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Complexity in Treatment of Syntactic Deficits

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Abstract

Purpose—This article addresses complexity in the context of treatment for sentence structural impairments in agrammatic aphasia, with emphasis on noncanonical sentences involving linguistic movement and their related counterparts. Extensions of the complexity effect to recovery of canonical sentences also are discussed, stressing the linguistic properties of verbs as well as grammatical morphology in building complexity hierarchies.

Method—A number of variables to consider in developing complexity hierarchies in the syntactic domain are addressed, and a series of studies using single-subject controlled experimental analysis are discussed.

Results—Findings across studies show that training complex sentences results in improvement of simpler structures when, and only when, the underlying linguistic properties are shared by both. The opposite approach, training simple structures first and building to more complex ones, does not provide the full benefit of treatment, in that little or no generalization occurs across structures.

Conclusion—Using complex language material as a starting point for treatment of sentence structural deficits in aphasia results in cascading generalization to simpler, linguistically related material and expands spontaneous language production in many language-disordered adults with aphasia. Clinicians are, therefore, urged to adopt this approach in clinical practice, even though it is counterintuitive and departs significantly from conventional treatment methods.

Keywords

aphasia treatment; complexity; generalization

Individuals with aphasia often show selective language impairments that affect one language domain to a greater extent than others. In one form of aphasia, Broca's aphasia with agrammatism, the symptom complex reflects deficits in grammatical structure, characterized by production of primarily short, simple sentences consisting of structurally impoverished word strings. Noun phrases (NPs) and other material often are misordered, verb production is compromised, and grammatical morphemes are substituted or omitted (Caramazza & Hillis, 1989; Goodglass, 1976; Kim & Thompson, 2000; Kohn, Lorch, & Pearson, 1989; Lee & Thompson, 2005; Menn & Obler, 1989; Miceli, Silveri, Romani, & Caramazza, 1989; Saffran, Berndt, & Schwartz, 1989; Thompson, Lange, Schneider, & Shapiro, 1997; Zingeser & Berndt, 1990). Notably, complex sentences in which NPs are moved out of their canonical position, such as passives and object relative clause constructions, present particular difficulty in both production and in comprehension (Bastiaanse, Hugen, Kos, & van Zonneveld, 2002; Caplan

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and Hildebrandt, 1988; Faroqi-Shah & Thompson, 2003; Grodzinsky, 1986, 1990; Schwartz, Linebarger, Saffran, & Pate, 1987).[1]

Two primary approaches have been advanced for remediation of these deficits: various forms of “mapping therapy” (see Haendiges, Berndt, & Mitchum, 1996; Rochon, Laird, Bose, & Scofield, 2005; Schwartz, Saffran, Fink, Myers, & Martin, 1994) and “treatment of underlying forms” (TUF; Thompson & Shapiro, 2005). Both approaches consider verbs and their thematic roles as well as the syntactic properties of sentences. TUF, however, is unique in that the focus is on syntactically complex structures rather than simple ones (e.g., active sentences). In a series of studies, we have found that training complex linguistic material results in improved production and comprehension of structures trained and that greater generalization to untrained sentences results from this approach as compared with training less complex forms (Ballard & Thompson, 1999; Thompson, Ballard, & Shapiro, 1998; Thompson, Shapiro, Kiran, & Sobecks, 2003; Thompson, Shapiro, & Roberts, 1993). Crucially, we have found that this pattern of generalization occurs when the trained and untrained structures are linguistically “related.” This account, the Complexity Account of Treatment Efficacy (CATE), is stated 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” (Thompson et al., 2003, p. 602).

The purpose of this article is to consider structural complexity on theoretical grounds, summarize our treatment findings, and explore the clinical impact of the complexity account.

Syntactic Complexity: Theoretical Considerations

Structural or syntactic complexity is influenced by several variables, including the number of propositions expressed (aligned with the number of verbs in a sentence; Caplan & Hanna, 1998), the number of embeddings in the sentence (Yngve, 1960), the order in which elements appear in sentences (i.e., canonical vs. noncanonical order; Bastiaanse et al., 2002; Grodzinsky, 1990), and the distance between crucial elements in the sentence (Gibson, 1998). To understand why these variables affect sentence complexity, a brief review of the formal linguistic constructs that function in formation of sentences is required. Here we address these as they relate to the sentence types that are difficult for individuals with agrammatic aphasia, and how they affect treatment and recovery. Consider the following sentences:

1. The thief chased the artist.
2. It was the artist who the thief chased.
3. The artist was chased by the thief.

What are the crucial distinctions between these structures? All three express the same (single) proposition and use the same verb and other lexical items. But their surface forms differ. Two linguistic constructs, *merge* and *move*, involved in sentence formation help to explain these differences (Chomsky, 1995, 1998; Marantz, 1995; see also Adger, 2003).

Merge

Theoretical accounts of sentence formation indicate that sentences are developed through phrase structure building operations. In the *minimalist program* (Chomsky, 1995), this is accomplished via a syntactic operation, *merge*, in which two categories merge to yield a higher order category, and a series of merge operations builds the syntactic structure. Simply put, a

[1]Canonical word order is the most usual order of the main sentence elements, subject (S), verb (V), and object (O) in a particular language (i.e., SVO in English, VSO in Arabic, SOV in Korean).

lexical item (e.g., a verb) is selected from the lexicon and combines with another selected item to form a higher order category such as a verb phrase (VP).

The verb plays a particularly important role in this process in that verbs have *argument structure* (Grimshaw, 1990); that is, participant roles that "go with" the verb and both the verb and its arguments must be present in the syntax in order for a sentence to be grammatical. The argument structure of each verb is encoded in the lexicon with the verb; for example, the verb *chase* entails a chaser (someone doing the chasing) and a chasee (someone or something being chased). In addition, each argument of the verb is assigned a *thematic role* (e.g., agent, theme, goal). The verb *chase* requires two arguments and therefore is a two-argument verb; that is, in the sentence "The thief chased the artist," *the thief* is assigned the role of *agent* and *the artist* is assigned the role of *theme*.

Figure 1 demonstrates how this occurs in Sentence 1 above, a simple, active, canonical sentence with one verb. V merges with a determiner phrase (DP) to yield V′, and the role of theme is assigned to the direct object argument, *the artist*. V′ then merges with another DP to form a VP, and the agent role is assigned to the subject, *the thief*. The VP then merges with higher nodes in the syntactic tree. These operations are similar in sentences with more than one verb or proposition, but the derived sentences are more complex.

Move

Another operation involved in sentence formation is *move*. Consider again Sentences 1, 2, and 3 above. What is different in 2 and 3 as compared with 1? One crucial difference is that 2 and 3 are noncanonical; that is, the order of words in the sentence have been moved from their basic (underlying) position to other sentence positions. Accordingly, sentences with movement are more syntactically complex than those with no movement. While there are several types of movement, those most relevant to the types of sentences that are difficult for individuals with agrammatic aphasia are *wh*-movement and NP-movement. Sentence 2 above is derived from *wh*-movement, whereas Sentence 3 involves NP-movement. While there are a number of differences between the two movement types, which we address below, a primary distinction concerns the position in the syntactic tree that serves as a landing site for the moved element. In *wh*-movement structures, moved material lands in what is called the Specifier position of the complementizer phrase (Spec, CP), whereas NP-movement structures land in the Specifier position of the tense phrase (Spec, TP; see Figure 2).[2] Spec, CP is a nonargument position (A′). That is, thematic roles are not assigned to elements occupying this position. However, Spec, TP is an argument position (A-position) associated with grammatical functions, for example, subject and object, or positions where a thematic role can be assigned.

Wh-movement (A′ movement)—In English, several sentence types involve *wh*-movement, including the following:

4. Who did the thief chase? (Object-extracted *wh*-question)

5. It was the artist who the thief chased. (Object cleft)

6. The man saw the artist who the thief chased. (Object relative)

All involve displacement of the direct object argument from its underlying position to a different position in the sentence. As shown in Figure 3, for formation of a *wh*-question such as in Sentence 4, the object of *chase* (in this case *who*) moves from the direct object position to Spec, CP. This operation leaves behind a trace or copy of the moved object.[3] However, once moved, it is linked (coindexed) with the position from which it was derived, and it inherits the

[2]TP, which refers to tense phrase, replaced IP (inflection phrase), following introduction of the Split IP Hypotheses (Pollock, 1989).

thematic role originally assigned to the object. Importantly, this movement occurs in the matrix (main) clause of the sentence.

The syntax of object cleft (Sentence 5) and object relative clause constructions (Sentence 6) involve movement identical to that in *wh*-questions. However, there are some differences. In 5 and 6, movement takes place within an embedded clause. Thus, while 4, 5, and 6 are structurally related in that they all involve *wh*-movement, object clefts and object relatives can be considered more complex than *wh*-questions based on depth of embedding (Yngve, 1960; also see Chomsky & Miller, 1963; Miller & Isard, 1964).

There also are crucial differences between object clefts (Sentence 5) and object relatives (Sentence 6). First, the number of propositions differs. In Sentence 6, there are two propositions as compared with only one in 5; Sentence 6 has two lexical verbs, one in the main clause (i.e., *saw*) and one in the embedded clause (i.e., *chase*), whereas 5 has a copula (*was*) in the main clause and a lexical, two-argument verb in the embedded clause.[4] Thus, the merge operations are more complex in 6 because of the linguistic material in the main clause. Further, recent linguistic theory holds that the surface subjects of sentences move from their base generated position in the VP to the subject position (see Koopman & Sportiche, 1991, for discussion of the VP internal subjects hypothesis). For example, in object relative structures (e.g., *The man saw the artist*…), the subject (*the man*) moves from its position in the VP to a higher node (i.e., Spec, IP). Conversely, in the main clause of object cleft constructions (e.g., *It was the artist*…), the subject is represented by a pronoun (*It*), which is generated in its surface position; thus, no subject movement is required, and it lacks a thematic role because the copula cannot assign one (see Figure 4). These differences render object relatives to be more complex than object clefts.

In summary, Sentences 4, 5, and 6 above are linguistically related because they all involve *wh*-movement. However, 6 is more complex than 5, and both 5 and 6 are more complex than 4.

NP-movement (A movement)—NP-movement is involved in formation of English passives and subject raising constructions as in Sentences 7 and 8 below:

7. The artist was chased by the thief. (Passive)

8. The thief seems to have chased the artist. (Subject raising structure)

NP-movement occurs because, in their underlying form, both sentence types have an empty subject position (φ), as shown in Sentences 9 and 10 below. This is because passive verbs (i.e., *chased*) and raising verbs (i.e., *seems*) take only one internal argument and, therefore, do not assign an external thematic role to the subject position (Haegeman, 1994).[5]

Because all grammatical English sentences must have subjects, the internal argument moves to the subject position.

9. φ chased *the artist* by the thief. (Underlying form of the passive)

10. φ seems *the thief* chased the artist. (Underlying form of subject raising)

[3]The *trace* or *copy* is an abstract marker, which denotes the place of origin of a moved sentence element in order to maintain the structural relation between the surface form of a sentence and its underlying form. The *trace* was used in Chomsky's Principles and Parameters (i.e., Government Binding theory; Chomsky, 1986) and replaced by *copy* in the Minimalist Program. While the details of the two theories differ, the basic function of *trace* and *copy* are the same.

[4]A lexical verb is a member of the open class of verbs, which assign thematic roles and form the primary verb vocabulary of a language. Closed-class verbs (e.g., the copula) do not assign thematic roles (Crystal, 1985; Quirk, Greenbaum, Leech, & Svartvik, 1985).

[5]Raising verbs are defined as those that lack an external argument.

There are, however, crucial differences between the two NP-movement structures. In passives (Sentence 9), an object NP is moved to the subject position of the same clause (see Figure 5), whereas in raising structures (Sentence 10), the subject NP is raised from a lower clause to a higher clause, resulting in an embedded sentence (see Figure 6). In addition, in Sentence 10 there are two verbs, the raising verb *seems* and the two-argument verb *chased*. Thus, subject raising structures can be considered more complex than passive sentence structures.

Wh- versus NP-movement—As established above, both *wh*- and NP-movement structures involve displacement of sentence elements in order to develop their surface form. Crucially, however, there are important differences between the two, primarily concerned with the landing site of the moved element. In *wh*-movement, the moved element occupies Spec, CP, a nonargument position. In NP-movement, the moved element lands in Spec, TP, an argument position. Thus, the distance between the moved element and the trace or copy site is greater for *wh*-movement structures than for NP-movement, as can be seen in Sentences 11 and 12 below:

11. *The artist* was chased [trace site] by the thief.

12. It was *the artist* who the thief chased [trace site].

The point here is that, while both types of movement render sentences more complex than those without movement, sentences with *wh*-movement can be considered more complex than those with NP-movement.

Relevance of Merge and Move to Sentence Processing

The linguistic constructs described above have important implications for human sentence processing as well as production (see, e.g., Garnsey, Tanenhaus, & Chapman, 1989; Hickok, Canseco-Gonzalez, Zurif, & Grimshaw, 1993; Sussman & Sedivy, 2003; Tanenhaus, Carlson, & Seidenberg, 1985; Zurif, Swinney, Prather, Solomon, & Bushell, 1993). For example, Zurif et al. (1993) tested unimpaired as well as aphasic participants' ability to process sentences with movement (called filler-gap sentences in psycholinguistic research) using a cross-modal lexical priming (CMLP) task. Participants were required to make a lexical decision (i.e., decide if a visually presented string of letters is a word or a nonword) while listening to sentences such as "Which doctor did the supervisor *call* to help with the emergency?" Crucially, a lexical decision was required at certain points in the sentence, for example, before and after the verb *call*. In addition, some of the real word letter strings were semantically related to the moved sentence constituent, *which doctor* (e.g., *patient*), and some were not (e.g., *current*). Results showed that lexical decision times (i.e., reaction times) were faster for semantically related words as compared to unrelated words (i.e., a semantic priming effect was found) at both test points. However, reaction times were even faster after the verb as compared with before the verb (i.e., at the gap, or trace/copy, site), suggesting sensitivity to the origin of the moved sentence constituent. A similar pattern also has been shown in studies using anomaly detection (Dickey & Thompson, 2004) and eye-tracking-while-listening paradigms (Dickey, Choy, & Thompson, 2007; Sussman & Sedivy, 2003).

It is interesting to note that individuals with agrammatic aphasia show patterns that differ somewhat from that of normal participants. That is, some CMLP studies have found a semantic priming effect both before and after the verb, but no difference between reaction times at the two probe sites, suggesting an insensitivity to movement (but see Blumstein et al., 1998; Dickey et al., 2007). Dickey and Thompson (2004) also found that untreated aphasic patients with agrammatism were unable to reject anomalous sentences with movement such as "The girl wore the shirt that her mother *fried* for her." However, following treatment of sentences with *wh*-movement, patients showed a normal pattern in which they were able to reject these sentences.

Summary

In summary, all sentences are similarly formed through phrase structure building operations, and the argument structure of selected verbs as well as the number of selected verbs influence sentence building complexity. In addition, some sentences are noncanonical; that is, the word order of their surface form is derived by moving sentence elements from their underlying position to other positions in the sentence, rendering them more complex than canonical sentences. In some cases, movement crosses clausal boundaries (i.e., from a lower clause to a higher one), creating a greater distance between the moved element and its original site, and clausal embedding results, which further influences sentence complexity. Importantly, these complexity variables affect human sentence processing.

Syntactic Tree Structure and Complexity

Another consideration in developing sentence complexity hierarchies concerns the position of elements in the syntactic tree. Hagiwara (1995) suggested that higher nodes in the tree are more susceptible to impairment than lower nodes for individuals with agrammatic aphasia. Studying a group of Japanese patients and considering data from French and Italian aphasic speakers, Hagiwara showed that when elements within CP (which take a high position in the tree as noted above) were impaired, elements in lower nodes (i.e., tense and negation) also were impaired. In no case did patients show a pattern of unimpaired higher nodes yet impaired lower nodes. Friedmann and Grodzinsky (1997) further reported a Hebrew-speaking patient who showed a dissociation between tense and agreement, where tense was impaired, but not agreement. On some accounts, agreement takes a lower position in the tree than tense; thus, they suggested that nodes lower in the tree are more accessible than those in higher positions. Further, they noted that elements within CP also were impaired and, therefore, formulated the Tree Pruning Hypothesis (TPH), positing that when the lower nodes are impaired, projecting higher nodes in the tree is impossible (also see Friedmann, 2001, 2002). Accordingly, higher nodes are more complex than lower nodes. This fits well with our conceptualization that *wh*-movement is more complex than NP-movement as noted above.

We now turn to discussion of the findings derived from treatment studies examining recovery of sentence production and comprehension in agrammatic aphasia. Results of these studies show that the complexity of structures trained affects recovery. In addition, they help to clarify the complexity metrics that are important to consider in designing treatment.

Overview of Treatment Studies and Findings

We have conducted several studies examining the effects of sentence production and comprehension treatment for agrammatic aphasia. These studies involve training sentences derived from either *wh*-movement or NP-movement and testing generalization to untrained sentences within and across movement types (Ballard & Thompson, 1999; Thompson et al., 1998; Thompson, Shapiro, et al., 1997; see below for a description of the treatment approach). Results of these studies have shown that sentences entered into treatment are acquired when treatment is provided and remain significantly above baseline performance levels through follow-up phases. Further, the generalization patterns show that training *wh*-movement constructions results in significantly increased production and comprehension of untrained *wh*-movement sentences (i.e., training object clefts improves *wh*-question production and comprehension). However, generalization from *wh*-movement to NP-movement structures is not seen. Similarly, training NP-movement structures (such as subject raising) improves untrained NP-movement structures (such as passives), but this training does not affect sentences with *wh*-movement.

This lack of cross-movement type generalization from *wh*- to NP-movement, and vice versa, is not surprising in that the syntactic computations involved in the two structures are quite different as described above. Notably, however, within the classes of *wh*- and NP-movement sentences, a complexity effect emerges in the learning and generalization patterns. Participants trained on more complex sentence types show better generalization than those trained on less complex ones.

Complexity in Treatment of Wh-Movement

In two studies, we directly examined the complexity effect (Thompson et al., 1998, 2003), testing the training and generalization effects of *wh*-movement structures. Participants were trained to produce (and comprehend) object relative clause structures (e.g., "The man saw the artist who the thief chased"), object clefts (e.g., "It was the artist who the thief chased"), and/or *wh*-questions (e.g., "Who did the thief chase?") in counterbalanced order. During treatment, generalization to untrained structures was tested.

Results of the first study (1998) showed that when treatment was applied to object clefts, object cleft production increased significantly above baseline levels. In addition, *wh*-question production emerged, with no treatment provided, and similar learning curves were noted for both constructions. Conversely, participants who received initial treatment focused on *wh*-questions showed no generalization to object clefts (see Figure 7). Rather, these structures required direct treatment. Notably, the production of passives did not increase above initial baseline levels for any of the participants, replicating our earlier findings that acquisition of *wh*-movement structures does not simultaneously improve NP-movement constructions. Similar results were found in our later study (Thompson et al., 2003). Training object relatives resulted in generalization to untrained object clefts and *wh*-questions, while training *wh*-questions did not improve untrained object relatives or clefts. Furthermore, when object clefts were entered into treatment, generalization was not observed to object relatives (see Figure 8).

In summary, across studies examining the generalization effects of training *wh*-movement constructions, more than 20 participants with agrammatic aphasia have undergone treatment. Notably, 85% of those trained to produce complex *wh*-movement structures, involving movement within an embedded clause, showed successful generalization to simpler structures with movement in the main clause (i.e., *wh*-questions). In contrast, only 17% of individuals trained to produce *wh*-questions showed generalization to more complex structures with embedded clauses (see Figure 9).

Complexity in Treatment of NP-Movement

We have found a similar pattern of training and generalization within and across NP-movement structures. That is, training more complex NP-movement structures (i.e., subject raising constructions) results in improved production and comprehension of less complex NP-movement structures (i.e., passive sentences), but the opposite pattern has not been noted (see Thompson, Shapiro, et al., 1997). We presently are investigating this effect in three sentences types: subject raising structures, passives, and active sentences with unaccusative verbs.[6] Like raising structures and passives, active sentences with unaccusative verbs entail NP-movement. Thus, on the complexity account, we predict the following generalization patterns: subject raising to passives and unaccusative forms, and passives to unaccusatives; however, we do not expect generalization from active sentences with unaccusative verbs to passives or subject

[6]Unaccusative verbs, within the class of intransitive verbs, have a theme-marked argument only, which is base generated in the verb object position. In order to satisfy the requirement that, in English, all sentences must have subjects/case, the theme-marked argument moves to the subject position.

raising sentences. To date, the findings support these predictions (see Dickey & Thompson, in press).

Discussion of Treatment Findings

Patterns of learning derived across studies indicate that treatment results in more pronounced effects when it is initiated on complex structures in that simpler structures emerge without direct treatment. The reverse approach—that is, beginning treatment with structures in which the underlying syntax is less complex and progressively increasing the complexity of material entered into treatment—appears to be less effective, even though it is embraced in traditional language intervention approaches.

Crucially, however, it appears that treatment of complex structures only improves less complex structures when they are linguistically linked to trained structures. As discussed above, there are important differences between *wh*- and NP-movement constructions; thus, generalization does not occur from one to the other, even though on some accounts NP-movement is less complex than *wh*-movement. Our findings, therefore, are not completely in line with the complexity metric established by the TPH. From a treatment perspective, the TPH suggests that training individuals with agrammatism to successfully produce elements that occupy higher nodes in the syntactic tree—for example, CP structures such as object clefts or *wh*-questions—would result in accessibility to elements that occupy lower nodes, as reported by Friedmann, Wenkert-Olenik, and Gil (2000). Indeed, NP-movement structures are lower in the tree than *wh*-movement structures. However, our data do not support this conceptualization. Further, persons with aphasia who improve on *wh*-movement still show impairments on lower structures, including verb inflections (i.e., agreement and tense) and unaccusative verbs (Dickey & Thompson, in press; Thompson, Shapiro, et al., 1997). On the complexity account (i.e., CATE), such generalization patterns would not be predicted because the underlying linguistic properties differ across structures.

The sentence generalization patterns noted also cannot be explained by nonlinguistic accounts of complexity. It could be argued, for example, that syntactically more complex forms differ from simpler forms in that they require greater processing resources. And treating more resource-demanding sentences improves general sentence processing/production ability (e.g., the ability to hold sentence elements in memory and simultaneously compute linguistic operations, grammatically encode sentences for production, and assemble phonological information). Therefore, it is possible that the noted generalization effects resulted because more complex forms are generally longer than simpler ones (i.e., object-relative clause constructions included eight words; *wh*-questions included five words). However, this interpretation would also predict *wh*- to NP-movement generalization. That is, object-cleft and passive structures are quite similar in length (eight and seven words, respectively), yet we found no generalization from one form to the other. In addition, on some accounts, the former require greater processing demands than the latter. That is, *wh*-movement structures are essentially unbounded (and cross clausal boundaries) and NP-movement structures are quite constrained (Berwick & Weinberg, 1984) as discussed above. We, therefore, conclude that the lack of generalization from *wh*- to NP-movement structures is because the two types of movement are fundamentally unrelated.

Clinical Relevance

Complexity in treatment of sentence production and comprehension has important clinical implications. First, as noted above, generalized production and comprehension of untrained sentences occurs to a greater extent by training complex items as compared to simple ones. This treatment outcome is crucial, because generalization has become a gold standard in treatment research. Without it, the efficacy of treatment can be questioned.

Substantial changes in spontaneous discourse also have been noted in most patients who undergo treatment of complex sentences (Thompson, Shapiro, et al., 1997; Thompson, Shapiro, Tait, Jacobs, & Schneider, 1996). In all studies, we collect language samples for each participant prior to and following treatment and analyze them for several linguistic variables. Improvements in the following have been noted: (a) mean length of utterance, (b) the proportion of grammatical sentences produced, and (c) the proportionate number of verbs as compared with nouns produced. Further, Ballard and Thompson (1999) conducted analyses of communicative informativeness and efficiency by calculating the percentage of correct information units (CIUs) and CIUs per minute produced in pre- and posttreatment narrative samples (after Nicholas & Brookshire, 1993). Results showed improvement for four of five participants. These findings are encouraging and indicate that treatment gains are not restricted to improvement on targeted sentence structures. Rather, they suggest that treatment results in improved access to a variety of language structures that are encountered when complex sentences become the focus of treatment and that it also affects the amount and efficiency of information expressed.

Another relevant finding is that the number of treatment sessions required for acquisition and generalization of target structures differs when complex versus simple linguistic material is entered into treatment. For example, in Thompson et al. (1998), participants who began treatment with complex structures required a mean of 13 sessions to reach criterion (i.e., 80% correct production/comprehension of target structures), whereas those trained from simple to complex structures required a mean of 34 sessions. Similarly, participants in Thompson et al. (2003), trained from complex to simple or from simple to complex, required 12 and 28 sessions, respectively. At the end of treatment, all participants were able to produce/comprehend all structures, but those receiving treatment on complex forms required fewer treatment sessions to do so, because treatment was required on only one sentence type. This observation is particularly important given the current health care climate in the United States. Even though individuals with chronic aphasia show language improvement when provided with treatment, most patients receive only a few weeks of therapy, usually shortly after the aphasia-inducing event. Given this, it is imperative that clinicians provide treatment that results in the greatest improvement in the shortest amount of time.

One question that begs discussion is whether the complexity effect occurs only because of the linguistic material entered into treatment or if the treatment approach itself affects outcome patterns. That is, can clinicians expect generalization to occur regardless of the treatment approach used? Let us consider this question. TUF uses the active, declarative form of target sentences as a starting point for treatment, and tasks are directed toward establishing and improving knowledge of and access to the thematic role information entailed in target verbs. Then instructions are provided as to how various sentence constituents move to derive the surface form of target sentences, while retaining their thematic roles. In essence, the procedures involve metalinguistic knowledge of verb properties and movement processes involved in forming noncanonical sentences.[7] Treatment studies establishing the effects of this and other similar approaches (i.e., mapping therapy as mentioned above) have shown that, in general, protocols that exploit the linguistic and psycholinguistic properties of sentences result in greater treatment and generalization effects than direct production approaches that consider only the surface form of target sentences (e.g., Helm-Estabrooks, 1981).

Different outcomes of mapping and TUF, however, have been noted, with the primary difference being that TUF appears to result in greater generalization effects than mapping type treatments (see Schwartz et al., 1994). There are several potential reasons for this finding. While both approaches include training steps concerned with the thematic roles assigned by

[7]See Thompson (2001) for detailed treatment protocols.

the verb, the two differ in some important ways: (a) mapping therapy focuses primarily on comprehension, and TUF focuses on both comprehension and production; (b) mapping therapy does not address movement operations involved in sentence formation, while this is a primary focus of TUF; and (c) mapping therapy begins by training syntactically simple sentences, whereas TUF uses complex sentences as a starting point. Thus, teasing out treatment variables underlying the recovery patterns that result from TUF is difficult.

We (Thompson, Shapiro, Kiran, Maas, & Hashimoto, 2007) recently completed data collection in a study investigating this question, at least in part, by directly comparing the effects of mapping therapy and TUF in a group study with 32 participants with agrammatic aphasia. All participants were trained on *wh*-movement structures (object relatives), NP-movement structures (passives), and simple active sentences, and generalization was tested to less complex *wh*-movement structures (object clefts and *wh*-questions) and more complex NP-movement forms (subject raising structures). The treatment type (mapping, TUF) and order of structures trained were counterbalanced across participant groups. Preliminary results indicate that both comprehension and production of trained forms improved for all participants, regardless of treatment approach. In addition, neither approach fostered generalization from NP- to *wh*-movment or *wh*- to NP-movement, nor did the approaches facilitate generalization from passives to more complex NP-movement structures (subject raising forms). However, all participants (n = 16) who received TUF showed generalization to object clefts and/or *wh*-questions when object relatives were trained, whereas, only 2 (of 16) who received mapping therapy showed this pattern. These data show that treatment variables involved in TUF but not mapping therapy are required to promote generalized production. It appears, then, that training both production and comprehension simultaneously and/or practicing the movement operations involved in complex sentences during treatment underlie the success of TUF.

Extensions of the Complexity Account

In addition to the structures that have been studied to date, the complexity account is applicable to other structures within the domain of sentence complexity. Here we discuss two applications relevant to agrammatic aphasia. One pertains to verb production, and the other concerns production of grammatical morphemes and other functional category items, both of which are difficult for many patients with agrammatic aphasia as noted above.

Complexity Hierarchies of Verbs

Some verbs are more complex than others based on the number of arguments entailed in the verbs' representation. For example, the verb *give* is a three-argument verb (e.g., "The artist *gave* the painting to the thief," where *the artist* is assigned the agent role, *the painting* is assigned theme, and *the thief* is assigned goal) and thus can be considered more complex than two-argument verbs like *chase* or one-place verbs like *run*, which entail fewer arguments (*chase* has two arguments as noted above, and *run* is a one-place verb with only one external argument, as in "*The artist* ran").[8]

One metric of verb complexity, then, pertains to verb argument structure. Indeed, a complexity hierarchy shows up in agrammatism. Simple verbs (i.e., one-argument verbs) are easier to produce than two- or three-argument verbs (De Bleser & Kauschke, 2003; Jonkers & Bastiaanse, 1996, 1998; Kegl, 1995; Kemmerer & Tranel, 2000; Kim & Thompson, 2000, 2004; Kiss, 2000; Luzzatti et al., 2002; Thompson, Lange, et al., 1997). Thus, it might be the

[8]Whether verb arguments are obligatory or optional also contributes to processing; Shapiro, Brookins, Gordon, and Nagel (1991) and Shapiro, Nagel, and Levine (1993) have shown that optional three-place verbs, such as *read* in which the third argument can be omitted even though it is part of the lexical entry of the verb, yield greater processing load than do obligatory three-place verbs like *put*.

case that training more complex three-argument verbs would improve less complex one- or two-argument verbs.

In fact, we found this pattern in two participants trained to produce questions with three-argument verbs such as “What did the boy *give* to his mother?,” which resulted in generalization to untrained sentences with two-argument verbs (e.g., “What did the boy *eat*?”; Thompson et al., 1993). Interestingly, the opposite pattern was not observed; that is, training two-argument verbs did not influence acquisition of questions with three-argument verbs. We attribute these effects to the complexity relation between the two verb types.

Verbs also can be considered in terms of the syntactic movement operations required. As noted above, unaccusative verbs, such as *fall*, involve NP-movement. These verbs are intransitive, one-argument verbs, and their single argument is a theme, which moves to the subject position (Burzio, 1986; Levin & Rappaport Hovav, 1995). This property of un-accusative verbs renders them more complex than verbs like *run* in which its one argument (an agent) is generated in the underlying subject position and no movement is required. Interestingly, when examining production patterns in agrammatism, unaccusative verbs that do not have a direct mapping of their thematic roles onto sentence positions are more difficult to produce than those that do; for example, *fall*-type verbs are more difficult than *run*-type verbs (Bastiaanse & van Zonneveld, 2005; Lee & Thompson, 2004, Luzzatti et al., 2002; see also Thompson, 2003, for discussion of the Argument Structure Complexity Hypothesis).

This same pattern holds when examining the production pattern of psychological (psych) verbs, defined as those that entail an Experience thematic role. Consider, for example, the verbs *admire* and *amuse* in the following sentences:

13. *The children* $_{\text{EXPERIENCER}}$ admired the clown $_{\text{THEME}}$. (Subject-Experiencer)

14. The clown $_{\text{THEME/CAUSER}}$ amused *the children* $_{\text{EXPERIENCER}}$. (Object-Experiencer)

Sentences with *admire* verbs as in 13 are easier to produce than *amuse* verbs as in 14 in agrammatic aphasia. Both 13 and 14 have two arguments: an Experiencer (i.e., *the children*) and a second argument (*the clown*). In 13, the Experiencer and Theme map directly onto the subject and object positions, respectively. However, in 14 the Experiencer occupies the object position, and, on some accounts, the subject argument is a Theme, which moves from its base generated (object) position (e.g., Belleti & Rizzi, 1998).[9] This movement, as in unaccusatives, renders *amuse*-type verbs more complex than *admire*-type psych verbs.

In consideration of complexity in treatment, it may be the case that training more complex verbs (i.e., unaccusatives or Object-Experiencer psych verbs) would result in improved production of simpler verbs that have a direct mapping of thematic roles on to the surface form of sentences (i.e., agentive intransitives or Subject-Experiencer psych verbs). While this pattern has not been tested, it is worthy of investigation.

Complexity of Functional Category Members

Another problem seen in agrammatism is difficulty producing functional morphology, an impairment for which few treatments have been developed or experimentally tested. Patients often, for example, present with patterns of omission and/or substitution of both bound and free-standing grammatical morphemes, resulting in production of grammatically ill-formed sentences (Benedet, Christiansen, & Goodglass, 1998; Faroqi-Shah & Thompson, 2003; Rochon, Saffran, Berndt, & Schwartz, 2000; Saffran et al., 1989). Consider the following:

[9]Other linguistic theories suggest that the Causer is marked with zero morphology to take the subject position (Pesetsky, 1995). Even on this account, however, the featural detail of *amuse*-type psych verbs is greater (and thus more complex) than that of *admire*-type verbs.

15. They wonder *if* the boy is tickling the girl.

16. The boy tickl*ed* the girl.

17. The boy tickle*s* the girl.

The complementizer, *wonder,* in 15 as well as morphemes marking verb tense and agreement in 16 and 17, respectively, are functional category members. Considering the linguistic relationship between these structures, it could be argued that 15 is more complex than either 16 or 17. For example, the TPH suggests this because complementizers occupy higher nodes in the syntactic tree than tense or agreement. Further, the TPH predicts that 16 is more complex than 17, again because tense is higher in the tree than agreement, at least according to Pollock (1989). However, complementizers have a different role in sentences than verb inflection. Complementizers introduce a complement (subordinate) clause; verb inflection specifies temporal and other verb detail. Thus, training production of complementizers should have no effect on production of verb tense or agreement, and training verb tense and agreement should have no effect on complementizers.

Predicting patterns of generalization from tense to agreement or from agreement to tense is more difficult, because there is little agreement in the literature with regard to how these elements are related to one another. On some linguistic accounts, the two elements are distinct (Ouhalla, 1990; Pollock, 1989), whereas others argue that they are not (Bobaljik & Thráinsson, 1998). Thus, although the complexity account predicts a relationship between tense and agreement, it makes no specific prediction regarding the direction of generalization.

We recently tested the effects of training complementizers, tense, and agreement in 12 participants with agrammatic aphasia (Thompson et al., 2006). Using a modified TUF approach, the three structures were trained in counterbalanced order across participants. Results showed that all participants improved on trained forms following stable baseline. However, training production of complementizers did not improve tense or agreement, and training tense or agreement did not influence complementizers, indicating that complementizers and verb inflections are not functionally related, even though both are members of the same grammatical category. More successful generalization was noted between tense and agreement, although not all participants showed the same pattern: some showed tense to agreement generalization, some showed agreement to tense generalization, and others showed no generalization from tense to agreement or from agreement to tense. These findings suggest that the two inflected forms are related to one another; however, one is not necessarily more complex than the other.

Conclusion

Our findings in the syntactic domain suggest that optimal generalization across sentence structures results when the underlying linguistic properties of sentences are shared. When the underlying properties differ across structures, generalization does not occur. Further, we find that when the structural complexity of sentences is controlled, treatment focused on more complex forms results in cascading generalization to simpler forms. Training complex material also results in widespread changes in the language system, suggesting that exploiting the variety of lexical and syntactic properties involved in complex sentences enhances access to a wide array of structures. Finally, we note that fewer treatment sessions are required for participants who receive treatment on complex forms first, even though by the end of treatment comparable performance levels are reached for all participants regardless of whether treatment starts with complex or simple forms. This latter finding is particularly important given current health care policies in the United States. The number of treatment sessions for individuals with aphasia often is restricted; therefore, providing treatment that results in optimal generalization is crucial.

The complexity effect, while counterintuitive and unconventional, holds much promise for maximizing treatment gains. Traditional treatment approaches for sentence deficits in aphasia have espoused beginning treatment at the level of the patient's language ability. Therefore, the starting point generally involves training simple structures (Bandur & Shewan, 2001; Crystal, 1984; Schwartz et al., 1994; Shewan & Kertesz, 1984). Training complex structures ensues only if and when simpler structures are improved. Our findings show, however, that when placed in proper complexity hierarchies, training complex material not only improves comprehension and production of complex sentences, it also simultaneously improves simpler structures.

We argue that there are a number of syntactic variables that need to be considered in developing complexity hierarchies, including the number of propositions (e.g., the number of verbs), the argument structure properties of verbs, the depth of embedding the type of syntactic dependencies within sentences, and the distance over which these dependencies are computed. However, we note that further experimental work is needed in order to completely understand how different aspects of complexity might influence generalization patterns in language recovery. Indeed, the more we learn about the variables that are most important for building a complexity metric, the more precise we can be about selection of treatment targets, and the more individuals with aphasia will benefit from treatment.

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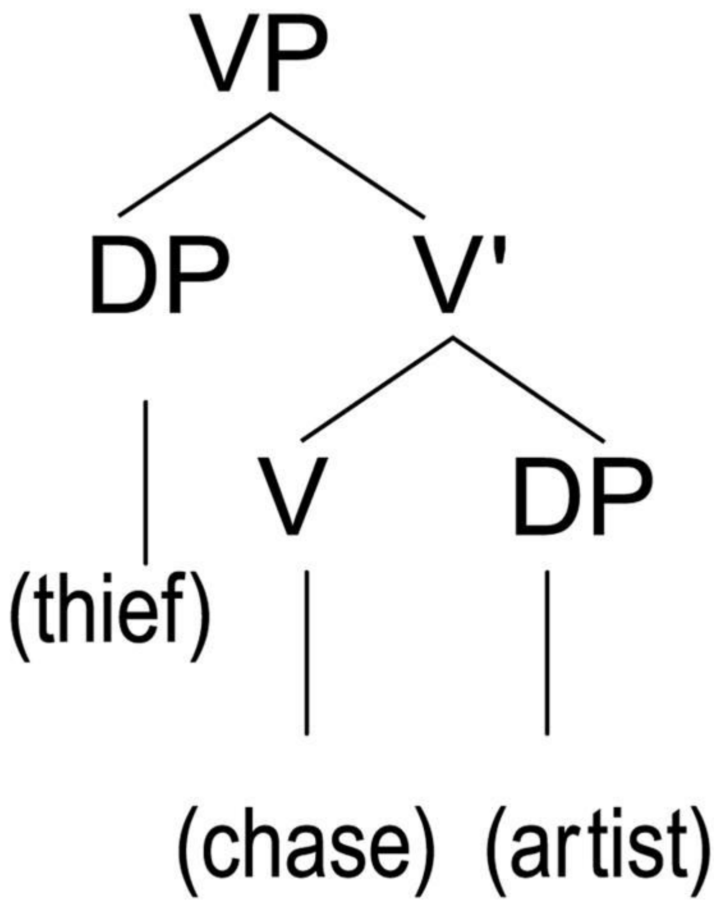

FIGURE 1.
Schematic representation of merge within the verb phrase (VP). DP = determiner phrase; V = verb.

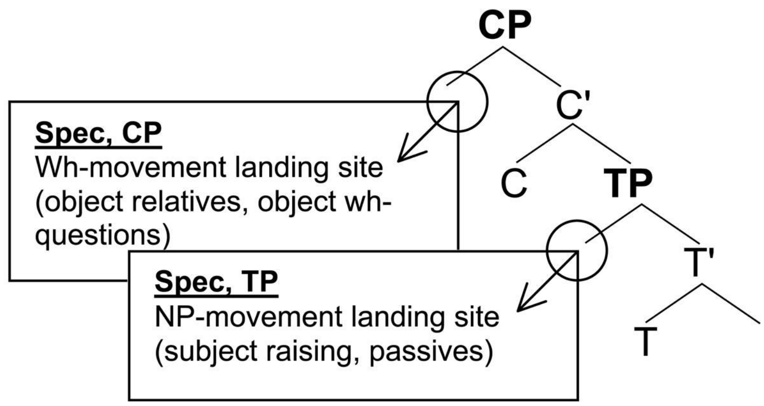

FIGURE 2.
Landing sites for moved elements in *wh*-movement (Spec, CP) and NP-movement (Spec, TP). Also shown are the head positions of complementizer phrase (CP) and tense phrase (TP), C° and T°, respectively. These positions project grammatical morphology licensed by CP (e.g., complementizers) and TP (e.g., tense).

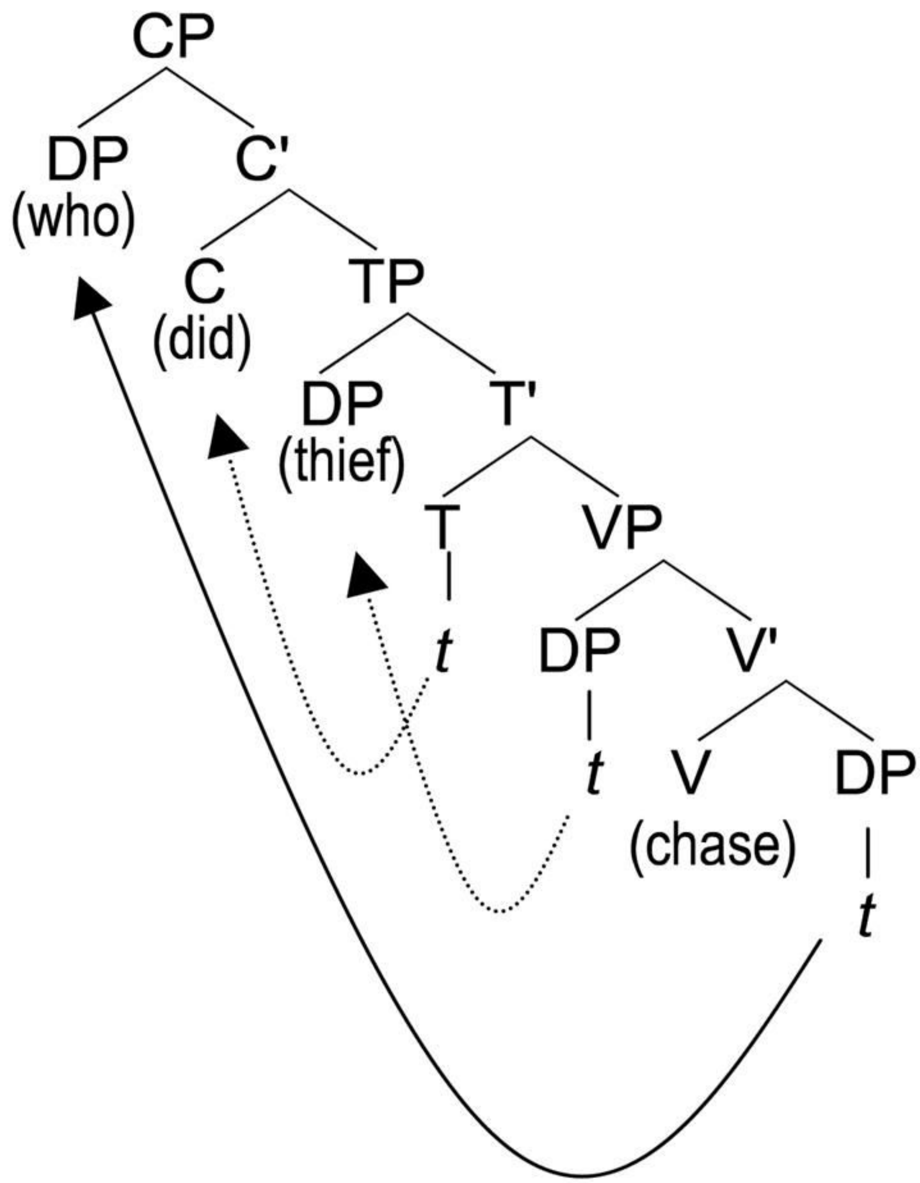

FIGURE 3.
Tree structure denoting *wh*-movement (A′ movement) in an object extracted *wh*-question construction. The object of the verb *chase* (*the artist/who*) moves to Spec-CP, leaving behind a trace/copy.

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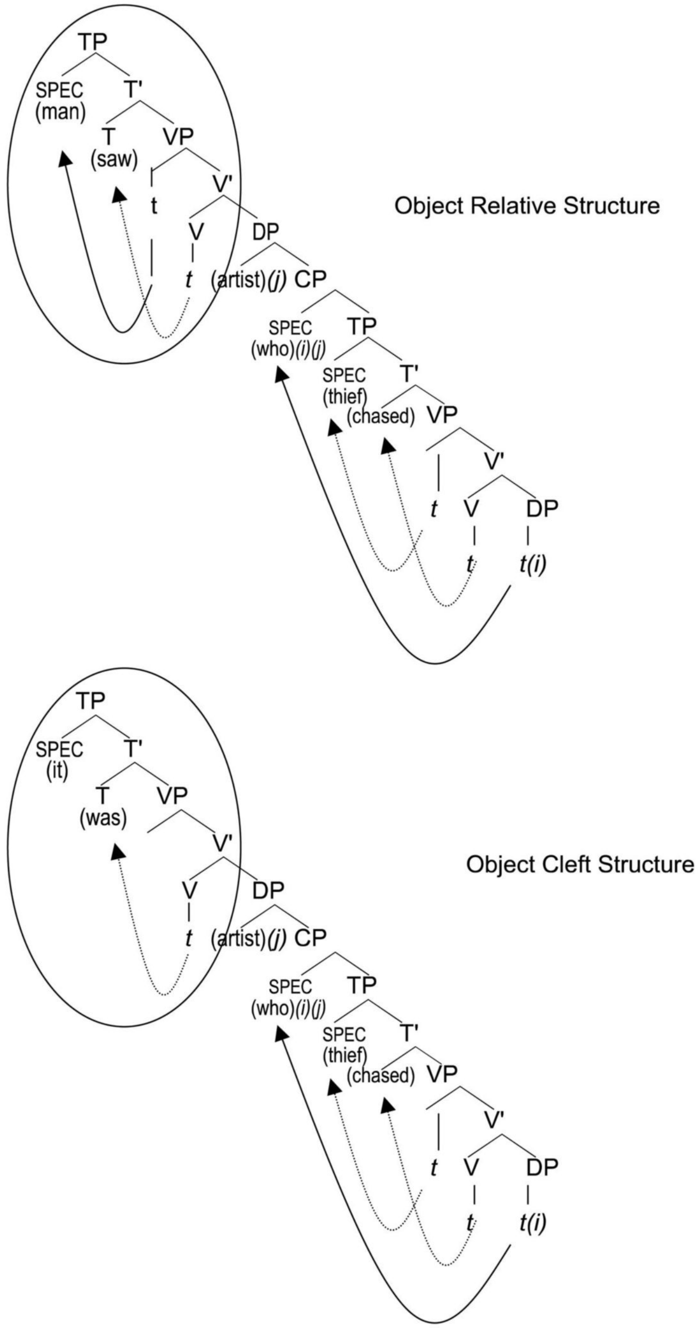

FIGURE 4.

Tree diagram showing object relative (top) and object cleft (bottom) constructions. Note that while *wh*-movement in both structures is identical to that in *wh*-questions (shown in Figure 3), the material in the main clause (circled) in the two structures is different. Subject movement from within the VP is shown for object relatives, which is not involved in object cleft sentences, rendering object relatives more complex than object clefts. Object relatives also require a lexical verb (i.e., *saw*) in the main clause, which assigns thematic roles; the verb in the main clause in object clefts is a copula, which cannot assign thematic roles.

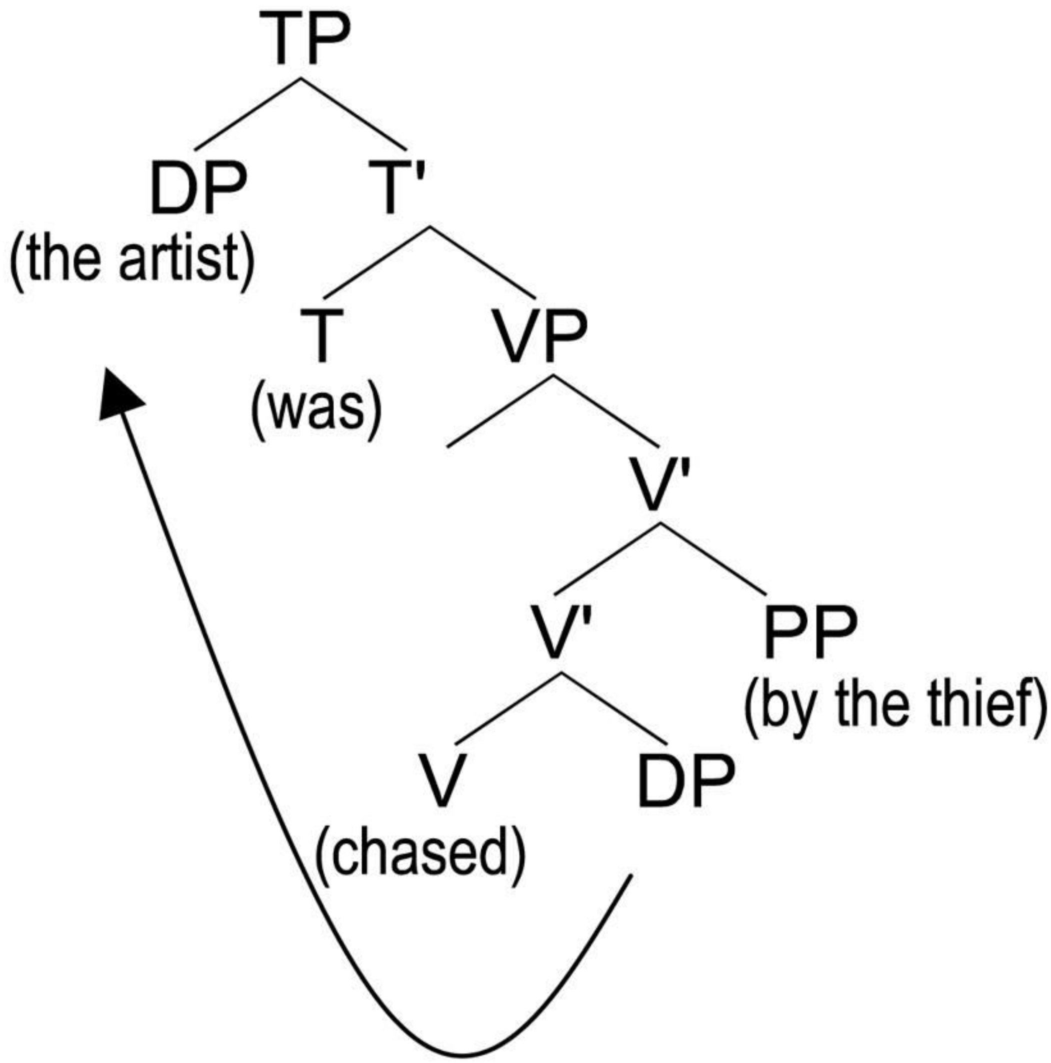

FIGURE 5.
Tree structure showing NP-movement in passive sentences. The object of the verb *chase* (*the artist*) moves to Spec, TP, leaving behind a trace/copy of movement.

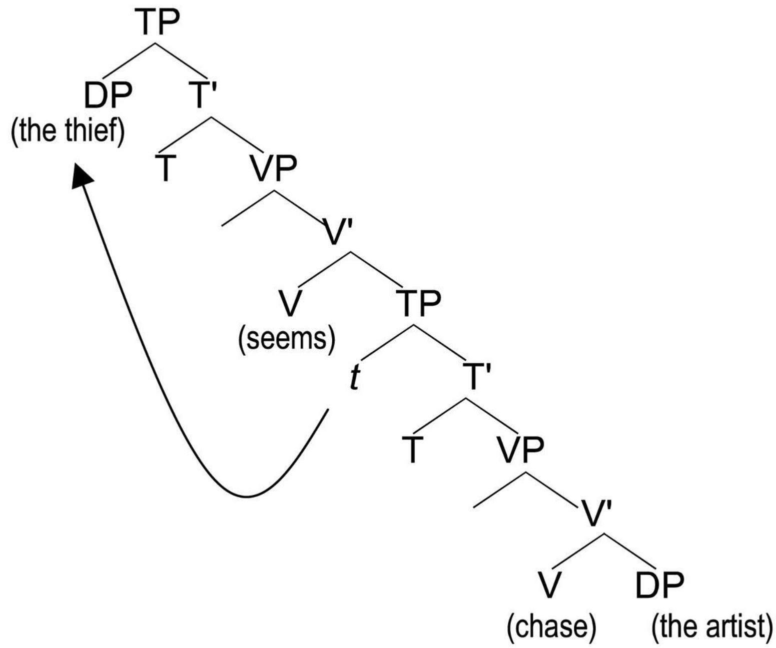

FIGURE 6.
Tree structure showing NP-movement in subject raising structures. The object of the raising verb, *seems (the thief)*, moves to Spec, TP, leaving behind a trace/copy of movement.

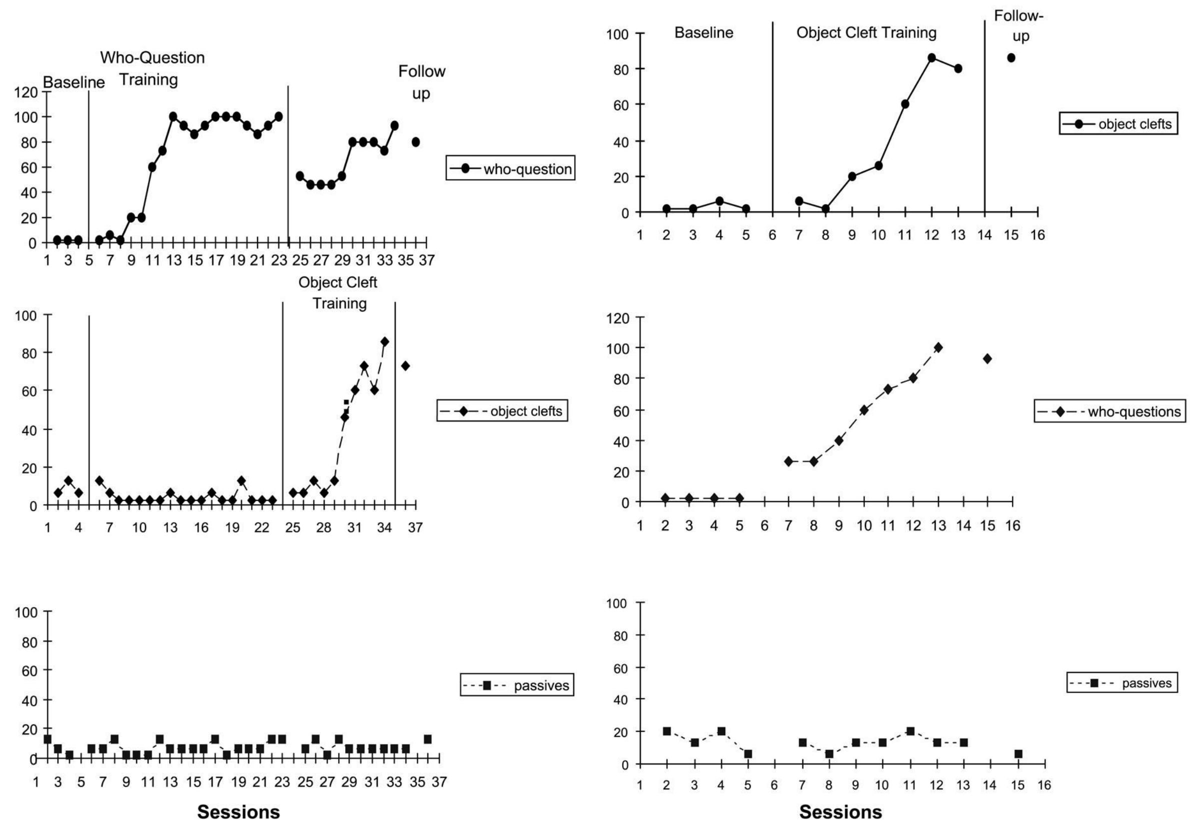

FIGURE 7.

Data from 2 participants in Thompson et al. (1998). Left panel shows acquisition and generalization effects of training simple *wh*-movement structures. Training who-questions did not improve object clefts. Right panel shows acquisition and generalization effects of training more complex *wh*-movement structures. Training object clefts improved who-questions.

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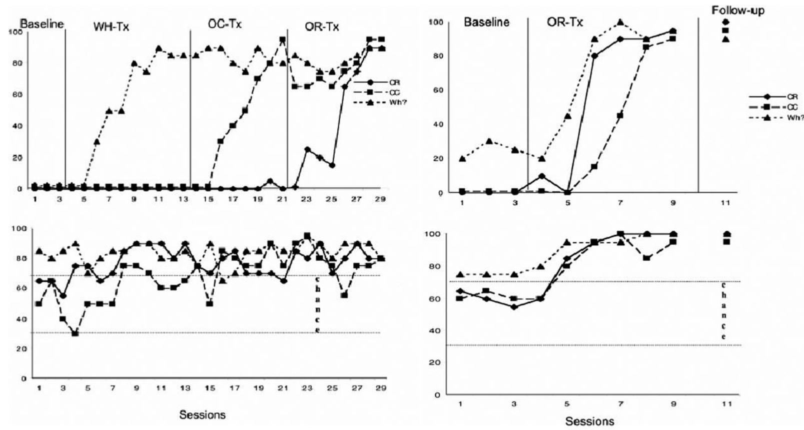

FIGURE 8.

Treatment effects resulting from training complex versus simple *wh*-movement structures. Data from 2 participants are shown (from Thompson et al., 2003). The left graph shows treatment progress when proceeding from simple object *wh*-questions to more complex forms (object clefts and object relatives); the right graph shows that for a participant trained first on the most complex syntactic form (object relatives).

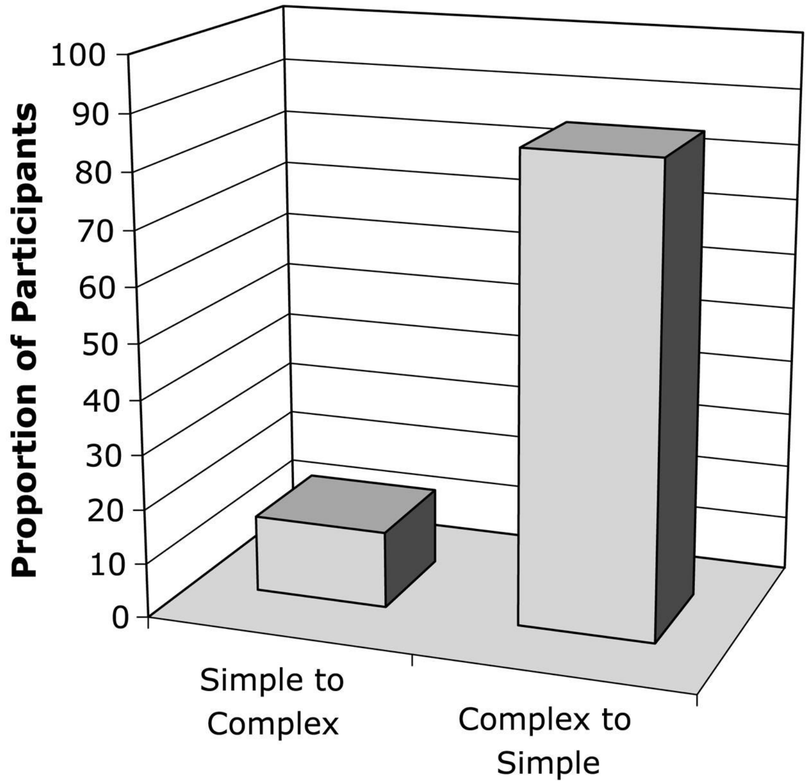

FIGURE 9.
Proportion of individuals with agrammatic aphasia who showed generalization from simple to complex and from complex to simple *wh*-movement structures across studies.