HHS Public Access

Author manuscript

Aphasiology. Author manuscript; available in PMC 2016 November 01.

Published in final edited form as:

Aphasiology. 2015 November 1; 29(11): 1289–1311. doi:10.1080/02687038.2014.997182.

The effect of a sentence comprehension treatment on discourse comprehension in aphasia

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Abstract

Background—While it is well understood that individuals with aphasia have difficulty with discourse comprehension, very few studies have examined the nature of discourse comprehension deficits in aphasia and the potential for improvement in discourse comprehension after rehabilitation. To address the first goal, we previously developed the Test of Syntactic Effects on Discourse Comprehension (TSEDC), which provides a measure of the extent to which a participant's sentence comprehension ability aids in comprehending passages (Levy et al., 2012).

Aims—The goal of this study was to examine the effect of a sentence comprehension treatment on the TSEDC to assess if training participants to understand sentences of different syntactic complexity would improve their ability to understand passages that vary by their level of syntactic complexity.

Methods & Procedures—Forty participants with aphasia received sentence comprehension treatment using one of two syntactic comprehension tasks: object manipulation (OM) or sentence to picture matching (SPM). The dependent measure was improved sentence comprehension of one sentence type in one task-related protocol, with the order of task and structure counterbalanced across participants. Before and after treatment, participants also completed a self-paced auditory story comprehension task which involved 9 passages that contained either semantically reversible canonical sentences (simple passages) or semantically reversible noncanonical sentences (complex passages). At the end of each passage, participants were asked explicit or implicit questions about

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the story. Accuracy and reaction times were measured for each patient for each story before and after treatment.

Outcomes & Results—Analysis of the treatment data revealed that participants improved in their ability to understand trained sentences (both in terms of effect size and percent change on trained structure), irrespective of whether the trained task was SPM or OM. There was no significant relationship between treatment improvements on the SPM/OM treatment (even when the task targeted in treatment was controlled for) and changes in performance on the TSEDC. Also, there was no significant improvement in TSEDC accuracy after treatment, even when various aspects of the narrative passages, including passage complexity (simple/complex), the nature of sentence type (semantically constrained/semantically reversible) and the nature of questions asked (explicit or implicit) were accounted for.

Conclusions—Inherent differences between the sentence comprehension treatment and the TSEDC may have precluded generalization.

Keywords

sentence comprehension; discourse comprehension; generalization; rehabilitation

Introduction

While it is understood that persons with aphasia have difficulty with discourse comprehension, few studies have examined the nature of discourse comprehension deficits in aphasia and the potential for improvement in discourse comprehension during rehabilitation. Thus far, most research in this area has examined macrolinguistic elements of discourse, such as comprehension of main ideas and details (Brookshire & Nicholas, 1984; Katsuki-Nakamura, Brookshire, & Nicholas, 1988; Nicholas & Brookshire, 1986; Nicholas & Brookshire, 1987, 1995; Wegner, Brookshire, & Nicholas, 1984). For example, Brookshire and Nicholas (1984) asked participants with aphasia to listen to narrative paragraphs each containing a main idea and related details and answer questions about the passage. It was found that participants understood main ideas better than details. Wegner and colleagues (1984) examined participants with aphasia and healthy controls in their ability to comprehend main ideas and details in coherent paragraphs (which contained a single main idea) versus noncoherent paragraphs (which switched to a new main idea every few sentences). While it was found that participants with aphasia comprehended main ideas better than details, it also found that these participants made fewer errors on the details of non-coherent paragraphs. This indicates that, while the participants were able to recall a list of non-coherent details, they had difficulty remembering details in a coherent story. This early work led to the Discourse Comprehension Test (Brookshire & Nicholas, 1993), which examines the nature of discourse comprehension in individuals with aphasia. This test, however, does not consistently require syntactic comprehension, since the meanings of many sentences can be determined using heuristics or real world knowledge.

Studies that have attempted to examine the relationship between sentence comprehension and discourse comprehension have found mixed results. Cannito and colleagues examined the extent to which participants with aphasia were able to access thematic, antecedent information in sentences located at the ends of paragraphs (Cannito, Jarecki, & Pierce, 1986). Results showed that participants were able to extract thematic information to comprehend these sentences even in cases when the paragraph as a whole was not semantically predictive of the underlying meaning of the sentence. However, Cannito, Vogel and Pierce (1991) showed that participants with aphasia showed superior comprehension of sentences that were preceded by a paragraph than of isolated sentences, suggesting that the context provided by the paragraph may have facilitated comprehension of the sentence. A study by Caplan and Evans (1990) compared syntactic comprehension and discourse comprehension in participants with aphasia and healthy controls. It was found that for participants with aphasia, performance on a syntactic comprehension test was positively correlated with performance on a discourse comprehension test in which passages differed in terms of level of syntactic complexity but not in terms of content or overall narrative structure. Interestingly, however, no differences were found between comprehension of the syntactically simpler versions of the passages and comprehension of the syntactically more complex versions of the passages for either group of participants: even individuals with syntactic comprehension deficits showed similar comprehension of the two versions of the passages. The results of this study suggest that while sentence comprehension ability and discourse comprehension ability are related to one another, discourse comprehension ability may depend on other factors besides syntactic comprehension.

Other work has also suggested that discourse processing presents additional demands not involved in sentence processing. Avrutin (2006) argues for differential processing of discourse and syntax in aphasia. His model suggests that processing sentences at the syntactic level activates lexical and syntactic elements of the sentences constrained within a sentence, whereas discourse processing requires analysis of aspects beyond sentence boundaries, as discourse elements have referents across multiple sentences. In the context of explaining syntactic errors in individuals with aphasia, Avrutin suggests that in healthy controls, there is an economy of operations such that syntactic parsing operation (the computation of the relationship between lexical items and syntactic symbols) is the most economical way of encoding individual aspects of a sentence as well as of building discourse structure. In aphasia, however, this economy hierarchy is disrupted, such that syntactic parsing may no longer be the most economical operation; in some cases, alternate operations emerge that facilitate building of discourse. This account of the deficit in aphasia could explain any dissociation between sentence processing and discourse processing.

More recently, Bos, Dragoy, Avrutin, Iskra, & Bastiaanse (2014) examined the performance of participants with aphasia on three aspects of discourse linking – deficits in time reference, *wh* questions, and object pronouns – across three tests that required sentence comprehension. Results showed that comprehension of these elements of discourse was impaired in both agrammatic and fluent aphasia. The authors concluded that comprehension of discourse-linking elements is more complex than comprehension of elements that are constrained to a single sentence or clause. Therefore, participants with aphasia are likely to have more difficulty processing discourse-linked elements than processing elements that are constrained to individual sentences. These results suggest that sentence processing and discourse processing may require different operations and resources.

Collectively, the above studies investigating the connection between sentence processing and discourse processing in aphasia have provided relatively mixed results, suggesting that while sentence processing and discourse processing are likely interlinked, the nature of this link in aphasia is complex and requires further study.

An important factor to consider when comparing discourse comprehension to sentence comprehension is the potential role of working memory. Discourse comprehension tasks, by definition, involve longer listening passages than simple sentence comprehension tasks, and may therefore implicitly place additional memory demands on the listener. It is difficult to control for this factor when comparing comprehension of sentences versus discourse; however, it is important to be aware of the possible role of memory in discourse comprehension and the ways in which it may be impacting performance.

In order to begin to further investigate the nature of discourse comprehension in aphasia, a test which was previously developed to provide a measure of the extent to which an individual's syntactic comprehension ability aids in comprehending passages (Levy et al., 2012). The Test of Syntactic Effects on Discourse Comprehension (TSEDC) examines discourse comprehension using semantically reversible stimuli while also evaluating comprehension of explicitly versus implicitly stated propositions. Specifically, explicitly stated propositions are the factual aspects of the discourse and are akin to the *stated aspects* in the Discourse Comprehension Test (Brookshire & Nicholas, 1993) whereas implicitly stated propositions are the inferential aspects of the discourse and similar to the *implied aspects* in the DCT. In the preliminary study describing the development of the TSEDC, 38 participants with aphasia and 30 healthy control subjects were presented with either the syntactically simple or syntactically complex version of various stories of the TSEDC. The aphasiac individuals performed significantly worse on this test than did the healthy controls; additionally, the participants with aphasia generally comprehended passages with syntactically simple sentences more accurately than passages with syntactically complex sentences. In addition, semantically reversible sentences in the passages were more difficult to comprehend than sentences that were not manipulated for their reversibility. These results suggest that the TSEDC is a sensitive measure of discourse comprehension in participants with aphasia, and also provides evidence in favor of a link between syntactic comprehension and discourse comprehension.

In the present study, we extended this premise further by examining the link between improvements following a sentence comprehension treatment targeting syntactic comprehension and improvements in discourse comprehension ability as measured by the TSEDC. The sentence comprehension treatment used in this study trained participants to map thematic roles, thereby training them on the relationships between syntactic features and the semantic meanings of sentences. There were two different possible treatment formats, one based on sentence-to-picture matching (SPM) and one based on object manipulation (OM); the details of the treatment are described more fully in Kiran et al (2012). The main hypothesis of the present study was that training participants with aphasia to comprehend sentences with given syntactic structures would result in improvements not only in the comprehension of sentences using those structures, but also in the comprehension of passages that included sentences with similar syntactic structures.

Methods

Participants

Forty individuals with aphasia (18 females) were recruited from hospitals and aphasia centers in the Boston area to participate in a sentence comprehension therapy study and, as part of the pre- and post-treatment language and behavioral assessment, were also asked to complete the TSEDC. Informed consent was obtained for all participants according to Boston University Institutional Review Board policies. Several initial selection criteria were met, including: aphasia secondary to stroke or brain injury with onset at least six months before participation in the study (with the exception of BUMA71 who was only five months post-onset), and normal or corrected-to-normal vision and hearing. The age of participants ranged from 26 to 86 years (*M* = 59, *SD* = 14) and time post-onset ranged from 5 to 278 months (*M* = 52, *SD* = 59), with a broad range of traditional clinical diagnoses. Participants completed the Western Aphasia Battery (WAB; Kertesz, 2007), which provided aphasia type and severity information, as well as the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001), which provided information on cognitive abilities. The participants had an average WAB Aphasia Quotient (AQ) of 71.6 (*SD* = 23.2), and the median score on the CLQT Composite Severity fell in the “Mild” range. These standardized measures were not used to determine eligibility but rather to gather additional information about participants’ language and cognitive status. All demographic information for the participants is provided in Table 1.

Eligibility was determined by several screening measures that were administered prior to treatment (refer to Figure 1 for the timeline of all assessments). All participants who were deemed eligible for the treatment study also completed the TSEDC. First, auditory comprehension of the single nouns and verbs contained in the treatment stimuli was tested using a two-option picture choice; this assessment was administered twice, where the distractor pictures in the first administration became the target pictures in the second administration. Accuracy on the noun portion of this screener ranged from 71.7% to 100% correct (*M* = 94.7%, *SD* = 6.0%) and on the verb portion was from 51.6% to 98.3% correct (*M* = 86.9%, *SD* = 9.9%). Generally, scores above 80% on both the noun and verb screeners were considered sufficient for eligibility, though some participants who scored below that cutoff were accepted on a case-by-case analysis. In addition, both a sentence-to-picture matching (SPM) and an object manipulation (OM) sentence comprehension screener (described below) were administered to assess each participant’s comprehension for a range of syntactic structures to obtain an overall index of sentence comprehension accuracy. The purpose of the screeners was to identify the optimal task and structure for each participant. As long as overall performance was less than 90% on either screener (OM or SPM), participants were included in the treatment study. Accuracy scores on the SPM screener ranged from 42.7% to 97.3% correct (*M*= 64.3%, *SD* = 14.2%), and accuracy scores on the OM screener ranged from 17.3% to 90.0% correct (*M*= 44.4%, *SD* = 20.5%).

Stimuli

Treatment and Monitoring Battery Stimuli—Three sets of stimuli were used in the treatment: a screener battery, a monitoring battery, and the treatment stimuli (refer to Table

2 for the sentences included in each set of stimuli). The details of these stimuli are described in detail in Kiran et al. (2012) and are briefly summarized here. All stimuli consisted of depictions of reversible sentences drawn by an artist, and all sentences contained in both the screener and monitoring battery were recorded by a male voice at a consistent pace. Items were presented using E-Prime software (Psychology Software Tools, Pittsburgh, PA). In the SPM tasks, a target picture depicting the actions in the sentence and a foil picture depicting the same items and actions with reversed thematic roles were presented for each sentence, with the position (left versus right) of the target picture counterbalanced across trials. In the OM tasks, paper dolls representing the nouns in the sentence were laid in front of the participant in random order to control for order effects of agent and theme within and across sentence types.

The screening battery, which along with the noun/verb screener was used to determine eligibility for the treatment study, consisted of a total of 110 sentences that included the following structures: passives (PA), unaccusatives (UNACC), object relatives (OR), object clefts (OC), 3 noun phrase, object relative with complex noun phrase (ORCNP), active (A), reflexive, pronoun-as-object, object control, subject control, and noun phrase raising). The monitoring battery, which was administered three times during pre-treatment[1] in order to obtain a set of baseline scores, which was used to determine treatment assignments (both task and sentence structure) for each participant for the treatment. The monitors were also administered once a week throughout the treatment in order to track changes in several sentence structures, including the trained structure. Another set of baselines was administered after completion of the treatment to calculate percent change and effect size. The monitor consisted of 15 examples each of two WH-movement structures (OR and OC) and of two NP movement structures (PA and UNACC). There were also two untrained control structures (Object relatives with a complex NP (ORCNP) and sentences with three NPs (3NP)). The 3NP sentence structures were included to account for the length of OR sentences, whereas ORCNP structures were included as a measure of added complexity. The treatment stimuli consisted of 15 examples of each of the following sentence structures: UNACC, PA, OC, OR. Since participants were only trained on sentences in either SPM or OM the same sentences for each sentence type were used for both tasks (SPM/OM). See Appendix A for sample treatment stimuli and treatment protocol.

TSEDC stimuli—To evaluate auditory comprehension of narrative discourse, the TSEDC (Levy et al., 2012) was administered. This test is composed of nine pairs of passages, each pair consisting of two versions of the same passage (the two versions of each pair are identical to each other, with the exception of two or three sentences). The sentences that remain constant across both versions of the passage are *semantically constrained sentences*, while the sentences that differ between versions are *semantically reversible sentences* (i.e., sentences in which either noun phrase could reasonably play either thematic role around the verb). One passage in each pair contained two or three semantically reversible sentences that were in canonical word order and was deemed a *syntactically simple version*. The other passage in each pair contained two or three semantically reversible sentences that were in

[1]Exceptions in pre-treatment being BUMA71, who received four baselines due to a rising baseline, and BUMA62, who completed three baselines but had time away from the study, then started again so was only given two baselines.

non-canonical word order and was deemed a *syntactically complex version*. The semantically reversible sentences in a given passage therefore differed in meaning between the syntactically simple and syntactically complex versions. The semantically reversible sentences in the syntactically simple/complex versions of each passage were comprised of one of four syntactic pairs: A/PA, Subject Cleft (SC)/OC, SR/OR, and Transitive (TR)/UNACC. Examples of these sentences are as follows:

A: The aunt followed the boy.

PA: The aunt was followed by the boy.

SC: It was the truck that scratched the car.

OC: It was the truck that the car scratched.

SR: The man who kissed the woman hugged the girl.

OR: The woman who the man kissed hugged the girl.

TR: The ice was shattering the cup.

UNACC: The ice was shattering.

The remaining sentences in each pair of passages remained the same across both versions of the passages. See Appendix B for a sample passage.

At the completion of each passage, there were four questions about characters or events from that passage. Every passage (whether semantically simple or semantically complex) had a similar set of four questions: (1) an *explicit* question referring to a semantically constrained sentence, (2) an *implicit* question referring to a semantically constrained sentence, (3) an *explicit* question referring to a semantically reversible sentence, (4) an *implicit* question referring to a semantically reversible sentence. All questions were formatted as multiple-choice questions with four possible answers and were presented in a randomized order across passages and subjects. The answers to both of the semantically reversible questions were different between the syntactically simple and the syntactically complex passages, due to the reversible sentences changing in meaning. The answers to both of the semantically constrained questions remained the same.

Procedure

Treatment Procedures—The participants received a theoretically based sentence comprehension treatment which focused on strengthening thematic role mapping in one of either the OM or SPM tasks. The dependent measure was improved sentence comprehension in one sentence type in one task-related protocol. The order of task and structure was counterbalanced across participants, according to OM/SPM screener and baseline scores; participants were assigned to sentence structures on which they scored below chance during pre-treatment testing. Both the SPM and OM treatments were similar in the number of steps as well as the basic procedures involved, but differ in terms of the nature of "thematic role mapping." Details of the treatment procedures are provided in Appendix A and in an appendix in Kiran et al. (2012). Briefly, treatment comprised a series of steps that required auditory comprehension of semantically reversible sentences, segmentation of those sentences into their respective constituents, and assignment of appropriate thematic roles. In the SPM task, the participant was asked to demonstrate the thematic roles in the trained sentence using pictures of the action(s), whereas in the OM task, the participants used paper dolls to enact the action(s) in the sentence representing each of the thematic roles (see Appendix A). The protocols for OR, OC, PA and UNACC were similar in terms of the basic procedures, but differed in terms of the number of steps to facilitate sentence comprehension.

TSEDC Procedures—Participants completed the TSEDC before and after the treatment period (see Figure 1). The task was presented auditorily on a computer using E-Prime software. The sentences contained in each passage were spoken by a previously recorded male native speaker of North American English. The task was self-timed: the participants were told to press a key to progress to the next sentence when they were ready. After the passage, four questions were consecutively presented in both auditory and written forms by the software. The participants answered the questions by pressing a key that corresponded to a number assigned to the multiple-choice response (for some participants, this button press was assisted by the clinician), which prompted the software to move on to the next question.

Before administration, participants completed a practice passage, which was not scored. During the pre-treatment administrations, participants alternated between the simple and complex passages throughout the nine passages, seeing a total of five complex passages and four simple passages, or vice versa. In post-treatment administration, participants were presented with the opposite version of the passage they had received during pre-treatment administration. This alternating presentation was counterbalanced across participants so that they never heard the same passage twice. Reaction time (in milliseconds) was recorded by the software for the self-timed listening portion of each passage. Accuracy and reaction time were recorded by the software for the questions.

Data Analysis

Treatment Data Analysis—Two indices of improvement were calculated using participants' pre-treatment and post-treatment baseline scores on the targeted sentence structure: the percent change in performance (the average of the post-treatment baselines minus the average of the pre-treatment baselines) and the effect size (the percent change in the baseline scores divided by the standard deviation of the pre-treatment baselines).

TSEDC data analysis—Accuracy from the TSEDC questions was used for all but one of the analyses. Reaction time from the questions, although recorded, was not used in the analysis due to frequent assistance by the clinician during this button press. However, all button presses during the sentences were completed by the participants, so reaction time for the sentences was used in one analysis. As noted above, there were several variables of interest, namely, time (pre- versus post-treatment), overall passage complexity (simple versus complex), sentence type (semantically reversible versus semantically constrained) and question type (implicit versus explicit). All the following analyses were completed using the statistical software package "R" (R Foundation for Statistical Computing, Vienna, Austria), Statistica software (StataCorp, College Station, TX), and Statistical Analysis Software (SAS Institute Inc., Cary, NC).

Results

Because the overall goal of the treatment project involved within- and across-task and structure generalization and is beyond the scope of this paper, we limit the treatment results here to the presentation of improvement in comprehension of the trained structure. Table 3 presents participant information, including which task and structure they were trained on during the treatment, their effect size and percent change on their trained task and structure, as well as the percent change in the TSEDC. Figure 2a depicts the change in percent accuracy on comprehension of the trained sentence structure from pre- to post-treatment for each participant; Figure 2b depicts the change in percent accuracy on the TSEDC from pre- to post-treatment for each participant.

Relationship between treatment outcomes and TSEDC change

Analysis of the treatment data revealed that, as a group, participants improved in their ability to understand trained sentences (measured by effect size and percent change on trained structure and task), irrespective of whether the trained task was SPM or OM (see Table 3). One-tailed t-tests of both effect size and percent change on trained structure, trained task were significant (effect size: t (39) = 6.57, $p < .0001$; percent change: t (39) = 7.37, $p < .0001$), revealing that participants showed improvement on both measures. Specifically, the average effect size was 3.27 (range = −1.18 to 11.55), and average percent change was 29.0% (range = −8.30% – 82%). In contrast, the average percent change on the TSEDC was 2.01% (with a range of −19.44% to 36.11%). A correlation analysis assessed how changes in accuracy on the TSEDC questions were correlated with pre-treatment WAB AQ scores, which was not significant (r (40) = −.068, p = .339. Since half the participants received SPM treatment and the other half received OM treatment, a partial correlation controlling for type of treatment was performed, which revealed no significance between either measure and change in accuracy on the TSEDC (effect size: (r (37) = −.046, p = .39), percent change: (r (37) = −.14, p = .20)). Another set of partial correlations assessed if performance on either pre-treatment screener was associated with changes on the TSEDC, which found no significant associations (OM screener: (r (37) = −.14, p = .20), SPM screener: (r (37) = .06, p = .36)).

Changes in TSEDC performance as a function of treatment

Table 4 breaks down the percentage of correct responses to the TSEDC questions by time (i.e. pre-treatment versus post-treatment), as well as by the other three main factors used in the analysis: passage complexity, syntactic reversibility of the sentences, and explicitness of the questions. Due to the method of counterbalancing the complexity of passages within participants across time, the analysis on accuracy cannot be completed using repeated measures analysis. Therefore, time was considered as another factor along with complexity, reversibility, and explicitness. First, to look for improvement before and after treatment across all participants on all questions, a paired t-test was completed, in which no significance was found (t (1439) = −1.20, p = .23). A paired t-test was also completed for differences between simple and complex passages, which was significant (t (1427) = −2.65, p = .008), where simple passages were answered more accurately than complex passages. Another paired t-test examined differences between constrained and reversible sentences which was significant (t (1439) = −8.08, p <.0001), where questions that referred to constrained sentences were answered more accurately than questions that referred to reversible sentences. A final paired t-test looking for differences between explicit and implicit questions was not significant (t (1439) = 0.20, p = .84).

To further examine the relationship between treatment, passage type, sentence type and question type, three mixed ANOVAs were conducted (Bonferroni corrections result in an alpha level of .01). A 3-way ANOVA was completed to look at the effects of time, complexity and reversibility. This analysis revealed a main effect of complexity (F (1, 2872) = 6.24, p = .01), where questions in simple passages were answered more accurately than questions in complex passages. There was also a main effect of reversibility (F (1, 2872) = 58.91, p < .0001), where questions that referred to constrained sentences were answered more accurately than questions that referred to reversible sentences. A 2-way interaction was also present between complexity and reversibility (F (1, 2872) = 8.27, p = .004). A Tukey HSD post-hoc analysis revealed several significant differences in this interaction: questions that referred to reversible sentences in simple passages were answered more accurately than questions that referred to reversible sentences in complex passages (p = .0008), questions that referred to constrained sentences in simple passages were answered more accurately than questions that referred to reversible sentences in simple passages (p = .004), questions that referred to constrained sentences in complex passages were answered more accurately than questions that referred to reversible sentences in simple passages (p = .001), questions that referred to constrained sentences in simple passages were answered more accurately than questions that referred to reversible sentences in complex passages (p < .0001), and questions that referred to constrained sentences in complex passages were answered more accurately than questions that referred to reversible sentences in complex passages (p < .0001). These results generally revealed a hierarchy of response difficulty where questions that referred to constrained sentences in simple passages were easier than constrained sentences in complex passages, which in turn were easier than reversible sentences in simple passages, which in turn were easier than reversible sentences in complex passages. Notably, there was no significant interaction with time.

A second 3-way ANOVA was completed to look at the effects of time, complexity and explicitness. This analysis only revealed a main effect of complexity (F (1, 2872) 6.12, p = .01), where questions in simple passages were answered more accurately than questions in complex passages. There was a 2-way interaction between complexity and explicitness (F (1, 2872) = 5.95, p= .01). Finally, a 3-way interaction between all three variables was above the Bonferroni threshold for significance (F (1, 2872) = 4.90, p = .03). Although non-significant, the accuracy results reveal a general hierarchy of response difficulty, with explicit questions in the simple passages being the easiest to understand, followed by implicit questions in the simple passages, then explicit and implicit questions in the complex passages. Importantly, there were no post-versus pre-treatment differences for any of the question types.

The final 3-way ANOVA was completed to look at the effects of time, reversibility and explicitness. This analysis revealed a main effect of reversibility (F (1, 2872) = 59.25, p <. 0001), where constrained questions were answered more accurately than reversible questions. There was a 2-way interaction between reversibility and explicitness (F (1, 2872) = 12.98, p = .0003). A Tukey HSD post hoc analysis revealed several significant differences in this interaction: explicit questions referring to a constrained sentence were answered more accurately than explicit questions referring to a reversible sentence (p < .0001), implicit questions referring to a constrained sentence were answered more accurately than explicit questions referring to a reversible sentence (p <.0001), explicit questions referring to a constrained sentence were answered more accurately than implicit questions referring to a reversible sentence (p < .0001); and also, although non-significant: explicit questions referring to a constrained sentence were answered more accurately than implicit questions referring to a constrained sentence (p = .04), and implicit questions referring to a constrained sentence were answered more accurately than implicit questions referring to a reversible sentence (p = .02). Once again, there was a general response hierarchy in which explicit questions referring to constrained sentences were easier to understand than implicit questions referring to constrained sentences, which were easier than explicit questions referring to reversible sentences, which were easier than implicit questions referring to reversible sentences.

Finally, the 3-way interaction between time, reversibility, and explicitness was found to be significant (F (1, 2872) = 7.25, p = .007). The post hoc analysis revealed several significant differences (Table 5); the first set revealed pre-treatment differences between certain question types. First, explicit questions referring to a constrained sentence during pre-testing were answered more accurately than explicit questions referring to a reversible sentence during pre-testing (p = .0003), implicit questions referring to a constrained sentence during pre-testing were answered more accurately than explicit questions referring to a reversible sentence during pre-testing (p = .004), explicit questions referring to a constrained sentence during pre-testing were answered more accurately than implicit questions referring to a reversible sentence during pre-testing (p = .001), and implicit questions referring to a constrained sentence during pre-testing were answered more accurately than implicit questions referring to a reversible sentence during pre-testing (p = .01).

Likewise, several differences between question and sentence types after treatment emerged. For instance, explicit questions referring to a constrained sentence during post-testing were answered more accurately than implicit questions referring to a constrained sentence during post-testing, though above the Bonferonni threshold (p = .03), explicit questions referring to a constrained sentence during post-testing were answered more accurately than implicit questions referring to a reversible sentence during post-testing (p = .004), implicit questions referring to a constrained sentence during post-testing were answered more accurately than explicit questions referring to a reversible sentence during post-testing (p = .005), explicit questions referring to a constrained sentence during post-testing were answered more accurately than explicit questions referring to a reversible sentence during post-testing (p < . 0001), and, though above the Bonferonni threshold, implicit questions referring to a reversible sentence during post-testing were answered more accurately than explicit questions referring to a reversible sentence during post-testing (p = .04).

There were differences between question and sentence types before and after treatment. For instance, explicit questions referring to a constrained sentence during post-testing were answered more accurately than explicit questions referring to a reversible sentence during pre-testing (p < .0001), explicit questions referring to a constrained sentence during pre-testing were answered more accurately than explicit questions referring to a reversible sentence during post-testing (p.<.0001), implicit questions referring to a constrained sentence during pre-testing were answered more accurately than explicit questions referring to a reversible sentence during post-testing (p = .0002), and explicit questions referring to a constrained sentence during post-testing were answered more correctly than implicit questions referring to a reversible sentence during pre-testing (p < .0001). It is important to note that despite several significant interactions with the time, no specific reversibility and explicitness conditions improved from pre-to post treatment.

All ANOVAs were also completed with pre-treatment screener average scores from the task that the participants were trained on as a covariate, but this additional factor did not change the results of the ANOVAs even though the screener was a significant covariate at the .05 significance level for all ANOVAs. Therefore, although the screener score was significant in determining how the participants performed, it did not factor into how treatment interacted with the other variables.

Analysis of Reaction Times on TSEDC

To examine if reaction times of listening to the different sentence types changed as a function of a treatment, a mixed model analysis was conducted with the reversible sentences that occurred across passages (A, OC, SC, OR, PA, SR, TR, and UNACC). Reaction times for listening to the constrained sentences were not analyzed, as these sentences were similar across the simple and complex passages. This analysis also included participant, session number and complexity as covariates as the experimental design was hierarchical in nature. Z-scores were calculated for the reaction times, separated by patient and by pre- and post-treatment. A significant cluster coefficient means that the factor significantly influenced the change in treatment outcomes. Mixed model effects on the z-scores showed no significant main effect of treatment (F (1, 8520) = 0.04, p = .83), however, the main effect of syntax was significant (F (8, 8520) = 26.64, p < .0001). Further analysis of the differences of least square means between the effect of syntax and treatment revealed that only OR sentences (t (8520) = 2.22, p < = .03) showed a significant effect of treatment where post-treatment reaction times were longer than pre-treatment reaction times. The results also showed that the correlations of clustering due to passage complexity (intra-cluster correlation = 0.14, p < .0001) and due to which passage was being listened to (intra-cluster correlation=0.18, p <. 0001) were high and significant. The correlation of clustering due to participant (intra-cluster correlation = 0.0004, p = .004) was also statistically significant.

Discussion

The goal of the present study was to examine the effect of a sentence comprehension treatment targeting specific sentence structures to performance on the TSEDC (i.e., generalization), which contained similar structures to those targeted in treatment. Overall, no significant relationship between treatment improvements on the SPM and OM tasks and changes in performance on the TSEDC was found, even when the task targeted in treatment was controlled for. Also, there was no significant relationship between performance on the pre-treatment screener (an index of participants' sentence comprehension skills) and changes in performance on the TSEDC.

We also examined changes in TSEDC accuracy as a function of treatment and by taking into account various aspects of the narrative passages, including passage complexity (simple versus complex), the nature of sentence type (semantically constrained versus semantically reversible) and the nature of questions asked (explicit versus implicit). Overall, there was no significant improvement in TSEDC accuracy after the sentence comprehension treatment; however, several other results emerged. First, participants achieved lower accuracy levels in response to questions on complex passages, indicating that those passages were harder to comprehend than simpler passages. It was also found that semantically reversible sentences were harder to comprehend than semantically constrained sentences, which was an expected finding for participants with syntactically based comprehension deficits. Also, implicit questions were harder to comprehend than explicit questions, indicating that answering inferential questions about passages were harder than answering factual questions. Additionally, significant interaction effects revealed that, in general, implicit questions about reversible sentences in complex passages were the most difficult for the participants, whereas explicit questions about semantically constrained sentences in simple passages were the easiest questions for the participants. These findings suggest that for participants with syntactic comprehension deficits, answering inferential questions to passages that contain complex syntactic manipulations is particularly difficult. Importantly, these effects appear to have been present both in the pre-treatment phase and the post-treatment phase, and there were no significant changes in comprehension accuracy after treatment when all of these variables were taken into account. Therefore, the above results are consistent with our previous examination of the TSEDC (Levy et al., 2012), which evaluated the effects of reversible and syntactically complex sentence on discourse comprehension. Absent in the present findings is the link between changes in sentence comprehension accuracy and changes in discourse comprehension after treatment for sentence comprehension. Improvement following the sentence comprehension treatment, in other words, was not sufficient to facilitate improvement on the TSEDC.

There are several possible reasons for the lack of generalization from the sentence comprehension treatment to the TSEDC; i.e., several ways in which the TSEDC may have presented challenges that were not present in the sentence comprehension treatment study. One possibility is simply that the two assessment tasks (the TSEDC and the screeners/monitors used in the treatment study) were set up differently from each other. To begin with, improvements following the sentence comprehension treatment were assessed by evaluating comprehension of single sentences using semantically reversible sentences as foils, whereas improvements in the TSEDC were assessed by evaluating comprehension of explicit (based on factual information) or implicit (based on inferential information) questions regarding the passage. Additionally, during treatment, participants were trained on specific syntactic structures and tasks; however, the TSEDC examined comprehension to all sentences types across the nine passages. It should be noted that in our continuing work in this project we are examining whether training on specific structures leads to generalization to other, untrained structures as well as improvement on these trained structures. These across-structure sentence comprehension generalization patterns are outside the scope of the current study, which focuses on generalization from the trained structure to discourse comprehension, and thus will not be discussed here.

Another possible reason for lack of generalization to performance on the TSEDC may be the increased cognitive demands involved in discourse comprehension relative to comprehension of sentences in isolation; it may be that discourse comprehension requires additional and/or more complex processes than those employed during sentence comprehension. As described in the methods, the treatment monitors consisted of individual presentations of sentences, and participants had to either point to pictures that contained semantically reversible foils (SPM task) or enact the sentence using dolls (OM task). The TSEDC task, however, required participants to listen to nine to sixteen sentences at their own pace and then answer four questions regarding each passage. Therefore, treatment involved segmentation of sentences into their respective constituents (see Appendix A), whereas the TSEDC focused on items requiring comprehension beyond a single sentence. Although this study was not designed to evaluate any theoretical model, it appears that the resource allocation model (McNeil, Odell, & Tseng, 1991) is well suited to explain these findings. According to this model, a limited pool of resources available for cognitive processing places constraints on the ability to successfully complete tasks. Thus, tasks with greater demands are affected more than tasks with lesser demands. The effect of brain damage is to further reduce the pool of available resources, and therefore, aspects of cognitive processing that are less resource-intensive are performed at the costs of tasks that are more resource-intensive. In the context of the present study, understanding a series of sentences within a passage is more taxing than understanding a single isolated sentence. This issue may also be closely connected to working memory. However, without specific measures of short-term memory performance to correlate the results to, this is only a tentative possibility.

As noted, results from the TSEDC showed that explicit questions referring to constrained sentences were easiest to understand and implicit questions referring to reversible sentences were the hardest to understand. Our sentence comprehension treatment was targeted at training thematic roles; the questions asked during treatment are best described as explicit questions for specific semantically reversible sentences. Even though the results were not significant, Table 3 shows that there were some improvements in the average accuracy for explicit questions to constrained sentences in the simple passages (from 63.9% accuracy pre-treatment to 68.0% accuracy post-treatment) and for explicit questions to constrained sentences in the complex passages (from 60.6% accuracy pre-treatment to 69.2% accuracy post-treatment). These modest changes suggest that the little improvement that may have occurred was limited to explicit questions referring to constrained sentences (that remain the same across both versions of the passages). From a resource standpoint, explicit questions to the constrained sentences in the simple passages may have been the least demanding of the questions to be answered. Interestingly, accuracy on implicit questions to reversible sentences in simple passages also improved after treatment (from 45.6% accuracy pre-treatment to 59.0% accuracy post-treatment); however, this comparison was also not significant. The reasons for such an observation are not entirely clear.

It should be noted that the syntactic aspects of the TSEDC passages were carefully manipulated to integrate sentence structures that were directly targeted in treatment (such as UNACC, PA, OR and OC); thus, analysis of reaction times to specific sentences provides an important insight into whether participants improved in their comprehension of specific sentences even though their overall accuracy on comprehending the questions did not improve. Unexpectedly, even though there was a significant main effect of treatment, the only structure that changed significantly from pre- to post-treatment was OR sentences; and reaction times to those sentences were longer after treatment than before treatment. This result is difficult to interpret, especially since we did not observe any relationship between participants' reaction times on the OR sentences in the passages and whether or not they were trained on the OR structures. However, it is possible that before the treatment, participants skipped more quickly through OR sentences because they seemed far too difficult to interpret, whereas after treatment they had had more practice in interpreting more complex sentences and therefore spent more time attempting to understand OR sentences before moving on.

In short, any of the above factors may have influenced the lack of generalization from the sentence comprehension treatment to performance on the TSEDC. Discourse comprehension is a complex skill which may involve a variety of other cognitive and/or linguistic operations in addition to single-sentence comprehension, and difficulty with any of these operations may have impacted scores on the TSEDC, despite the fact that sentence comprehension improved as a result of the therapy study.

Conclusion

The present study examined the effect of a theoretically based sentence comprehension treatment and potential generalization of the effects of the treatment to discourse comprehension by examining performance on passages which contained similar syntactic structures to those targeted in treatment. There was no significant relationship between treatment improvements on the SPM/OM treatment (even when the task targeted in treatment was controlled for) and changes in performance on the TSEDC. Also, there was no significant improvement in TSEDC accuracy after the sentence comprehension treatment, even when various aspects of the passages, including passage complexity (simple versus complex), the nature of sentence type (semantically constrained versus semantically reversible) and the nature of questions asked (explicit versus implicit) were accounted for. Inherent differences in the two tasks, which are difficult to overcome, may have precluded generalization.

Acknowledgments

The authors thank David Caplan for his contributions to the project, and Elsa Ascenso and Nadia Lonsdale for their assistance in data collection.

This work was supported by the National Institutes of Health/National Institute on Deafness and Other Communication Disorders through grant NIH/NIDCD 1R21/R33DC010461-01.

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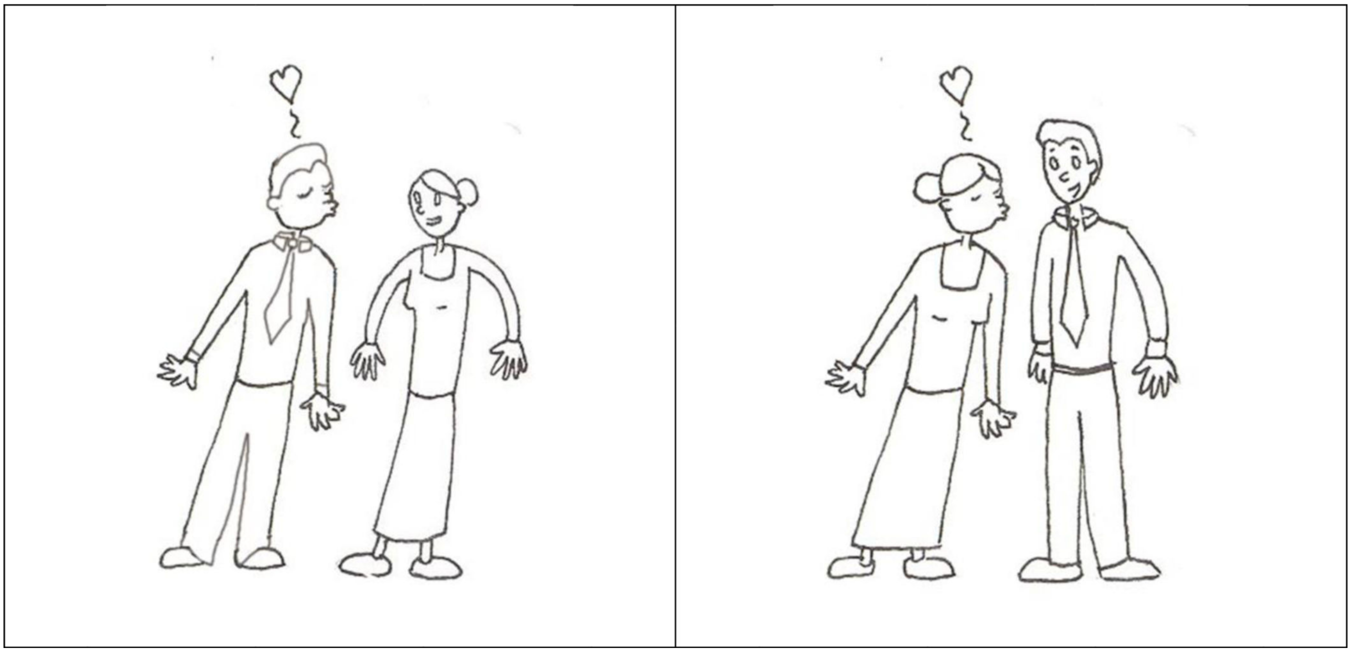
Appendix A

Sample Treatment Stimuli for SPM task and Sample Protocol for SPM and OM tasks:



Step	SPM Treatment Protocol	OM Treatment Protocol
1	Two pictures are placed on the table, a target and a foil with agent and theme reversed.	Two paper dolls are placed table, one depicting each of the nouns in the sentence.
2	The clinician reads the sentence aloud and asks the participant to choose the picture that matches the meaning of the sentence.	The clinician reads the sentence aloud and asks the participant to use the dolls to perform the action in the sentence.
3	The participant chooses a picture and is given feedback.	The participant attempts to enact the action and is given feedback.
4	The clinician removes the foil picture and produces a sentence strip with the target sentence.	The clinician produces a sentence strip with the target sentence.
5	The clinician reads the sentence aloud and explains its meaning.	[same as SPM]
6	The clinician trains the agent of the sentence; the participant is asked three times to indicate who is doing the action.	[same as SPM]
7	The clinician trains the theme of the sentence; the participant is asked three times to indicate who is receiving the action.	[same as SPM]
8	The clinician trains the entire sentence again.	[same as SPM]
9	The clinician returns the foil picture to the table and repeats steps 1–3.	The clinician repeats steps 1–3.

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Appendix B

Sample TSEDC Passage and Questions

Passage:

Chris decided to have a party on Saturday.

He invited his friends Harry and Bill from out of town.

Unfortunately, Bill couldn't come on Saturday.

Chris moved the party to Sunday.

There was a heavy snowstorm the day of the party.

The roads were icy.

On his way to the party, a truck began to pass Harry's car.

The car and the truck began to swerve.

The truck hit the car.[2]**/The car was hit by the truck.**[3]

Harry and the truck driver got out of their vehicles and began arguing.

Suddenly, the arguing stopped.

Harry was shaking the truck driver.[1]**/Harry was shaking.**[2]

A bystander called 911.

Questions:

1. Explicit question, semantically constrained sentence

When was the party?

a. Thursday

b. Friday

c. Saturday

d. Sunday

2. Implicit question, semantically constrained sentence

Why did Chris move the day of the party?

a. Bill couldn't come on Saturday

b. Harry couldn't come on Saturday

c. There was a heavy snowstorm on Saturday

d. There was a heavy snowstorm on Sunday

3. Explicit question, semantically reversible sentence

What happened after the truck began to pass Harry's car?

a. Only the truck swerved

b. Only the car swerved

c. The car hit the truck

d. The truck hit the car

4. Implicit question, semantically reversible sentence

When calling 911, would the bystander ask for?

a. Animal control to help Harry

b. An ambulance to help the truck driver

c. Animal control to help the truck driver

d. An ambulance to help Harry

[2] included in syntactically simple version of passage

[3] included in syntactically complex version of passage

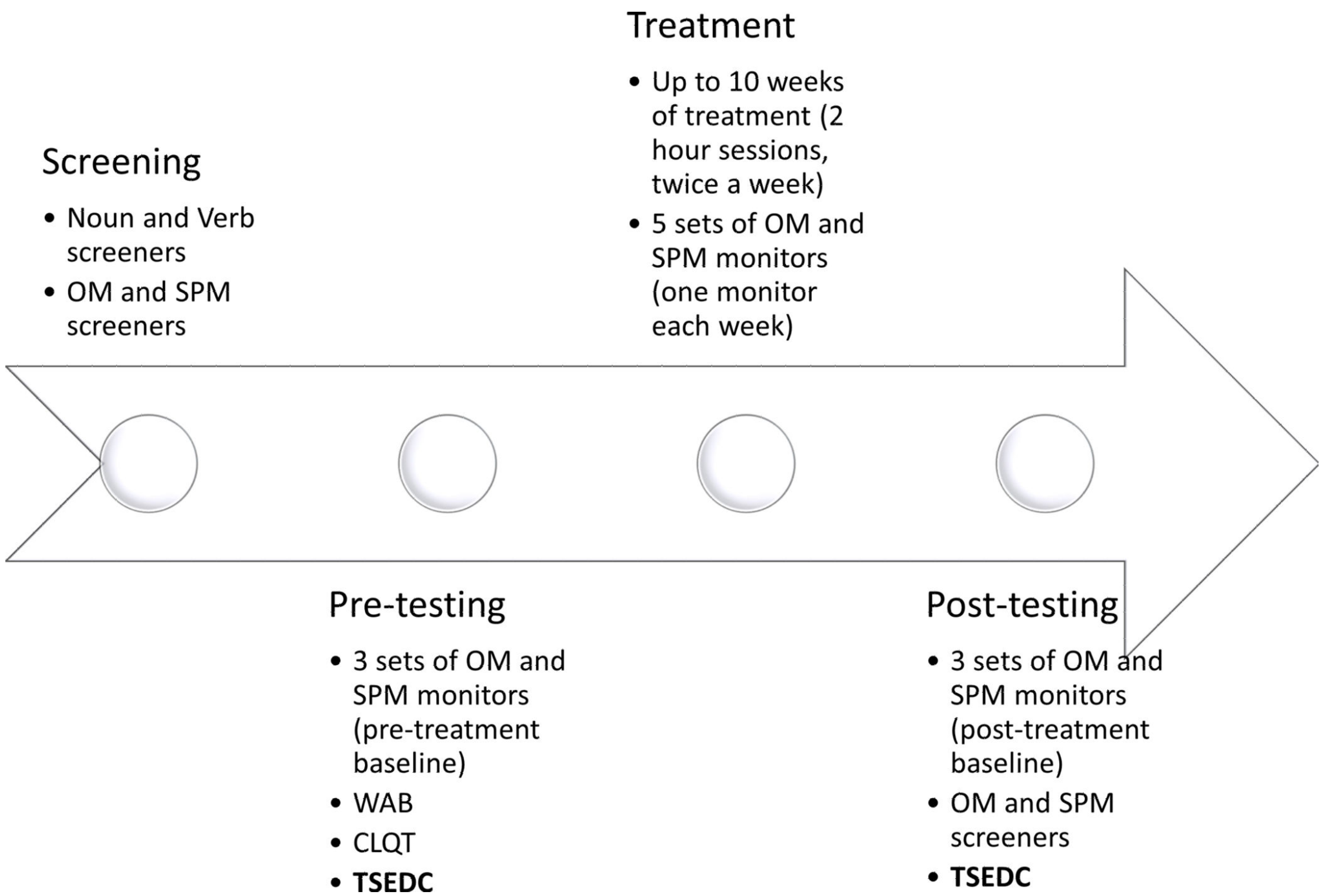
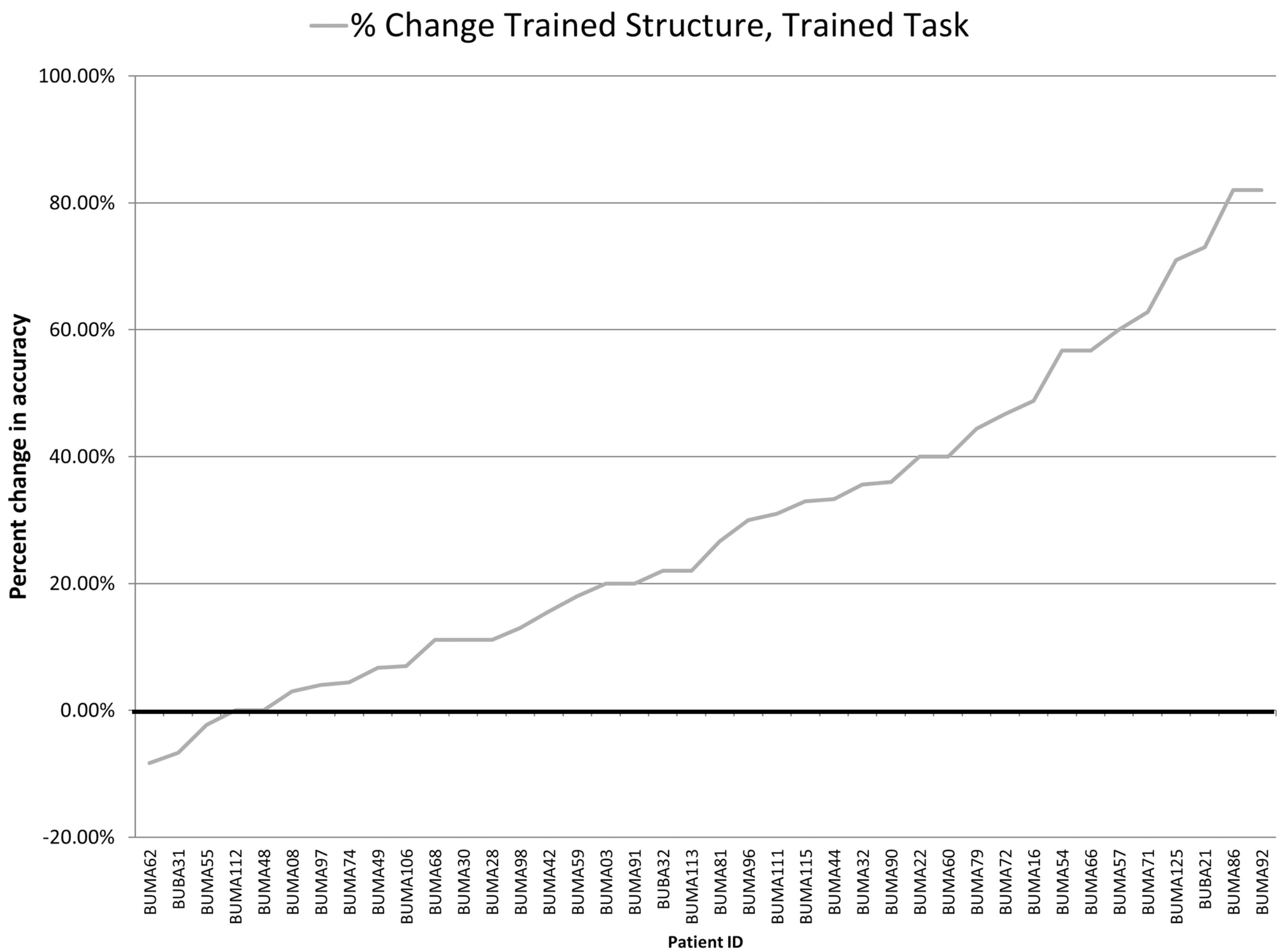


Figure 1.

Timeline of assessments. Noun and verb screeners are only given during the screening time point. The OM and SPM screeners are administered during both the screening and post-testing time points. OM and SPM monitors are administered up to a total of 11 times each (three times each during both pre- and post-testing, and five times each during the treatment, with a frequency of once a week, alternating between the two tasks). Standardized measures (WAB and CLQT) are administered during the pre-testing time point. The TSEDC is administered during both the pre- and post-testing time points.


% Change Trained Structure, Trained Task
Percent change in accuracy
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-20.00%
BUMA62 BUBA31 BUMA55 BUMA112 BUMA48 BUMA08 BUMA97 BUMA74 BUMA49 BUMA106 BUMA68 BUMA30 BUMA28 BUMA98 BUMA42 BUMA59 BUMA03 BUMA91 BUBA32 BUMA113 BUMA81 BUMA96 BUMA111 BUMA115 BUMA44 BUMA32 BUMA90 BUMA22 BUMA60 BUMA79 BUMA72 BUMA16 BUMA54 BUMA66 BUMA57 BUMA71 BUMA125 BUBA21 BUMA86 BUMA92
Patient ID

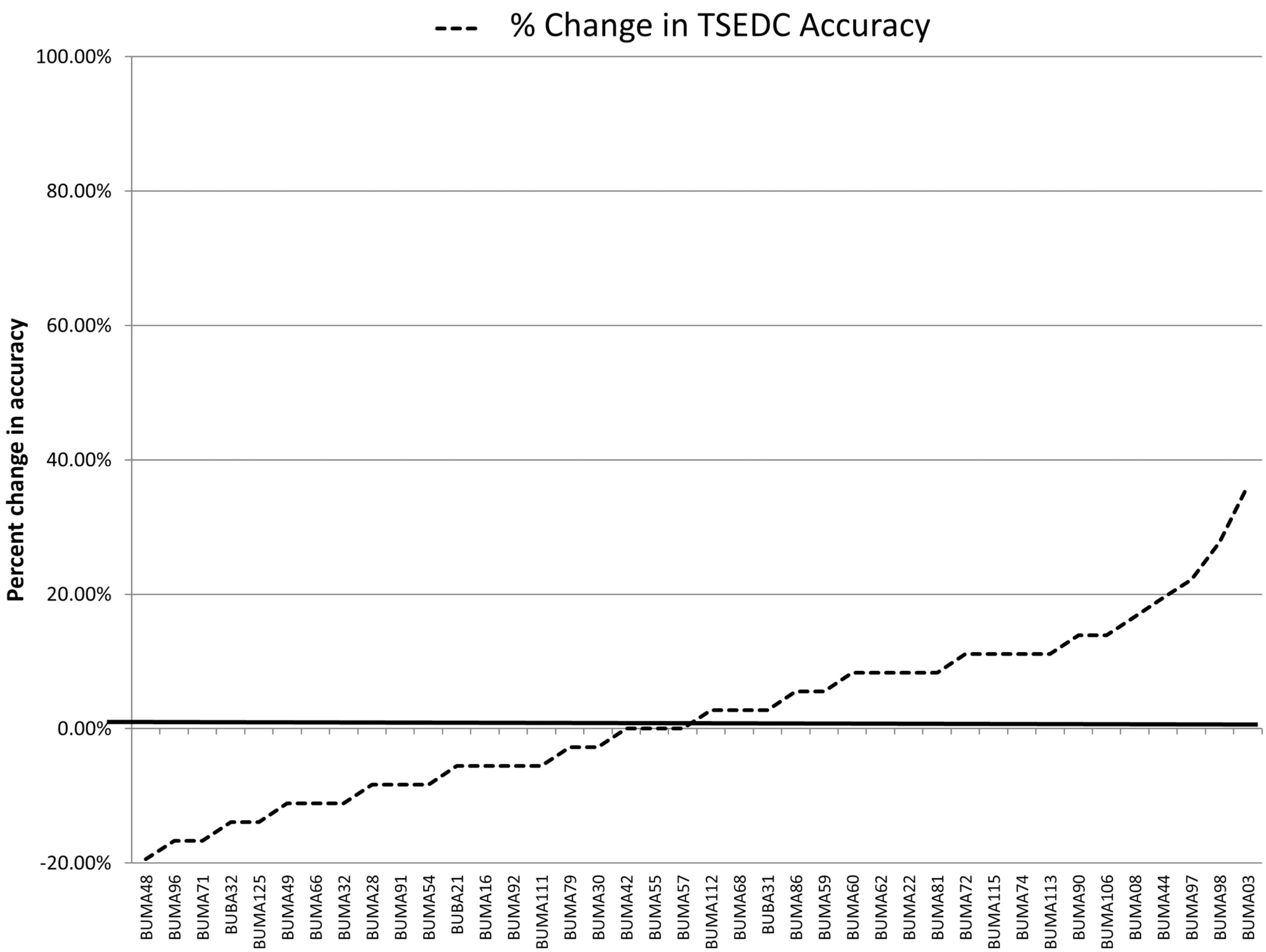


Figure 2.
Change in percent accuracy (post-treatment accuracy minus pre-treatment accuracy) on (a) comprehension of the trained sentence structure and (b) TSEDC, for individual participants. Note that more participants show non-negative changes on the trained structure (35 participants) than on the TSEDC (20 participants).

Table 1

Participant demographic information.

Participant	Gender	Age	Months post onset	CLQT Composite Severity Rating	WAB Aphasia Quotient	Aphasia Type (determined by WAB)
BUMA111	Male	67	9	WNL	100	Anomic
BUMA03	Female	66	66	WNL*	98	Anomic
BUMA30	Female	86	121	WNL	97.4	Anomic
BUBA21	Female	48	32	Mild	96.4	Anomic
BUMA92	Male	67	17	WNL	95	Anomic
BUMA79	Female	49	24	WNL	93.9	Anomic
BUMA28	Female	29	73	WNL	92.8	Anomic
BUMA71	Male	60	5	Mild	91	Anomic
BUMA86	Male	53	23	Mild	91	Anomic
BUMA91	Female	82	33	WNL	90.7	Anomic
BUMA68	Male	59	25	*Mild*	*89.3*	*Anomic*
BUMA74	Male	86	11	Mild	88.7	Anomic
BUMA113	Female	66	6	WNL	86.8	Anomic
BUMA98	Female	55	6	WNL	84.7	Anomic
BUMA49	Female	67	25	*Severe*	*82.2*	*Transcortical Motor*
BUMA97	Male	75	18	Mild	81.1	Transcortical Motor
BUMA22	Female	57	66	Moderate	80	Anomic
BUMA81	Male	71	14	Mild	77.9	Broca's
BUMA16	Male	55	74	*WNL*	*77.7*	*Anomic*
BUMA90	Female	37	46	Mild	77.7	Anomic
BUMA125	Male	26	37	WNL	77.6	Anomic
BUBA32	Male	47	28	Mild	77.2	Anomic
BUMA66	Male	67	10	Moderate	74.5	Anomic
BUMA08	Female	61	51	*Mild*	74.4	Transcortical Motor
BUMA42	Male	47	82	*Mild*	*72.5*	*Broca's vs. Conduction*
BUMA48	Female	66	65	*Mild*	*70.5*	*Conduction*
BUMA72	Female	63	15	Moderate	67.7	Anomic
BUMA55	Male	51	260	*Moderate*	*61.3*	*Broca's*

Participant	Gender	Age	Months post onset	CLQT Composite Severity Rating	WAB Aphasia Quotient	Aphasia Type (determined by WAB)
BUMA62	Male	48	278	*Moderate*	*58.2*	*Broca's*
BUMA60	Male	57	83	Mild	57.2	Broca's
BUMA115	Female	63	101	Mild	56.8	Conduction
BUMA96	Male	74	11	Moderate	49.7	Transcortical Motor
BUMA32	Male	52	105	Mild	48	Broca's
BUMA59	Male	71	52	Mild	45	Wernicke's
BUMA57	Female	52	24	*Moderate*	*41.4*	*Wernicke's*
BUMA112	Female	48	18	Mild	33	Broca's
BUMA106	Male	70	18	Mild	23.1	Broca's
BUBA31	Female	38	62	Moderate	20.1	Broca's
BUMA54	Male	70	49	Severe	10.2	Global
BUMA44	Male	60	40	DNT	DNT	DNT

* WNL = within normal limits; DNT = did not test; *italicized text* = taken from different time point than pre-testing

Table 2

Sentence types included in screener and monitoring batteries. For each sentence type, the abbreviation code, an example of the sentence, the number the number of items in the screener and the monitoring batteries, as well as the number of items in the TSEDC is detailed. Also provided is the number of participants assigned that sentence type for treatment is provided.

Sentence Structure	Code	Example	Screener battery	Monitoring battery	Treatment	TSEDC*
3 noun phrase	3NP	The king said that the boy pushed the girl.	5 items	10 items		
Active	A	The king shook the girl.	10 items			8 items
Noun phrase raising	NP	The king appeared to the niece to be pushing the grandmother.	10 items			
Object cleft	OC	It was the boy who the grandmother patted.	10 items	15 items	10 patients	3 items
Object control		The king convinced the man to carry the girl.	10 items			
Object relative	OR	The boy who the niece lowered poked the king.	10 items	15 items	14 patients	2 items
Object relative with complex noun phrase	ORCNP	The king who the niece of the man kissed hugged the grandmother.	5 items	10 items		
Passive	PA	The niece was pulled by the man.	10 items	15 items	9 patients	8 items
Pronoun-as-object		The man said that the niece hugged him.	10 items			
Reflexive		The boy said that the grandmother washed herself.	10 items			
Subject cleft	SC	It was the niece who buried the man.				3 items
Subject control		The boy promised the niece to wash the grandmother.	10 items			
Subject relative	SR	The girl who poked the boy kissed the grandmother.				2 items
Transitive	TR	The niece was choking the uncle.				5 items
Unaccusative	UNACC	The girl was shaking next to the king.	10 items	10 items	7 patients	5 items

*TSEDC items based on perfect counterbalance of syntactically simple/complex stories from pre- to post-treatment

Table 3

Participant results for treatment and TSEDC. For each participant, the trained task, the trained structure, the pre-treatment overall OM and SPM screener performance is provided. Also provided is each participant's effect size for the trained structure, trained task, percent change on the trained structure, trained task and percent change in overall TSEDC accuracy.

Participant	Trained Task	Trained structure	Overall SPM Screener (pre-testing)	Overall OM Screener (pre-testing)	Effect size of trained structure, trained task	% Change Trained Structure, Trained Task	% Change in TSEDC Accuracy
BUMA03	SPM	OR	83.6%	90.0%	2.60	20.00%	36.11%
BUMA98	SPM	OR	67.3%	62.7%	1.15	13.00%	27.78%
BUMA97	SPM	OC	61.8%	24.5%	1.15	4.00%	22.22%
BUMA44	SPM	OR	56.4%	54.5%	8.66	33.30%	19.44%
BUMA08	SPM	UNACC	42.7%	41.8%	0.58	3.00%	16.67%
BUMA106	OM	OC	50.0%	27.3%	0.87	7.00%	13.89%
BUMA90	OM	PA	70.9%	51.8%	3.08	36.00%	13.89%
BUMA74	SPM	OR	68.2%	47.3%	0.44	4.40%	11.11%
BUMA113	SPM	OR	85.5%	36.4%	5.77	22.00%	11.11%
BUMA72	SPM	UNACC	51.8%	26.4%	4.67	46.70%	11.11%
BUMA115	SPM	PA	52.7%	20.0%	2.89	33.00%	11.11%
BUMA22	OM	PA	60.9%	34.5%	3.00	40.00%	8.33%
BUMA81	SPM	OC	55.5%	29.1%	4.00	26.70%	8.33%
BUMA60	OM	OC	50.0%	36.4%	1.30	40.00%	8.33%
BUMA62	SPM	UNACC	51.8%	28.2%	−1.18	−8.30%	8.33%
BUMA59	OM	PA	59.1%	17.3%	2.67	18.00%	5.56%
BUMA86	OM	OR	89.1%	77.3%	7.12	82.00%	5.56%
BUMA68	OM	OR	64.5%	60.9%	1.44	11.10%	2.78%
BUMA112	OM	UNACC	55.5%	20.0%	0.00	0.00%	2.78%
BUBA31	SPM	OC	0.6636	0.3273	−0.48	−0.0667	0.0278
BUMA42	SPM	OC	54.5%	22.7%	2.33	15.60%	0.00%
BUMA55	OM	OC	60.9%	47.3%	−0.30	−2.30%	0.00%
BUMA57	OM	PA	52.7%	30.9%	5.89	60.00%	0.00%
BUMA30	SPM	OR	80.9%	--	0.66	11.11%	−2.78%
BUMA79	OM	OR	85.5%	82.7%	11.55	44.40%	−2.78%

Participant	Trained Task	Trained structure	Overall SPM Screener (pre-testing)	Overall OM Screener (pre-testing)	Effect size of trained structure, trained task	% Change Trained Structure, Trained Task	% Change in TSEDC Accuracy
BUBA21	OM	OR	80.0%	55.5%	7.20	73.00%	−5.56%
BUMA16	SPM	PA	51.8%	41.8%	6.34	48.78%	−5.56%
BUMA92	OM	OR	97.3%	80.0%	5.48	82.00%	−5.56%
BUMA111	OM	OR	86.4%	84.5%	3.06	31.00%	−5.56%
BUMA28	SPM	OC	70.0%	71.8%	0.80	11.11%	−8.33%
BUMA54	OM	UNACC	46.4%	30.9%	9.81	56.70%	−8.33%
BUMA91	OM	PA	70.0%	37.3%	1.73	20.00%	−8.33%
BUMA32	OM	OR	60.9%	28.2%	1.55	35.60%	−11.11%
BUMA49	SPM	OC	52.7%	32.7%	0.58	6.70%	−11.11%
BUMA66	OM	UNACC	52.7%	31.8%	9.81	56.70%	−11.11%
BUMA125	OM	OC	74.5%	48.2%	6.16	71.00%	−13.89%
BUBA32	OM	PA	61.8%	41.8%	3.33	22.00%	−13.89%
BUMA71	OM	OR	89.1%	78.2%	2.06	62.80%	−16.67%
BUMA96	SPM	UNACC	50.9%	25.5%	3.00	30.00%	−16.67%
BUMA48	SPM	PA	48.2%	41.8%	0.00	0.00%	−19.44%

Note: -- = missing data point; BUMA54, BUMA55, BUMA57, BUMA41, BUMA48 completed a second phase of treatment in which they were trained on a second structure/task. In this table, only effect sizes from the first phase are reported for all participants.

Table 4

Percentage of correct responses before and after treatment to the TSEDC components by time, passage complexity, sentence type and question type.

Passage type	Sentence type	Question type	Pre-treatment Average	Pre-treatment Standard Deviation	Post-treatment Average	Post-treatment Standard Deviation
Simple	Constrained	Explicit	63.9	48.2	68.0	46.8
Simple	Constrained	Implicit	55.6	49.8	59.0	49.3
Simple	Reversible	Explicit	55.6	49.8	51.1	50.1
Simple	Reversible	Implicit	45.6	49.9	59.0	49.3
Complex	Constrained	Explicit	60.6	49.0	69.2	46.3
Complex	Constrained	Implicit	64.4	48.0	54.9	49.9
Complex	Reversible	Explicit	36.7	48.3	35.7	48.0
Complex	Reversible	Implicit	48.9	50.1	50.5	50.1

Table 5

Post hoc results for Time × Reversibility × Explicitness. Differences in the mean for comparisons between the levels of time, reversibility, and explicitness, within 95% confidence intervals. Cells that are highlighted in gray are considered significant at p = .05.

Tukey HSD test
Error: Between MS = .24208, df = 2872

Factors		Time	Pre	Pre	Pre	Pre	Post	Post	Post	Post
		Explicitness	Explicit	Explicit	Implicit	Implicit	Explicit	Explicit	Implicit	Implicit
Time	Explicitness	Reversibility	Constrained	Reversible	Constrained	Reversible	Constrained	Reversible	Constrained	Reversible
Pre	Explicit	Constrained	-	.0003	1	.001	.66	.00004	.84	.45
Pre	Explicit	Reversible	.0003	-	.004	1	.00003	1	.06	.27
Pre	Implicit	Constrained	1	.004	-	.01	.27	.0002	.99	.84
Pre	Implicit	Reversible	.001	1	.01	-	.00003	.96	.14	.45
Post	Explicit	Constrained	.66	.00003	.27	.00003	-	.00003	.03	.004
Post	Explicit	Reversible	.00004	1	.0002	.96	.00003	-	.005	.04
Post	Implicit	Constrained	.84	.06	.99	.14	.03	.005	-	1
Post	Implicit	Reversible	.45	.27	.84	.45	.004	.04	1	-