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The role of syntactic complexity in training *wh*-movement structures in agrammatic aphasia: Optimal order for promoting generalization

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Abstract

This study examined the postulate that training production of syntactically complex sentences results in generalization to less complex sentences that have processes in common with treated structures. Three agrammatic aphasic patients were trained to produce *wh*-movement structures, object clefts and/or object extracted *who*-questions, while generalization between these structures was tested. One NP-movement structure, passive sentences, also was tested for control purposes. *Wh*-movement occurs from the direct object position to *specifier* position in the complementizer phrase [SPEC, CP] for both *wh*-movement structures. In *who*-questions movement occurs in the matrix sentence, whereas, in object clefts movement occurs within an embedded relative clause, rendering them the most complex. Results showed robust generalization effects from object clefts to matrix *who*-question for 1 participant (D.L.); however, no generalization was noted from *who*-questions to object clefts for another (F.P.), and 1 participant (C.H.) showed acquisition of *who*-questions, but not object clefts, during the baseline condition without direct treatment. As expected, none of the participants showed improved production of passives. These findings supported those derived from our previous studies, indicating that generalization is enhanced not only when target structures are related along dimensions articulated by linguistic theory, but also when the direction of treatment is from more to less complex structures. The present findings also support proposals that projections of higher levels in the syntactic treatment are dependent on successful projection of lower levels. For our participants, training movement within CP in a lower (embedded) clause resulted in their ability to project to CP at higher levels. (*JINS*, 1998, *4*, 661–674.)

Keywords: Agrammatic aphasia, Neurolinguistics, Treatment, Generalization

INTRODUCTION

It is well documented that complex, noncanonical sentences, such as object extracted *wh*-questions, object relatives and passive sentences present difficulty for agrammatic aphasic individuals in both comprehension (Caramazza & Zurif, 1976; Hickok & Avrutin, 1996; Schwartz et al., 1980; Thompson et al., in press) and in production (Christiansen et al., 1993; Saffran et al., 1980; Thompson et al., 1995). Current research focused on improving sentence deficits has shown that treatment based on linguistic theory can be efficacious for these patients. In a series of studies, it has been shown, for example, that training sentences that require *wh*-movement (i.e., object clefts, object extracted *wh*-questions) results in generalization only to other *wh*-movement structures, comparable both in their underlying representation and in the movement operations involved in their derivation. Similarly, training NP-movement derived sentences (i.e., passives and subject raising structures) results in generalization only to other NP-movement structures (Thompson & Shapiro, 1994; Thompson et al., 1997). Findings from these studies suggest that the degree of generalization resulting from

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treatment relies to a large extent on the relation between trained and untrained constructions. Generalization is seen from one structure to another when the two structures are related along dimensions articulated by linguistic theory. Conversely, unrelated structures appear not to enjoy a pattern of effective generalization.

Close examination of data reported in earlier studies (i.e., Thompson & Shapiro, 1994, and Thompson et al., 1997), however, showed that for the 5 patients who received *wh*-movement training, better generalization was noted from object clefts to *who*-questions than from *who*-questions to object clefts. The 2 patients, M.D. and H.H., who were trained to produce object clefts showed generalization to *who*-questions. However, only 1 of 2 participants trained to produce *who*-questions (A.H.) showed generalization to object clefts. The 5th participant (P.R.) demonstrated ability to produce *who*-questions, but not object clefts, during baseline testing. Therefore, generalization from *who*-questions to object clefts could not be examined. This performance pattern raised questions regarding the relation between the two structures. Indeed, if these *wh*-movement structures are related to one another, we might have expected P.R. to produce both structures in baseline. These findings indicated that further study of the relation between *wh*-movement structures is needed. Perhaps factors other than the movement operations required to derive certain sentences are relevant to successful generalization.

One factor related to successful generalization may be the complexity of structures trained. That is, generalization may be enhanced if the direction of treatment is from more complex to less complex structures, when treated structures encompass processes relevant to untreated ones. While training complex structures prior to training simpler ones may seem counterintuitive, recent studies have suggested that optimal generalization may result from this approach even though no clear metric of complexity has been articulated in the psycholinguistic literature. Plaut (1996) found that retraining a computer simulated network based on connectionist modeling to acquire atypical exemplars of semantic categories resulted in greater generalization than training more typical exemplars. Thompson et al. (1993) also applied this postulate to the (re)learning of syntax in aphasia. Participants trained to produce complex *wh*-questions that included both arguments and adjuncts (e.g., *Who did the boy hit* [trace] *in the park*?) showed improved ability to produce these complex forms and, in addition, generalization to less complex *wh*-questions that did not contain adjuncts was noted (e.g., *Who did the woman chase* [trace]?).

With regard to object clefts and *who*-questions, object clefts can be considered to be the most complex. The two structures are similar in that they both require *wh*-movement within a *complementizer phrase* (CP); however, the movement in object clefts is within an embedded clause. The movement in who-questions (of the type trained in our studies) occurs in the matrix clause; no embedding is required. We discuss the similarities and differences between the two structures below.

Linguistic Considerations

According to Chomsky (1986), the hierarchical structure of a basic sentence is comprised of a VP (*verb phrase*), dominated by an IP (*inflection phrase*), dominated, in turn, by a *complementizer phrase* (CP) as shown in Figure 1.[1] Thus, CP is the highest projection in the syntactic tree. Recent descriptions of the syntactic impairments seen in aphasia have indicated that CP is particularly vulnerable because of its position in the syntactic hierarchy. For example, Hagiwara (1995) observed that aphasic patients who demonstrated impairments at lower levels of the tree showed impairments affecting all structures higher in the tree; that is, without successful projection of IP, CP could not be projected. Hagiwara, therefore, suggested that projections of higher levels in the tree are dependent on successful projection of lower levels.

Friedmann and Grodzinsky (1997) presented data supporting Hagiwara's observation. Following Pollock's (1989) *split inflection* analysis elaborating IP to include projections for agreement (AGR) and tense (*T*; with *T* being higher than AGR in the syntactic tree), they showed that one Hebrew-speaking aphasic individual presented with intact representation of AGR, but selective impairment in the use of *T*. Too, their patient showed difficulty with complementizers and embeddings, indicating impaired CP as well. Based on this observation, they advanced the *tree-pruning hypothesis*, which postulates that in agrammatic aphasia certain nodes in the syntactic tree are underspecified and that when any node is underspecified it cannot project to higher levels. In Friedmann & Grodzinsky's patient T was underspecified and, therefore, it could not project higher. While this analysis may not be completely correct once converging data examining aphasic deficits are examined, data from both Hagiwara and Friedmann and Grodzinsky help to characterize the syntactic deficit seen in some aphasic patients.

Projections of CP: Wh-*movement structures*

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

1. $[_{CP}$ Who$_i$ $[_{C}$ has $[_{IP}$ the thief chased t_i]]]. (Matrix *who*-question)

2. $[_{IP}$ It was $[_{NP}$ the artist$_j$ $[_{CP}$ who $_{j\ i}$ $[_{IP}$ the thief chased t_i]]]]. (Object cleft)

Although these sentences appear to be quite different, they are fundamentally similar in that they both rely on the syntactic operation: *wh*-movement. We show how *wh*-movement operates in the two sentence types below; as well we point out some distinctions between them.

[1] See Shapiro (1997) for a more detailed description of syntactic theory and its relevance to the study of aphasia.

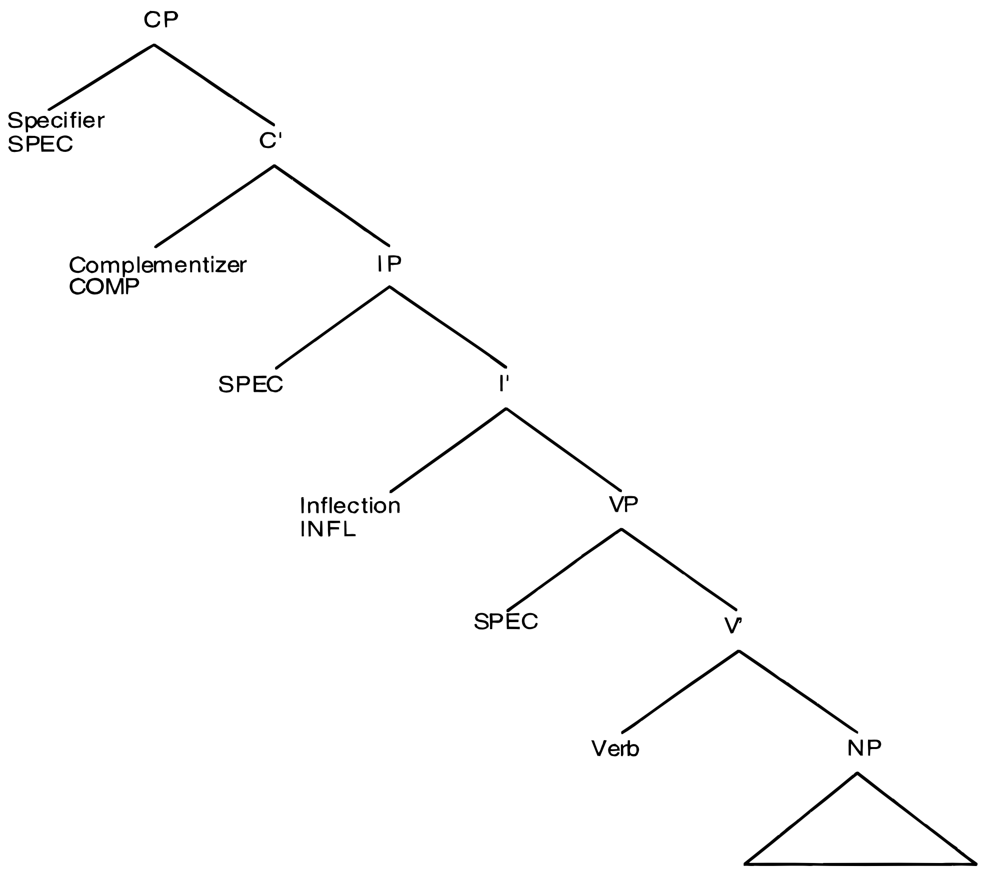

Fig. 1. The major phrasal geometry of a sentence and the relations among elements within a tree structure. Shown here are the local trees headed by CP (complementizer phrase), IP (inflectional phrase), and VP (verb phrase).

Who-*questions*

Who-questions, like all noncanonical sentences, are derived from an underlying or *d*-structure as approximated in (3).

3. ϕ the thief chased [who][2]

To form a *who*-question, *who*, which occupies an argument position in the *d*-structure, is moved to the front of the sentence. With reference to the linguistic tree, *who* moves from the direct object position in the VP to the specifier position of CP: [SPEC, CP] (see Figure 2). Importantly, before *wh*-movement occurs thematic roles are assigned by the verb to all argument positions. The verb *chase* in (3) assigns a thematic role to *who*. When movement occurs, a trace (t) is left behind in the original position occupied by *who* and a chain is formed between the trace and *who*. In this manner, the antecedent to the trace (in this case *who*) retains its thematic role and is coindexed with the trace.

Also shown in Figure 2 is the additional verb movement required to form *wh*-questions. This head to head movement (or subject–auxiliary verb inversion) does not typi-

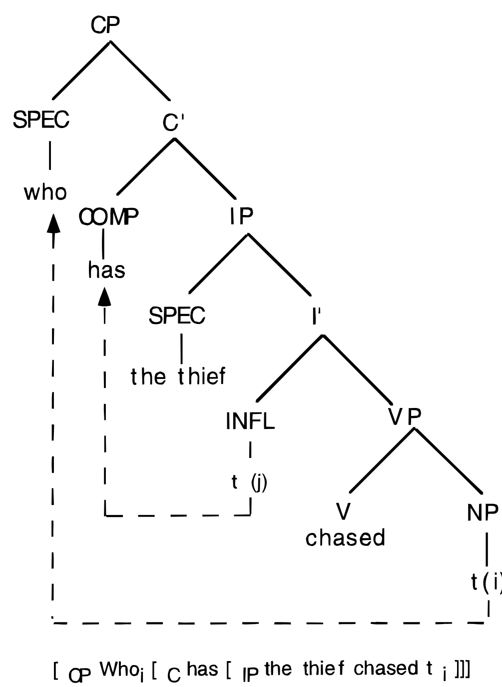

Fig. 2. Tree diagram illustrating *wh*-movement in matrix *who*-questions. Verb (head to head) movement also is shown.

[2]The symbol ϕ is used here to indicate a movement site that is vacant at *d*-structure.

cally present problems for agrammatic aphasic individuals (Grodzinsky, l995; Lonzi & Luzzatti, l993).

Object clefts

Object cleft constructions also involve *wh*-movement. As in *who*-questions, movement occurs from direct object position and the landing site is the specifier of CP [SPEC, CP] as shown in Figure 3. Once again, the noncanonical form is derived from its *d*-structure representation as shown in (4):

4. It was the artist [ϕ the thief chased who]

One distinguishing feature is that the CP, containing the moved element, in object clefts is embedded within a higher clause. The embedding, an optional relative clause, modifies the preceding matrix NP and is, therefore, dominated by it. Thus, in object clefts an additional referential relation between the head NP, *the artist* in (5), and the *wh*-phrase is required.

5. It was the $[_{NP}$ artist^{j} $[_{CP}$ *who*^{j}i $[_{IP}$ the thief chased $t_i]]$.

In addition, object clefts contain a pleonastic *it* in the matrix clause. This expletive pronoun carries no theta role and plays no semantic role in such sentences (Haegeman, l994).

To summarize, *wh*-questions and object clefts are formed through *wh*-movement operations. Movement occurs from the direct object position to [SPEC, CP] in both sentences. In *who*-questions this movement occurs in the matrix sentence; whereas, in object clefts, movement occurs within an embedded relative clause, adding a level of syntactic complexity.

In this paper we extended our analysis of the relation between object clefts and *who*-questions in three additional subjects with agrammatic aphasia. Generalization to NP-movement structures (i.e., passive sentences) also was examined. We predicted that training agrammatic aphasic patients to produce object clefts, in which CP is embedded within a higher clause, would provide information relevant to performing both *wh*-movement and embedding and would, thus, result in generalization to matrix *wh*-questions. Too, we conjectured that training CP within IP at a lower level of the tree might allow IP to project to higher levels. Con-

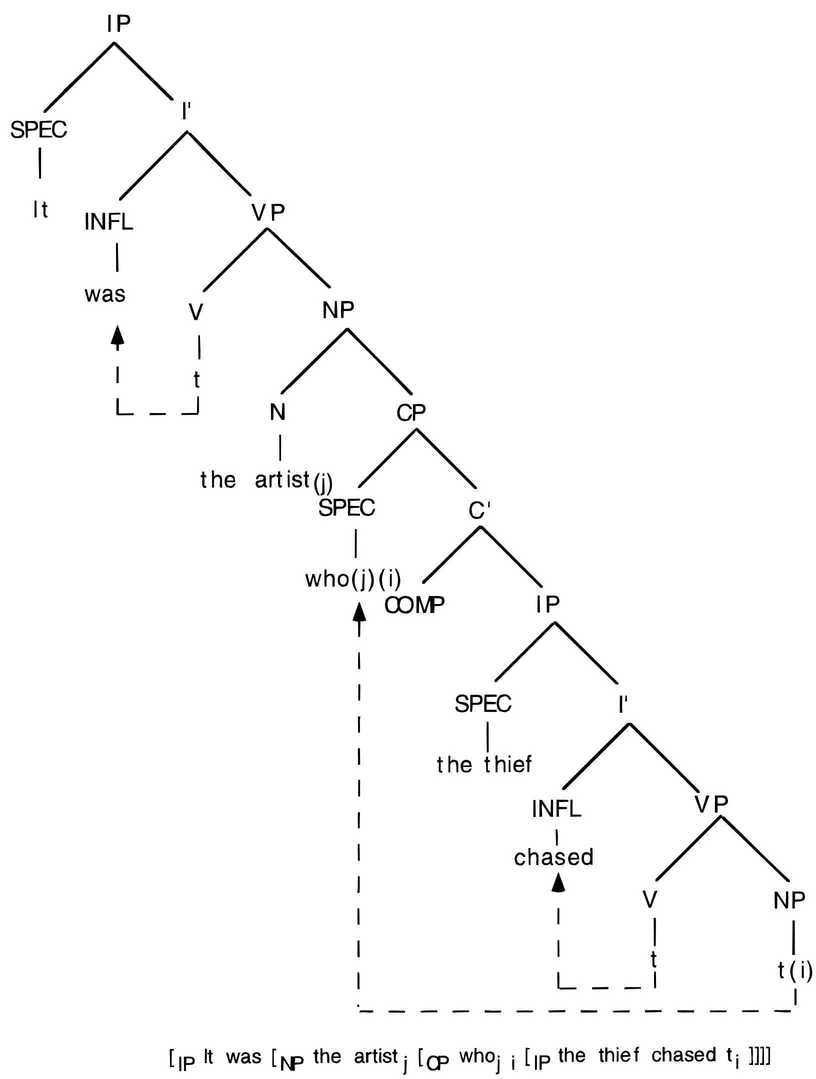

Fig. 3. Tree diagram illustrating *wh*-movement in object cleft constructions. The referential relation between the head NP (*the artist*) and the *wh*-phrase also is shown as is V to INFL movement in the matrix clause.

versely, we predicted that training matrix *wh*-questions, providing information relevant only to *wh*-movement and not to clausal embeddings, would not influence object cleft production. Because passive sentences rely on NP-movement, generalization to this structure was not expected as we have shown in previous studies (Ballard & Thompson, in press; Jacobs & Thompson, in press; Thompson & Shapiro, 1994; Thompson et al., 1997).

METHODS

Research Participants

Three right-handed Broca's aphasic individuals with agrammatism, two male and one female, similar to those included in our previous experiments, served as participants. They ranged in age from 29 to 68 years, and had from 12 to 16 years of education. Aphasia resulted from a left-hemisphere, thromboembolic stroke for all patients. CT scans showed lesions involving the left frontoparietal area; in addition, Participant 3's (F.P.'s) lesion extended to the left temporal lobe with a sparing of Wernicke's area. No right hemisphere involvement was noted for any of the patients. At the time of the study, the patients were 3 to 4 years poststroke. All were native English (standard American) speakers, right handed, and passed a pure-tone audiological screening at 40 dB HL at 500, 1000, and 2000 Hz in at least one ear. Table 1 presents data for these three subjects and, for comparison, the data for the participants of Thompson and Shapiro (1994) and Thompson et al. (1997).

Aphasia quotients between 66.5 and 80.9 were derived from the Western Aphasia Battery (Kertesz, 1982). On comprehension testing, using the Philadelphia Comprehension Battery for Aphasia (PCBA; Saffran et al., n.d.), patients showed better comprehension of actives and subject relatives than passives and object relatives. Lexical comprehension was superior to sentence comprehension for all participants (see Table 2).

Analysis of narrative language samples using a method developed by Thompson et al. (1995) showed patterns of agrammatic production for all participants. In samples collected by asking subjects to tell the *Cinderella* story, after they had been familiarized with the story using a picture book, they produced primarily short utterances of which most were simple sentences with no embeddings or moved sentence constituents (59–86%). Production was slow and nonfluent and word retrieval difficulty as well as grammatical errors were evident in both simple and complex sentences. Noun:verb ratios and open:closed class ratios were elevated for participants 1 (C.H.) and 2 (D.L.), indicating that they produced more nouns than verbs and more open class than closed class words in their narrative discourse. Participant 3 (F.P.) produced more grammatical sentences (79%) and complex sentences (41%) than the other participants and her mean length of utterance (MLU) was higher (9.5). Too, she did not show the typical pattern of producing more open class than closed class words and she produced more verbs than nouns. However, she showed particularly poor production of verb morphology with correct verb morphology noted on only 69% of verbs and 28% of verbs were produced with incorrect argument structure (see Table 3).

Experimental stimuli

The experimental stimuli used in the study were identical to those used by Thompson et al. (1997). Fifteen active, semantically reversible, sentences of the form NP–V–NP were developed using 15 one-to-two-syllable transitive verbs and 30 animate nouns. Mean frequency of occurrence for the verbs was 116 (per 1,000,000) with a range of 2 to 298; mean frequency of occurrence for the nouns was 228 per 1,000,000 (range = 3–2110; Frances & Kucera, 1982). From these active sentences, target *wh*-movement structures and passive sentences were formed (see Appendix). Picture stimuli (black-and-white, 21 $\times$ 14 cm line drawings) were developed for each sentence and its semantically reversible counterpart. For example, one sentence stimulus was, *The*

Table 1. Participant data

Participant	Sex	Age (years), $M = 49$	Etiology	Site of lesion	Months postonset, $M = 47.3$	Education (years), $M = 14.6$	Handedness
1. (C.H.)	M	43	CVA	LFP	48	14	R
2. (D.L.)	M	29	CVA	LFP	36	16	R
3. (F.P.)	F	68	CVA	LFTP	48	12	R
M.D.*	M	44	CVA	LF	42	21	L
P.R.*	M	41	CVA	LFP	121	14	R
H.H.**	F	61	CVA	LFP	24	14	R
K.D.**	M	39	OHI	LFT	40	12	L
A.H.**	F	68	PPA	NA	20	14	R

Note. CVA = cerebral vascular accident, PPA = primary progressive aphasia, OHI = open head injury (gunshot wound), LF = left frontal, LFP = left frontoparietal, LFTP = left frontotemporoparietal.
*Participant from Thompson et al., 1997.
**Participant from Thompson & Shapiro, 1994.

Table 2. Language testing data

Test	Participant							
	P1. (C.H.)	P2. (D.L.)	P3. (F.P.)	M.D.*	P.R.*	H.H.**	K.D.**	A.H.**
Western Aphasia Battery								
Aphasia Quotient	80.4	80.9	66.5	74.0	64.4	82	75	93.6
Fluency	4.0	4.0	4.0	4.0	4.0	4.0	4.0	9.0
Comprehension	8.0	8.9	8.5	9.0	7.3	8.0	7.9	10.0
Repetition	8.6	8.3	5.2	5.7	6.0	8.8	8.4	7.8
Naming	9.1	8.7	6.5	8.3	6.9	8.7	7.2	10.0
Reading	8.4	8.2	6.0	8.0	6.0	8.3	7.4	10.0
Philadelphia Comprehension Battery for Aphasia								
Lexical Comprehension	100%	100%	100%	98%	100%	100%	97%	100%
Sentence Comprehension								
Active–subject relative	80%	95%	75%	83%	80%	70%	80%	100%
Passive–object relative	57%	55%	35%	65%	61%	60%	50%	85%

*Participants from Thompson et al., 1997.
**Participants from Thompson & Shapiro, 1994.

thief chased the artist. For this sentence, one picture (the target) showed a thief chasing an artist and the other (the foil) showed an artist chasing a thief. Noun and verb labels were included on the pictures to assist patients with word retrieval. Nouns were placed at the top of each picture; verbs were centered at the bottom. For treatment purposes 8.9 × 13 cm cards that identified individual sentence constituents contained within each training sentence (i.e., NPs and verbs) as well as grammatical elements required in the *s*-structure of target sentence types were developed. For example, for the training sentence, *It was the artist who the thief chased*, the following five cards were constructed: *it was*, *the artist*, *who*, *the thief*, *chased*.

Experimental design

A single-subject multiple baseline design across behaviors and participants was utilized. This design requires testing production of all sentence types on repeated occasions during a baseline condition that is increased in length across participants. When stable performance of all sentences is noted, treatment is applied to one sentence type at a time while baseline testing is continued for untrained sentences. In this study, participants were trained to produce either object-clefts or matrix *who*-questions in counterbalanced order while generalization to the untrained sentence type was tested. Who-questions were targeted first for Participants 1

Table 3. Narrative language characteristics

Characteristic	Participant								
	P1. (C.H.)	P2. (D.L.)	P3. (F.P.)	M.D.*	P.R.*	H.H.**	K.D.**	A.H.**	Normals*** *M* (*SD*)
Language variable									
Number of sentences	83	68	37	85	114	9	47	30	NA
Number of words	380	301	348	345	310	256	222	193	323
Mean length of utterance	4.81	5.06	9.5	4.93	4.24	5.65	5.02	6.5	14.47 (2.20)
Percent grammatical sentences	56	23	79	26	19	27	57	32	89.8 (8.0)
Percent simple sentences	86	90	59	68	99	79	67	56	42.5 (16.9)
Percent complex sentences	14	10	41	32	01	21	33	44	57.5 (16.9)
Mean embeddings	.12	.11	.23	.40	.01	.18	.29	.48	1.03 (.234)
Noun:verb ratio	1.92	1.89	.88	1.30	1.44	1.92	.83	1.08	1.21 (0.25)
Open:closed class ratio	1.12	1.49	.92	2.06	2.56	1.17	1.31	1.14	0.91 (0.08)
Percent correct verb morphology	89	50	69	68	44	54	75	62	NA
Percent verbs with correct argument structure	74	49	72	42	44	54	75	65	98 (3.0)

Note. Normal data derived from Thompson et al., 1995. NA = data not available for normal participants.
*Participants from Thompson et al., 1997.
**Participants from Thompson & Shapiro, 1994.

(C.H.) and 3 (F.P.); Participant 2 (D.L.) was first trained to produce object clefts. If generalization across structures did not occur as a result of training, the alternate *wh*-movement structure was trained. Production of passive sentences was tested throughout the study for additional experimental control. As mentioned previously, treating *wh*-movement structures was not expected to affect passive sentence production because the sentence types are fundamentally syntactically different. Monitoring passive production, therefore, provided an additional measure that, in the event that generalization across *wh*-movement structures occurred, would remain stable throughout treatment.

Baseline procedures: sentence production priming

Production of the three sentence types was tested during baseline using a sentence production priming task. A picture pair was presented, the examiner modeled the target sentence with the foil picture, and the participant was instructed to produce a like sentence for the target picture. The 15 pairs were presented three times per session (once for elicitation of each sentence type) in random order. Responses produced were scored as correct or incorrect. Grammatically correct productions containing minor inflectional errors or lexical substitutions were scored as correct. All other responses were considered incorrect. Feedback as to the accuracy of response was not given during baseline, however intermittent encouragement was provided.

Treatment and production probes

Sentence production was trained using the simple active form of target sentences. Participants were trained to (1) identify the verb and NPs representing the thematic roles of the verb and (2) perform the movement operations required to derive the surface form of target constructions. Treatment, therefore, emphasized the lexical and syntactic properties of the active form of target sentences and, in addition, provided information regarding the movement required to form the *s*-structure representation of target sentences.

Each training trial began with presentation of a stimulus picture pair and, as in baseline, the participant was given the opportunity to produce the target sentence type using the sentence production priming task. If a correct response was produced, feedback was given and the next item was presented. If an incorrect response was produced, the target picture was presented together with the sentence constituent stimulus cards representing the active form of the target sentence. For example, a sentence like (6) was presented (with each NP and the verb written on separate cards):

6. [the thief] [chased] [the artist]

The additional sentence constituent cards needed to complete the target sentence type also were presented. Using the active sentence, the examiner identified the verb as well as the subject and object NPs and explained their roles in relation to the verb. *Who* then was introduced as in (7) and its relation to the object NP was explained.

7. [the thief] [chased] [the artist] [who]

The examiner then moved the object NP and *who* cards to the sentence initial position and *it was* was added to the beginning as in (8).

8. [it was] [the artist] [who] [the thief] [chased]

Participants then read the *s*-structure sentence. Finally, the sentence constituent cards were rearranged in their original order and the participant was instructed to form the target sentence. Assistance was provided as needed. The foil picture stimulus then was re-presented and the sentence production priming procedure was repeated.

Participants received treatment twice per week. During each session each training sentence was practiced at least one time and not more than two for a maximum of 30 training trials per session. The training portion of sessions usually lasted about 45 min.

Production of all sentence types was tested, prior to each treatment session, to examine emergent sentence production and generalization. This was accomplished using procedures identical to those used during baseline testing.

Reliability

All responses produced by the participants on the sentence production priming task, during baseline testing and during treatment probes, were transcribed on-line by both the examiner and an independent reliability observer situated behind a one-way mirror. Disagreements were discussed in order to improve scoring accuracy. Overall point-to-point agreement between the primary coder and the independent observer was 97% across probe sessions.

Results

Data representing correct responses produced on the sentence production priming task for Participants 1, 2, and 3 are shown in Figures 4, 5, and 6, respectively. These data indicated that during the baseline phase, performance was at a low, stable level across sentence types for Participants 2 (D.L.) and 3 (F.P.). However, Participant 1 (C.H.) showed an increase in the accuracy of *who*-question production during baseline testing, while object cleft and passive sentence productions remained low and stable. All participants produced errors during baseline similar to those seen in our previous studies (cf. Thompson et al., 1997). For example, errors of coreference were noted, in which a gap was not established or in which it was filled erroneously. In the latter case, gaps were filled by a possible, albeit incorrect, antecedent (e.g., *Who has the artist chased the artist*? for the target *Who has the artist chased*?). Syntactically correct responses that contained movement errors also were pro-

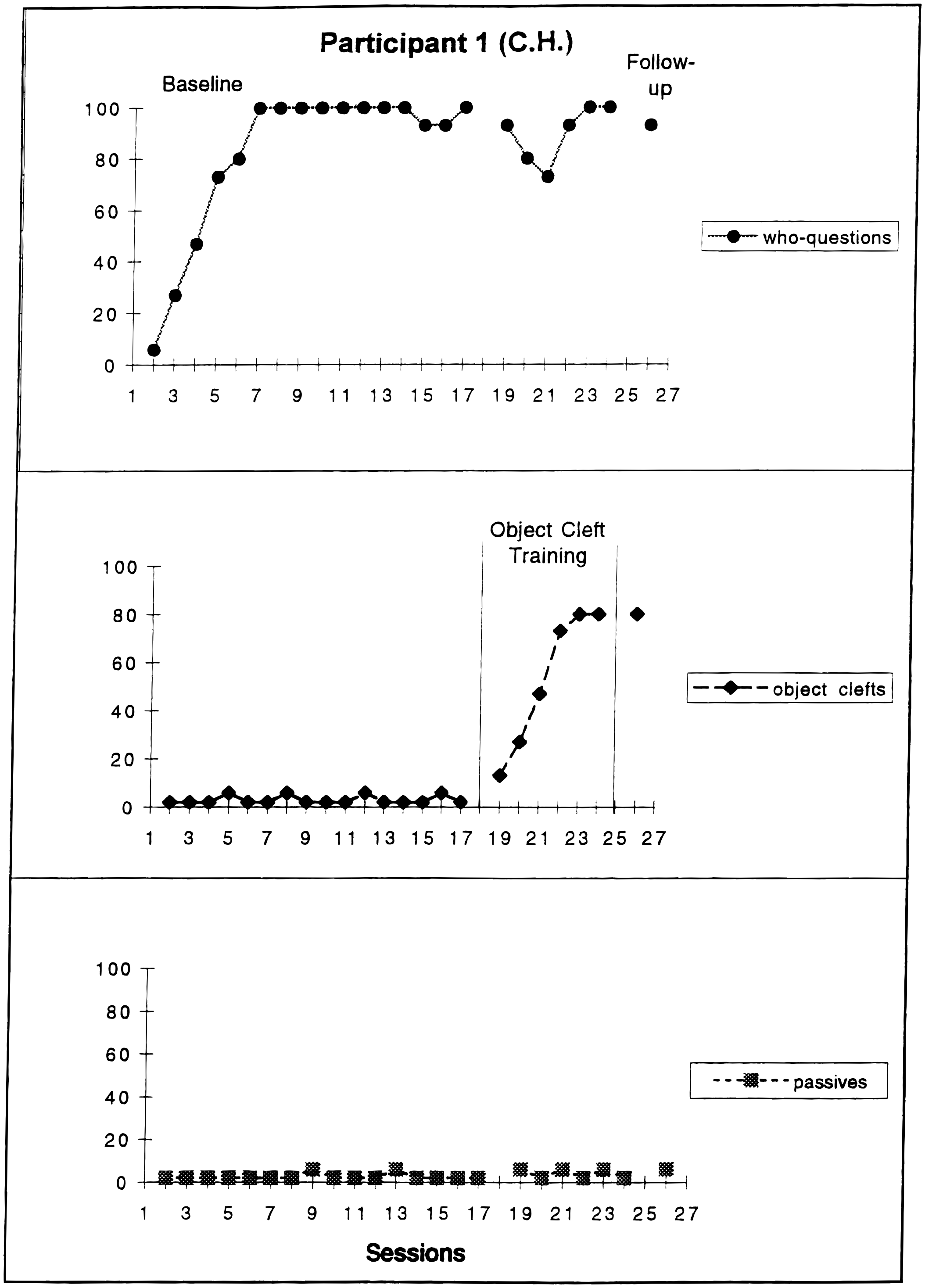

Fig. 4. Percent correct production of *who*-questions, object clefts, and passive sentences during baseline, treatment, and maintenance phases of the study for Participant 1 (C.H.).

duced (e.g., *Who chased the thief*? for the target *Who has the artist chased*?). Participants also produced simple active sentences instead of the target sentences. Importantly, many error responses showed respect for the lexical properties of verbs even though obligatory arguments were sometimes deleted. These data showed that while the participants retained knowledge of the grammar, they were unable to use this knowledge to generate complex sentences.

Because Participant 1 (C.H.) showed acquisition of *who*-questions using the sentence production priming task, baseline testing was continued and no treatment specific for this structure was instituted. Within six testing sessions, *who*-

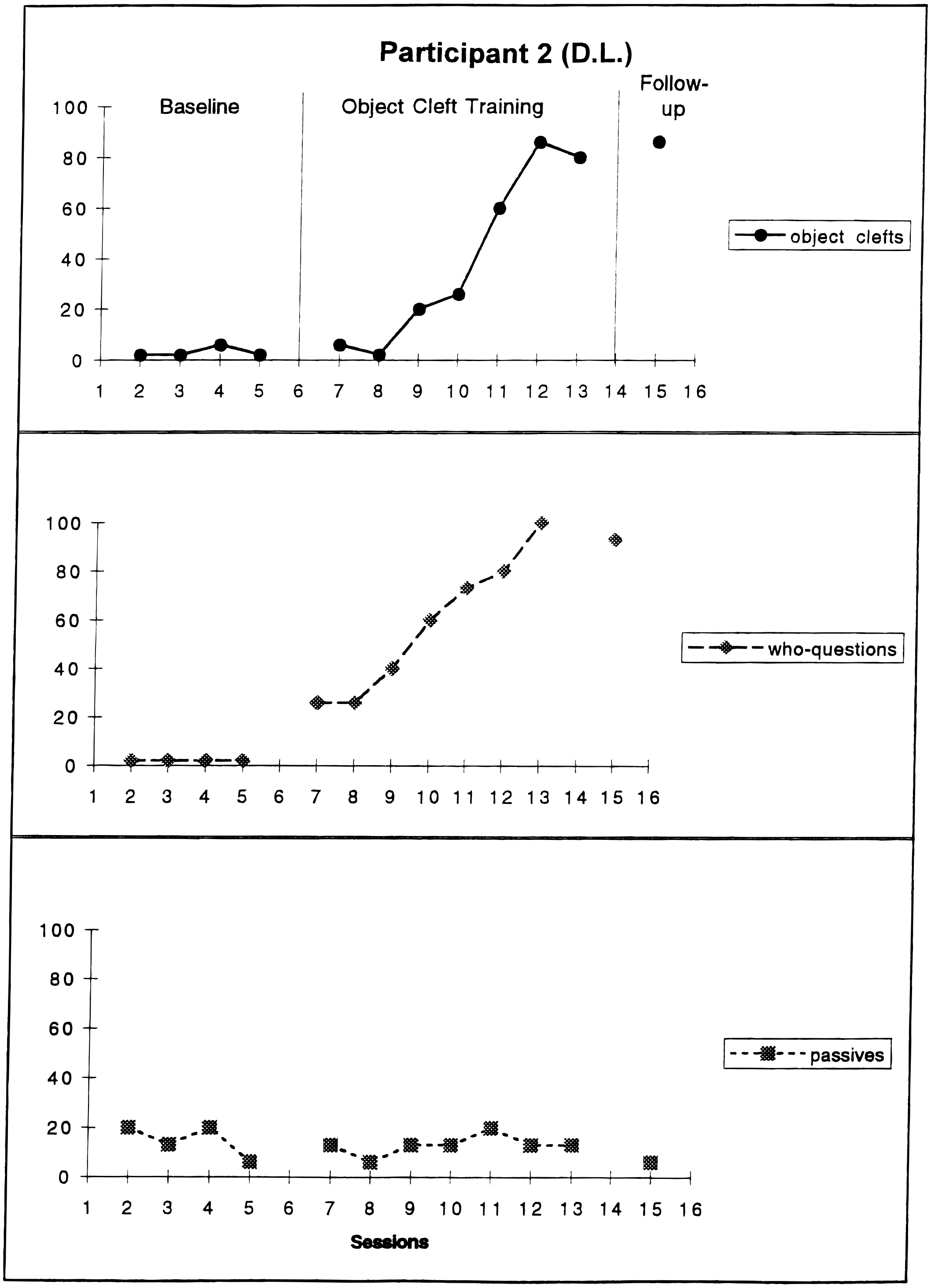

Fig. 5. Percent correct production of object clefts, *who*-questions, and passive sentences during baseline, treatment, and maintenance phases of the study for Participant 2 (D.L.).

question production increased to 100% correct, while object cleft productions (and passives) remained at low levels. Baseline testing was continued for an additional 10 sessions to observe the effects of this repeated *who*-question production (without direct treatment or accuracy feedback) on the production of object clefts. As can be seen in Figure 4, object cleft production was not influenced by *who*-question production. Participant 1 (C.H.) was then trained to produce object clefts, which resulted in acquisition of this structure within six training sessions; however, production of passive sentences was unchanged. Initial training of object clefts resulted in a slight regression in production of *who*-

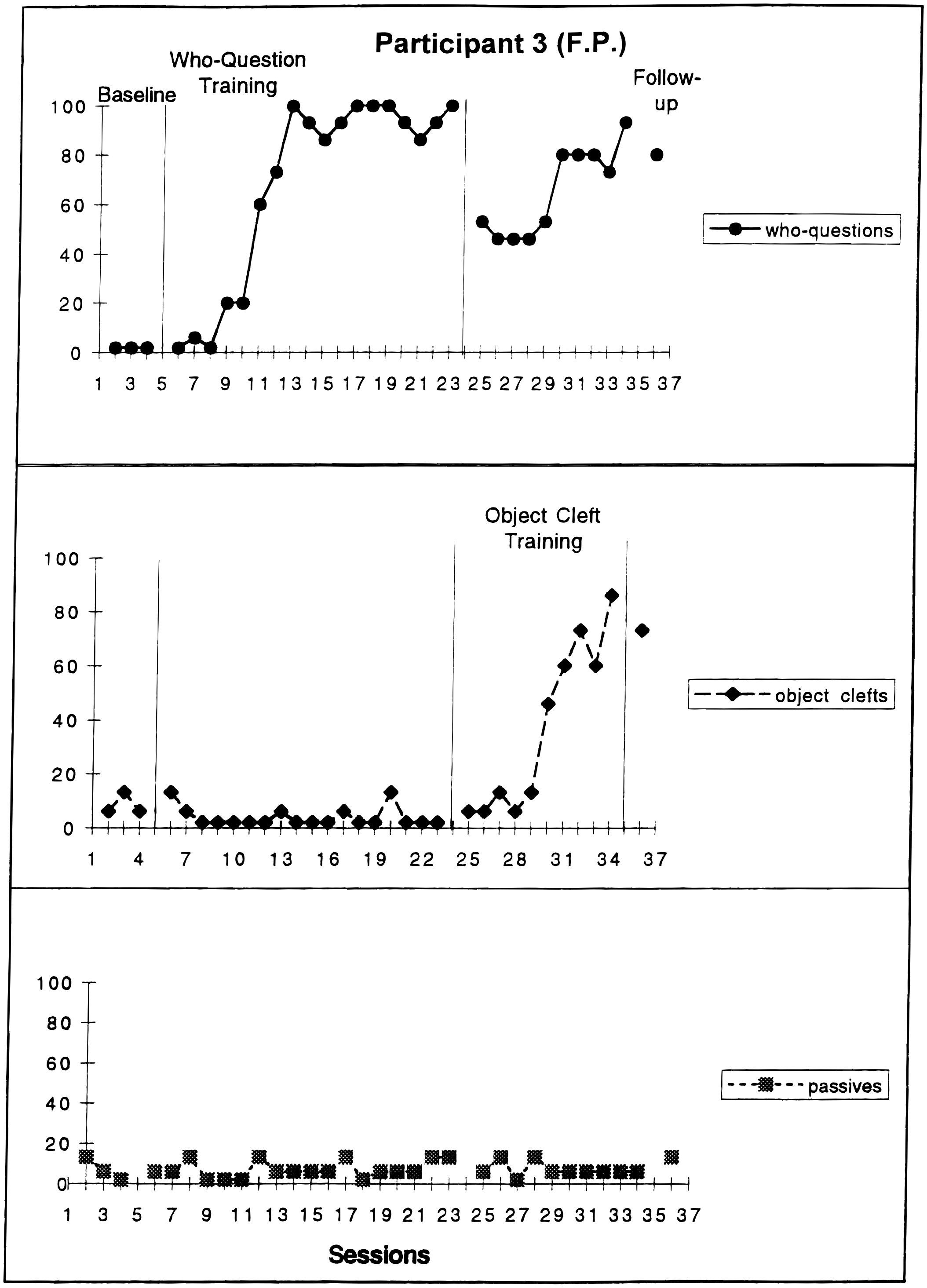

Fig. 6. Percent correct production of *who*-questions, object clefts, and passive sentences during baseline, treatment, and maintenance phases of the study for Participant 3 (F.P.).

questions with high levels of correct production regained once object cleft structures were acquired. This performance pattern has been noted in other treatment studies with aphasic patients (Thompson et al., 1996, 1997) and is consistent with learning curves seen in normal language development (Gershkoff-Stowe & Smith, 1997; Goodluck, 1991).

For Participant 2 (D.L.), treatment resulted in successful acquisition of object clefts. Following a stable baseline, object cleft production increased to 100% correct in seven training sessions. For this participant, a concomitant increase in *who*-question production during object cleft treatment also was seen; therefore, *who*-question treatment was not provided. During object cleft training production of *who*-questions increased from 6 to 86% correct (see Figure 5). Once again, however, passive sentence production remained unchanged throughout the treatment period.

Participant 3 (P.F.) was trained to produce *who*-questions following a stable baseline period. Within eight training sessions, production of *who*-questions increased to 100% correct. However, during this training, generalization did not occur to the other sentence types. Treatment for *who*-questions was, therefore, continued for an additional 10 sessions in order to maximize potential for generalization to occur. Even with this additional training object cleft production remained unchanged. Thus, object cleft sentences were trained, resulting in acquisition of this structure. Like C.H., P.F. also showed an initial decrease in correct production of *who*-questions when object clefts were trained; however, no change in production of passive sentences was seen (see Figure 6).

Follow-up testing was undertaken 2 weeks following the completion of treatment for all 3 participants. The ability to produce both *wh*-movement structures (*who*-questions and object clefts) was maintained in all cases.

DISCUSSION

This experiment was undertaken in order to further examine generalization patterns among *wh*-movement structures. Results showed robust generalization effects from object clefts to matrix *who*-questions for Participant 2 (D.L.), however, no generalization was noted from *who*-questions to object clefts for Participant 3 (F.P.). Participant 1 (C.H.) showed acquisition of *who*-questions, but not object clefts in conjunction with repeated exposure to the probe task, without direct training. These data, considered together with those derived from our previous studies examining the relation between these structures, indicate that of 8 patients studied to date, all 3 who received object cleft treatment showed generalization to matrix *who*-questions (D.L., M.D., and H.H.). In contrast, only 1 participant of 3 showed generalization from matrix *who*-questions to object clefts (A.H.). Two participants did not show this pattern (F.P. and K.D.); *who*-question training had no effect on object cleft structures. In addition, 2 participants (C.H. and P.R.) showed acquisition of *who*-questions during baseline probing, but were unable to generate the object cleft structure without direct treatment (see Table 4).

The only participant (A.H.) who showed generalization to object clefts when *who*-questions were acquired requires comment. A.H. was unlike the other participants in that her aphasia did not result from stroke. Instead, she presented with primary progressive aphasia of unknown etiology. In addition, she demonstrated a very mild aphasia at the time of the study (WAB AQ = 93.6). It is possible that these factors contributed to her unique generalization pattern. Perhaps because A.H. showed a milder impairment, her ability to project CP was less impaired and, therefore, more conducive to improvement. It also is possible that patients with aphasia resulting from degenerative disease processes may show different generalization patterns than those with aphasia resulting from a single focal lesion.

As noted in previous studies, the participants in this study did not show generalization from *wh*-movement structures to passive sentences that rely on NP-movement (Ballard & Thompson, in press; Jacobs & Thompson, in press; Thompson & Shapiro, 1994; Thompson et al., 1997). These findings indicate, once again, that generalization is unlikely to occur to sentences that are linguistically dissimilar. Training *wh*-movement structures that involve movement to [SPEC, CP], a nonargument position, results in generalized production only to untrained sentences that also contain *wh*-movement. Such training does not influence production of NP-movement structures that involve movement to [SPEC, IP], an argument position. These data indicate that generalization patterns seen in recovery of sentence production follow patterns based on specific properties of move-alpha, the general transformational rule involved in the derivation of

Table 4. Generalization patterns between object cleft structures and matrix *who*-questions

Participant	Trained *Wh*-movement structure		Untrained *Wh*-movement structure		Untrained NP-movement structure
D.L. (P2)	Object cleft	$\longrightarrow$	*Who*-questions	$\not\Rightarrow$	Passives
M.D.*	Object cleft	$\longrightarrow$	*Who*-questions	$\not\Rightarrow$	Passives
H.H.**	Object cleft	$\longrightarrow$	*Who*-questions	$\not\Rightarrow$	Passives
A.H.**	*Who*-questions	$\longrightarrow$	Object cleft	$\not\Rightarrow$	Passives
F.P. (P3)	*Who*-questions	$\not\Rightarrow$	Object cleft	$\not\Rightarrow$	Passives
K.D.**	*Who*-questions	$\not\Rightarrow$	Object cleft	$\not\Rightarrow$	Passives
C.H. (P1)	*Who*-questions	$\not\Rightarrow$	Object cleft	$\not\Rightarrow$	Passives
P.R.*	*Who*-questions	$\not\Rightarrow$	Object cleft	$\not\Rightarrow$	Passives

*Participants reported from Thompson et al., 1997.
**Participants reported from Thompson & Shapiro, 1994.
Note. C.H. and P.R. did not receive treatment on *who*-questions. These participants showed acquisition of *who*-questions, but not object cleft production, during the probe task.

noncanonical sentences (Chomsky, 1986), and thus show that the theoretical distinction between *wh*- and NP-movement is important to consider in treatment for aphasia.

The present findings suggest that generalization also may be influenced by the complexity of structures trained. For *wh*-movement structures training more complex exemplars, in this case, structures with *wh*-movement within an embedded clause, resulted in generalization to less complex exemplars, those with *wh*-movement in the matrix sentence. These data indicate that, when treated structures encompass processes relevant to untreated ones, generalization occurs.

The present findings also support both Hagiwara's (1995) and Friedmann and Grodzinsky's (1997) proposal that projections of higher levels in the syntactic tree are dependent on successful projection of lower levels. In our patients CP was underspecified as indicated by their inability to produce complementizer phrases in either lower clauses (embedded clauses) or in higher ones (matrix clauses). As pointed out earlier and also shown in Figure 7, the CP in object clefts is dominated by an NP within IP, whereas, the CP in matrix questions is not dominated by a higher clause. Strengthening projections of IP by training CP in a lower clause, resulted in participants' ability to project to CP in a matrix clause. This training thus provided information relevant to generating CP in either an embedded clause or in a matrix clause. Conversely, training matrix CP in an unconstrained environment, undominated by a higher phrasal node, did not provide information relevant to generating a CP that is dominated by a higher clause.

It is also interesting to note that the emergence of CP structures in children's language appears to follow this pattern. DeVilliers (l992) examined seven longitudinal sets of English transcripts in the CHILDS data and found a striking relationship between embedded questions and matrix questions: Matrix *wh*-questions appeared after the children began using embedded questions. These data suggest that CP structures are indeed related to one another and that information about movement operations required in embedded structures may trigger the movement of matrix *wh*-questions. Further, it appears that early grammars as well as those impaired by brain damage are sensitive to universal constraints on movement.

The present data indicate that treatment improved access to CP in our participants with agrammatic aphasia and that training CP in more complex structures, embedded within IP, resulted in generalized production of unembedded CP in matrix sentences. These latter constructions can be considered less complex than the former because their production is not constrained by IP. However, both structures are similar in that they involve *wh*-movement. We conclude, then, that training more complex *wh*-movement structures results in generalization to less complex ones.

These findings, like those derived from our previous work indicate that syntactic formulations of agrammatism can be useful for guiding treatment efforts and for making predictions regarding generalization. Indeed, several researchers have indicated that agrammatic aphasic individuals have difficulty generating complex sentences. However, like inflec-

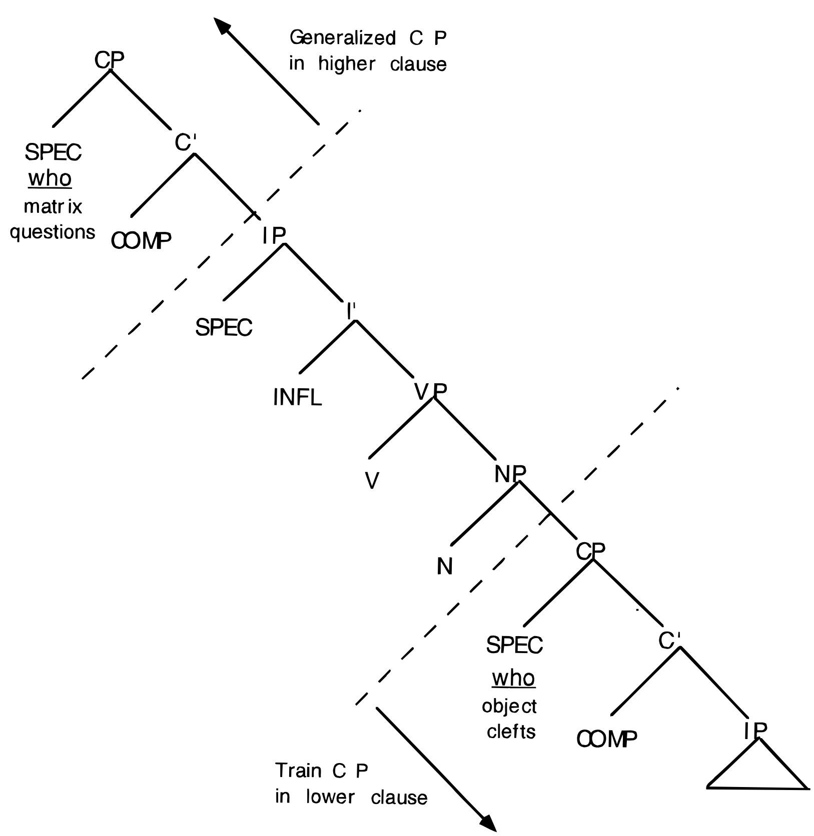

Fig. 7. Tree structure illustrating generalization pattern from object cleft sentences to matrix *who*-questions. Training CP in the lower clause resulted in participants' ability to project to CP at higher levels.

tion errors that also are prevalent in agrammatism, not all complex sentences are alike when their linguistic properties are considered and, importantly, not all aphasic individuals present with problems with the same types of sentences. Linguistic theory provides a framework for investigating the nature of complex sentence deficits and the relation between the sentence types that are impaired.

In addition to considering linguistic theory in investigations of aphasia, controlled experimental analyses are important for discovering the relations among sentences and other aspects of language. Examining language patterns as they emerge throughout the course of treatment by experimentally manipulating certain sentences while observing the effects of this manipulation on other sentences is a powerful way to examine these relations. Single-subject experimental designs are, therefore, particularly appropriate for research in aphasia (McReynolds, & Thompson, l986; Thompson & Kearns, l991). If we had not used this experimental paradigm in the present study or in our previous work we might not have discovered the discrepant emergence of object cleft and *wh*-question productions in our participants.

The findings from this study also have important clinical implications. Because of restrictions in health care for aphasic individuals, it is essential that clinicians provide treatment that will result in optimal generalization. Our data suggest that optimal generalization results from treatment when structures that are linguistically similar are selected as treatment targets and when treatment is applied to the most complex of these structures first. While additional data are needed to further substantiate the latter, we conclude that linguistically-based treatment such as that investigated here may be used successfully for training sentence production in aphasic individuals who present with deficits like those seen in our participants.

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Appendix

Active sentences and pictures (targets and foils) used to elicit target sentences [*wh*-question (wh); object cleft (oc); and passives (pa)].

Active (pictures) and target sentences	Reversible foils (pictures)
1. The thief chased the artist. (wh): Who has the thief chased? (oc): It was the artist who the thief chased. (pa): The artist was chased by the thief.	The artist chased the thief.
2. The skater hugged the coach.	The coach hugged the skater.
3. The sailor pushed the soldier.	The soldier pushed the sailor.
4. The sheriff kicked the convict.	The convict kicked the sheriff.
5. The boy tickled the girl.	The girl tickled the boy.
6. The judge tripped the clerk.	The clerk tripped the judge.
7. The driver stopped the cop.	The cop stopped the driver.
8. The skater passed the biker.	The biker passed the skater.
9. The guest watched the waiter.	The waiter watched the guest.
10. The woman kissed the man.	The man kissed the woman.
11. The biker lifted the student.	The student lifted the biker.
12. The wife covered the husband.	The husband covered the wife.
13. The thief trapped the cop.	The cop trapped the thief.
14. The farmer carried the hunter.	The hunter carried the farmer.
15. The girl shoved the boy.	The boy shoved the girl.