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Cross-Modal Generalization Effects of Training Noncanonical Sentence Comprehension and Production in Agrammatic Aphasia

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Abstract

The cross-modal generalization effects of training complex sentence comprehension and complex sentence production were examined in 4 individuals with agrammatic Broca's aphasia who showed difficulty comprehending and producing complex, noncanonical sentences. Object-cleft and passive sentences were selected for treatment because the two are linguistically distinct, relying on *wh*-and NP movement, respectively (Chomsky, 1986). Two participants received comprehension training, and 2 received production training using linguistic specific treatment (LST). LST takes participants through a series of steps that emphasize the verb and verb argument structure, as well as the linguistic movement required to derive target sentences. A single-subject multiple-baseline design across behaviors was used to measure acquisition and generalization within and across sentence types, as well as cross-modal generalization (i.e., from comprehension to production and vice versa) and generalization to discourse. Results indicated that both treatment methods were effective for training comprehension and production of target sentences and that comprehension treatment resulted in generalization to spoken and written sentence production. Sentence production treatment generalized to written sentence production only; generalization to comprehension did not occur. Across sentence types generalization also did not occur, as predicted, and the effects of treatment on discourse were inconsistent across participants. These data are discussed with regard to models of normal sentence comprehension and production.

Keywords

agrammatic aphasia; treatment; sentence production; sentence comprehension; cross-modal generalization

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Until the early 1970s agrammatism was considered largely a problem of sentence production reflecting an absence of grammatical structure (Goodglass, 1968; Goodglass & Berko, 1960; Goodglass & Hunt, 1958). Later characterizations have shown that, in addition to sentence production deficits, individuals with agrammatic aphasia also show difficulty comprehending sentences (Caplan & Futter, 1986; Caplan & Hildebrandt, 1988; Caramazza & Zurif, 1976), although not all such individuals show this pattern (Berndt, Mitchum, & Haendiges, 1996). Notably, in individuals with sentence comprehension difficulty, the

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deficit is restricted to sentences that are semantically reversible (e.g., *Quinn chased Zack*, in which the two nouns are equally probable candidates for the thematic role of "agent") and is particularly appreciable in complex sentences in which noun phrases (NPs) have been moved out of the canonical (S-V-O) position as in passives (e.g., *Zack was chased by Quinn*) and object-cleft sentences (*It was Zack who Quinn chased*).

Although the relation between sentence comprehension and production is not completely clear, current theories show parallels of organization between the two systems (Garrett, 1995). This paper focuses on individuals with aphasia who have such co-occurring deficits and experimentally examines the generalization effects of training sentence comprehension on sentence production and vice versa, using linguistic specific treatment (LST). Before detailing the current experiment, we present a brief linguistic description of the two complex-sentence types of interest here and discuss some theoretical issues concerned with the relation between sentence production and comprehension.

Complex Sentence Formation

According to linguistic theory, in particular Chomsky's (1986) government and binding (GB) theory, there are at least two levels of description for noncanonical sentences such as passives and object clefts: the underlying or d-structure and the surface or s-structure. In order to form the s-structure of such sentences, movement of certain sentence constituents (usually NPs) from d-structure to s-structure is required. This transformation is referred to as "move alpha." When movement occurs, a "trace" or phonologically empty gap is left behind in the position from which the moved constituent originated, and a link or "chain" between the trace site and the moved constituent is set up.

There are two types of movement: NP movement (for passives, subject raising, etc.) and *wh*-movement (for object clefts, object extracted *wh*- questions, etc.). These types of movement are similar in that both leave behind traces in positions that are assigned thematic roles by the verb (i.e., in the direct-object position). They differ, however, in the position that the moved sentence constituent takes in the s-structure. In NP movement, the moved NP lands in another argument position forming an argument chain; whereas, in *wh*- movement, it lands in a nonargument position, forming a nonargument chain. Regardless of landing site, however, the thematic role of the moved sentence constituent (assigned in d-structure prior to movement) is retained. We provide further detail about passive and object-cleft sentences (the sentence types that are the focus of this study) below.

Passives—Passives, like other noncanonical sentences, are derived from an underlying or d-structure approximated in (1). The symbol Ø is used to indicate a site that is vacant at d-structure. In this case, the vacant slot is an argument position (i.e., the subject position). Thus, when the direct object NP *the student* is moved, it moves to an argument position, rendering an argument chain as in (2). A trace is left behind, marked with *t*, and a chain is established between the trace site and the moved NP. The chain is shown with the notational subscript *i*.

(1) Ø was lifted the student by the biker.

(2) [The student_i was lifted t_i [by the biker]].

Object Clefts—The underlying or d-structure for an object-cleft construction is approximated in (3). Notably, in (3) the Ø marks a nonargument position (a position that does not accept an argument of the verb). To form the object cleft as in (4), movement occurs from the direct object position to this nonargument position, thus a nonargument chain is established. When the direct object is moved, a trace of its movement is left behind, marked as *t*. The chain, shown in (4), shows the relation between the trace site (*t*) and the landing site. Object clefts also involve a co-referential relation between the head of the relative clause *the artist* and *who.* This is shown with the superscript *j*.

(3) It was the artist [Ø the thief chased who].

(4) It was the [the artist ^{j} [who $^{j}{}_{i}$ [the thief chased t_i].

The reader is referred to Shapiro (1997); Thompson, Shapiro, Ballard, Jacobs, Schneider, & Tait (1997); and Thompson, Ballard, & Shapiro (1998) for further linguistic descriptions of these two types of movement.

It turns out that the fundamental linguistic distinction between these types of movement has implications for sentence processing (i.e., *wh*- movement structures require more processing resources than NP movement structures because *wh*- movement involves movement across clausal boundaries; Berwick & Weinberg, 1984). Thompson et al. (1997) and Ballard & Thompson (1999) also have shown that the recovery patterns for sentences involving the two types of movement are distinct. For example, training structures requiring *wh*-movement (e.g., object clefts) has no influence on structures requiring NP movement (e.g., passives). Interestingly, however, structures relying on the same type of movement (e.g., object clefts and who questions) show similar recovery patterns.

Importantly, individuals with agrammatic aphasia who have comprehension deficits have difficulty comprehending both types of sentences, perhaps because of failure to generate syntactic representations such as traces marking lexical positions (the trace deletion hypothesis, Grodzinsky, 1995). This failure results in inability to coindex traces with antecedents. Without this co-indexation, individuals with aphasia resort to a default strategy, interpreting sentence NPs in linear order (i.e., agent first). Other theories consider the impairment to be related to difficulties with operations that “map” the thematic (semantic) roles of nouns onto grammatical categories in the syntax (Linebarger, Schwarz, & Saffran, 1983; Saffran, & Schwartz, 1988; Schwartz, Linebarger, Saffran, & Pate, 1987). Production of noncanonical sentence constructions, such as passives and object clefts, is also problematic for individuals with agrammatic aphasia (i.e., they tend to produce mostly simple sentences constructions in connected speech; Bates, Friederici, Wulfeck, & Juarez, 1988; Saffran, Berndt, & Schwartz, 1989).

Relation Between Sentence Comprehension and Production

The relationship between comprehension and production abilities in aphasia is not well understood. Some studies have reported dissociations between production and comprehension ability in individuals with agrammatism (Caramazza & Hillis, 1989; Miceli, Mazzucchi, Menn, & Goodglass, 1983). Martin, Wetzel, Blossom-Stach, & Feher (1989), for example, found no clear relationship between production and comprehension of morphological or structural sentence variables. Such dissociations suggest that common mechanisms are not utilized in comprehension and production of sentences (Shallice, 1988). However, the observation that many individuals with agrammatic aphasia show difficulties with both comprehension and production of noncanonical sentences suggests that further study of this cooccurrence is warranted.

Models of normal sentence comprehension and production do not articulate clearly the relation between the two processes, although they illustrate their minimal requirements. For example, Garrett’s (1980, 1984) model of normal sentence production includes several stages of sentence planning, from an early conceptual stage (message level) where ideas to be expressed are generated, to an articulatory stage where motor codes for production are accessed. Two separate intermediate levels are concerned with structural formulation of sentences, the functional level wherein semantically specified lexical content items (open-class words) are accessed and their thematic roles are assigned, and a positional level wherein grammatical elements (closed-class bound and free-standing morphemes) are accessed, phonologically specified, and inserted into a sentence frame together with now phonologically specified content words.

Garrett (1995) presents an aggregate model of sentence comprehension and production, which includes processing levels for phonology, prosody, lexical structure, syntax, and message-level expressions, and two major processing streams, one concerned with accessing lexical elements and the other with constructing a framework into which lexical elements are integrated (see Figure 1). This model indicates that the two systems are parallel; however, there are differences between comprehension (input) and production (output) processes. For example, planning operations for production begin with internalistic conceptual processes concerned with the message that the speaker intends to convey. The opposite is true for comprehension; the listener performs operations on externally provided input.

Garrett (1995) asserts that "production and comprehension processes are distinct, but intricately intertwined; both are deployed in time, and both draw on multiple cognitive resources" (page 881). Comprehension involves mapping from acoustic-phonetic representations to message via intervening lexical recognition/integration and prosodic/syntactic analyses. A prosodically motivated phrasal structure is first developed into which lexical forms are assimilated. Next, sentence parsing routines are engaged, which involve both lexical and syntactic processes: designation of constituent structure (i.e., noun phrases, verb phrases), thematic role assignment, determination of predication relations, and co-referential processes. In production, lexical selection (e.g., open class item choice, thematic role assignment) and syntactic construction (sentence frame generation) precede word-form selection and prosodic construction.

In spite of the considerable overlap in comprehension and production processes, the extent to which comprehension and production deficits seen in agrammatic aphasia result from impairment to a shared component remains unknown. One way to examine functional relationships is to use a treatment research paradigm. If deficits in comprehension and production processes result from the impairment of a shared component or components, then treatment focused on that component would be expected to result in parallel improvements in both processes, even if only one is targeted in treatment.

Treatment for Sentence Comprehension and Production Deficits

Several treatment studies have examined the effects of "thematic mapping" on sentence comprehension (Byng, 1988; Jones, 1986; Mitchum, Haendiges, & Berndt, 1995; Nickels, Byng, & Black, 1991; Schwartz, Saffran, Fink, Myers, & Martin, 1994). This approach is focused on training individuals to map the grammatical roles of nouns (e.g., subject, object) onto their corresponding semantic (thematic) roles (e.g., agent, patient). Using this approach, Schwartz et al. (1994) documented improvements in sentence comprehension. However, the improvements were limited to the types of sentences treated (canonical sentences) with little improvement noted on noncanonical sentence types such as passives and object relatives. Improvements in production also were noted for some participants in the study.

Mitchum et al. (1995) used a different thematic mapping approach to improve auditory comprehension of sentences. Their approach focused on the relation between NP order and verb morphology (sentence surface structure and morphology) in semantically reversible active and passive sentences. Results showed that treatment improved comprehension of thematic roles in spoken sentences but had little effect on production of thematic roles in the same types of sentences. An unanticipated result was improved comprehension of written sentences, even though no written stimuli were used in treatment. Although the reasons for this cross-modal improvement were not clear, Mitchum et al. suggested that "the locus of improvement might have involved abstract representations or procedures that are not tightly bound to the nature of the input" (p. 531).

Mitchum, Haendiges, and Berndt (1993) also reported cross-modal generalization resulting from treating written sentence production. Using Garrett's (1984) model as a guide, two interventions were provided: the first focused on written naming of verbs, and the second focused on learning to construct a grammatical frame. Results indicated improvement in the syntactic well formedness and lexical/semantic content of both trained and untrained written sentences and generalization to spoken sentences. Mitchum et al. interpreted the improvement in sentence construction across output modalities as a type of "intra-linguistic" generalization, suggesting that intervention focused on processing operations shared by all output modalities would be expected to generalize without training to other output modalities. The finding of cross-modality generalization challenged Garrett's (1984) assertion that positional level representations are phonological in form and supported the argument that they are, instead, a more abstract, modality-neutral code.

The recent work of Thompson and colleagues (Thompson et al., 1997, 1998; Thompson, Shapiro, & Roberts, 1993; Thompson, Shapiro, Tait, Jacobs, & Schneider, 1996), which focused on training individuals with agrammatic aphasia to produce noncanonical sentences (e.g., object-extracted *who* questions, object clefts), has shown that generalization occurs to sentences that are linguistically similar to those trained. Their linguistic specific treatment (LST) controls the lexical (e.g., verb type and argument structure) and syntactic properties (e.g., type of movement) of sentences entered into treatment, and generalization to sentences that are linguistically similar and to those that are linguistically dissimilar is examined. Using the active form (e.g., *The thief chased the artist*) of target noncanonical sentences (e.g., *It was the artist who the thief chased*), participants with agrammatic aphasia first learn to identify the verb and the thematic roles of the sentence NPs. This first treatment step is similar to mapping therapy. Next, and crucially, participants are trained to produce target sentences by going though a series of steps emphasizing the movement that is required to derive the noncanonical surface form, and how the thematic role of sentence NPs are retained regardless of the position they take in the surface string. LST, therefore, goes one step beyond mapping therapy, emphasizing the position that sentence constituents take in the surface form.

Thompson and associates' most recent experiments (Thompson et al., 1997, 1998) used this approach to examine the relation between *wh*- and NP movement constructions. It was predicted that training production of sentences that require, for example, *wh*- movement (e.g., object clefts) would result in generalization to untrained sentences that also require *wh*- movement (e.g., *who* questions) but that this training would have no influence on production of sentences that require NP movement such as passives. Results followed the predicted pattern: treatment resulted in generalization to sentences with the same type of movement, but no generalization was noted to sentences with differing movement. These findings, considered together with the results of studies of mapping therapy, suggest that generalization occurs when the training condition unites processes that are used for both trained and untrained structures (e.g., thematic role assignment, type of linguistic movement), and for both trained and untrained domains (e.g., verbal production and written production).

None of the aforementioned studies have explicitly examined the relation between sentence comprehension and production in individuals with agrammatic aphasia. Studying abilities in both domains is important, not only to contribute to our understanding of comprehension and production processes, but also to ascertain the extent of generalization resulting from treatment. The present study extends Thompson and colleagues' previous research and additionally examines the functional relation between sentence comprehension and production as well as between spoken and written sentence production. The primary focus of this study was to evaluate the effectiveness of sentence comprehension and production training on production and comprehension of two complex sentence constructions, passives and object clefts, that involve NP and *wh*- movement, respectively, in individuals with agrammatic aphasia. The following questions were posed:

1. Does linguistic-specific comprehension or production treatment result in improved comprehension or spoken production of reversible passive and object-cleft sentences in individuals with agrammatic aphasia?

2. If comprehension and/or production of the target sentence type improve with treatment, does generalization occur to untrained exemplars of the trained type and/or to untrained sentences of the alternate type?

3. If comprehension and/or production of the target-sentence type improve, does generalization occur from comprehension treatment to spoken production, from production treatment to comprehension, or to written production and oral discourse?

Based on the results of previous studies that employed LST (Thompson et al. 1997, 1998), it was predicted that production treatment would facilitate improvement of both trained and untrained exemplars of the trained form, but that generalization across sentence types would not occur. Because written and spoken production require similar formulation processes, we postulated that generalization across domains might be forthcoming. We also considered that such generalization might not occur, for example, if graphemic output encoding and/or processes involved in written execution were impaired. Similarly, we predicted that training comprehension of certain sentence types would result in improved comprehension of sentences like those trained, but that generalized comprehension across sentence types would not be forthcoming. Finally, we postulated, based on Garrett (1995), that focusing treatment on lexical and syntactic processes that are involved in both comprehension and production might facilitate cross-modal generalization. However, we also entertained the notion that such generalization might not be seen, primarily because the starting point for the two processes is different.

Method

Participants

Four neurologically stable adults with aphasia (ages 39 to 79; 2 men and 2 women) who had difficulty comprehending reversible noncanonical sentences and showed agrammatic patterns of sentence production participated in the study. All were monolingual English speakers with at least a high-school education. Each had aphasia caused by a single left-hemisphere CVA that had occurred at least 6 months prior to the initiation of the study (range = 27–198 months). Intact peripheral hearing was verified by audiological screening at 500 Hz and 1 kHz at 30 dB and 2 kHz at 35 dB binaurally, and vision screening documented at least 20/40 acuity with or without corrective lenses. Participants' histories were negative for other neurological disorders or psychiatric problems. All had received prior speech-language treatment of a traditional nature (i.e., it was unlike the present approach and was not explicitly focused on sentence production or comprehension) for varying periods of time; none were involved in any other treatment during the course of this study.

Prior to initiating treatment, the tests summarized in Table 1 were administered to all participants. On the Western Aphasia Battery (WAB; Kertesz, 1982), individuals' scores were consistent with a profile of Broca's aphasia: auditory comprehension was superior to production, and spontaneous speech was nonfluent and agrammatic. Their repetition scores reflected mild to moderate motor programming difficulty; as the length and complexity of stimuli increased so did production difficulty. Degree of motor difficulty, however, did not compromise sentence intelligibility. Scores on the Naming Subtest of the WAB and the Test of Adolescent/Adult Word Finding (TAWF; German, 1990) indicated moderate word retrieval problems.

The participants' scores on both the WAB and the Revised Token Test (RTT; McNeil & Prescott, 1978) indicated difficulty with auditory comprehension as the length and complexity of stimuli were increased. The Philadelphia Comprehension Battery for Aphasia (PCBA; Saffran, Schwartz, Linebarger, Martin, & Bochetto, n.d.) was administered to test grammaticality judgement, contrast their lexical comprehension with sentence comprehension, and assess their comprehension of different sentence types, particularly those of interest in this study. Scores on the PCBA indicated that the participants' lexical comprehension was superior to their overall sentence comprehension; comprehension of lexical (nonreversible) sentences was better than comprehension of reversible sentences. Likewise, scores on canonical active and subject-relative clause sentences were better than scores on noncanonical passive and object-relative clause sentences. All participants' grammaticality judgment scores were superior to their overall sentence comprehension scores.

Four discourse samples (two narrative and two conversational) were obtained from each participant prior to treatment in order to document agrammatic production profiles and to compare pre- to posttreatment ability. Narratives were elicited by asking participants to tell the Cinderella story. Conversational samples were obtained by having the participant and a family member view and subsequently discuss short (5-minute) randomly selected, prerecorded ABC "American Agenda" news segments. All samples were audiotaped, transcribed, and coded for a number of linguistic variables using the procedures developed by Thompson, Shapiro, Tait, Jacobs, Schneider, and Ballard (1995). The coded transcripts were analyzed using the Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1986) computer program. The senior author transcribed and coded all language samples. All transcripts were checked for transcription accuracy, and half of the samples were recoded for reliability by a trained independent judge. Disagreements of transcription and coding were discussed and resolved by the senior author. Interjudge agreement of both utterance segmentation and coding across all linguistic variables exceeded 80%.

Participants' pretreatment mean scores (Table 2) across the four discourse samples indicated MLUs ranging from 3.01 to 6.09. The percentage of grammatically correct sentences ranged from 10% to 35%. All individuals used more simple than complex sentences, and they produced few utterances with embedded clauses. In addition, all participants produced more open- than closed-class words; however, only 1 individual (Participant 2) used more nouns than verbs.

Experimental Stimuli

Twenty active semantically reversible sentences of the form NP-V-NP were developed. Ten were selected for training, and 10 were used to assess generalization to untrained exemplars. The sentences were all five words in length, and each sentence contained two concrete, picturable, singular nouns representing humans (e.g., woman, man, mother, baby, runner, coach, waiter, cook, doctor, nurse, etc.). The same 10 regular transitive verbs were used in the trained and untrained sentence sets (kissed, chased, touched, measured, tickled, followed, handcuffed, kicked, covered, phoned). The nouns and verbs in the sentences were one or two syllables long. Mean frequency for nouns was 151.2 per million words; mean frequency for verbs was 46.8 per million (Francis & Kucera, 1982). All nouns and verbs received high familiarity ratings from non-brain-damaged individuals (Nusbaum, Pisoni, & Davis, 1984).

Foils for each of the 20 stimulus sentences were constructed by reversing the NPs in the target sentences. For example, for the target sentence *The mother kissed the baby*, the foil sentence was *The baby kissed the mother*. Black line drawings and written sentences were prepared for each target and foil sentence. Individual sentence elements (e.g., NPs, Vs) used during training were written on index cards.

Experimental Design

A multiple-baseline across-behaviors (Kearns, 1986; Connell & Thompson, 1986) design was used to assess generalization across sentence types (one type was held in baseline and monitored for change while treatment was applied to the other). Two multiple baseline studies resulted; one investigated the effects of comprehension treatment, and the other investigated the effects of production treatment.[1] The order of treatments and behaviors was counterbalanced across participants; Table 3 outlines the treatment method and order of sentence types trained.

Upon completion of treatment, two narrative language samples and two conversational samples were obtained in the same manner as before treatment and analyzed to assess generalization of treatment effects to discourse. Generalization to written production of experimental sentences was tested at treatment phase changes and at posttreatment.

Baseline Procedures—Comprehension and oral and written production of passive and object-cleft sentences were assessed prior to treatment in a baseline phase. Comprehension was tested by randomly presenting a target and foil picture pair. Pictures were randomly placed side-by-side. The participant was instructed to point to the picture that corresponded to the target sentence after the examiner said it. No repetitions were given, and responses within 5 seconds were scored as either correct or incorrect by the examiner. If the individual made no response within 5 seconds, the item was scored as incorrect, the stimulus pair was removed, and the next pair was presented.

Sentence production was tested using a sentence production priming procedure. Each stimulus picture pair along with the corresponding written active sentences (to ameliorate potential word retrieval difficulty) was presented. The examiner pointed to the pictures and said, “Here are two pictures. Both show a woman and a man kissing.” An oral model was given for the foil picture (e.g., “In this picture, *the woman was kissed by the man*”). The individual’s attention was then directed to the target picture, and an oral prompt was provided (e.g., “But in this picture…”). Five seconds were allowed for a response to be initiated before removing the stimulus pair and presenting the next randomly selected pair. Responses were immediately transcribed, scored by the examiner, and audiotaped for later reliability transcription and scoring.

Written sentences were elicited in a manner similar to that for oral production; however, 2 minutes were allowed for an individual to write his or her response before the examiner removed the stimulus pair and presented the next randomly selected pair. This procedure

[1]A modified alternating treatment design (ATD; Barlow & Hayes, 1979; Thompson & McReynolds, 1986) was originally planned to compare the effects of the two treatments following application of each treatment independently. If improvement on the first sentence type trained was not noted within 15 sessions using one of the treatments independently, both treatments would be applied simultaneously—one to one sentence type and the other to the other sentence type. This phase was not necessary for any of the subjects, as all showed treatment effects during the first treatment phase for both treatment methods and sentence types.

was repeated until all stimuli for both sentence types were presented. Oral and written responses were scored as correct when a grammatical, appropriate, and intelligible or legible sentence for the target picture was produced (minor paraphasias, paragraphias, and/or spelling errors were allowed).

Treatment—When a stable baseline was obtained over at least two test sessions, treatment began with application of one treatment (comprehension or production) to one sentence type (passive or object cleft) for each individual. All participants were treated individually two or three times weekly; treatment sessions were 1 to 1.5 hours in length. Approximately half of the beginning of each session was spent testing acquisition and generalization using procedures identical to those used during baseline; the remaining half was devoted to training. Each of the 10 target sentences was trained twice in random order during each treatment session.

Comprehension and production training required identification of the verb and thematic roles associated with the verb. Individual index cards with the written subject NP, verb, and object NP representing the target picture were presented along with additional individual cards required for the target sentence (*was* and *by* cards for passives, *It was* and *who* cards for object clefts). Using the written active form of target sentences (e.g., *The mother kissed the baby*) and its corresponding picture, individuals receiving comprehension training were instructed to identify by pointing to the appropriate NP or verb (e.g., “Point to the action, the person who performed the action, the person who received the action.”); whereas, individuals receiving production training were instructed to produce responses to questions (e.g., “What is the action? Who performed the action? Who received the action?”). Feedback was provided for correct responses.

For both comprehension and production treatment, individuals were provided information concerning the movement required to form target noncanonical sentences. For example, to train the passive using its active counterpart (*The mother kissed the baby*), the object NP (*the baby*) was moved from sentence-final to initial position, and it was explained that *The baby was kissed;* the auxiliary verb *was* was added, and the subject NP was moved to the post verbal position. Finally, it was explained that in order to make a grammatical sentence the word *by* is needed, and this grammatical morpheme was added to the sentence frame.

During production training, individuals were instructed to read the newly formed target sentence orally; then the sentence elements were rearranged in their active form, and the participant was instructed to add and move the elements as previously demonstrated to formulate the target sentence. When the correct sentence was formed, the individual was again instructed to read it aloud. Assistance was provided as needed and oral reading errors were corrected with a verbal model.

During comprehension training, the newly formed target sentence was read aloud by the trainer, and the participant was instructed to identify, by pointing to the verb, the subject NP and the object NP in the surface structure of the target sentence. The examiner pointed to correct sentence elements when the participant identified an erroneous sentence constituent.

The comprehension training protocols did not demand any overt oral response from the participants; whereas, the production training protocols did not demand any overt response to indicate comprehension (no pointing response to indicate understanding of sentence constituents). The primary difference between the training methods (other than overt comprehension response vs. overt production response) was in the final step in the training procedures. The comprehension procedures required individuals to demonstrate their understanding of the thematic roles of the subject and object NPs in the surface structure of the target sentence after the NPs were moved from canonical position; whereas, the production procedures required individuals to formulate the target sentence by moving the elements from the active form and adding the elements necessary to derive the surface noncanonical form.

When the criterion of 80% accuracy of the 10 target sentences in two of three consecutive sessions (or a maximum of 15 treatment sessions) was reached, the second sentence type was trained by applying the same treatment used for the first sentence type. When criterion was reached on the second sentence type, treatment ended, and a follow-up measurement was obtained 2 weeks later to assess maintenance. The total number of treatment sessions ranged from 8 to 11 over a 5-week period for the individuals who received production treatment and from 13 to 19 over a 7- to 10-week period for the individuals who received comprehension treatment.

Reliability

Interjudge reliability of responses produced on baseline and treatment testing of oral and written production and comprehension was examined. Half of the baseline sessions and one-third of the treatment sessions for each subject were scored by the primary clinician and a trained, independent judge. Point-to-point agreement ranged from 80% to 100% (M = 93%) for all responses scored.

Results

Production Treatment

Figures 2 and 3 show the effects of production treatment on spoken production of trained and untrained sentences by Participants 1 and 3, respectively. Following baseline, when production of target sentences was at 0% correct for both participants, treatment was initiated, during which time production improved to 100% correct within three to four sessions. Production of untrained exemplars of the trained sentence types also increased, whereas production of the untrained sentence type remained essentially unchanged (0–25% accurate). When the second sentence type was treated, the treatment effect was replicated; once again, both participants reached high performance levels on trained items and showed corresponding increases on untrained sentences. Because Participant 1’s performance on object-cleft sentences declined during training of passives, treatment was reapplied for three additional sessions; this training resulted in a return to high levels of correct production on this sentence type. During follow-up testing 2 weeks posttreatment, both individuals performed at levels substantially above baseline for both sentence types.

Baseline comprehension performance for both Participants 1 and 3 was at or below chance (ranging from 15% to 40% correct for Participant 1 and from 45% to 65% for Participant 2).[2] During the first treatment phase, both participants’ comprehension of the trained sentence type was essentially unchanged from baseline; whereas, their comprehension of the untrained type increased slightly. During the second treatment phase, Participant 1’s comprehension of the trained sentence type (passives) showed a gradual increase; however, overall performance was unchanged from baseline. Participant 3’s comprehension of the trained sentence type (object clefts) declined during production training. Retraining of object-cleft sentences in the third treatment phase for Participant 1 had little effect on comprehension. Follow-up testing 2 weeks posttreatment reflected performance levels that were no better than baseline for either sentence type for either participant.

[2]Performance below 40% correct was significantly below chance; performance above 65% correct was significantly above chance.

Comprehension Treatment

Figures 4 and 5 show the effects of comprehension treatment for Participants 2 and 4, respectively. During baseline sessions, both showed comprehension ability similar to that of Participants 1 and 3 (at or below chance levels), ranging between 20% and 50% accuracy for Participant 2 and 40% and 60% accuracy for Participant 4. Once treatment was initiated, comprehension of trained sentences gradually increased, and Participant 2 reached an 80% correct level within five sessions, although variable performance was noted during the remainder of this treatment phase. Participant 4 showed similar performance, with comprehension increasing to the 90% level and then dropping. Comprehension of untrained exemplars of the trained sentence type also increased, but accuracy levels remained largely within the range of chance. Comprehension of the untrained sentence type remained unchanged during this training phase. When the second sentence type was trained, both participants' comprehension increased to above chance levels. Both individuals continued to comprehend trained sentences at levels above baseline on follow-up testing; however, performance declined on untrained sentences.

During comprehension training, both Participants 2 and 4 showed generalization to production. When passive comprehension was trained for Participant 2, production of passives increased from 0% to a high of 90% correct; when object-cleft comprehension was trained, object-cleft production increased to a high of 95% correct. Similarly, Participant 4 showed improved production of object clefts during object-cleft comprehension training (production increased to 100% correct), and of passives during passive comprehension training (production increased to 90% correct). Participant 2 maintained his ability to produce both sentence types on follow-up testing. Participant 4's production of object-cleft sentences declined during training of passives; however, her performance increased on follow-up testing. This pattern has been noted in other treatment studies of individuals with aphasia (Thompson et al., 1996, 1997, 1998) and is consistent with learning curves seen in normal language development (Gershkoff-Stowe & Smith, 1997; Goodluck, 1991).

Generalization to Written Sentence Production

Writing of trained and untrained sentences for both sentence types was tested four times during the study: prior to treatment, at treatment phase changes, and at 2 weeks posttreatment. Table 4 shows that written sentence performance for all participants was 0% accurate in baseline for both passive and object-cleft sentences. Production or comprehension training during Treatment Phase 1 resulted in increased written performance for the trained sentence types, but written production of the untrained types remained at 0% accuracy for all participants. Following training of the second sentence type during Treatment Phase 2, all participants' ability to write the trained sentence type also increased. The follow-up test showed performance on both sentence types was maintained above baseline levels.

Generalization to Discourse

Data from the narrative and conversational samples were combined and averaged to produce the pre- and posttreatment means presented in Table 2. Analysis of the data indicated that MLUs were slightly increased for 3 of the 4 participants (2, 3, and 4) and that 3 of the 4 participants used a greater percentage of complex versus simple sentences posttreatment (Participants 1, 2 and 3). All participants' ratios of open- versus closed-class words were unchanged posttreatment.

Discussion

The data from this study indicate that both linguistic-specific comprehension and production training resulted in acquisition of sentence types entered into treatment. Generalization to untrained exemplars of the trained sentence type also was seen. Generalization was not seen across sentence types, as predicted, in that the sentence types entered into the study were carefully selected to preclude such generalization. This latter finding supports Thompson and colleagues' earlier findings (Ballard & Thompson, 1999; Thompson et al., 1997) and provides further evidence that the linguistic nature of sentences influences recovery in aphasia. *Wh*-and NP movements are distinct linguistic constructs; therefore, generalization from one to the other should not be expected.

Of primary interest in this study was the relation between sentence comprehension and production. Interestingly, we showed that comprehension training resulted in generalization to production, whereas production treatment had little effect on comprehension ability. Our finding that comprehension training improved production ability supports observations made by Schwartz et al. (1994) in their study of the effects of mapping therapy. However, some mapping therapy studies have not shown such generalization, and questions have been raised pertaining to the purity of the comprehension training provided by Schwartz et al. (1994). Mitchum et al. (1995) pointed out that some mapping treatments allow spoken production (i.e., oral reading) as part of comprehension training, suggesting that this practice could influence production ability. In the present study, we did not require oral reading of written sentence stimuli during comprehension training. However, the written form of target sentences was available during treatment; therefore, participants may have subvocally produced target sentences during comprehension training. So it is possible that production improved because the comprehension treatment contained a production component.

It is also possible that comprehension treatment enhanced production more than production treatment enhanced comprehension for the participants in this study because production treatment required fewer treatment sessions than comprehension treatment. Indeed, participants receiving comprehension treatment received up to twice as many treatment sessions as those receiving production treatment. However, production improvement was noted for both participants after only a few comprehension treatment sessions. Thus, the length of treatment provided could not explain the disparate generalization patterns noted.

It also could be suggested that sentence production improved secondary to comprehension treatment because the functional mechanism(s) that was improved may have involved general principles used both in understanding and producing sentences. The present treatment, for example, provided explicit steps focused on the constituents of the sentence, thematic role assignment, *and* co-referential operations that function when sentence constituents move to noncanonical sentence positions, while retaining their thematic roles. In consideration of Garrett's (1995) model, it could be that treatment enhanced lexical recognition and integration, thereby improving the ability to correctly analyze or interpret the syntax. This ability could then be exploited in lexical selection and syntactic construction, resulting in improvements in both comprehension and production.

Why, then, was comprehension not influenced by production treatment? Indeed, the production treatment provided was quite similar to the comprehension treatment. Participants were required to produce the constituents of the sentence, including the verb and the NPs corresponding to the agent and theme of sentences, and they were provided with practice in formulating the correct position of sentence constituents in their non-canonical form. Finally, they were given practice in producing (reading) the target sentence form. The key to the failure of this approach to influence comprehension perhaps relates to the starting point for the two operations. As pointed out earlier, planning operations for production begin with internalistic conceptual processes concerned with the message that the speaker intends to convey. Lexical and syntactic operations are then engaged as well as phonological selection, prosodic construction, and articulatory processes. The opposite is true for comprehension; the listener performs operations on externally provided input. Our data suggest that practice accessing lexical and syntactic material for production is not enough to substantially influence sentence-parsing operations. Although similar mechanisms may be engaged for the two processes, there remain key processes involved in sentence parsing that were not influenced by production treatment.

Both comprehension and production training were effective in facilitating cross-modal generalization to written production for all 4 participants. These results are consistent with the findings of Mitchum et al. (1993) and support a model of sentence production in which positional level representations are modality neutral. They further suggest that pre-output operations (i.e., prior to construction of positional level representations) are shared between oral and written production. However, the finding of cross-modal generalization in the present study again questions the influence of using written stimuli in treatment. That is, this effect might not have emerged if written sentences had not been used in the training. Further research is needed to examine the influence of this component of treatment. This finding does suggest, however, that the “later” requirements of production (e.g., articulatory and graphemic output encoding and motor speech and writing execution processes) were not the source of spoken or written sentence production impairments in these participants.

Although positive changes in some participants’ posttreatment language samples were noted, the absence of consistent generalization to discourse suggests that either the treatment effects were not strong enough to substantially improve language production in more naturalistic conditions, or that the elicitation conditions used in the present study were not sensitive enough to capture changes in language ability that resulted from treatment. Indeed, it may be the case that the type of treatment provided here could not be expected to substantially influence language ability, although positive changes in the proportion of grammatical sentences and in the proportion of verbs produced with correct argument structure in posttreatment narrative samples have been reported in earlier studies (Thompson et al., 1997, 1998). The tasks used to elicit discourse samples also perhaps influenced output. For example, the narrative (Cinderella story) task is limited with regard to the types of verbs and sentence structures that it elicits, thus restricting the opportunity for participants to demonstrate language changes in the narrative condition. Similarly, partners in conversational interactions influence participants’ responses. Partners who use open-ended questions or comments provide more opportunity for participants to expand their responses beyond single words than those who ask primarily yes-no questions. Further research is needed to examine the influence of elicitation condition on language production.

Conclusion

The present study indicated that treatment resulted in improved ability to either produce or comprehend sentences entered into treatment in all of the individuals who participated in the study. Of greatest importance was the finding that comprehension treatment was superior to production treatment in facilitating cross-modal generalization (i.e., from comprehension to production), and that both treatments resulted in improvements in written sentence production. These generalization effects have important implications for models of normal sentence comprehension and production and help to further elucidate the nature of sentence comprehension and production impairments in individuals with agrammatic aphasia. Our data also are meaningful clinically. As pointed out by Thompson et al. (1997), given the current health care climate, which substantially restricts provision of treatment for individuals with aphasia, it is essential that clinicians provide treatment that will result in generalization. The present data suggest that training sentence comprehension might result in greater effects than training sentence production for individuals who present with deficit patterns like those seen in the individuals studied here.

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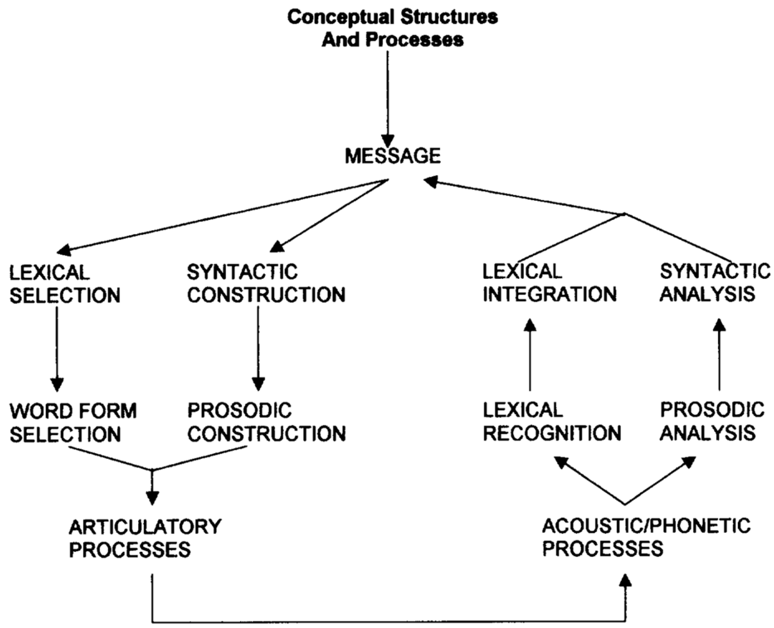

Figure 1.
Garrett's (1995) outline of information flow for language-production and language-comprehension systems.

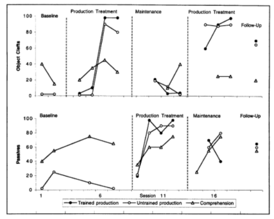

Figure 2.

Percent correct production and auditory comprehension of object-cleft and passive sentences for Participant 1 during baseline, production treatment, and maintenance phases of the study.

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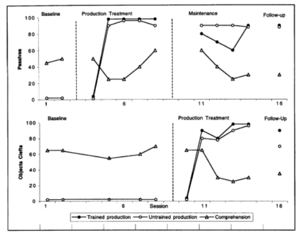

Figure 3.

Percent correct production and auditory comprehension of passive and object-cleft sentences for Participant 3 during baseline, production treatment, and maintenance phases of the study.

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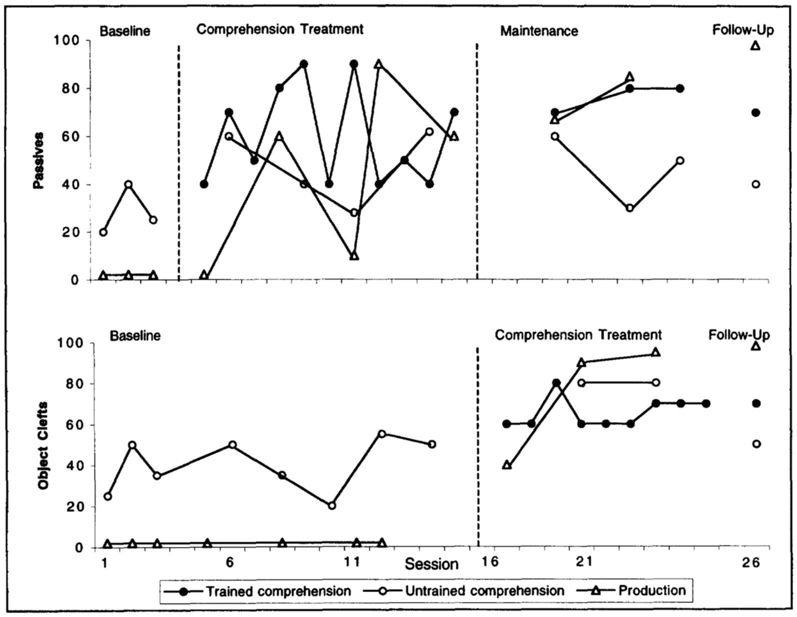

Figure 4.

Percent correct auditory comprehension and production of passive and object-cleft sentences for Participant 2 during baseline, comprehension treatment, and maintenance phases of the study.

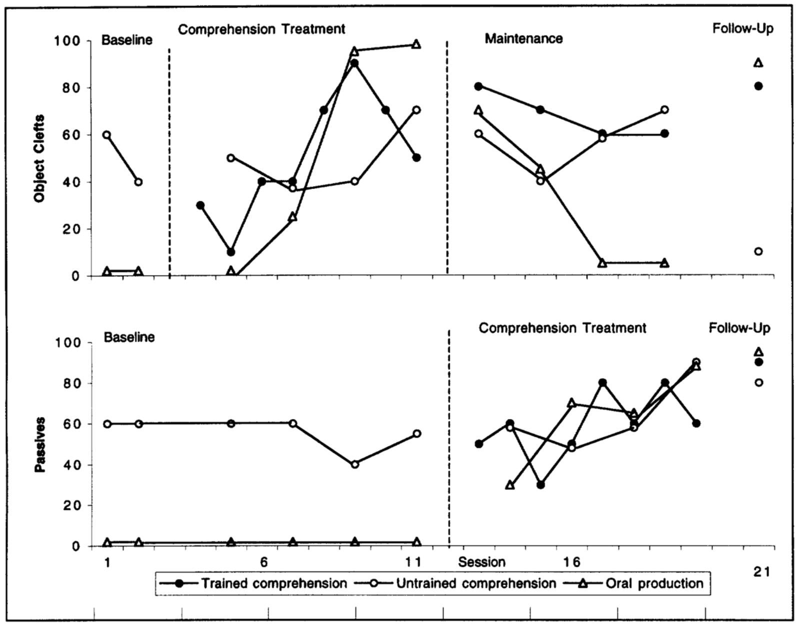

Figure 5.

Percent correct auditory comprehension and oral production of object-cleft and passive sentences for Participant 4 during baseline, comprehension treatment, and maintenance phases of the study

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Table 1

Language test data.

Participant	1	2	3	4
Western Aphasia Battery				
Aphasia quotient	77.0	63.3	62.4	68.0
Cortical quotient	80.4	68.1	72.4	73.9
Spontaneous speech	13.0	13.0	12.0	13.0
Fluency	5.0	4.0	4.0	5.0
Comprehension	9.6	7.5	8.1	7.9
Repetition	9.0	6.8	5.2	5.9
Naming	6.9	4.9	6.9	7.2
Reading	7.6	4.8	8.3	7.6
Writing	8.8	6.0	5.8	7.2
Revised Token Test				
Overall mean score	11.0	10.4	9.8	12.9
Test of Adolescent/Adult Word Finding				
Total items named across all subtests	41%	34%	39%	15%
Philadelphia Comprehension				
Battery for Aphasia				
Lexical comprehension	98% (43/44)	98% (43/44)	100% (44/44)	98% (43/44)
Sentence comprehension	77% (46/60)	67% (40/60)	77% (46/60)	82% (49/60)
Reversible sentences	60% (18/30)	47% (14/30)	53% (16/30)	70% (21/30)
Lexical sentences	93% (28/30)	87% (26/30)	100% (30/30)	90% (27/30)
Active/Subject- relative	83% (25/30)	77% (23/30)	87% (26/30)	87% (26/30)
Passives/Object-relative	75% (15/20)	50% (10/20)	60% (12/20)	75% (15/20)
Grammaticality judgment	95% (57/60)	86% (52/60)	92% (55/60)	93% (56/60)

Table 2

Pre- and posttreatment discourse data for the 4 participants in the study. Each entry represents means derived from two narrative and two conversational discourse samples.

	1		2		3		4		Normal in dividuals	
Participant Language variables	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Mean**	**(*SD*)**
Mean length of utterance (MLU)	4.99	4.98	3.02	3.15	3.01	3.17	6.09	6.36	13.33	(2.72)
% of grammatical sentences	35	37	10	9	13	10	21	16	77	(.08)
% of simple sentences	63	41	99	95	71	61	55	66	41	(14)
% of complex sentences	37	59	1	4	29	39	45	34	55	(13)
Mean embeddings (per utterance)	.40	.70	.01	.02	.25	.34	.50	.38	1.15	(.33)
Noun/verb ratio	1.0	.69	2.3	3.0	1.1	1.0	.71	.77	1.11	(.28)
Open/closed class ratio	1.1	1.1	1.9	2.4	3.2	3.3	1.2	1.3	.92	(.10)

Note. Normal individuals' data from Thompson et al., 1995.

Table 3

Order of sentence types trained and treatment method used across participants.

Participant	**1**	**2**	**3**	**4**
Treatment method	Production	Comprehension	Production	Comprehension
First type trained	Object-cleft	Passive	Passive	Object-cleft
Second type trained	Passive	Object-cleft	Object-cleft	Passive

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Table 4

Percent correct written sentence production.

Participant	1	2	3	4
Baseline				
Object cleft	0	0	0	0
Passive	0	0	0	0
Post-Training Phase 1				
Object cleft	85	0	0	70
Passive	0	100	100	0
Post-Training Phase 2				
Object cleft	45	85	60	0
Passive	15	70	100	80
Follow-up				
Object cleft	70	100	85	80
Passive	85	70	100	70