Treatment and Generalization of Complex Sentence Production in Agrammatism

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The present study applies single-subject experimental design to examine (a) the acquisition and generalization of complex sentence production in agrammatism using Linguistic Specific Treatment (LST) and (b) the utility of syntactic theory in guiding hypotheses of treatment effects. LST trains construction and production of complex sentence structures. Four sentence types were selected for study: object clefts and object-extracted matrix and embedded questions (which are noncanonical with *wh*-movement), and embedded actives (which are canonical with no overt movement). All sentences contain overt material in the complementizer phrase (CP) of the syntactic tree. Three of five participants (1, 2, and 3) demonstrated generalization from object cleft treatment to production of matrix questions. Thus, LST was effective in improving their ability to generate less complex sentences with *wh*-movement. Once production of object clefts and matrix questions was acquired, all 5 participants demonstrated generalization from treatment to improved production of embedded questions and/or embedded actives. This generalization involved improved ability to generate embedded clausal structure to form complex sentences but continuing inability to express overt material in CP. Finally, direct treatment for embedded questions did not result in accurate production of embedded actives or vice versa. There were no trends across participants toward improved production of morphosyntactic behaviors in narrative. Persons 1, 2, and 3 showed generalization to increased informativeness and efficiency of expression and were judged by independent listeners to improve in content, coherence, and fluency of spontaneous production. The remaining two participants showed no change or a decline in performance in narrative language production (4 and 5, respectively). These participants demonstrated more severe Broca's aphasia at pretesting compared to Persons 1, 2, and 3, with greater impairments in auditory comprehension, naming, and reading. Etiology and size of lesion did not appear to account for the different behavioral patterns. This study supports the use of LST, which applies syntactic theory to predict patterns of generalization, as an effective treatment approach.

KEY WORDS: Broca's aphasia, agrammatism, sentence production, treatment, neurolinguistics

The present study was conducted to investigate further the efficacy of Linguistic Specific Treatment (LST) for the sentence production impairment in agrammatism (Shapiro & Thompson, 1994; Thompson & Shapiro, 1994, 1995; Thompson, Shapiro, & Roberts, 1993; Thompson, Shapiro, Tait, Jacobs, & Schneider, 1996; Thompson et al., 1997). Specifically, we examined (a) the extent of generalization obtained between sentence types and (b) the relevance of theoretical distinctions between syntactic structures for predicting patterns of generalization.

LST utilizes Government and Binding Theory (Chomsky, 1981) to provide a testable hypothesis of the effects of training a given sentence structure.

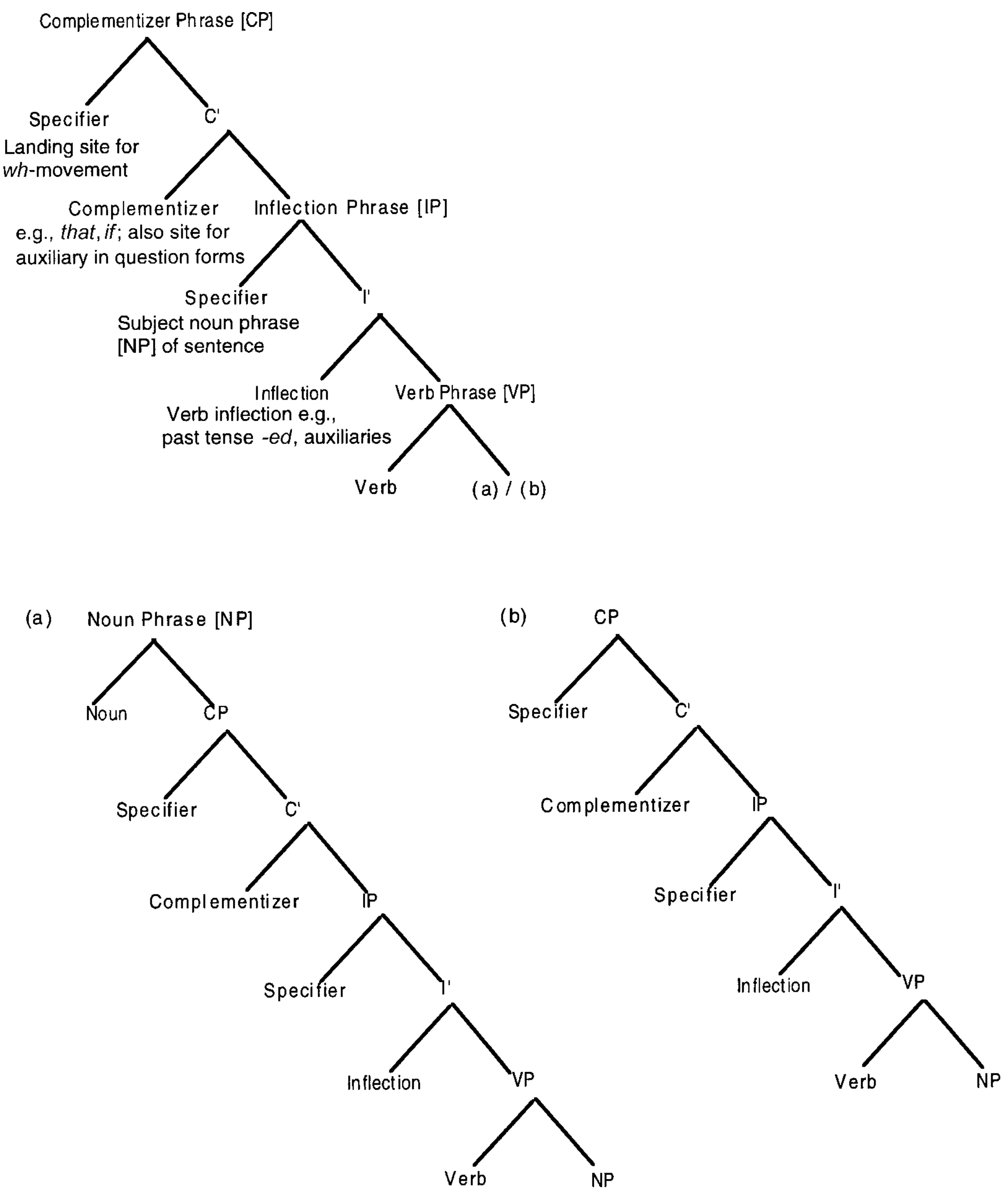
The basic structure of a sentence includes a verb phrase (VP), which is dominated by an inflection phrase (IP), which in turn is dominated by a complementizer phrase (CP); see Figure 1.[1] Although the CP is not required in a simple declarative sentence (as in [1], below), it is utilized in complex sentence structures such as *wh*-questions and object clefts with *wh*-movement (as in [2] and [3], respectively). The *wh*-movement operation involves moving a phrase from its underlying, or d-structure, position to the beginning of the clause. The original site is marked by a *trace*, a phonologically null element, that is coindexed (i) with the moved *wh*-phrase to show that the two nonadjacent positions co-refer.

[1] [$_{CP}$ [$_{IP}$The artist chased the thief]].

[2] [$_{CP}$Who$_i$ has [$_{IP}$the artist chased *trace*$_i$]]?

[1]The reader is directed to Shapiro (1997) for a detailed introduction to the linguistic theory relevant to this paper.

Figure 1. The syntactic structure of a sentence (Chomsky, 1986) is recursive, allowing clauses to be embedded within the matrix clause. In (a) a matrix noun phrase (NP) dominates the embedded complementizer phrase (CP), as in object clefts (e.g., [$_{IP}$It was [$_{NP}$the thief [$_{CP}$who the artist chased]]]). In (b), a matrix verb phrase (VP) dominates the embedded CP, as in embedded questions (e.g., [$_{IP}$I [$_{VP}$know [$_{CP}$who the thief chased]]]).



[3] [$_{IP}$It was the thief$_i$ [$_{CP}$who$_i$ [$_{IP}$the artist chased *trace*$_i$]]].

It has been demonstrated that individuals with agrammatism have difficulty comprehending and producing complex sentence structures (e.g., Caplan & Futter, 1986; Caramazza & Zurif, 1976; Saffran, Schwartz, & Marin, 1980; Schwartz, Saffran, & Marin, 1980; Thompson et al., 1995). Hagiwara (1994, 1995) proposed that the impairment in production of complementizers and verb inflection is at the heart of the syntactic deficits observed in agrammatism. Hagiwara argued that, in construction of a sentence, projection of the higher levels in the syntactic tree is dependent upon successful projection of the levels below. An impairment in verb inflectional morphology represents unsuccessful projection of IP and so CP cannot be projected. This projection deficit follows from the fact that a head (e.g., Inflection, the head of Inflection Phrase) projects "upward" in the tree to an intermediate level (e.g., I′) that, in turn, projects to a phrasal level (e.g., IP). Therefore, if a lower node is affected, so too are the higher nodes that are projected from it. On examination of language production and grammaticality judgment data, Hagiwara (1995) observed that individuals with agrammatism demonstrate a locus of impairment at a specific level in the tree which prevents all structure higher in the tree from being realized. Furthermore, more severe cases of agrammatism have the locus of impairment at lower levels. Hagiwara's hypothesis of hierarchical degradation of the syntactic tree structure in agrammatism was supported by Friedmann and Grodzinsky (1997), who referred to it formally as the tree pruning hypothesis.

Following the tree pruning hypothesis, CP will always be impaired to some degree in agrammatism as it is the highest projection in the syntactic tree. Thus, sentence forms requiring projection of CP such as *wh*-questions (as in [2]) and object clefts (as in [3]) should be difficult for all individuals with agrammatism to produce. This hypothesis is consistent with observations that these individuals rarely produce complex sentences containing *wh*-movement or embedded clausal structure (Thompson et al., 1995).

LST focuses on treating production of complex noncanonical sentence structures, which are defined as having constituents overtly moved from their underlying, or d-structure, position or having embedded clausal structure such as *wh*-questions and object clefts. The basic premise underlying LST is that the effects of a treatment should result in generalization to related behaviors if treatment that is focused on a subset of items provides information relevant to relearning an entire set of items. Syntactic theory (Chomsky, 1981, 1986, 1993) is applied to postulate which syntactic structures belong to the same set and which structures will provide the relevant information to the damaged cognitive system to permit maximal generalization. Thompson et al. (1997) have demonstrated that treating production of a syntactic structure only results in generalization to production of syntactically related structures. For example, treatment for production of *wh*-movement structures (e.g., object clefts as in [3]) results in generalization to other *wh*-movement structures (e.g., *wh*-questions as in [2]) but not to noun phrase movement structures (e.g., passives as in [4]).

[4] [$_{IP}$The thief$_i$ was chased *trace*$_i$ by the artist].

There appears to be an optimal ordering of treatment that will maximize generalization between related sentence structures (Thompson, Ballard, & Shapiro, 1998; Thompson & Shapiro, 1994; Thompson et al., 1997). For seven people with moderate agrammatism, Thompson et al. (1998) showed that (a) treatment for object cleft production results in generalization to production of *who*-questions; (b) treatment for *who*-question production does *not* result in generalization to production of object cleft sentences; and (c) for individuals able to produce matrix *who*-questions without intervention, production of object clefts is not forthcoming without direct treatment. These results support the hypothesis that training production of a *wh*-movement structure embedded within a higher clause (that is, object clefts) provides information relevant to generating a less complex matrix level *wh*-movement structure such as *wh*-questions. However, training production of matrix questions provides information relevant to performing *wh*-movement but not to embedding that structure within a higher clause.

The purposes of the present LST study were to examine further (a) the extent of generalization between *wh*-movement structures and sentence structures of differing complexity, (b) generalization to narrative language production, and (c) maintenance of treatment and generalization effects. We also aimed to investigate the social validity of this treatment approach. We utilized a single-subject experimental design to study acquisition and generalization across four sentence types: object clefts (as in [5]), matrix questions (as in [6]), embedded questions (as in [7]), and embedded actives (as in [8]). Embedded actives were selected because they represent a sentence structure that is less complex than object clefts. That is, although embedded actives contain embedded clausal structure, they do not involve *wh*-movement. As an additional measure of control, we also probed production of passive sentences (as in [9]) that involve a different type of phrasal movement: noun phrase movement. While one sentence type was trained, the remaining sentences were probed for generalization.

[5] [$_{IP}$It was the thief$_i$ [$_{CP}$who$_i$ [$_{IP}$the artist chased *trace*$_i$]]].

[6] [$_{CP}$Who$_i$ has [$_{IP}$the artist chased *trace*$_i$]]?

[7] [$_{IP}$I know [$_{CP}$who$_i$ [$_{IP}$the artist chased *trace*$_i$]]].

[8] [$_{IP}$I believe [$_{CP}$that [$_{IP}$the artist chased the thief]]].

[9] [$_{IP}$The thief$_i$ was chased *trace*$_i$ by the artist].

All participants were first trained on object cleft production, and generalization to the remaining sentence types was probed. The effect of order of treatment could not be ruled out as a confound given the present data alone. However, it is important to note that Thompson et al. (1998) counterbalanced the order of object cleft and matrix question treatment across subjects and reported that there appears to be an optimal ordering of treatment for sentence structures that results in maximal generalization between *wh*-movement structures. Therefore, we purposefully presented object cleft treatment first to all participants.

Consistent with Thompson et al. (1998), it was predicted that treatment for production of object clefts would result in generalization to production of other *wh*-movement structures of equal or lesser complexity, specifically matrix questions and embedded questions. Matrix questions are syntactically less complex because they involve *wh*-movement but do not contain embedded clausal structure. Embedded questions are of similar complexity in that both these and object clefts involve *wh*-movement and embedded clausal structure. Effects of treatment for object cleft production were not expected to generalize to embedded actives. Although embedded actives are less complex than object clefts, in that they contain embedded clausal structure but no phrasal movement, it is hypothesized that object cleft treatment will only generalize to less complex sentence types with *wh*-movement. We predicted that object cleft production treatment would not result in generalization to production of passives that involve a different type of phrasal movement: noun phrase movement (Thompson & Shapiro, 1994; Thompson et al., 1997).

In this study, we examined generalization to narrative language as a measure of treatment efficacy. Narrative samples were collected pre- and posttreatment to determine the effects of treatment on specific morphosyntactic behaviors and on informativeness and efficiency of expression. It was assumed that improvement in these areas posttreatment would indicate that LST brought about changes in the language production systems of the participants which could be applied to production of spontaneous language. Following Doyle, Goldstein, and Bourgeois (1987), we extended previous LST studies by examining social validity of the treatment. We asked 10 university students to rank randomized narrative samples to determine whether any qualitative changes in language production were perceived. This approach supported the results of the treatment study.

Method

Participants

The study involved 3 Caucasian men (Persons 1, 2, and 4) and 2 African American women (Persons 3 and 5) diagnosed with Broca's aphasia with language production characterized by agrammatism. Persons 1, 4, and 5 had experienced a single left-hemisphere cerebrovascular accident (CVA) within the distribution of the left middle cerebral artery. They also presented with right-sided hemiplegia. Person 2 had sustained an open head injury to the left side of the head. He underwent surgery for evacuation of an epidural and subdural hematoma. The injury resulted in right hemiparesis and right homonymous hemianopsia. Note that Person 2 compensated for the hemianopsia and did not demonstrate visual field neglect in a shape cancellation test (see Language and Neuropsychological Testing below). Person 3 had suffered two left-hemisphere infarctions, both within the distribution of the left middle cerebral artery. A mild right-sided hemiplegia was present. Lesions for all individuals were restricted to the left hemisphere, involving Broca's area with extension into adjacent frontal cortex, insula, subcortical structures, and/or anterior areas of the parietal lobe. Two individuals demonstrated extension into Wernicke's area (Persons 2 and 3) and one into the occipital cortex (Person 2). Time post-onset ranged from 10 to 168 months.

All participants were right-handed, native English speakers with no history of speech and language disorders, progressive neurological disease, psychiatric disorders, or substance abuse. Ages ranged from 38 to 69 years (M = 54.6) and education level from 13 to 24 years (M = 17.8). All participants passed a pure tone audiometric screening at 40 dB SPL at 500, 1000, and 2000 Hz bilaterally. Visual acuity, corrected or uncorrected, was 20/40.

Language and Neuropsychological Testing

Language testing was conducted no more than one month before the experiment (see Table 1). All participants were classified with moderate Broca's aphasia based on results of the Western Aphasia Battery (WAB; Kertesz, 1982). Although auditory comprehension was impaired, this was superior to expressive abilities. Lexical comprehension and grammaticality judgment, as tested by the Philadelphia Comprehension Battery for Aphasia (PCBA; Saffran, Schwartz, Linebarger, Martin, & Bochetto, n.d.), reflected near-normal skills. Comprehension of semantically reversible canonical sentences (i.e., simple actives as in [10] and subject relatives as in [11]) and noncanonical sentences (i.e., passives as in [12] and object relatives as in [13]) was tested with the Northwestern University Sentence Comprehension

Table 1. Results of formal language pretesting for each participant.

Measure	Participant				
	1	2	3	4	5
Western Aphasia Battery					
Aphasia Quotient (/100)	69.5	70.3	63.4	57.6	53.7
Fluency (/10)	4.0	4.0	4.0	4.0	4.0
Comprehension (/10)	9.8	7.9	8.8	7.3	6.1
Repetition (/10)	5.3	7.0	5.4	6.0	5.5
Naming (/10)	7.7	7.3	6.5	5.5	4.3
Cognitive Quotient (/100)	78.0	70.7	76.1	60.8	56.8
Reading (/10)	9.0	6.7	9.7	5.8	3.1
Writing (/10)	4.9	5.0	8.5	4.8	4.9
Praxis (/10)	10.0	7.0	9.0	7.2	8.2
Construction (/10)	9.6	9.0	8.4	6.9	7.7
Philadelphia Comprehension Battery for Aphasia					
Lexical comprehension (%)	100	86	98	100	95
Grammaticality judgment (%)	88	92	70	88	83
Northwestern University Sentence Comprehension Test[a]					
Active/Subject relative (%)	85/85	73/<u>56</u>	100/<u>67</u>	<u>55</u>/<u>67</u>	<u>55</u>/<u>56</u>
Mean canonical	85	<u>64.5</u>	83.5	<u>61</u>	<u>55.5</u>
Passive/Object relative	80/<u>60</u>	<u>67</u>/<u>55</u>	<u>0</u>/<u>44</u>	89/<u>45</u>	<u>56</u>/<u>45</u>
Mean noncanonical	<u>70</u>	<u>61</u>	<u>22</u>	<u>67</u>	<u>50.5</u>

[a]Based on the binomial distribution ($p = .05$), when $9 \le N \le 11$ performance >70% correct is above chance, performance at or between 20% and 70% is at chance, performance below 20% is below chance. Underlined values represent performance at or below chance levels.

Test for Aphasia (NU Test; Thompson, n.d.), a sentence-to-picture matching task. Persons 1 and 3 demonstrated comprehension of canonical sentences above chance, with comprehension of noncanonical sentences at chance. Persons 2, 4, and 5 comprehended both sentence types at chance levels. Notably, Persons 1, 2, and 3 demonstrated above-chance comprehension of simple active sentences, whereas Persons 4 and 5 demonstrated chance performance, indicating the latter had a more severe syntactic comprehension deficit.

[10] The thief chased the artist.

[11] I saw the thief who chased the artist.

[12] The artist was chased by the thief.

[13] I saw the artist who the thief chased.

Narrative language samples were elicited to analyze lexical and morphosyntactic production pre- and posttreatment. Participants retold the Cinderella and Red Riding Hood fairy tales. The narrative samples were analyzed using the linguistic coding method of Thompson et al. (1995) whereby (a) sentences are coded for grammaticality and complexity, (b) words are coded for type and class, and (c) verbs are coded for type, argument structure, and morphological complexity. Results of the pretreatment narrative analyses, presented in Table 2, indicated that all individuals demonstrated agrammatism, with reduced utterance length, reduced grammaticality, dominance of simple sentence structures with few instances of embedded clausal structure, and omission of obligatory verb arguments. Four participants (1, 2, 4, and 5) demonstrated elevated ratios of open to closed class words and nouns to verbs produced. Notably, Person 3 was diagnosed with moderate Broca's aphasia, but her language production was only mildly agrammatic. Furthermore, this participant used elements of both Standard American English (SAE) and African American English (AAE) dialects and was not penalized when AAE forms were used. An independent judge, familiar with the features of AAE, checked each of Person 3's narrative samples to ensure accurate identification of these features. Although Person 5 was African American, premorbidly she used SAE dialect.

To measure informativeness and efficiency of expression, percentage of words classified as correct information units (CIUs), the number of CIUs produced per minute, and the number of words produced per minute were calculated using a system based on Nicholas and Brookshire (1993); see Table 2. An information unit is roughly defined as a word that is accurate, relevant, and informative for the given stimulus regardless of the

Table 2. Linguistic analysis of participants' narrative language pretreatment, posttreatment, and at follow-up.

	Participant															Normal	
	1			2			3			4			5				
	Pre	Post	F/Up	Pre	Post	F/Up	Pre	Post	F/Up	Pre	Post	F/Up	Pre	Post	F/Up	*M*	(*SD*)
Linguistic variables																	
Number of utterances	71	116	135	93	107	101	44	46	56	85	59	50	113	74	94	23.6	(7.1)
Mean length of utterance	2.8	3.0	2.7	3.6	3.4	3.9	8.1	9.1	10.0	2.8	3.9	4.2	3.7	3.0	3.3	14.5	(2.2)
Proportion of grammatical sentences	.38	.23	.13	.10	.07	.03	.29	.35	.38	.09	.05	.00	.21	.21	.27	.90	(.0)
Complex: simple sentences	.23	.07	.07	.05	.09	.00	.40	1.12	.39	.0	.05	.05	.19	.27	.16	1.4	(.2)
Proportion of verbs w/correct argument structure	.50	.60	.45	.60	.87	.74	.98	.96	.95	.29	.25	.71	.73	.64	.50	—	—
Open:closed class words	1.66	2.05	2.81	1.67	2.96	2.17	.72	.86	.85	2.33	2.23	2.22	1.70	3.30	2.45	.91	(.1)
Noun:verb	3.06	2.26	2.40	2.89	4.05	3.13	1.05	1.39	1.72	4.29	2.64	3.76	1.45	3.57	3.29	1.2	(.3)
Informativeness/efficiency																	
CIUs/words	.54	.63	.87	.59	.63	.63	.45	.61	.62	.49	.34	.35	.51	.35	.56	.80	
CIUs/minute	10.2	11.5	15.3	8.7	10.4	13.8	11.1	19.9	20.5	3.9	4.4	5.1	7.8	2.4	4.9	114	
Words/minute	18.8	18.1	17.7	14.8	16.5	22.1	24.8	32.8	32.8	7.9	13.3	14.6	15.4	7.0	8.8	145	

Note. Normal data for morphosyntactic variables are from Thompson et al. (1995); normal data for informativeness and efficiency variables are from Jacobs (1996). CIU = Correct Information Unit.

grammatical context in which it is uttered. All participants demonstrated impaired performance on these variables.

Neuropsychological testing was carried out to rule out any additional cognitive deficits that may have interfered with individuals' performance in treatment. Results, presented in Table 3, indicated that no participants demonstrated visual field neglect. Persons 2, 4, and 5 performed slightly poorer than Persons 1 and 3 on a test of visual recognition memory. All participants showed near-normal nonverbal abstract reasoning skills and were able to complete the tests without prompts to sustain attention to the tasks presented.

Materials

Ten pairs of black-and-white line drawings, 10 cm by 14 cm, were used to elicit the five targeted sentence structures during baseline testing, experimental probes, and follow-up testing. These picture pairs represented the two permutations of semantically reversible sentences involving transitive verbs and two participants (e.g., "The artist chased the thief" and "The thief chased the artist"; see Thompson et al., 1997). An additional 40 black-and-white picture pairs were generated for use in treatment. These pictures were divided into four sets of 10, with one set being used to train each of four sentence structures: Set A for object clefts, Set B for matrix questions, Set C for embedded questions, and Set D for embedded actives. Within each set there was an equal number of verbs (*N* = 5) and nouns (*N* = 10) in common with the probe picture set and an equal number of novel vocabulary items (5 verbs, 10 nouns). Nouns and verbs were controlled for *frequency* (nouns: *M* = 151.79, *SD* = 346.20; verbs: *M* = 121.45, *SD* = 157.10; Francis & Kucera, 1982), *familiarity* (nouns: *M* = 6.97, *SD* = .13; verbs: *M* = 6.94, *SD* = .15; Francis & Kucera, 1982), *word length in syllables* (1-2), *pictureability* (all were pictured and elicited the appropriate nouns and verbs from adults with normal language skills), and *verb type* (transitive).

Five men and 5 women matched to the individuals with aphasia by age (*M* = 51.7 years, *SD* = 10.6), race (6 Caucasian, 4 African American), and education level (*M* = 17.8 years, *SD* = 3.6) were tested to ensure that (a) the pictures and the probe task elicited the target nouns and verbs and (b) the targeted sentence structures posed no difficulty for adults with normal language skill. All adults reported a negative history for

Table 3. Results of neuropsychological pretesting for each participant.

	Participant				
	1	2	3	4	5
Shape Cancellation Test					
Upper left quadrant (/15)	15	15	14	15	12
Lower left quadrant (/15)	15	15	15	15	13
Upper right quadrant (/15)	15	14	15	15	13
Lower right quadrant (/15)	15	14	15	15	13
Benton Visual Form Discrimination[a]					
Score (/15)	15	13	14	14	15
Benton Visual Recognition Memory[a]					
Score (/15)	15	11	14	10	11
Visual-Verbal Test[b]					
Abstract Reasoning Score (/20)	19	18	20	17	18
Shifts (/10)	9	8	10	7	8

[a]Benton (1983). [b]Feldman & Drasgow (1976).

speech and language disorders, progressive neurological disease, psychiatric disorders, or substance abuse. Nine of the 10 people were right-handed. All individuals produced the correct nouns and verbs for all picture stimuli. Production of the sentences by each person ranged from 90 to 100% correct, with the following exceptions. One participant produced subject clefts for object cleft sentences. For embedded active sentences, where the complementizer *that* is optional, one participant omitted *that* on 20% of trials and another on 60% of trials.

Cards with written words or phrases were made to identify the nouns and verbs in each picture pair. In all probe tasks the noun cards were placed above the pictured character and the verb was placed below the picture to reduce the influence of word-retrieval difficulties on sentence formulation. Cards representing the additional lexical items required to generate the target sentence structures were constructed for use in treatment only. These cards were never present during the sentence production priming task in which the examiner attempted to elicit the target sentence (see Baseline Testing Procedure and Treatment Procedure, below).

Experimental Design

A single-subject, combined multiple-baseline design across subjects and behaviors (McReynolds & Kearns, 1983) was used to examine changes related to treatment. In a multiple-baseline design across subjects, participants are exposed to progressively longer baseline phases. In so doing, experimental control is demonstrated by changes in performance occurring when, and only when, treatment is introduced to a given behavior. A multiple-baseline design across behaviors involves treating one behavior while holding other behaviors in baseline to examine generalization across sentence types within an individual. Control is demonstrated when untrained behaviors remain at baseline levels while performance on trained behaviors improves. This combined design permits experimental control to be maintained even when generalization occurs across behaviors (Connell & Thompson, 1986).

During the treatment phase, acquisition and generalization of targeted behaviors were measured by administering an experimental probe (see Experimental Probe Procedure below) before every session. LST was utilized to train production of the target sentence structures (see Treatment Procedure below). Generalization was measured to (a) untrained exemplars of the same structure and (b) untrained sentence structures. All participants first received treatment for object cleft structures. Treatment was terminated once participants demonstrated ≥60% correct production of object cleft sentences during the experimental probe over three consecutive probes. If this criterion was not reached, treatment for a given structure was terminated after nine sessions. This time period was judged to represent a sufficient number of trials to measure effectiveness of the treatment (McReynolds & Kearns, 1983). Following object cleft treatment, a new structure was entered into treatment depending on patterns of generalization for each participant. The treatment phase continued until all sentence types, except passives, had been acquired through direct training or generalization or until a maximum of 36 sessions had been completed.

Baseline Testing Procedure

Each baseline session consisted of eliciting each of the five sentence types 10 times each for a total of 50 items per probe. The experimenter cycled through the set of 10 picture pairs five times. A sentence-production priming procedure (Thompson et al., 1997) was used to elicit the sentences. Briefly, the examiner modeled the target structure with the first picture in a randomly selected picture pair (e.g., "Who has the artist chased?") and then prompted the individual to produce a similar sentence to describe the remaining semantically reversed picture (i.e., "Who has the thief chased?"). Participants' responses were recorded on audiotape and transcribed. The scoring procedure indicated whether a response was (a) correct, (b) missing overt material in CP (e.g., *who* in embedded questions as in [14] and *that* in embedded actives as in [15]), or (c) a substitution of the structure being trained (i.e., overgeneralization). Note that omission of overt material in CP for embedded actives, as in [15], does not render the sentence ungrammatical. However, the complementizer *that* was always produced in the examiner's model, and in a preliminary test of the sentence-production priming procedure with 10 normal participants (see Materials, above) the complementizer was produced on 91% of embedded active trials. Therefore, a high rate of omission was attributed to agrammatism.

[14] [$_{IP}$I know [$_{CP}$___ [$_{IP}$the thief chased *trace*]]].

[15] [$_{IP}$I believe [$_{CP}$___ [$_{IP}$the thief chased the artist]]].

Treatment Procedure

For each trial, participants were shown one of the 10 randomly selected picture pairs from the relevant training set. The sentence-production priming procedure used in testing was presented and then the individual attempted the target structure. The examiner provided feedback on correctness and then proceeded through the training protocol. The protocol involved the examiner (a) displaying the active sentence with word and phrase cards and identifying the verb and thematic roles and (b) demonstrating how to construct the target structure using word and phrase cards. Then the participant (c) produced the target sentence and identified the verb and thematic roles and (d) constructed and produced the target sentence and identified the verb and thematic roles. Finally, the examiner (e) made an attempt to elicit the target sentence using the sentence-production priming paradigm. This procedure was repeated for each stimulus picture pair. This protocol differed slightly from previous studies (Thompson & Shapiro, 1994; Thompson et al., 1997) in that Thompson and colleagues did not have individuals identify the verb and thematic roles in the target structures. This step was added to emphasize to participants that noun phrases retain their thematic roles when they move to a different position in a sentence.

Treatment sessions were 60 to 90 min. long and were conducted two or three times per week. Each session consisted of administering the treatment procedure using the relevant set of pictures and cycling through the 10 picture pairs a maximum of four times.

Experimental Probe Procedure

Every treatment session was preceded by the experimental probe. The procedure was identical to that used in baseline testing and represented the primary dependent variable to measure effects of treatment. Four weeks after completion of treatment a complete probe was administered to all participants to measure maintenance of trained and generalized behaviors. Participants' responses to all probes were recorded on audiotape, transcribed, and scored for accuracy in relation to the target structure.

Posttreatment Testing

Narrative samples were collected within one week posttreatment and at 4 weeks posttreatment. The samples were analyzed to determine whether effects of treatment generalized to changes in morphosyntactic behaviors and to increased informativeness and efficiency of expression in narrative language.

We were interested in determining whether LST produced perceivable changes in spontaneous expression and, therefore, had social validity. Ten university students were recruited to judge pretreatment, posttreatment, and follow-up narrative samples on numerical scales for (a) content, (b) coherence, (c) fluency and efficiency of expression, (d) length and complexity of sentences used, and (e) grammaticality of utterances. All students were enrolled in graduate programs in the Department of Communication Sciences and Disorders, Northwestern University, and had a mean age of 25.4 years (SD = 3.4) and a mean of 17.2 years of education (SD = 1.5). All reported a negative history for speech and language disorders, progressive neurological disease, psychiatric disorders, or substance abuse. The listeners were unaware that the treatment study had occurred and that the samples represented pre- and posttreatment measures. The first 15 utterances from each participant's three narrative samples were presented. Two composite audiotapes were made: one with three samples from each of three randomly selected participants and one with three samples from each of the remaining two participants. On a given tape, the three samples for each individual were randomized and presented in a block, to minimize effects of drift in perception over samples and time. Listeners were asked to make comparisons among samples for a given participant but not among participants. Order of audiotape presentation was counterbalanced across listeners.

Reliability

One quarter of all baseline and experimental probes were randomly selected and rescored by an independent scorer and the examiner. Mean interrater point-to-point reliability in scoring was 94.8% (SD = 6.1), and intrarater reliability was 97.0% (SD = 3.4). In order to obtain reliability on the independent variable, one third of the treatment sessions were scored for adherence to the steps in the treatment protocol and accuracy of rating participants' responses to the treatment steps. Mean interrater reliability was 99.9% (SD = 0.65) and 96.5% (SD = 3.6), respectively, and intrarater reliability was 99.7% (SD = 0.59) and 98.0% (SD = 1.6), respectively. One third of all narratives were randomly selected for determining inter- and intrarater reliability in transcription and coding of each lexical and morphosyntactic variable. Interrater reliability ranged from 78.6 to 100% (M = 90.8%, SD = 7.0), and intrarater reliability from 87.1 to 99.5% (M = 96.0%, SD = 3.5).

Results

Data representing acquisition, generalization, and maintenance of sentence production are presented for Persons 1 to 5 in Figures 2 to 6, respectively. The figures represent (a) grammatically correct production of each sentence structure in the baseline and experimental probes and (b) the number of responses representing production of the target syntactic structure but lacking overt material in CP.

Generalization Between Sentence Structures

All participants demonstrated stable baseline performance for percent-correct production of the five sentence structures and were entered into the object cleft treatment phase on schedule. Person 1 showed a rising baseline for embedded questions without overt material in CP (embedded questions [-wh] as in [16]). Persons 1 and 3 showed rising baselines for production of embedded actives without overt material in CP (embedded actives [-comp] as in [17]). The remaining participants' productions of both embedded questions and actives without overt material in CP were stable throughout baseline testing.

[16] $[_{IP}$I know $[_{CP}$___ $[_{IP}$the thief chased *trace*]]].

[17] $[_{IP}$I believe $[_{CP}$___ $[_{IP}$the thief chased the artist]]].

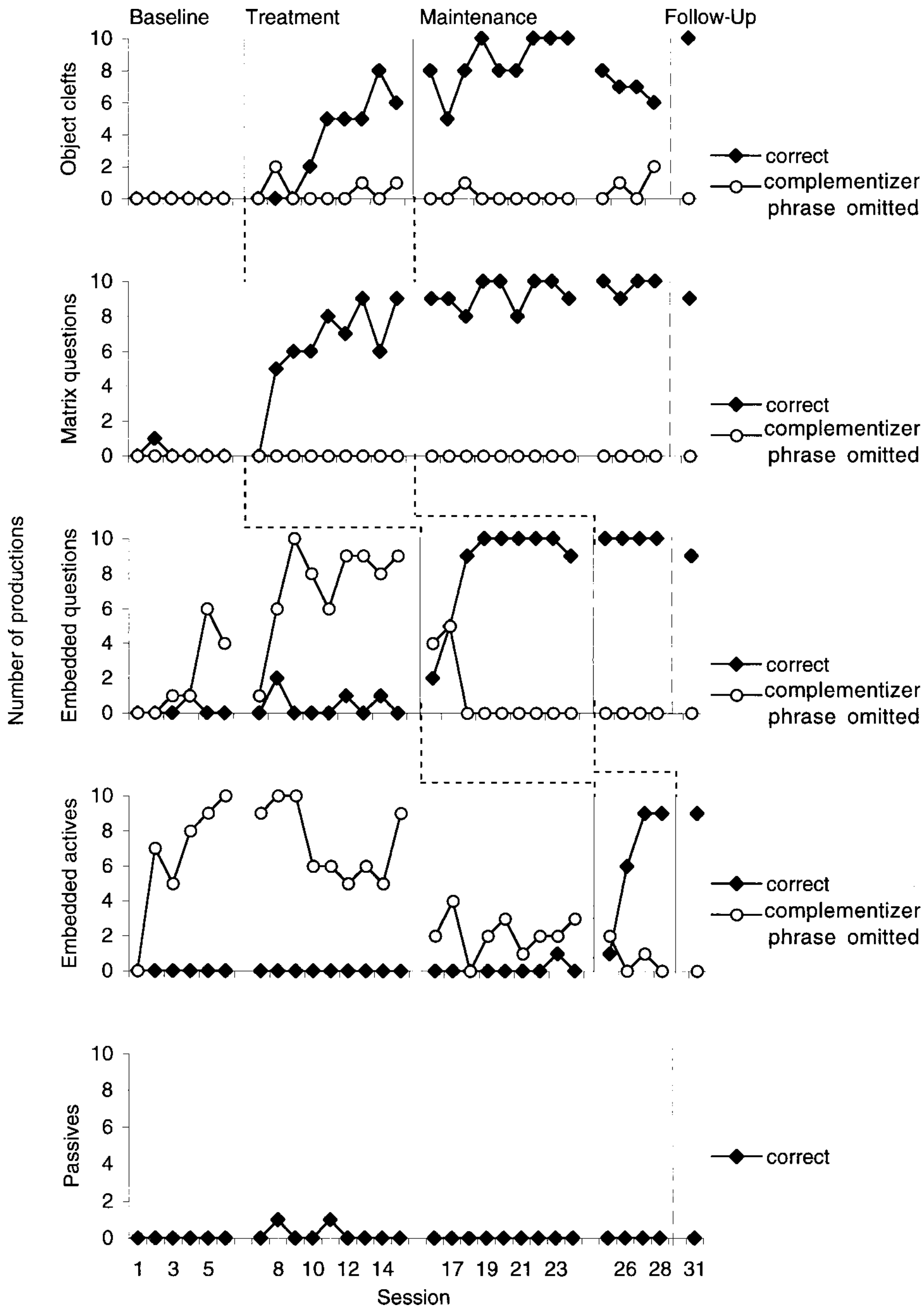
Experimental probes administered during treatment tested production of (a) untrained exemplars of trained structures and (b) untrained sentence structures. Performance on these probes indicated that, for all participants, object cleft treatment resulted in improved production of untrained object cleft sentences. When generalization to untrained sentence structures was examined, two patterns of behavior emerged. For three participants (1, 2, and 3), object cleft treatment resulted in generalization to production of matrix *who*-questions. Persons 4 and 5 did not demonstrate this generalization pattern but, instead, overgeneralized the effects of treatment. That is, substitution of object clefts for the other sentence structures being probed was the most frequent error type (except for embedded actives for Person 4; see Figure 5). When direct treatment was applied to matrix questions, Persons 4 and 5 rapidly acquired the ability to produce them and generalized the treatment effects to untrained matrix questions in the probe task.

No participants demonstrated the predicted generalization from object cleft treatment to accurate production of embedded questions. However, error analyses revealed interesting effects on the participants' behavior (see Figures 2 to 6). Persons 1, 2, 3, and 5 developed or improved the ability to produce embedded questions [-wh] during acquisition of object clefts and matrix questions. Person 1's production of embedded questions [-wh] increased from baseline levels and stabilized, whereas Persons 2, 3, and 5 developed the ability to generate embedded questions [-wh]. Person 4 demonstrated overgeneralization, substituting object clefts and matrix questions on 8/10 embedded question trials during the final sessions of object cleft and matrix question treatment, respectively.

As predicted, object cleft treatment did not result in complete generalization to production of embedded actives. However, Persons 2 and 4 developed the ability to generate embedded actives [-comp] during object cleft treatment. For Person 4, production of embedded actives [-comp] diminished during object cleft treatment, and overgeneralization errors became more frequent. This pattern of overgeneralization abated during matrix question treatment, and the embedded active [-comp] form re-emerged. Person 3, who produced embedded actives [-comp] during baseline testing, also demonstrated increasing overgeneralization errors during object cleft treatment. Person 5's production of the embedded active [-comp] form during object cleft and matrix question treatment was similar to baseline levels (i.e., ranging from 0 to 50% of trials per probe), with overgeneralization accounting for other errors.

As no participant demonstrated generalization of object cleft or matrix question treatment effects to accurate production of embedded questions or embedded active sentences, subsequent treatment for these two structures was applied in a counterbalanced order across participants. Treatment of both structures resulted in generalization to untrained exemplars of that structure

Figure 2. Performance of Person 1 on sentence production probes. Note that treatment for embedded question production was continued after criterion was reached to give maximum opportunity for generalization to embedded active production.



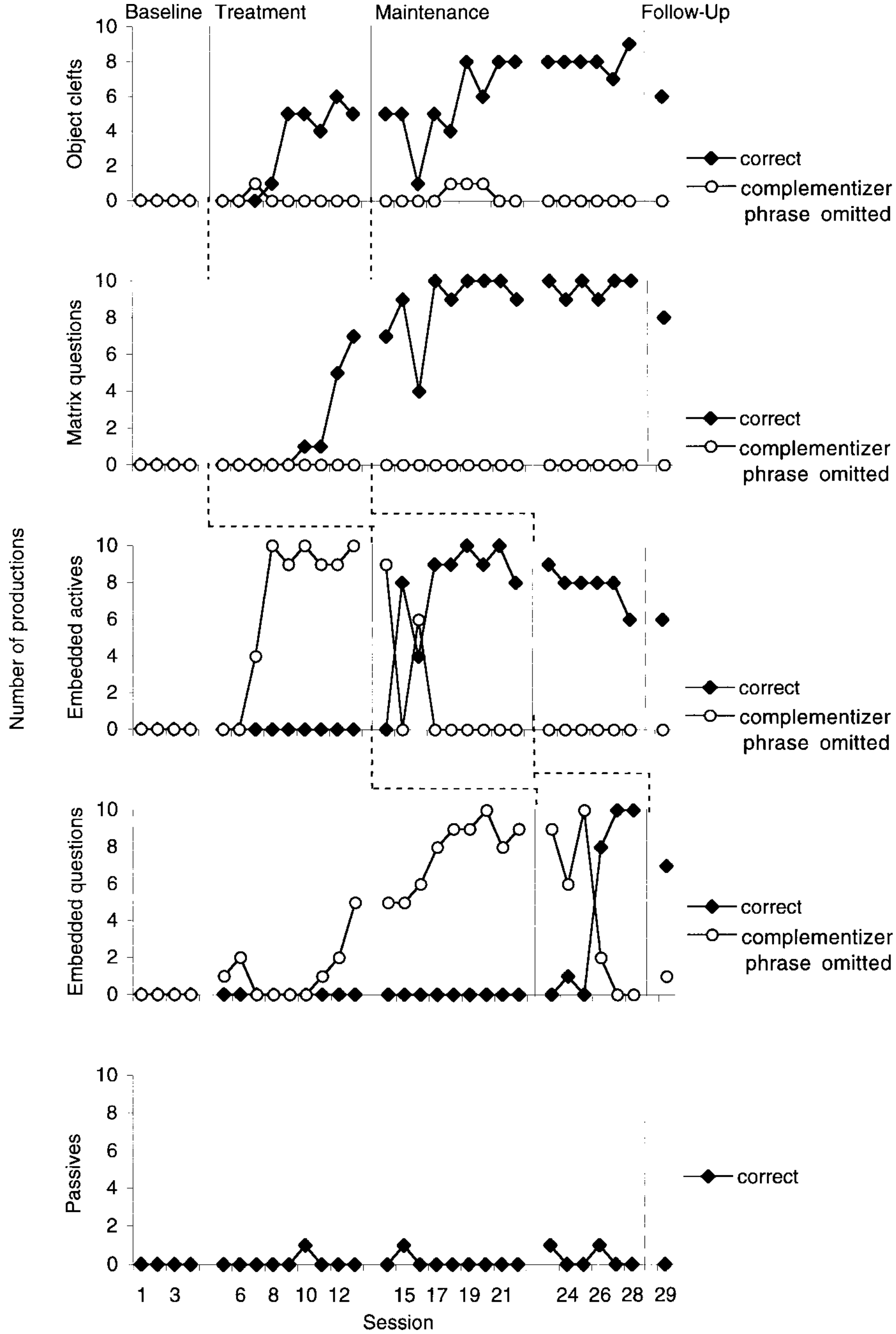
on the probe task. No participant demonstrated generalization between these sentence types. Furthermore, at the completion of treatment no participants had developed the ability to produce passive sentences.

A final probe was administered 4 weeks after completion of treatment. All participants maintained the effects of treatment with correct production of object clefts, matrix *who*-questions, embedded *who*-questions, and embedded actives above baseline levels. Passives continued to be produced incorrectly by all individuals.

Narrative Language Data

Analyses of morphosyntactic variables for the five participants pretreatment, posttreatment, and at follow-up are presented in Table 2. We did not statistically

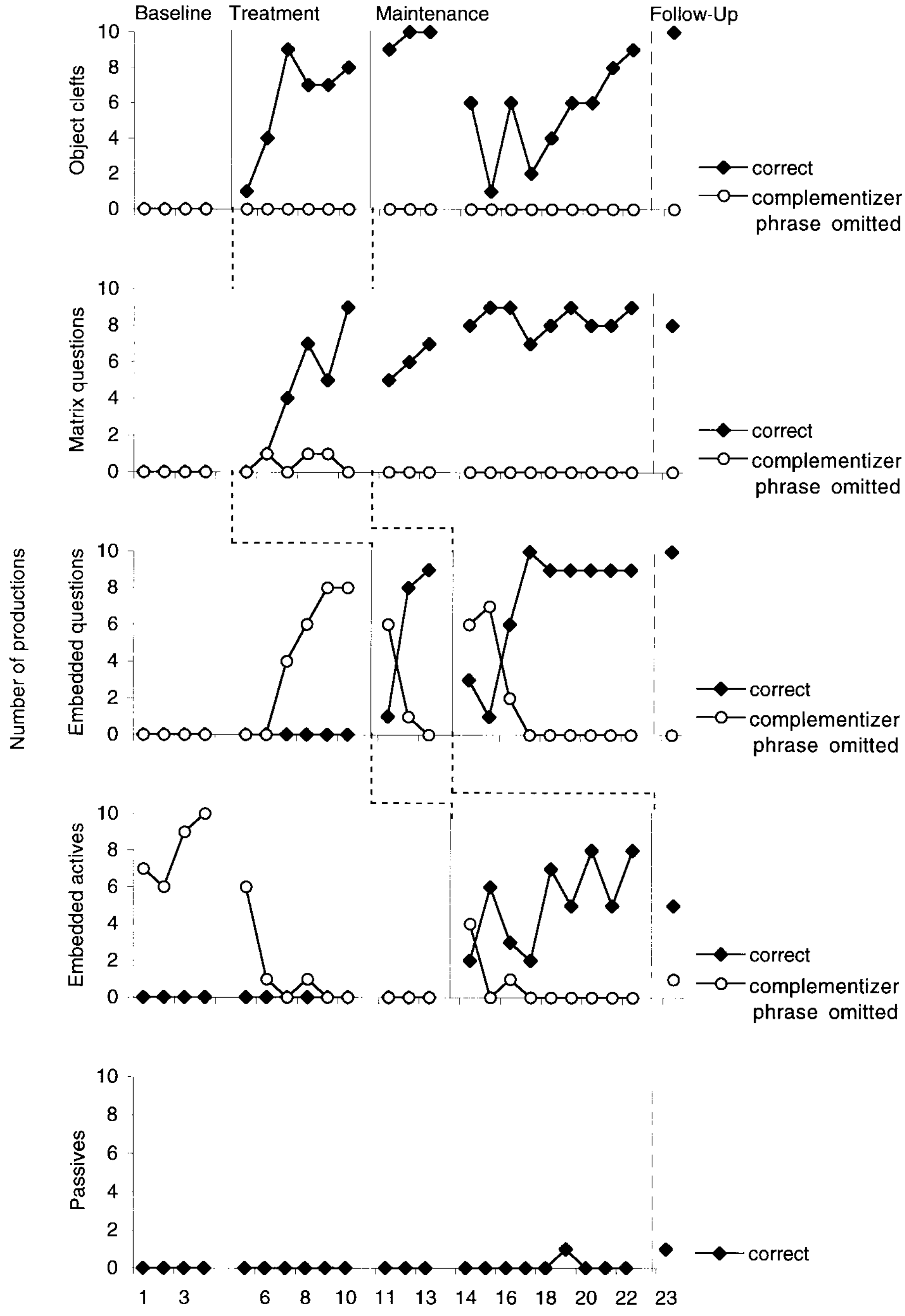
Figure 3. Performance of Person 2 on sentence production probes. Treatment for embedded active production was extended to give maximum opportunity for generalization to embedded question production.



analyze these data because of the small number of participants. However, no trends were observed across participants.

Analyses of informativeness and efficiency of expression for the five participants pretreatment, posttreatment, and at follow-up are presented in Table 2. Persons 1, 2, and 3 showed an increase in the percentage of words scored as CIUs and the number of CIUs produced per minute posttreatment. This increase was maintained at follow-up. These results are indicative of increased informativeness and efficiency of expression. The increased number of words produced per minute by Persons 2 and 3, combined with increased number of words scored as CIUs, represents a greater increase in efficiency than that achieved by Person 1, whose rate of words per minute did not change. Person 4 demonstrated

Figure 4. Performance of Person 3 on sentence production probes. Treatment for object cleft production was extended to ensure stable generalization to matrix question production. Embedded question treatment was terminated before reaching criterion because of examiner error.

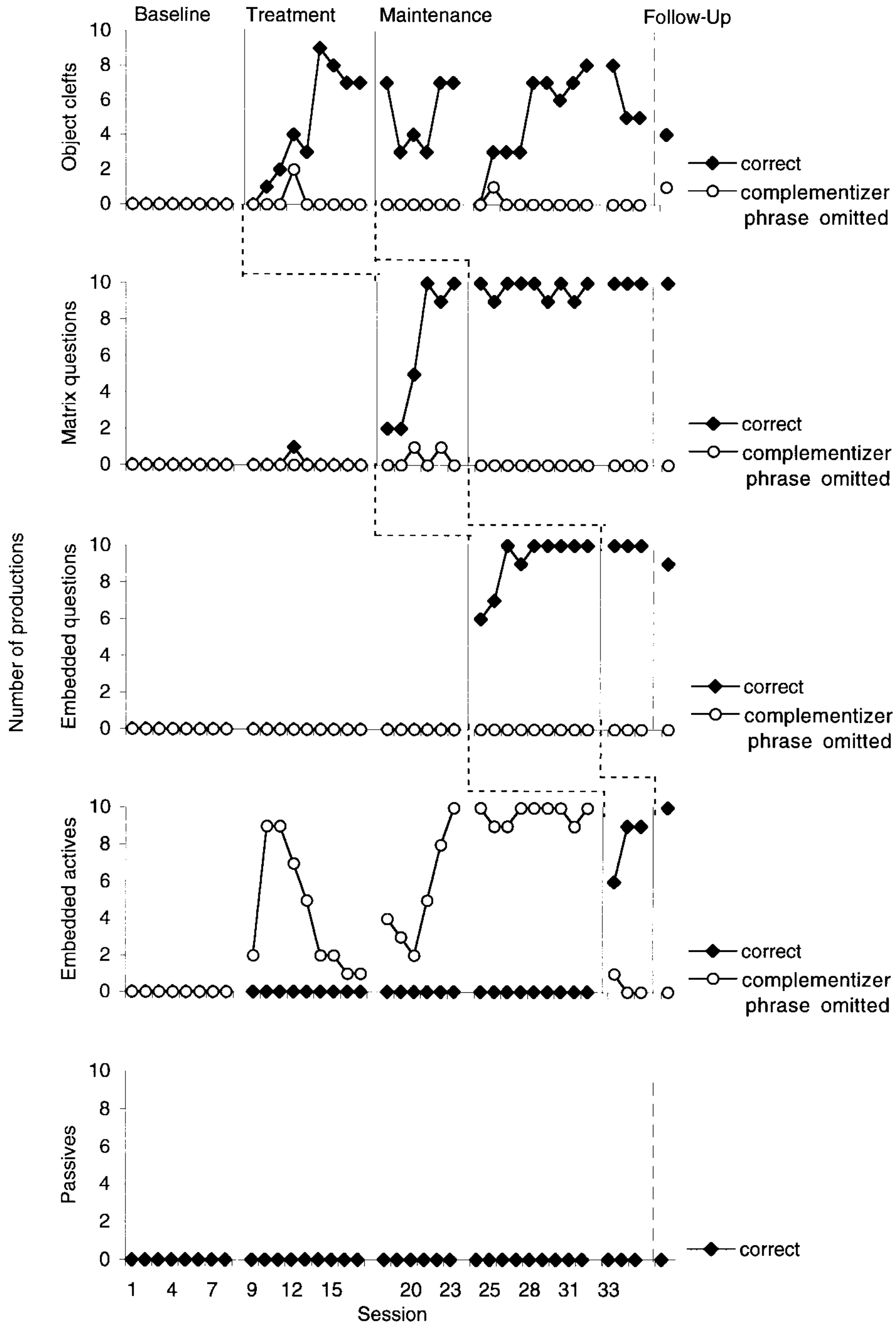


an increase in number of CIUs produced per minute and in words produced per minute but a decrease in percentage of words scored as CIUs. These data suggest that he was generally more informative in a given time span but was less efficient in conveying that information. Person 5 demonstrated a decrease in all of these variables from pre- to posttreatment. Only number of words scored as CIUs had returned to pretreatment levels at follow-up.

Social Validity

The three narrative samples for each participant were rated for content, coherence, fluency, length and complexity of sentences, and grammaticality. A composite score, combining the ratings for all behaviors on each sample, was calculated and analyzed to determine whether the samples, as a whole, were rated differently.

Figure 5. Performance of Person 4 on sentence production probes. Treatment for object cleft production was extended to ensure stable performance. Embedded question treatment was extended to give maximum opportunity for generalization to embedded active production.

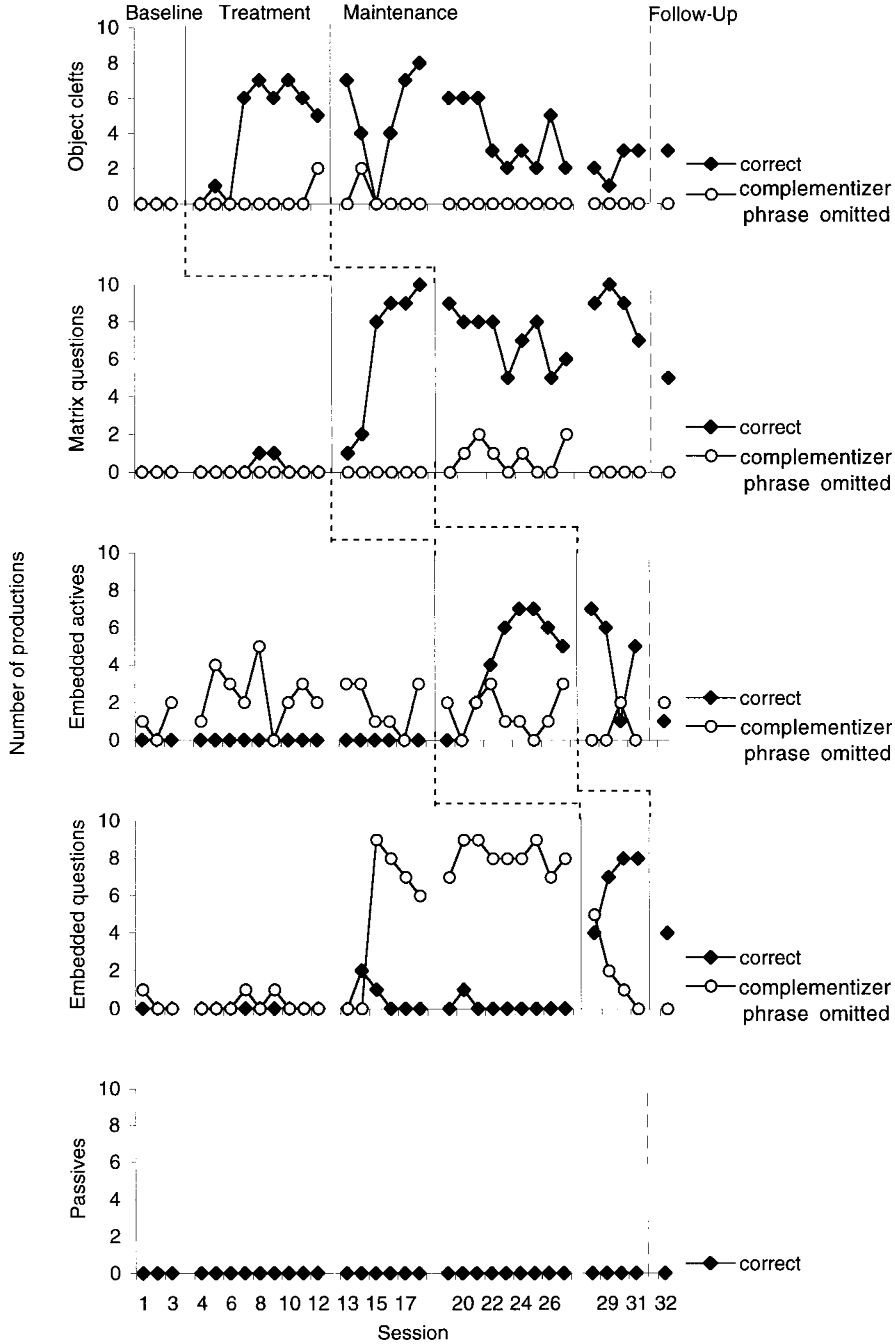


The Friedman two-way analysis of variance by ranks (Friedman, 1937, 1940) was used to analyze changes over time on each variable and the composite score. A significance level of $p < .01$ was employed in this study because multiple independent comparisons were conducted. These data support the treatment results and quantitative narrative analyses in that Persons 1, 2, and 3 demonstrated improvement whereas Persons 4 and 5 did not.

Ratings for Person 1 increased significantly over the three samples in composite score ($F_r = 13.95$). Ratings for Persons 2 and 3 increased significantly in content ($F_r = 10.4$ and $F_r = 13.85$, respectively), coherence ($F_r = 9.6$ and $F_r = 10.05$, respectively), and composite score ($F_r = 15.05$ and $F_r = 12.2$, respectively).

For Person 4, the three samples did not differ significantly on any behavior nor on the composite score (F_r =

Figure 6. Performance of Person 5 on sentence production probes. Treatments for object cleft and embedded active production were extended to give maximum opportunity for generalization to untrained sentence types.



0.95). The listeners consistently rated this participant as having the most severe expressive language impairment. For Person 5, the three samples differed significantly in content (F_r = 9.8), coherence (F_r = 11.45), length and complexity of sentences (F_r = 9.65), and composite score (F_r = 15.35). Notably, these differences represented poorer performance after treatment.

Discussion

This experiment was conducted to investigate (a) the extent of generalization obtained between sentence types with Linguistic Specific Treatment (LST) and (b) the utility of syntactic theory in guiding hypotheses of treatment effects. All participants were trained first on production of object cleft sentences. It was predicted that treatment for a given sentence would generalize to production of untrained exemplars of that sentence. This pattern has been seen in previous treatment studies focused on sentence production (Thompson et al., 1996; Thompson et al., 1997) and sentence comprehension (Haendiges, Berndt, & Mitchum, 1996; Mitchum, Haendiges, & Berndt, 1995). Further, it was predicted that effects of object cleft treatment would generalize to production of the other equally or less complex *wh*-movement structures—matrix questions (e.g., Thompson et al., 1998) and embedded questions—but not to production of embedded actives that do not involve *wh*-movement. Generalization was not expected to the noun phrase movement structure of passives (Thompson et al., 1997). Finally, effects of treatment were expected to lead to improved narrative language production.

The patterns of generalization were more extensive than predicted and suggested that treatment for object clefts emphasizes two syntactic skills: *wh*-movement and generation of embedded clauses. Three participants (1, 2, and 3) demonstrated generalization to production of matrix questions, embedded questions, and embedded actives, suggesting improved ability in both syntactic skills. They generalized the effects of treatment to production of matrix *wh*-questions, demonstrating relearning of *wh*-movement in a less complex sentence structure. This supports the hypothesis of Thompson et al. (1998) that treatment for production of a *wh*-movement structure results in generalization to other less complex *wh*-movement structures. Persons 1, 2, and 3 also developed or improved the ability to produce embedded clausal structure in embedded questions and/or embedded actives, although the overt material in the embedded complementizer phrase (CP; i.e., *who* or *that*) was consistently omitted. That is, these participants were unable to combine the two syntactic operations emphasized in treatment to generate an untrained embedded structure with *wh*-movement (i.e., embedded questions) and were unable to generate novel material in an embedded CP structure (i.e., *that* in embedded actives). Production of passive sentences was not influenced by object cleft treatment, supporting the findings of Thompson et al. (1997).

In the case of Persons 4 and 5, generalization of the effects of object cleft treatment was observed but was more limited. They did not generalize the ability to perform *wh*-movement and so required direct treatment for matrix question production. The ability to generate embedded clausal structure emerged in only one of the two untrained embedded sentence types. Person 4 developed the reduced embedded active [-comp] form during object cleft treatment, and production of this was strengthened during matrix question treatment. Embedded questions [-wh] were never produced. Person 5 developed the embedded question [-wh] form during matrix question treatment. Embedded actives [-comp] were produced with low frequency in baseline, and production did not increase with object cleft or matrix question treatment. In the case of Person 5, order effects obscure the generalization effects. It is unclear whether improved production of embedded questions was due to a delayed effect of object cleft treatment or due to implementation of matrix question treatment. The former scenario would support the hypothesis of Thompson et al. (1998), which suggests that training a more complex structure results in generalization to production of less complex but related structures. Further research is required for clarification.

The production of embedded actives by some participants during baseline requires attention. Three of five participants (1, 3, and 5) demonstrated some ability to produce the reduced [-comp] form during baseline, suggesting that this structure presented less challenge. This form is a simple active (e.g., *The thief chased the artist*) with an additional clause preceding it (i.e., *I believe*). However, the emergence of the reduced [-comp] form in Persons 2 and 4 during object cleft treatment supports the analysis of a generalization effect. Although Person 4's ability to produce embedded actives [-comp] diminished as object cleft treatment progressed, succumbing to overgeneralization, the skill returned after object cleft production was acquired and matrix question treatment had commenced. Furthermore, the data for embedded actives [-comp] combined with Person 1's ability to produce embedded questions [-wh] during baseline suggests that embedding is a less challenging syntactic operation to perform than *wh*-movement. Although this is speculative, there is some evidence that phrasal movement is particularly impaired in agrammatism (Bastiaanse & van Zonnevelt, 1998; but see Lonzi & Luzzatti, 1993). Bastiaanse and van Zonnevelt, examining Dutch individuals with agrammatism, argued that errors of verb inflection were directly related to the presence of verb movement.

As no participants demonstrated generalization of object cleft treatment effects to accurate production of embedded questions or embedded actives, these structures received direct treatment. All participants rapidly acquired accurate production of these structures. In no case did treatment for production of embedded questions influence ability to generate the complementizer *that* in embedded actives. Likewise, in no case did treatment for production of embedded actives influence production of the relative pronoun *who* in embedded questions. These results suggest that treatment involving production of one type of function word (e.g., a *wh*-question morpheme) does not generalize to production of other types of function words (e.g., the complementizer *that*). This would be logical, given that different types of function words serve different syntactic purposes.

It is of interest that no participants were able to generate the function words *who* and *that* in embedded contexts without direct treatment. This result may be explained by an impairment in access to function words (i.e., closed class words). Thompson et al. (1996) found that some participants undergoing treatment for production of *wh*-movement structures demonstrated recovery of the ability to perform *wh*-movement in targeted sentences but persistence of a *wh*-question morpheme retrieval or selection difficulty. However, this explanation does not account for the ability of Persons 1, 2, and 3 to generalize production of the function word *who* from object cleft treatment to matrix question production but not embedded question production. This finding suggests that access to function words for embedded clauses is problematic, even when the words are modeled in the target syntactic structure as in the syntax priming paradigm. Both the relative pronoun *who* and the complementizer *that* project to form the complementizer phrase (CP). As follows from the research of Hagiwara (1994, 1995) and Friedmann and Grodzinsky (1997), projection of CP is always impaired in agrammatism. The *wh*-phrase in the embedded CP of object clefts is dominated by the object noun phrase in the matrix clause, and these two phrases are co-referential. The CP in matrix questions is undominated by a higher phrasal node, whereas the CP in embedded questions and embedded actives is dominated and constrained by the higher verb phrase. Persons 1, 2, and 3 were able to generalize the effects of object cleft treatment to an undominated matrix CP in matrix questions. However, there was no generalization to production of a CP embedded within a verb phrase (i.e., in embedded questions and embedded actives). Persons 4 and 5, who presented with a more severe language impairment, were unable to generalize the effects of object cleft treatment to project a CP in either an untrained matrix clause or verb phrase embedded clauses.

To further examine the efficacy of the LST approach, generalization of treatment effects to narrative language production was examined. For Persons 1, 2, and 3, no trends toward improved morphosyntactic skills were observed. These results do not support those of previous studies (Thompson et al., 1996; Thompson et al., 1997). This may be due to several factors, such as the different sentence structures being targeted and heterogeneity among participants within and across studies. However, on examination of informativeness and efficiency of production, Persons 1, 2, and 3 demonstrated improvement from pre- to posttreatment and maintenance of improvement after 4 weeks. Furthermore, improvements were perceived by independent judges. In a similar analysis, Jacobs (1996) reported significant increases in informativeness and efficiency of spontaneous language production in an LST study involving seven participants with pretesting profiles similar to Persons 1, 2, and 3 here. These data support the use of LST as an effective treatment approach for sentence production impairments in agrammatism.

On examination of narrative language data for Persons 4 and 5, no improvement was demonstrated in morphosyntactic skills or in informativeness and efficiency of expression. Furthermore, no positive changes were perceived by independent judges. One explanation for the more limited pattern of generalization in these participants, both between sentence types during treatment and to narrative language production, is the severity of Broca's aphasia. These participants presented with lower scores on the Western Aphasia Battery (Kertesz, 1982) in subtests for naming, auditory comprehension, reading, and construction and evinced lower Aphasia and Cognitive Quotients. Even though all participants were diagnosed with moderate Broca's aphasia, these results suggest that severity of language impairment and possible involvement of other cognitive skills may have affected treatment outcome. Furthermore, Person 5 was further post-onset of aphasia than the other participants, which may have negatively affected her potential for improvement. Extent of lesion and etiology did not correspond with the clustering of participants.

Finally, the social validity of LST was examined. Social validity of treatment programs is rarely addressed but provides an independent test of effectiveness. Doyle et al. (1987) considered the impact of a syntax stimulation program (Helm-Estabrooks, Fitzpatrick, & Barresi, 1981) on the spontaneous communication skills of four individuals with agrammatism. Judges unfamiliar with the purpose of the experiment perceived no change in adequacy of response or amount of information conveyed in a picture description task, even though the participants had demonstrated improvement in the experimental probe task. These findings suggested that effects of the syntax-stimulation program did not generalize to another language production context. In the present study, however, listeners unfamiliar with the purpose of the experiment perceived positive changes in narrative language production for Persons 1, 2, and 3. Once again, Persons 4 and 5 stood apart as showing no changes or a decline in function. This analysis corroborates the results of the treatment study and the quantitative analysis of informativeness and efficiency in narrative.

Conclusions

The findings presented here indicate that treatment improved sentence production in all of our participants, with the greatest improvement observed in those participants with less severe Broca's aphasia profiles. Improvement was also noted for the latter participants in informativeness and efficiency of narrative language. Finally, judgments of unfamiliar listeners corroborated the quantitative narrative analyses. Thus, we suggest that for those individuals with less severe Broca's aphasia this treatment approach is socially valid. It is important to note, however, that this study included a small number of participants. Continued research is required to specifically test the effect of severity of agrammatism on treatment outcome. Furthermore, the efficacy of LST has yet to be formally measured against other treatment approaches.

A primary goal of language treatment is to maximize generalization within and across language contexts and to achieve this result in a time-efficient manner. The present study supports the use of LST as an efficient and effective treatment approach. We advocate the use of linguistic theory as a tool for motivating sentence production treatment and interpreting patterns of recovery in agrammatism.

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