The Role of Syntactic Complexity in Treatment of Sentence Deficits in Agrammatic Aphasia: The Complexity Account of Treatment Efficacy (CATE)

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This experiment examined the hypothesis that training production of syntactically complex sentences results in generalization to less complex sentences that have processes in common with treated structures. Using a single subject experimental design, 4 individuals with agrammatic aphasia were trained to comprehend and produce filler-gap sentences with *wh*-movement, including, from least to most complex, object-extracted *who*-questions, object clefts, and sentences with object-relative clausal embedding. Two participants received treatment first on the least complex structure (*who*-questions), and 2 received treatment first on the most complex form (object-relative constructions), while untrained sentences and narrative language samples were tested for generalization. When generalization did not occur across structures, each was successively entered into treatment. Results showed no generalization across sentence types when *who*-questions were trained; however, as predicted, object-relative training resulted in robust generalization to both object clefts and *who*-questions. These findings support those derived from previous work, indicating not only that generalization occurs across structures that are linguistically related, but also that generalization is enhanced when the direction of treatment is from more complex to less complex constructions. This latter finding supports the authors' newly coined "complexity account of treatment efficacy" (CATE).

KEY WORDS: agrammatism, aphasia, sentence production, treatment, generalization

It is well known that many individuals with agrammatic aphasia present with difficulty comprehending and producing semantically reversible sentences such as passives and object-relative clause constructions in which the arguments of the verb do not appear in their canonical order, that is, those with "filler-gap dependencies" (Caplan & Hildebrandt, 1988; Goodglass, Christiansen, & Gallagher, 1993; Grodzinsky, 1986; Saffran, Schwartz, & Marin, 1980). Research focused on improving these sentence deficits has resulted in mixed findings. Although most studies of treatment efficacy show improvements on trained sentences, several have shown little, if any, generalization from trained to untrained forms (Haendiges, Berndt, & Mitchum, 1996; Schwartz, Saffran, Fink, Myers, & Martin, 1994; Wambaugh & Thompson, 1989).

For example, training sentences such as *wh*-questions has not resulted in improved passive sentence production (Doyle, Goldstein, & Bourgeois, 1987; Fink et al., 1995). However, successful generalization from trained to untrained sentences has been forthcoming when the untrained forms are linguistically related to the trained forms. For example, in a series of studies we have shown that training sentences requiring *wh*-movement (e.g., object clefts, object-extracted *who*-questions), a linguistic operation that serves to move certain sentence constituents from their underlying (d-structure) position to their surface (s-structure) position, results in generalization to other *wh*-movement structures, comparable both in their underlying representation and in the movement operations involved in their derivation. Similarly, training structures relying on another type of linguistic movement—NP movement (e.g., passives and subject raising structures)—results in generalization to other NP movement forms (Ballard & Thompson, 1999; Jacobs & Thompson, 2000; Thompson et al., 1997). It is interesting, however, that we do not see generalization across linguistically unrelated forms, that is, from *wh*-movement to NP movement structures (Thompson, Ballard, & Shapiro, 1998; Thompson et al., 1997), which supports the aforementioned treatment studies in which generalization was not observed. These findings indicate that the linguistic relation between trained and untrained structures is important to consider in the treatment of sentence deficits.

Another factor related to successful generalization concerns the complexity of structures trained. Generalization appears to be enhanced if the direction of treatment is from more complex to less complex structures, when treated structures encompass processes relevant to untreated ones. Although training complex structures prior to training simpler ones may seem counterintuitive, in that the traditional approach to treatment is to begin with simpler forms and progress to more complex material, recent studies have suggested that stronger generalization may result from this approach. For example, in an early sentence production study examining the effects of treatment of underlying forms (TUF), Thompson (2001) found generalization from complex *wh*-questions, which included both arguments and adjuncts (e.g., *Who did the boy kiss in the park*?), to less complex *wh*-questions that did not contain adjuncts (e.g., *Who did the woman chase?*) (Thompson, Shapiro, & Roberts, 1993). Also, in several studies in which *wh*-movement structures were trained, training more complex forms (i.e., object clefts such as *It was the artist who the thief chased*) resulted in generalization to less complex ones (i.e., object-extracted *wh*-questions such as *Who did the thief chase?*) but training less complex structures did not result in generalized learning of the more complex forms (Thompson et al., 1997, 1998). Both object clefts and *wh*-questions involve identical *wh*-movement; however, object clefts are the more complex of the two structures because movement occurs within an embedded clause rather than in the matrix (main) clause as in *wh*-questions.

Complexity also appears to be relevant for training sentence production in other populations and for treating other language impairments. Studies aimed at teaching English as a second language show that training complex sentence structures in early stages of learning results in more rapid acquisition of the grammar of the second language than does training simpler forms (Eckman, Bell, & Nelson, 1988). For example, teaching object-relative clause constructions improves subject-relative and active forms, without their direct training. In addition, in a series of studies, Gierut and colleagues (Gierut, 1990, 1992, 2001; Gierut & Champion, 2001; Gierut, Elbert, & Dinnsen, 1987) reported that children with developmental phonological disorders evince enhanced phonological restructuring when more complex, rather than less complex, phonological forms are selected as treatment targets. For example, in studies examining consonant cluster acquisition, treating complex syllable onsets results in improved production of clusters of lesser phonological complexity.

Finally, complexity has been implicated in treatment of lexical-semantic deficits. Plaut (1996), for example, showed in a computer simulation that items within semantic categories are (re)learned more successfully when complex (i.e., atypical items), rather than simple (i.e., typical), items within a category are trained. Kiran and Thompson (2003) found this same effect in 4 patients with fluent aphasia; that is, training atypical exemplars of *birds* and *vegetables* resulted in improved naming of more typical items. Training typical items within categories had no effect on naming of atypical items.

In all of these studies, information relevant to the simpler, untrained forms is contained within the more complex, trained forms. That is, the less complex material lies in a subset relation to the more complex material. As noted above, the *wh*-movement entailed within object clefts is identical to that encountered in object-extracted *wh*-questions. Therefore, training this common property in the more complex structures enhances learning of the less complex form. The structures selected for treatment and for generalization analysis in the English as a second language literature are similarly related to one another, and a comparable relation between trained and untrained structures exists in studies focused on improving production of phonological material; that is, the phonological material trained in the complex forms is contained within the simpler ones. A similar situation holds in the lexical-semantic domain,

Figure 1. Tree diagram showing *wh*- movement involved in formation of an object-extracted *wh*- question (e.g., *Who*$_{(i)}$ *did the thief chased*$_{(ti)}$*?*). Verb movement (subject–auxiliary [AUX] inversion) also is shown. Going from the top down, within the complementizer phrase (CP), the specifier position (SPEC) is the landing site for movement in *wh*- questions. The head of the CP, Comp, is the landing site for the auxiliary verb (i.e., in subject–AUX inversion [verb movement]). The next level down is the Inflection Phrase (IP), headed by INFL. The external argument of the verb (e.g., the subject) is located in the Specifier position (Spec of IP), following its movement from Spec of VP. The main verb is inserted in the head of the VP, and in its sister position are complements of the verb, that is, the internal argument (theme that moves and leaves behind a trace [t]).

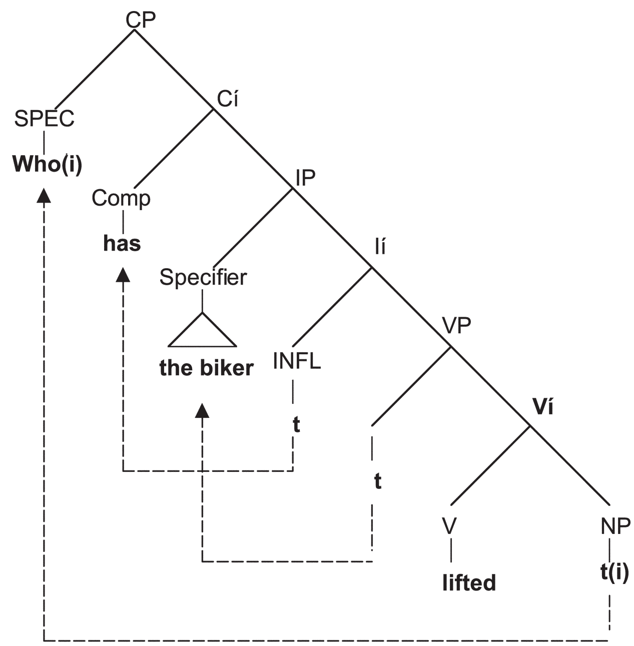
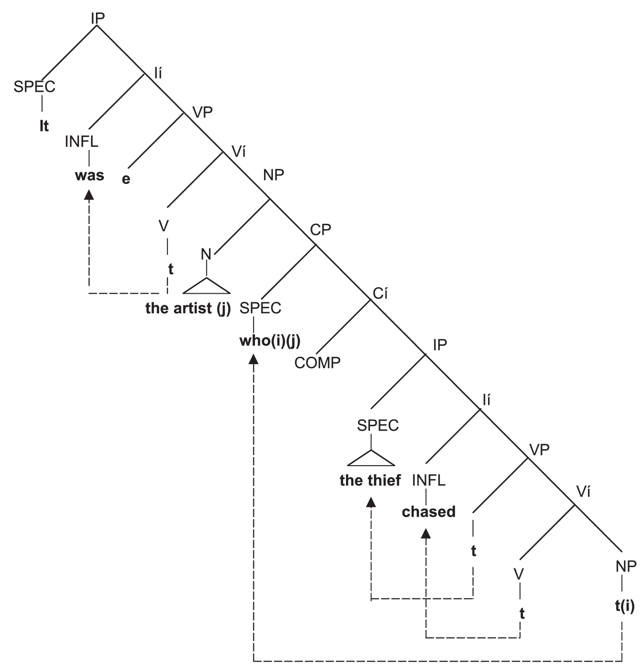


Figure 2. Tree diagram showing *wh*- movement involved in formation of an object-cleft sentence (e.g., *It was the artist who*$_{(i)}$ *the thief chased*$_{(ti)}$.). Here, the highest node is IP, the main clause of the sentence. *Wh*- movement occurs within the embedded CP, modifying the head NP of the matrix clause (artist). Note the co-referential relation between moved constituent (*who*) and the head NP of the matrix clause (j).



even though we recognize that semantic complexity may be manifested differently than what is observed in other language domains (see Kiran & Thompson, 2003, for discussion of this issue). In Kiran and Thompson, the typical items were composed of a core subset of features that were common among items in a particular category; atypical items included some features within this subset as well as other less common features.

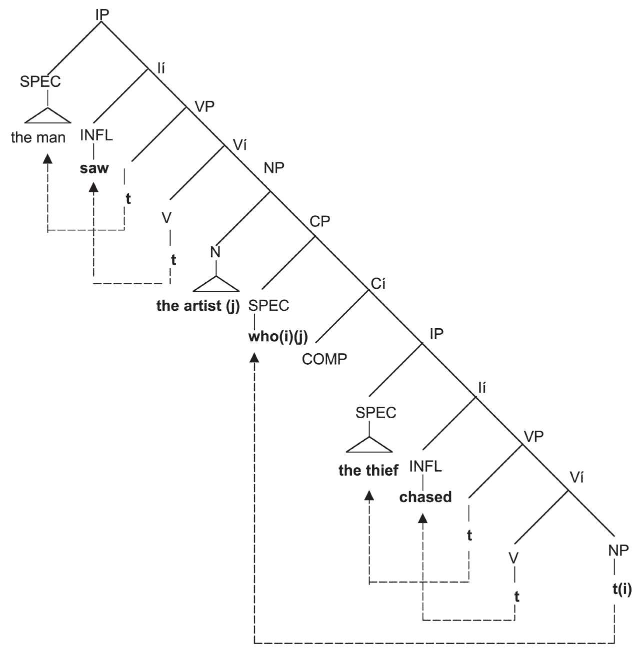
In the present experiment, we replicate and extend the findings of Thompson et al. (1998), examining training and generalization of sentences with *wh*-movement. The sentence types of interest included not only object-extracted *who*-questions (see Example 1 below) and object clefts (as in Example 2), as in our previous studies, but also object-relative clause constructions (see Example 3). Generalization from trained to untrained sentences was examined throughout the experiment and generalization to narrative production and a series of aphasia tests was tested following treatment.

1. [$_{CP}$ Who$_i$ [$_C$ has [$_{IP}$ the thief chased t$_i$]]]. (*wh*-question)
2. [$_{IP}$ It was [$_{NP}$ the artist$_j$ [$_{CP}$ who $_{j\,i}$ [$_{IP}$ the thief chased t$_i$]]]]. (Object cleft)
3. [$_{IP}$ The man saw [$_{NP}$ the artist$_j$ [$_{CP}$ who $_{j\,i}$ [$_{IP}$ the thief chased t$_i$]]]]. (Object relative)

Before detailing the study, it is important to discuss our target sentences with regard to complexity. As noted above, All three sentence types are similar in that they involve *wh*-movement[1] to derive their noncanonical form; that is, *who* moves from the direct object position in the verb phrase (VP; Chomsky, 1986, 1993; also see Shapiro, 1997). The landing site for *who* also is identical across sentences—the specifier position of the complementizer phrase (Spec of CP; see Figures 1–3). One final commonality is that prior to movement, thematic roles are assigned by the verb. In our example, the verb *chase* assigns the role of theme to *who*. When

[1]*Who*-questions also involve verb movement (or subject–auxiliary verb inversion). Although structures with verb movement (i.e., yes/no questions) present difficulty for production relative to active structures for agrammatic aphasic individuals (Bastiaanse & Thompson, 2003), verb movement is considered less problematic than *wh*- movement (Friedmann & Shapiro, 2003; Lonzi & Luzzatti, 1993).

Figure 3. Tree diagram showing *wh-* movement, occurring in an embedded clause, involved in formation of an object-relative clause structure (e.g., *The man saw the artist who$_{(i)}$ the thief chased$_{(ti)}$.*). Note the co-referential relation between moved constituent (*who*) and the head NP of the matrix clause (artist). Subject movement from Spec of VP to Spec of IP in the matrix clause also is shown.



movement occurs, a trace (t) is left behind in the postverbal position and a chain connects the trace with the moved NP, resulting in a co-referential relationship between the two sentence elements (the trace and *who*, denoted by subscripted $_i$ in our examples and figures).

One important feature distinguishing *who*-questions (in Example 1) and the other two forms is that movement in *who*-questions occurs in the matrix (main) clause. As shown in Examples 2 and 3, however, movement in object clefts and object-relative clause constructions occurs within an embedded relative clause, rendering the latter forms more complex than *who*-questions. Because clausal embedding is involved in both object clefts and object relatives, an additional co-referential relation exists between the head NP, here *the artist*, and the *wh*-phrase (denoted by subscripted $_j$).

In considering differences between object relatives and object cleft forms, the primary distinction concerns the lexical material in the matrix clause and its derivation. The subject of the matrix clause in object-cleft structures (i.e., *it*) is an expletive (pleonastic) NP that is not a verb argument and, thus, is not assigned a thematic role; it is a mere slot filler and has no semantic content (see Haegeman, 1994). The subject (e.g., *the man*) in object relatives is a verb argument and, therefore, has a thematic role and semantic content. In addition, as with all subjects per the VP-internal subject hypothesis (Koopman & Sportiche, 1991), *the man* is base-generated in VP and, therefore, undergoes movement to reach its surface position—the specifier position of the inflection phrase (Spec of IP; see Figure 3). In contrast, *it* in object clefts is base-generated in Spec of IP and does not undergo subject movement (see Figure 2). Thus, the matrix clause of object relatives is more complex than that of object cleft structures.

To summarize, object-extracted *who*-questions, object clefts, and object relatives are formed through *wh*-movement operations. Movement occurs from the direct object position to the Spec of CP in all sentences. In *who*-questions this movement occurs in the matrix clause, whereas in object clefts and object relatives, movement occurs in an embedded clause, adding a level of syntactic complexity. In addition, for object relatives, the subject of the matrix clause is base-generated in VP, is assigned a thematic role, and has semantic content. These details render object relatives more linguistically complex than object clefts. If we assume that such linguistic complexity is translated into sentence production and comprehension difficulty, we predict that training agrammatic patients to produce the most complex form—object-relative clause structures—would provide information relevant to performing both *wh*-movement and clausal embedding and would thus result in generalization to object-cleft sentences and matrix *who*-questions. Conversely, we predicted that training *wh*-questions would provide information relevant only to *wh*-movement and not to clausal embeddings, and would, therefore, not influence object-cleft or object-relative productions.

Method

Participants

Four individuals with Broca's aphasia with agrammatism participated in the study. Three of the participants' aphasia resulted from a single episode, left hemisphere thromboembolic stroke in the distribution of the middle cerebral artery. One patient (D.L.) had a lesion in the left basal ganglia. At the time of the experiment, participants were between 1 and 11 years poststroke. All were native English speakers, premorbidly right handed, and had completed high school. All participants passed a pure tone audiological screening in both ears.

Language Testing

A series of language tests was administered to all participants with results consistent with a diagnosis of

Broca's aphasia (see Table 1). The Western Aphasia Battery (WAB; Kertesz, 1982) showed Aphasia Quotients ranging from 61 to 72, with all participants demonstrating superior auditory comprehension relative to expressive abilities. Moderately impaired naming but good ability to orally read short phrases and sentences was noted. Motor speech examination revealed no dysarthria or apraxia of speech for any of the participants.

Verb production was tested extensively using a battery of tests developed to examine naming and comprehension of verbs by argument structure type as well as production of verbs and their arguments in sentences (The Northwestern Verb Production Battery; Thompson, unpublished). Results indicated relatively spared verb comprehension but impaired verb naming for all participants. All participants also showed impoverished production of verb arguments, with a greater proportion of correct production of agents than themes or goals.

Sentence comprehension was further tested using the Northwestern Sentence Comprehension Test (Thompson, unpublished), which evaluates active, passive, subject-relative, and object-relative structures using semantically reversible picture pairs. Two participants (D.L. and K.G.) demonstrated better comprehension of canonical forms (active and subject-relative sentences) than noncanonical (passive and object-relative) ones. The others (R.M. and H.R.) demonstrated difficulty comprehending all sentence types.

Table 1. Language test data.

	P1: R.M.		**P2: H.R.**		**P3: D.L.**		**P4: K.G.**	
Test	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Western Aphasia Battery								
Aphasia Quotient	62.4	60.8	72.1	71.3	69.6	76.7	60.7	64.7
Fluency	4	4	4	4	5	5	4	4
Comprehension	7.2	7.7	8.15	8.45	8.2	9.25	7.65	7.65
Repetition	4.8	4.0	8.4	8.7	5.4	7.7	5.8	7.4
Naming	7.1	7.7	6.5	6.5	7.2	8.4	4.9	6.3
Northwestern Verb Battery (total % correct)								
Verb naming	25	36	71	76	59	86	40	50
Intransitive	42	66	83	75	88	83	41	83
Transitive	25	50	65	73	85	91	46	33
Ditransitive	22	17	38	66	10	58	21	21
Sentence production	60	93	80	83	72	76	2	56
Verb comprehension	90	100	98	100	100	100	98	100
Northwestern Sentence Comprehension Battery (% correct)								
Actives	45	15	55	80	95	95	85	85
Passives	70	50	50	65	80	90	25	70
Subject relatives	45	15	60	85	90	90	65	80
Object relatives	50	70	55	85	65	85	55	80
Morphosyntactic data from narrative samples								
MLU	3.92	4.11	3.9	4.92	5.29	7.83	2.12	3.54
% grammatical sentences	35	37	4	52	38	45	50	63
% simple sentences	96	92	96	94	92	85	100	90
% complex sentences	4	8	4	6	7	15	0	10
Noun:verb ratio	1.10	1.50	1.13	1.64	1.09	0.96	1.75	2.00
Open-classed:closed-class ratio	1.14	0.96	1.08	1.19	1.09	1.71	1.93	1.69
% verbs with correct argument structure	67	73	33	75	74	93	75	86

Note. P = participant; MLU = mean length of utterance.

Pretreatment Narrative Discourse Analysis

Narrative language samples were collected by asking participants to tell the story of Cinderella. All samples were segmented into utterances and analyzed using a method developed by Thompson et al. (1995). This method entailed coding of sentences for grammaticality, sentence type, and embeddings. All open-class and closed-class words were coded by class; additionally, verbs were coded by type and argument structure.

Results showed agrammatic production patterns for all participants. As shown in Table 1, utterances were short and primarily ungrammatical. Most sentences were grammatically simple, devoid of moved sentence constituents or embeddings. Noun:verb ratios were greater than 1, indicating production of more nouns than verbs, and when verbs were produced, the proportion with correct argument structure ranged from 33% to 75%. In addition, open:closed class ratios indicated a greater production of open-class compared to closed-class words.

Experimental Stimuli

Using a set of 20 transitive verbs, 20 active (NP–V–NP) sentences were developed. All sentences were semantically reversible and utilized animate nouns. Neither the nouns nor the verbs were more than two syllables in length. Mean frequency of occurrence for the verbs was 116 per million; mean frequency of the nouns was 228 per million (Frances & Kucera, 1982). For each sentence, two pictures were developed, one depicting the target sentence and the other depicting its semantically reversible counterpart. All picture stimuli were artist drawn, black and white line drawings measuring 8.5 x 5.5 in. A complete list of the target sentences and corresponding pictures is presented in Appendix A. These stimuli were used to test comprehension and production of the three sentence types during probe tasks. They also were used during treatment trials as detailed below.

Written stimuli also were developed to coincide with the NPs and the verb of all active sentences (e.g., [the thief] [is] [chasing] [the artist]). Sentence constituent cards displaying additional morphemes required for the surface form of each sentence type also were constructed (e.g., [who], [it was]).

Experimental Design

A single subject multiple baseline design across behaviors and participants was used (McReynolds & Kearns, 1983). Prior to application of treatment—during the baseline phase—comprehension and production of all three sentence types was tested; Participants 1 and 2 (R.M. and H.R.) received four separate baseline probes prior to treatment, and Participants 3 and 4 (D.L. and K.G.) received three. One sentence type then was trained, while the remaining two were tested for generalization. Participants 1 and 3 were first trained to produce object-relative clause structures, while generalized production of object-cleft sentences and *wh*-questions was tested. Participants 2 and 4 were trained to produce object-extracted *who*-questions first. If generalization to untrained sentence types did not occur within a maximum of 10 treatment sessions, treatment was shifted to the next set of sentences (i.e., object clefts) and finally to the third sentence type (i.e., object relatives).

Baseline Procedures

Sentence Comprehension

Auditory comprehension of the three sentence types was tested using an auditory sentence, picture-matching task. On each trial, a randomly selected stimulus pair was presented and the participant was instructed to point to the picture representing the sentence presented. If a response did not occur within the allotted 5-s period, a new stimulus pair was presented. Feedback as to accuracy of response was not provided, although intermittent encouragement was given. During each probe session, each picture pair was presented three times, once for elicitation of each sentence type.

Sentence Production

Production of the three sentence types was tested using a sentence production priming paradigm. Using the stimulus picture pairs, target sentence types were modeled using the foil picture, and the patient was required to produce a sentence with the same structure for the target picture. For example, to elicit the target structure "*It was the artist who the thief chased,*" the examiner explained "Here are two pictures. Both show an artist (pointing to the artists) and both show a thief (pointing to the thieves). The action is chase. For this picture (pointing to the foil) the sentence is *It was the thief who the artist chased*. For this picture (pointing to the target) you could say?" A 10-s response time was provided. Again, each picture pair was presented three times per probe session, in random order, to elicit each of the three sentence types under study.

Responses were scored as correct if they were syntactically well-formed representations of the target sentence type; omissions or substitutions of grammatical morphemes, or lexical substitutions were accepted as correct. In addition, reduced relative clause productions were accepted as correct (i.e., *It was the artist the chief chased* for *It was the artist who the thief chased*). All errors produced were coded by type, including (a) filled (no) gap (e.g., *Who did the thief chase the artist?* for *Who did the thief chase?*), (b) thematic role reversal (e.g., *It was the artist who chased the thief* for *It was the artist who the thief chased*); (c) overgeneralized response (i.e., substitution of the form in training for the elicited form), (d) ill-formed sentence (e.g., *Thief chase?*, for *Who did the thief chase?*), (e) active sentence substitution, and (f) no response or refusal. Feedback as to the accuracy of response was not given during baseline, although intermittent encouragement was provided.

All target sentences (20 of each type) were tested for both comprehension and production during baseline (and treatment) probe sessions. Production was always tested prior to comprehension.

Treatment

Participants were trained to comprehend and produce each sentence type using TUF. This linguistic-specific treatment uses the active form of target sentences to train participants to (a) comprehend and produce the verbs and the NPs representing the arguments of the verb in each sentence, (b) move the proper sentence constituents to form target sentence structures, (c) produce the surface form of the target sentence, and (d) comprehend and produce the verbs and verb arguments in their noncanonical position.

Each training trial was begun with a comprehension probe using the target picture stimulus and its foil (e.g., the participant was required to point to the picture depicting the aurally presented target sentence). Incorrect responses were corrected by the examiner repeating the target sentence and, using the picture stimuli, pointing out the agent and theme of the action depicted. Following this, the participant was given the opportunity to produce the target sentence type using the sentence production priming paradigm. If an incorrect response was produced, the foil picture was removed, the sentence constituent stimulus cards representing the active form of the target picture were presented, and steps for deriving the target noncanonical form from the active form were administered. Participants then read aloud the derived structure and identified the verb and verb arguments in their noncanonical position. Finally, the sentence constituent cards were rearranged in their original order and participants were instructed to form the target sentence. Assistance was provided as required. The foil picture was then re-presented and the comprehension test (with correction procedure) and sentence production priming procedure were repeated (see Appendix B for specific training steps for each sentence type). Participants received two 2-hr sessions per week during which all 20 sentences were practiced between one and three times.

Production and Comprehension Probes

Throughout treatment, sentence production and comprehension probes like those presented during baseline were administered to assess comprehension and production of the three sentence types. Responses to these probes, scored in the same manner as in baseline, served as the primary dependent variable in the study and revealed emergent acquisition and generalization patterns. Generalized production to untrained sentences was considered to have occurred when levels of performance changed by at least 40% over observed baseline levels. Four weeks following the completion of treatment, follow-up production and comprehension probes were conducted to evaluate how well levels reached in treatment phases would be maintained once treatment was discontinued.

Reliability

All responses produced on the comprehension and production priming tasks, during baseline testing and during treatment probes, were transcribed online by both the examiner and an independent reliability observer situated behind a one-way mirror. Overall point-to-point agreement between the primary coder and independent observer was 97% across probe sessions.

Results

Data representing correct responses produced on the sentence comprehension and production priming task for Participants 1, 2, 3, and 4 are shown in Figures 4, 5, 6, and 7, respectively. As can be seen, prior to treatment, all participants evinced marked difficulty producing all three sentence types. Comprehension performance did not differ significantly from chance during baseline testing for any of the participants for any sentence type, with the exception of *who*-questions for Participants 1, 3, and 4, for which performance was significantly above chance level.[2]

The production and comprehension data for Participants 1 (R.M.) and 3 (D.L.), who received treatment focused on the most complex, object-relative, sentence type while generalization to object-cleft and *who*-questions forms was tested, showed similar patterns. For Participant 1 (R.M.), production of object relatives improved from 0% to 80% accuracy within four treatment sessions, and by Session 10 performance was at 90% accuracy. In

[2]The binomial test (see Siegel & Castellan, 1988, pp. 43–44) was used to compute performance levels significantly above and below chance; with an alpha level of $p = .05$ (with 20 items per sentence type), percent correct performance between 32% and 68% was not significantly different than chance.

Figure 4. Percent correct production (top graph) and comprehension (bottom graph) of object-relative, object-cleft and *who*-questions in baseline and during object-relative clause treatment (OR-Tx) for Participant 1 (R.M.). Follow-up probes (4 weeks posttreatment) also are shown. Vertical lines (top graph) represent treatment phase changes. Horizontal lines (bottom graph) depict range of chance performance.

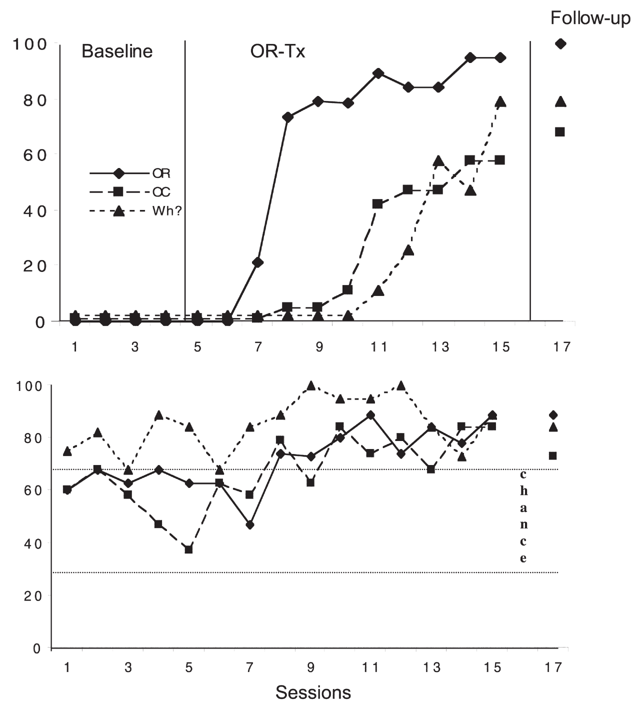
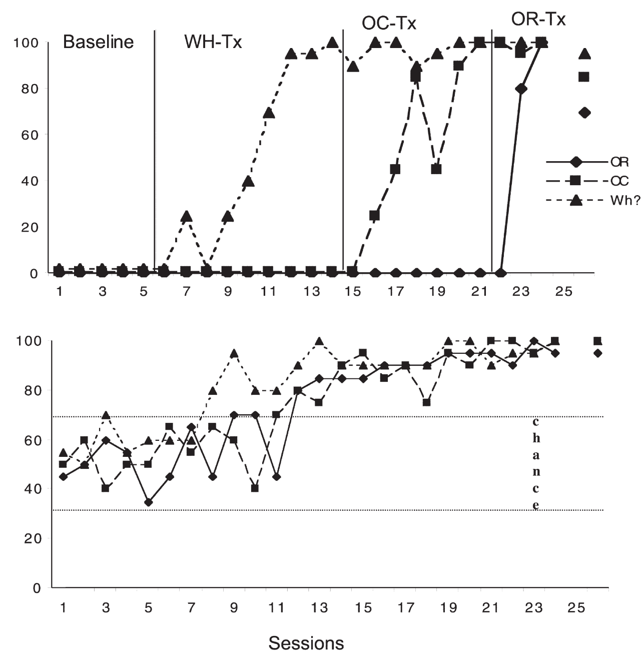


Figure 5. Percent correct production (top graph) and comprehension (bottom graph) of object-relative, object-cleft, and *who*-question constructions during baseline, *who*- question (WH-Tx), object-cleft (OC-Tx), and object-relative clause (OR-Tx) treatment for Participant 2 (H.R.). Follow-up probes at 4 weeks posttreatment also are shown. Vertical lines (top graph) represent treatment phase changes. Horizontal lines (bottom graph) depict range of chance performance.



addition, generalization occurred to object clefts, reaching 50% correct with no treatment by Session 6. Similarly, generalized production of *who*-questions was noted during object-relative treatment, reaching 60% correct by Session 8 and 80% accuracy by the end of treatment (see Figure 4). Comprehension also improved during the treatment period. Although *who*-question comprehension was above chance during baseline, the other two forms improved from chance level to well above chance (85%–100% correct) by the end of the object-relative treatment phase.

Participant 3 (D.L.; see Figure 6) showed similar performance patterns: Treatment of object-relative constructions improved production of the trained form quite rapidly (by Session 3, production had improved to 80% correct). In addition, concomitant improvement on untrained object-cleft and *who*-question forms was noted. By the end of six sessions (3 weeks) focused on object-relative treatment, production of all three sentence types was near 100% correct. Corresponding improvements in sentence comprehension also were noted. Like R.M., comprehension of both object clefts and object relatives was at chance levels during baseline, whereas comprehension of *who*-questions was above chance. Throughout treatment, comprehension of all three sentence types reached near perfect accuracy levels.

Both Participants 2 (H.R.) and 4 (K.G.) received treatment on the least complex form, *who*-questions, immediately following baseline. For both participants, *who*-question production improved once treatment was initiated. However, no generalization was noted to either object-cleft or object-relative sentences after 10 treatment sessions. Rather, each sentence type required direct training in order to impact production. Specifically, when Participant 2 (H.R.) was trained on *who*-questions, accuracy improved from 0% to 100%, while object-cleft and object-relative production remained at 0% correct. Subsequent treatment applied to object-cleft sentences also improved production from 0% to 90%, but, once again, no generalization to object-relative sentences was noted. However, when object relatives were directly trained, performance improved from 0% to 80% within three training sessions (see Figure 5). Throughout training, sentence comprehension improved from chance level during baseline sessions, to above chance for all sentence types.

For Participant 4 (K.G.), training *who*-questions

Figure 6. Percent correct production (top graph) and comprehension (bottom graph) of object-relative, object-cleft, and *who*-questions in baseline and during object-relative clause treatment (OR-Tx) for Participant 3 (D.L.). Follow-up probes (4 weeks posttreatment) also are shown. Vertical lines (top graph) represent treatment phase changes. Horizontal lines (bottom graph) depict range of chance performance.

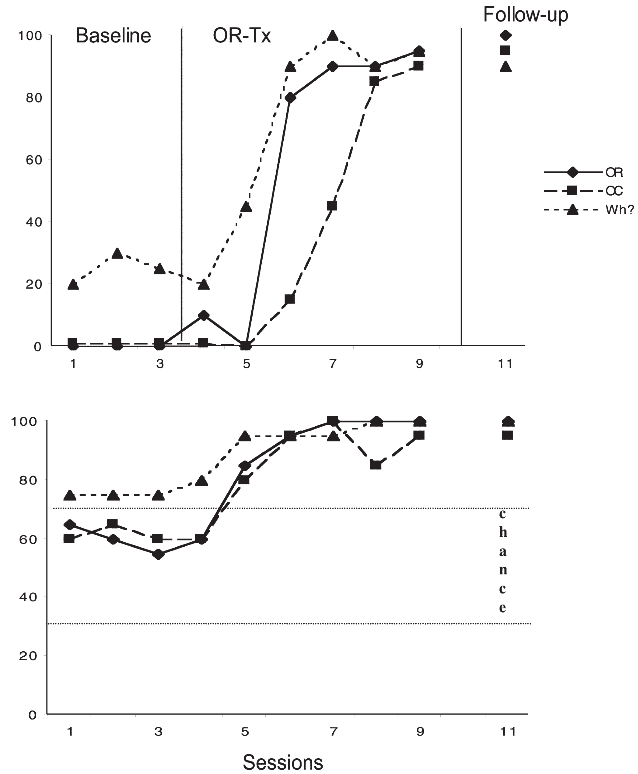
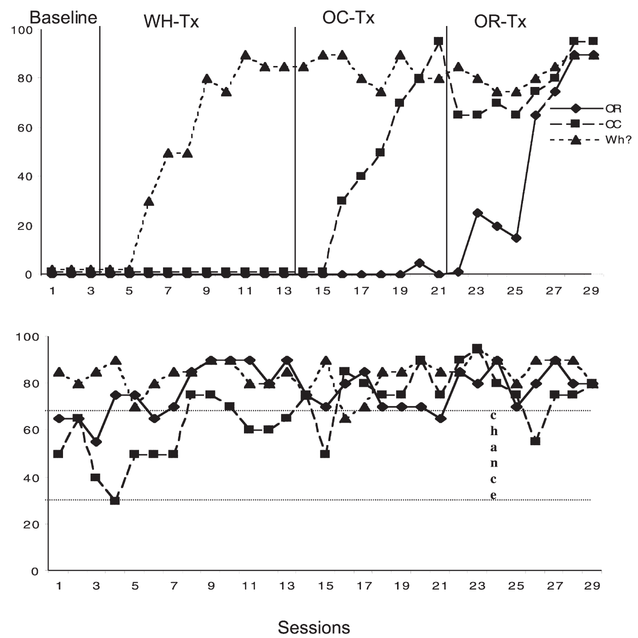


Figure 7. Percent correct production (top graph) and comprehension (bottom graph) of object-relative, object-cleft, and *who*-question constructions during baseline, *who*- question (WH-Tx), object-cleft (OC-Tx), and object-relative clause (OR-Tx) treatment for Participant 2 (H.R.). Follow-up probes at 4 weeks posttreatment also are shown. Vertical lines (top graph) represent treatment phase changes. Horizontal lines (bottom graph) depict range of chance performance.



resulted in improvement from 0% to 90% correct *who*-question production within the allotted 10 sessions, whereas no changes were noted on object-cleft or object-relative sentences. Likewise, during object-cleft training, only object clefts improved (from 0% to 100% correct), with no generalization to untrained object-relative sentences. Only when object-relative sentences were trained did production of this structure improve (from 0% to 90%; see Figure 7). As with the other participants, sentence comprehension steadily improved throughout treatment; by the end of treatment, comprehension of all structures was well above chance level.

Follow-Up Probe Data

The data derived from production and comprehension probes administered 4 weeks following completion of treatment are shown in Figures 4, 5, and 6 for Participants 1, 2, and 3, respectively. Participant 4 was unavailable for follow-up probes. The data for Participants 1–3 show that both production and comprehension were maintained at levels well above baseline and consistent with performance ability noted upon completion of treatment.

Error Analysis

The proportion of errors produced by type was calculated for every third baseline and treatment probe session, as well as for the final treatment probe for each participant. These data, presented in Table 2, indicate that all participants demonstrated a similar pattern of error evolution over the course of the study. At the beginning of treatment, errors consisted primarily of ill-formed sentences, active sentence errors, or no response/refusal, although production of filled gap errors also were noted early in treatment for Participant 4. As treatment progressed, a greater number of filled gaps and thematic role reversal errors was noted, with the majority of errors noted on the final probe being overgeneralized responses, irrespective of the type of sentence trained.

Posttreatment Language Testing Data

Performance on posttreatment language testing showed little change from pretreatment on WAB performance, although the Aphasia Quotient improved

Table 2. Number of errors produced by type on sentence production priming probes across sessions of the study for each participant.

	Probe session number									
Error type by participant	**1**	**4**	**7**	**10**	**13**	**16**	**19**	**22**	**26**	**29**
Participant 1										
Filled gap	0	0	0	13	8	4				
Thematic role reversal	0	0	0	0	0	0				
Overgeneralization	0	0	0	0	10	7				
Ill-formed sentence	5	6	24	13	4	3				
Active sentence	42	41	32	16	2	0				
No response/refusal	13	13	0	0	0	0				
Total number of errors	60	60	56	42	24	14				
Participant 2										
Filled gap	0	0	0	0	0	0	0	0	0	
Thematic role reversal	0	0	0	0	0	0	3	4	0	
Overgeneralization	0	0	0	0	2	2	12	16	0	
Ill-formed sentence	5	4	8	0	5	5	2	0	0	
Active sentence	55	50	40	55	34	35	8	0	0	
No response/refusal	0	6	12	0	0	0	0	0	0	
Total number of errors	60	60	60	55	41	42	25	20	0	
Participant 3										
Filled gap	0	0	0	0						
Thematic role reversal	6	8	1	0						
Overgeneralization	0	0	4	3						
Ill-formed sentence	5	10	0	0						
Active sentence	49	33	0	0						
No response/refusal	0	0	0	0						
Total number of errors	60	51	5	3						
Participant 4										
Filled gap	4	6	12	10	9	8	6	5	4	2
Thematic role reversal	0	0	2	3	4	3	3	7	9	0
Overgeneralization	0	0	0	0	0	0	5	13	7	4
Ill-formed sentence	40	43	33	30	26	22	11	9	9	0
Active sentence	14	7	5	1	3	3	2	0	0	0
No response/refusal	2	4	2	0	1	1	0	0	0	0
Total number of errors	60	60	54	44	43	37	27	34	29	6

somewhat for all participants (see Table 1). More notably, changes from pre- to posttreatment were seen on the Verb Production Battery. All participants showed improved verb naming and sentence production, reflecting improved production of verbs and verb argument structure. In addition, improvement was noted on posttreatment administration of the Northwestern Sentence Comprehension Test for some sentence types. All showed increases in percent correct production of object relatives; Participant 2 showed gains in comprehension of actives; Participants 2, 3, and 4 evinced increases in comprehension of passives; Participants 2 and 4 improved their comprehension of subject relatives.

Pretreatment–Posttreatment Changes in Narrative Production Patterns

All 4 participants also showed changes in narrative discourse. Increases in mean length of utterance were noted, as were increases in the proportion of grammatical sentences produced. In addition, all participants showed increases in the proportion of verbs produced with correct argument structure in their narrative samples. However, noun:verb and open:closed class ratios were relatively unchanged.

Discussion

This experiment examined generalization patterns among *wh*-movement constructions, with the hypothesis that treatment focused on more complex forms would result in generalization to less complex structures requiring the same type of movement. Results confirmed our hypothesis, showing robust generalization effects from object-relative sentences to object clefts and object-extracted *who*-questions for Participants 1 (R.M.) and 3 (D.L.), in the face of a complete lack of generalization from simpler, *who*-question structures to object clefts or object relatives for the other two participants (H.R. and K.G.). Examination of the data for H.R. and K.G. further showed that training object-cleft forms had no effect on object relatives. Only direct training of the more complex forms resulted in their improved production. These findings, considered together with those derived from previous work (Ballard & Thompson, 1999; Thompson et al., 1997, 1998), provide compelling evidence indicating that training more complex structures results in generalization to less complex ones. Across studies, we have trained 17 patients with agrammatic aphasia on *wh*-movement forms. Notably, 70% of patients (7 of 10) trained to produce more complex, *wh*-movement structures, involving movement within an embedded clause, have shown successful generalization to simpler structures with movement in the main clause (i.e., *who*-questions). In contrast, only 14% (1 of 7 patients) trained to produce *who*-questions showed generalization to more complex structures with clausal embedding.

Our findings suggest, then, that the complexity of structures entered into treatment is important to consider. Although there is no widely agreed upon metric of complexity in the psycholinguistic literature, there are a number of syntactic variables that have been manipulated to yield increased processing load and/or performance degradations. For example, the number and type of syntactic dependencies, which arguably must be held in memory until they are resolved (Berwick & Weinberg, 1984; Gibson, 1991; Kimball, 1973; Stabler, 1994), and the distance over which such dependencies are computed (Gibson, 1998) influence various aspects of sentence processing performance. However, in the present study these complexity variables were controlled in that the number of dependencies to be resolved and the distance over which they had to be carried out were identical in the three sentences selected. The depth of embedding involved (Yngve, 1960) or the ratio of terminal to nonterminal nodes in a syntactic tree also affects sentence performance (Chomsky & Miller, 1963; Miller & Isard, 1964). Indeed, one of the crucial variables distinguishing our complex versus simple structures in this experiment was depth of embedding. Object relatives and object clefts involve one embedding, whereas *who*-questions involve none. We, therefore, conclude that syntactic structural complexity—defined in terms of computing syntactic dependencies and embedding—is relevant to the current results. However, it is an interesting and open question as to how these differing aspects of complexity would influence generalization patterns observed in recovery.

It also is important to consider other interpretations of the present findings. As pointed out above, syntactically more complex forms differ from the simpler forms in that they require greater processing resources. In addition, we note that our more complex forms were longer than the simpler ones (i.e., the object-relative clause constructions were longer at 8 words than our *who*-questions at 5 words. Therefore, it is possible that training on the longest, most resource-demanding sentences improved general sentence processing/production ability (e.g., ability to hold sentence elements in memory and simultaneously compute linguistic operations, ability to grammatically encode sentences for production, and/or assemble phonological information) and that these abilities translated to improvements in processing of sentences of shorter length and/or with lesser resource demands. This interpretation, however, would predict that training *wh*-movement structures would improve NP movement structures, because the former can involve long-distance dependencies that are essentially unbounded (and cross clausal boundaries) and, therefore, require greater processing demands than the latter, which are quite constrained (Berwick & Weinberg, 1984). However, previous studies do not show such generalization. Indeed, none of the agrammatic aphasic patients trained to produce *wh*-movement structures (e.g., object clefts) have shown concomitant improvement on NP movement forms (e.g., passive sentences; Ballard & Thompson, 1999; Jacobs & Thompson, 2000; Thompson et al., 1997, 1998; also see Ebbles & van der Lely, 2002, for similar evidence in children with specific language impairments). Further, object-cleft and passive structures were quite similar in length (eight and seven words, respectively), yet we found no generalization from one form to the other.

In addition, we considered linguistic variables other than strictly syntactic ones in determining sentence complexity in the present study. That is, the subject of the matrix clause in object relatives is an argument, whereas in object clefts it is not. Processing arguments requires operations that activate semantic content and thematic roles, whereas the expletive *it* in object clefts does not, because it contributes no meaning to the sentence. Further, on syntactic grounds, the subject in object relatives is base-generated in VP and, therefore, undergoes subject movement as per the VP-internal subject hypothesis (Koopman & Sportiche, 1991). In contrast, *it* in object clefts is base-generated in Spec of IP and does not undergo subject movement. Indeed, based on the present data, the constructs predicted to be more complex on a linguistic basis turned out to be the most difficult behaviorally for our agrammatic patients. The present data, then, demonstrate the importance of linguistic theory in developing complexity metrics for treatment of sentence deficits.

In consideration of our present and previous findings as well as those derived from second language learning studies (Eckman et al., 1988) and studies aimed at improving phonological impairments (Gierut, 2001; also see Maas, Marlow, Robin, & Shapiro, 2002, for evidence from aphasia) and lexical–semantic deficits (Kiran & Thompson, 2003; Plaut 1996), it is suggested that complexity is an overarching principle that should be considered in language treatment. Across all studies examining sentence production, as well as those focused on other language domains, training complex material has been shown to promote generalization to less complex material. We, therefore, advance the complexity account of treatment efficacy (CATE) as follows:

> Training complex structures results in generalization to less complex structures when untreated structures encompass processes relevant to (i.e., are in a subset relation to) treated ones.

Another finding from the present study was that comprehension, as well as production, improved during treatment. This result, too, was expected because a component of the treatment provided was focused on comprehension. Indeed, we added this component to the treatment program purposefully, based on our earlier finding that treating production of filler-gap structures did not substantially influence comprehension (Jacobs & Thompson, 2000). Interestingly, however, even though comprehension was clearly improved in the present study, less clear-cut generalization patterns were noted in the comprehension data, as compared to the production data. That is, for Participants 2 and 4, whereas *who*-question treatment appeared to increase *who*-question comprehension more so than the other structures, comprehension of both object clefts and object relatives were also improved during *who*-question treatment. This finding suggests that perhaps the complexity effect does not extend to comprehension. However, current theories suggest that a single deficit underlies filler-gap comprehension deficits in agrammatism. For example, Grodzinsky (1986, 2000) and Mauner, Fromkin, and Cornell (1993) suggested that the representations that aphasic comprehenders build are somehow defective and, therefore, that proper coreferential relationships between moved sentence constituents and their traces are not formed. Others suggest that the process of mapping representations onto an interpretation is disrupted (Schwartz, Linebarger, Saffran, & Pate, 1987). Regardless of which characterization is correct, our data suggest that if treatment successfully ameliorates the underlying deficit, then improved comprehension of several sentence types with similar properties will result. Here, training patients in the necessary operations to correctly interpret filler-gap constructions resulted in access to a whole family of such forms, that is, those with *wh*-movement.

We also found that treatment improved the narrative language ability of our participants, regardless of whether they received treatment on complex versus simple sentence types. At the cessation of treatment, all participants showed essentially identical performance on sentence production and comprehension probe tasks; thus, we did not expect a difference in their posttreatment test data. All 4 participants showed increased utterance length and a greater proportion of grammatical sentences in posttreatment narratives as compared to pretreatment samples. In addition, the proportion of verbs produced with correct argument structure increased from pre- to posttreatment. Participants also showed improvements on other posttreatment language measures (i.e., all showed improved verb naming and sentence production on the Verb Production Battery). In addition, posttreatment administration of the Northwestern Sentence Comprehension Test showed improved comprehension of all sentence types for most participants. These findings largely are in keeping with the results of our previous work (Jacobs & Thompson, 2000; Thompson, Shapiro, Tait, Jacobs, & Schneider, 1996; but see Ballard & Thompson, 1999), and indicate that treatment, which was focused explicitly on the lexical and syntactic properties of sentences, resulted in more general, rather than task-specific, improvements in sentence comprehension and production.

Another clinically relevant issue concerns the length of treatment required. Clearly, fewer treatment sessions were required for those who received treatment on complex forms first, even though, by the end of treatment, comparable performance levels were reached for all participants. Participant 1 acquired both production and comprehension of all sentence types within 10 sessions; Participant 3 required only 6 sessions. In contrast, Participants 2 and 4 required 20 and 26 sessions, respectively. Because of health care policies restricting the number of treatment sessions for aphasia, it is essential that clinicians provide treatment that will result in the strongest generalization. Our data suggest that optimal generalization results from treatment in which structures that are linguistically similar are selected as treatment targets and when treatment is applied to the most complex of these structures first.

Conclusions

The data from the present study indicate that linguistic operations such as movement are important to consider in aphasia treatment and for predicting how the linguistic system recovers. The present data further show that training more complex *wh*-movement structures results in generalization to less complex ones and adds to the body of literature indicating that complexity is an overarching principle of treatment for linguistic disorders, including aphasia. We, therefore, advance the complexity account of treatment efficacy (CATE), and suggest that, regardless of the language domain that becomes the focus of intervention, the linguistic complexity of the material selected for treatment will influence learning and generalization patterns.

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Appendix A. Picture stimulus pairs and target sentences (OR = object-relative clause structures; OC = object clefts; WH = who-questions).

1.The artist chased the thief/The thief chased the artist.
OR: The man saw the thief who the artist chased.
OC: It was the thief who the artist chased.
WH: Who did the artist chase?

2. The wife covered the husband/The husband covered the wife.
OR: The man saw the husband who the wife covered.
OC: It was the husband who the wife covered.
WH: Who did the wife cover?

3. The waiter watched the guest/The guest watched the waiter.
OR: The man saw the guest who the waiter watched.
OC: It was the guest who the waiter watched.
WH: Who did the waiter watch?

4. The cop stopped the driver/The driver stopped the cop.
OR: The man saw the driver who the cop stopped.
OC: It was the driver who the cop stopped.
WH: Who did the cop stop?

5. The biker lifted the student/The student lifted the biker.
OR: The man saw the student who the biker lifted.
OC: It was the student who the biker lifted.
WH: Who did the biker lift?

6. The hunter carried the farmer/The farmer carried the hunter.
OR: The man saw the farmer who the hunter carried.
OC: It was the farmer who the hunter carried.
WH: Who did the hunter carry?

7. The soldier pushed the sailor/The sailor pushed the soldier.
OR: The man saw the sailor who the soldier pushed
OC: It was the sailor who the soldier pushed.
WH: Who did the soldier push?

8. The fellow kissed the woman/The woman kissed the fellow.
OR: The man saw the woman who the fellow kissed.
OC: It was the woman who the fellow kissed.
WH: Who did the woman kiss?

9. The clerk tripped the judge/The judge tripped the clerk.
OR: The man saw the judge who the clerk tripped.
OC: It was the judge who the clerk tripped.
WH: Who did the clerk trip?

10. The skater passed the biker/The biker passed the skater.
OR: The man saw the biker who the skater passed.
OC: It was the biker who the skater passed.
WH: Who did the skater pass?

11. The coach hugged the skater/The skater hugged the coach.
OR: The man saw the skater who the coach hugged.
OC: It was the skater who the coach hugged.
WH: Who did the coach hug?

12. The boy shoved the girl/The girl shoved the boy
OR: The man saw the girl who the boy shoved.
OC: It was the girl who the boy shoved.
WH: Who did the boy shove?

13. The girl pinched the waiter/The waiter pinched the girl
OR: The man saw the waiter who the girl pinched.
OC: It was the waiter who the girl pinched.
WH: Who did the girl pinch?

14. The cow kicked the rancher/The rancher kicked the cow
OR: The man saw the rancher who the cow kicked.
OC: It was the rancher who the cow kicked.
WH: Who did the cow kick?

15. The dancer pulled the lady/The lady pulled the dancer
OR: The man saw the lady who the dancer pulled.
OC: It was the lady who the dancer pulled.
WH: Who did the dancer pull?

16. The boy tickled the coach/The coach tickled the boy
OR: The man saw the coach who the boy tickled.
OC: It was the coach who the boy tickled.
WH: Who did the boy tickle?

17. The woman touched the soldier/The soldier touched the woman
OR: The man saw the soldier who the woman touched.
OC: It was the soldier who the woman touched.
WH: Who did the woman touch?

18. The girl called the driver/The driver called the girl
OR: The man saw the driver who the girl called.
OC: It was the driver who the girl called.
WH: Who did the girl call?

19. The convict hit the judge/The judge hit the convict
OR: The man saw the convict who the judge hit.
OC: It was the convict who the judge hit.
WH: Who did the judge hit?

20. The cop trapped the thief/The thief trapped the cop
OR: The man saw the thief who the cop trapped.
OC: It was the thief who the cop trapped.
WH: Who did the cop trap?

Appendix B. Treatment protocols.

Object-Extracted Wh-Questions

Example of Training: *Who did the thief chase?*

Step 1. Comprehension probe and correction procedure. A randomly selected semantically reversible stimulus (picture) pair is presented—for example: (a) artist chasing thief and (b) thief chasing artist. The examiner reads aloud the target sentence and the participant points to the corresponding picture. Incorrect responses are corrected by the examiner repeating the target sentence, and using the target picture, pointing out the agent and theme.

Step 2. Sentence production priming probe. The selected stimulus (picture) pair remains on the table and a *who*- question is elicited using the sentence production priming task (see text). If a grammatically correct *wh*- question is produced, the next item is presented. When a grammatically correct *who*- question is not produced, Training Steps 3–9 are followed.

Step 3. Verb and verb argument comprehension. Sentence constituents comprising the active training sentence are presented under the target picture on individual cards (e.g., [the thief] [did] [chase] [the artist]). The [who] and [?] cards also are placed on the table to the side. The examiner says, "point to the action word, chase", "point to the person doing the chasing", and "the person being chased". Error responses are corrected with reference to the target picture.

Step 4. Verb and verb argument production. With constituent cards still in their active order, the examiner points to the verb and says, "name the action". Errors are corrected using a verbal model. Next the examiner queries the agent and theme, respectively, saying "who did the chasing?" and "who was chased?". Errors again are corrected, by repeating the query and modeling the correct response.

Step 5. Question formation (a). The examiner explains that we want to make a new sentence, a question. It is explained that the artist is the one who is being chased and the examiner replaces [the artist] with [who]. The participant then reads/repeats the constituent cards: [the thief] [did] [chase] [who].

Step 6. Question formation (b). Subject/auxiliary verb inversion is demonstrated to result in [did] [the thief] [chase] [who].

Step 7. Question formation (c). The examiner explains that [who] belongs at the beginning of the sentence and demonstrates this movement, resulting in the following constituent string: [who] [did] [the thief] [chase] [?]. A question mark card is added.

Step 8. Sentence constituents are rearranged in their active sentence form together with the [who] and [?] cards (as in Step 3). Steps 4–7 are repeated, with the participant replacing/selecting/moving the cards to form a correct *wh*- question. Assistance is provided if needed.

Step 9. Repeat Steps 1 and 2.

Object Clefts

Example of Training: *It was the artist who the thief chased.*

Step 1. Comprehension probe and correction procedure. A randomly selected semantically reversible stimulus (picture) pair is presented—for example: (a) artist chasing thief and (b) thief chasing artist. The examiner reads aloud the target sentence and the participant points to the corresponding picture. Incorrect responses are corrected by the examiner repeating the target sentence, and using the target picture, pointing out the agent and theme.

Step 2. Sentence production priming probe. The selected stimulus (picture) pair remains on the table and an object-cleft construction is elicited using the sentence production priming task (see text). If a grammatically correct object cleft is produced, the next item is presented. When a grammatically correct object cleft is not produced, Training Steps 3–8 are followed.

Step 3. Verb and verb argument comprehension. Sentence constituents comprising the active training sentence are presented under the target picture on individual cards (e.g., [the thief] [chased] [the artist]). Constituents of the matrix clause also are presented ([it was] [the artist]) to the left of the active sentence, and the [who] card is placed on the table to the right. Using the active sentence, the examiner says: "point to the action word, chase", "point to the person doing the chasing", and "the person being chased". Error responses are corrected with reference to the target picture.

Step 4. Verb and verb argument production. With constituent cards still in their active order, the examiner points to the verb and says: "name the action". Errors are corrected using a verbal model. Next the examiner queries the agent and theme, respectively, saying, "who did the chasing?" and "who was chased?". Errors again are corrected, by repeating the query and modeling the correct response.

Step 5. Object-cleft formation (a). The examiner explains that we want to make a new sentence. The theme card [the artist] in the active sentence is replaced by [who] as the examiner explains that the artist is the person who was chased. The client is instructed to read/repeat the sentence in the word card order that now appears: [the thief] [chased] [who].

Step 6. Object-cleft formation (b). Referring to the matrix clause cards ([it was] and [the artist], the examiner explains that [the artist] is the person who was chased, so the [who] card is moved next to [the artist] to result in the following: [it was] [the artist] [who] [the thief] [chased].

Step 7. Sentence constituents are rearranged in their active sentence form together with the [it was] and [who] cards (as in Step 3). Steps 4–6 are repeated with the participant replacing/selecting/moving the cards to form a correct object-cleft construction. Assistance is provided if needed.

Step 8. Repeat Steps 1 and 2.

Object-Relative Clause Constructions: *The man saw the artist who the thief chased.*

Step 1. Comprehension probe and correction procedure. A randomly selected, semantically reversible stimulus (picture) pair is presented—for example: (a) artist chasing thief and (b) thief chasing artist. The examiner reads aloud the target sentence and the participant points to the corresponding picture. Incorrect responses are corrected by the examiner repeating the target sentence, and using the target picture, pointing out the agent and theme.

Step 2. Sentence production priming probe. The selected stimulus (picture) pair remains on the table and an object-relative construction is elicited using the sentence production priming task (see text). If a grammatically correct object relative is produced, the next item is presented. When a grammatically correct object relative is not produced, Training Steps 3–8 are followed.

Step 3. Verb and verb argument comprehension. Sentence constituents comprising the active training sentence for each clause or the target are presented under the target picture on individual cards (e.g., [the man] [saw] [the artist] / [the thief] [chased] [the artist]). The [who] card also is placed on the table to the side. The examiner says, "point to the action word" in each clause (*saw* and *chase*), "point to the person who saw/chased", and "the person who was seen/chased". Error responses are corrected with reference to the target picture.

Step 4. Verb and verb argument production. With constituent cards still in their active order, the examiner points to the verb in the first (then second) clause and says: "name the action". Errors are corrected using a verbal model. Next, the examiner queries the agents and themes, respectively, saying "who saw/chased?" and "who was seen/chased?". Errors again are corrected, by repeating the query and modeling the correct response.

Step 5. Object-relative clause formation (a). The examiner explains that we want to make a new sentence, one that combines the two clauses. The [who] card replaces the theme card [the artist] in the second clause. The clinician explains that the artist is the person who was chased. The client is instructed to read/repeat the clauses in the word order that now appears on the cards: [the man] [saw] [the artist] / [the thief] [chased] [who].

Step 6. Object-relative clause formation (b). Referring to the first clause cards ([the man] [saw] [the artist]), the examiner explains that [the artist] that the man saw and the artist who was chased are the same person, so the they are moved next to each other. The examiner moves [who] next to [the artist] to result in the following: [the man][saw][the artist][who][the thief][chased].

Step 7. Sentence constituents are rearranged in their active sentence form for each clause, together with the [who] card (as in Step 3). Steps 4–6 are repeated, with the participant replacing/selecting/moving the cards to form a correct object-relative construction. Assistance is provided if needed.

Step 8. Repeat Steps 1 and 2.