme selection error (*wh*-sl). Production of incorrect *wh*-morpheme, however, all other sentence constituents correctly selected and ordered (e.g., *What* is the soldier pushing into the street? instead of: *Who* is the soldier pushing into the street?).

Wh-morpheme selection error plus movement error (*wh*-sl/mvt). Incorrect *wh*-morpheme produced in place of the proper sentence constituent to be moved, however, no movement is established. That is, the *wh*-morpheme is not moved to the sentence initial position, leaving behind a trace of its movement (e.g., The soldier is pushing *where* into the street? instead of: *Who*$_i$ is the soldier *trace*$_i$ pushing into the street?).

Wh-morpheme selection error plus co-referencing error (*wh*-sl/co-ref). Incorrect *wh*-morpheme produced as well as improper co-reference established between *wh*-morpheme and moved NP (e.g., *What* is the soldier pushing *the woman?* instead of: *Who*$_i$ is the soldier *trace*$_i$ pushing into the street?).

APPENDIX D

Experimental Protocol for Training Wh-Question Production

(a) *What*- and *Who*-Questions (Argument Movement Treatment)

Step 1. *Wh*-question elicitation. A randomly selected stimulus sentence for eliciting *who/what* questions (e.g., *The soldier is pushing the woman into the street*) was presented for the subject to read/repeat. The subject was instructed to produce a question response as in baseline (i.e., You want to know the person/thing the subject is pushing into the street so you ask . . . ?). A 5 sec response interval was provided. If a grammatically correct *wh*-question of the appropriate type was produced, a new stimulus sentence was presented for elicitation of a new *wh*-question. When a grammatically correct *wh*-question of the appropriate type was not produced, training steps 2–7 were followed.

Step 2. Sentence constituents comprising the active training sentence were presented on individual cards, together with WHO, WHAT, and ? cards (e.g., the soldier, is, pushing, the woman, into the street, WHO, WHAT, ?). The verb and verb arguments (thematic roles), and adjunct prepositional phrase were identified by the examiner in the following manner: Pointing to the verb, the examiner explained: ''This is *pushing;* it is the action of the sentence''; pointing to the subject NP, the examiner explained: ''This is *the soldier;* he is the person doing the pushing''; pointing to the object NP, the examiner explained: ''This is *the woman;* she is the person/thing being pushed''; and finally, pointing to the PP, the examiner explained: ''This is *into the street;* this is the place/time the pushing occurred''.

Step 3. The examiner replaced the object NP with either WHO or WHAT, explaining that the person/thing is WHO/WHAT is being pushed. The question mark card then was placed at the end of the card string which formed an echo question (e.g., *The soldier is pushing* WHO *into the street?*). Subjects then were required to read/repeat the echo question.

Step 4. Subject/auxiliary verb inversion is demonstrated (e.g., *is the soldier pushing* WHO *into the street?*).

Step 5. The examiner demonstrated movement of the *wh*-morpheme to the sentence initial position (e.g., WHO *is the soldier pushing into the street?*) and the subject was instructed to read/repeat the resultant question.

Step 6. Sentence constituents are re-arranged in active sentence form together with WHO, WHAT, and ? cards (as in step 2). Steps 3, 4, and 5 are repeated with the subject replacing/selecting/moving the cards to form the correct s-structure representation of the target *wh*-question. Assistance was provided as needed.

Step 7. Repeat Step 1.

(b) *When*- and *Where*-Questions (Adjunct Movement Treatment)

Step 1. *Wh*-question elicitation. A randomly selected stimulus sentence for eliciting *where/when* questions (e.g., *The student is helping the doctor during the evening*) was presented for the subject to read/repeat. The subject was instructed to produce a question response as in baseline (i.e., You want to know the place/time the subject helping the doctor so you ask . . . ?). A 5 sec response interval was provided. If a grammatically correct *wh*-question of the appropriate type was produced, a new stimulus sentence was presented for elicitation of a new *wh*-question. When a grammatically correct *wh*-question of the appropriate type was not produced, training steps 2–7 were followed.

Step 2. Sentence constituents comprising the active training sentence were presented on individual cards, together with WHEN, WHERE, and ? cards (e.g., the student, is, helping, the doctor, during the evening, WHEN, WHERE, ?). The verb, verb arguments (thematic roles), and adjunct prepositional phrase were identified in the following manner: Pointing to the verb, the examiner explained: ''This is *helping;* it is the action of the sentence''; pointing to the subject NP, the examiner explained: ''This is *the student;* he is the person doing the helping''; pointing to the object NP, the examiner explained: ''This is *the doctor;* she is the person/thing being helped''; and finally, pointing to the PP, the examiner explained: ''This is *during the night;* this is the place/time the helping occurred''.

Step 3. The examiner replaced the adjunct PP with either WHERE or WHEN, explaining that the place/time is WHERE or WHEN the helping occurred. The question mark card then was placed at the end of the card string which formed an echo question (e.g., *The student is helping the doctor* WHEN ?). Subjects then were required to read/repeat the echo question.

Step 4. Subject/auxiliary verb inversion is demonstrated (e.g., *is the student helping the doctor* WHEN ?).

Step 5. The examiner demonstrated movement of the *wh*-morpheme to the sentence initial position (e.g., WHEN *is the student helping the doctor* ?) and the subject was instructed to read/repeat the resultant question.

Step 6. Sentence constituents are re-arranged in active sentence form together with WHERE, WHEN, and ? cards (as in step 2). Steps 3, 4, and 5 are repeated with the subject replacing/selecting/moving the cards to form the correct s-structure representation of the target *wh*-question. Assistance was provided as needed.

Step 7. Repeat Step 1.

APPENDIX E

Wh-Morpheme Discrimination/Production Training Tasks

(a) Matching written *wh*-words with their written referential equivalent (e.g., *who*-person, *what*-thing, *where*-place, *when*-time).

(b) Matching auditorily and visually presented *wh*-words with pictured representations using action pictures.

(c) Matching sentence embedded *wh*-words with pictured representations using action pictures (i.e., ''You want to know who the dog is biting, so you point to . . .'').

(d) Matching sentence embedded words (i.e., person, thing, time, or place) with pictured representations using action pictures (e.g., ''You want to know the person the dog is biting, so you point to'').

(e) Producing *wh*-morphemes when presented with pictured representations and their referential equivalent (i.e., an action picture was presented, the examiner pointed to a referential equivalent of one of the *wh*-words (e.g., person) and said ''This is a person, so you use the word . . .'').

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