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Development of a Theoretically Based Treatment for Sentence Comprehension Deficits in Individuals With Aphasia

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Purpose: Two new treatments, 1 based on sentence to picture matching (SPM) and the other on object manipulation (OM), that train participants on the thematic roles of sentences using pictures or by manipulating objects were piloted.
Method: Using a single-subject multiple-baseline design, sentence comprehension was trained on the affected sentence type in 1 task-related protocol in 15 participants with aphasia. The 2 tasks were SPM and OM; the treatment stimuli were object relatives, object clefts, passives, and unaccusatives, as well as two control structures—object relatives with a complex noun phrase (NP) and active sentences with three NPs.
Results: The criteria for efficacious treatment was an increase in the level of performance from the pretreatment probes to the posttreatment probes for the treated structure such that accuracy rose from at or below chance to above chance and either (a) accuracy rose by 33% or (b) the effect size was 2.6. Based on these criteria, the success rate for training the target structure was 2/6 participants in the SPM condition and 4/7 participants in the OM condition.
Conclusion: The outcome of this study illustrates the utility of this theoretically motivated and efficacious treatment for sentence comprehension deficits in individuals with aphasia.

Key Words: rehabilitation, aphasia, sentence comprehension, treatment

The goal of this study was to develop a clinically applicable treatment for individuals with disorders affecting the ability to use syntactic structure to understand sentences. Our project builds on work that characterizes the nature of sentence comprehension disorder and work that explores the factors that influence the effects of treatment. Many researchers maintain that syntactic comprehension deficits result from loss of knowledge regarding certain syntactic constituents or from loss of the ability to use that knowledge in comprehension (*specific deficit* models). One example of this type of theory is the trace deletion hypothesis (Grodzinsky, 2000), which relies on Chomsky's (1995) theory of syntactic structure. The trace deletion hypothesis postulates that certain participants with aphasia have lost the ability to relate certain types of these moved constituents to their sites of origin through the co-indexation of traces, resulting in an inability to assign thematic roles to these constituents. Trace deletion leads to abnormal sentential comprehension in instances where compensatory mechanisms of thematic role assignment (i.e., *heuristic* mechanisms) also fail to accurately assign thematic roles.

Other descriptions of aphasic comprehension deficits also are of the specific deficit type. For instance, several alternative characterizations of a deficit affecting traces have been proposed (Beretta, 2001; Beretta, Harford, Patterson, & Piñango, 1996; Mauner, 1995; Mauner, Fromkin, & Cornell, 1993). The mapping deficit account (e.g., Linebarger, 1995) proposes a specific deficit in the syntactic comprehension process that is wider ranging than the trace deletion account and argues that individuals with aphasia assign syntactic structures but have lost the ability to map them onto sentential semantic meanings.

A second view of syntactic comprehension deficits states that individuals with aphasia display reductions in the resources (e.g., working memory) necessary for normal operation of the processes associated with syntactic comprehension. These models maintain that individuals with syntactic comprehension problems do not lose specific syntactic constituents or parsing/interpretive operations but rather have

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pathological limitations in their abilities to undertake the computations that assign and interpret syntactic structure (a resource limitation). These limitations could be due to a reduced capacity to maintain representations in memory while computations are applied to them (i.e., a working memory deficit: Caplan & Waters, 1999); a slow rise time or fast decay rate for representations, which makes them unavailable when needed (i.e., a speed of processing deficit: Haarmann & Kolk, 1994); or some other impairment that affects syntactic processing across the board (Tseng, McNeil, & Milenkovic, 1993). Evidence for a capacity reduction comes from the finding that sentences that are more complex linguistically and require more processing are more affected than sentences that require less syntactic processing (Caplan, Baker, & Dehaut, 1985; Caplan & Futter, 1986; Caplan & Hildebrandt, 1988a, 1988b; Caplan, Waters, & Hildebrandt, 1997).

Specific deficits are rare. Caplan and colleagues (Caplan & Futter, 1986; Caplan & Hildebrandt, 1988a, 1988b; Caplan et al., 1985, 1997) obtained multiple measures (e.g., accuracy, response times, online data) regarding participants' performances on two constructions instantiating each of three syntactic operations (*wh*-movement, noun phrase [NP]-movement, co-indexation of reflexives) across different tasks including sentence comprehension and grammaticality judgment in both sentence to picture matching (SPM) and object manipulation (OM) modalities (Caplan, Waters, DeDe, Michaud, & Reddy, 2007). Results showed that every participant with a task-independent deficit affecting one structure also had abnormal performances affecting other structures. Further, sentences with noncanonical thematic role order were more difficult than sentences with canonical thematic role order for the participants with deficits, and OM tasks were more difficult than SPM tasks. These results point to resource reduction as the major cause of syntactic comprehension disorders and suggest that OM is a more demanding task than SPM (Caplan, DeDe, & Michaud, 2006; Caplan & Waters, 2006; Caplan et al., 2007; DeDe & Caplan, 2006). We should note that other studies that have implemented tasks similar to SPM and enactment have also observed task-specific effects in the comprehension of canonical and noncanonical sentences (Cupples & Inglis, 1993; Salis & Edwards, 2009).

Each of the above-mentioned theoretical viewpoints is relevant to treatment as they generate suggestions regarding the structures that need to be targeted in training. Theories that argue for a specific deficit in syntactic comprehension may suggest that improvements be restricted to trained structures; consequently, participants will have to be trained on a large number of structures to achieve overall improvements in comprehension. The resource view of syntactic comprehension deficits is more optimistic about generalization of successful training from one structure to another; if training targets an ability to use resources in the service of syntactic comprehension, successful training might generalize to all structures, or to all structures that require the same or fewer resources.

Few treatment studies have specifically targeted sentence comprehension as a goal of rehabilitation. Mitchum, Greenwald, and Berndt (2000) divided studies into three broad categories—verb-centered treatments, active feedback treatments, and prepositional/locative treatments. They reviewed data from 17 participants across these studies and reported variable outcomes across different participants. In a series of studies that focused on syntactic structure, Berndt, Mitchum, Haendiges and colleagues (Berndt, Mitchum, Burton, & Haendiges, 2004; Haendiges, Berndt, & Mitchum, 1996; Mitchum, Haendiges, & Berndt, 1995, 2004) trained active and passive reversible sentences, emphasizing the association between the surface sentence structure and the meaning of the sentence. Across these studies, participants demonstrated improvements on trained items but continued to have persisting deficits in other aspects of sentence comprehension, and generalization effects were variable. One group study (Crerar, Ellis, & Dean, 1996) examined treatment of sentence comprehension using a computer-based written SPM task. Fourteen participants with aphasia, divided into two equal groups, received either verb comprehension followed by preposition comprehension training or the reverse order of treatment. Both groups showed improved comprehension, and the group receiving verb comprehension treatment first demonstrated generalization to preposition comprehension.

Schwartz, Saffran, Fink, Myers, and Martin (1994) argued that treatment aimed at the mapping of a sentence's thematic roles onto its syntactic structure achieved better results than traditional repetition-based treatment. In this study, eight participants with agrammatism received treatment that focused on thematic role assignment on sentence structures that ranged from simple actives to more complex structures. Improvements occurred in several participants. Several similar approaches have been reported in which treatment targeted the mapping of thematic roles onto a variety of structures in either comprehension or, more frequently, production. For instance, some studies targeted thematic role mapping by manipulating the word order of sentences using either NPs or prepositions (Byng, 1988; Nickels, Byng, & Black, 1991). Across these studies, participants showed variable sentence-specific improvements and generalization to untrained structures, with some notable successes (e.g., Byng, 1988) and other outcomes that were much less favorable.

There is a more developed literature pertaining to the combination of training with respect to sentence production and to sentence comprehension. Several trends seem to emerge from this literature. Pertinent to the present study, Thompson, Shapiro, and colleagues (Jacobs & Thompson, 2000; Thompson, Ballard, & Shapiro, 1998; Thompson & Shapiro, 2005; Thompson, Shapiro, Kiran, & Sobecks, 2003) developed the "treatment of underlying forms" (TUF), which is an approach that is similar to mapping treatment in that participants are taught aspects of the relation between thematic roles and syntactic structure, focusing on the syntactic realization of verbal argument structure in more complex sentences. One study using this approach examined the effect of training comprehension on production and vice versa using object clefts (OCs) and passives (PAs) and found that training comprehension improved production, whereas training production was less effective at improving comprehension (Jacobs & Thompson, 2000).

A second feature of the work done by Thompson and colleagues that is relevant to the present study is the complexity account of treatment efficacy (CATE; Thompson & Shapiro, 2007; Thompson et al., 2003). The CATE maintains that successful training on more complex but similar structures leads to generalization to less complex structures but not vice versa. For instance, Thompson et al. (1998) reported that successful training in the production of OCs generalized to *wh*-questions, but not vice versa. Similarly, Thompson et al. (2003) extended these results to object relative clauses (ORs), which are more complex than OCs; the same pattern of generalization only from complex to simple *wh*-movement structures was found. Thompson et al. (1997) reported a CATE effect in training NP-movement, with generalization from successfully trained "raising" structures to PAs (which are argued to be less complex). Jacobs and Thompson (2000) and Thompson et al. (1997, 1998) reported that successful training on either *wh*-movement or NP-movement did not generalize to the other type of structure.

Taken together, mapping treatment, TUF, and other syntactically constrained treatment studies provide an important foundation for developing a sentence comprehension treatment for individuals with aphasia, but new therapeutic techniques are important to explore. Many treatments that have examined comprehension outcomes require a combination of production and comprehension, making it difficult to determine the extent to which they would be effective for sentence comprehension regardless of the production capacity of the participants.

In this project, we piloted two treatments (one based on SPM and the other on OM) and systematically manipulated the syntactic structures of sentences trained in order to train participants on the relation between features of syntactic structure and the meanings of sentences by having participants indicate thematic roles pictured in drawings or by manipulating objects. Although the treatment methods reviewed earlier are directed at relating semantic values to syntactic structure, the methods consist of having participants arrange written words to indicate thematic roles or syntactic categories. The goal of our study was to develop a single treatment approach that could be implemented in two tasks (OM and SPM) and therefore allow us to compare the enactment-based treatment (OM) with one that required identification of thematic roles using pictures (SPM). We hypothesized that displaying thematic roles while manipulating objects would be a more engaging and effective treatment approach than identifying thematic roles using picture stimuli. This is because demonstrating accurate sentence comprehension during the OM task requires the participant to develop a mental visual schema of the action and subsequently generate the motor plan to implement the enactment. In contrast, in SPM, the participant is required to recognize a visual schema of the action depicted and match that image to one of two picture options. In general, retrieval of items from memory is more difficult than recognition, leading to the assumption that OM is more demanding than SPM.

We also systematically manipulated the treatment dosage to identify the stimulus and treatment parameters that are optimal for promoting improvements in participants with comprehension deficits. Previous treatment studies that targeted sentence comprehension provided treatment at various frequencies, but frequency of treatment has been confounded with intensity of treatment and, in some cases, type of treatment. For instance, Byng's (1988) client was seen for treatment for 2 weeks only but showed generalization both to untrained items and from comprehension to production; whereas Schwartz, Saffran, Fink, Myers, and Martin (1994) trained their participants three times a week for 60–90 min up to 4 months and reported a variety of outcomes in different participants. Jacobs and Thompson (2000) trained their participants two to three times a week for 60–90 min for ~10 weeks. Mitchum et al. (1995) also trained participants for extensive periods, and their participants did not show generalization. In this study, we examined whether more or less treatment dosage at the same frequency (twice a week) was more effective in determining treatment outcomes.

Finally, we also examined generalization from the trained to untrained sentences within the trained task. Our choice of stimuli was motivated by previous work that has shown OR structures to be more difficult to understand than OC structures, and PAs were found to be more difficult than unaccusatives (UNACC; e.g., Caplan et al., 1985; Caplan, DeDe, & Michaud, 2006, 2007; McAllister, Bachrach, Waters, Michaud, & Caplan, 2009; Salis & Edwards, 2009). We hypothesized that if structure is not a barrier to generalization, because participants have resource reductions serving sentence comprehension and not specific deficits, generalization may be expected from successful training of both *wh*-movement structures to both NP-movement structures and vice versa. Alternatively, based on the CATE hypothesis, generalization may occur within *wh*- and NP-movement structures but not across structures, and only from the complex structures to the less complex structures (e.g., OR → OC and PA → UNACC).

Method

Participants

We recruited 15 monolingual English-speaking individuals with aphasia from local hospitals within the Boston area to participate in the study. Participant ages ranged from 29 to 73 years (M = 57 years). Time post onset ranged from 6 to 147 months (M = 55 months). Several initial selection criteria were met, including (a) a single left-hemisphere stroke, (b) onset of stroke at least 6 months before participation in the study, (c) premorbid right-handedness, and (d) at least a high school diploma (see Table 1). There was one exception: BUMA05 was premorbidly left-handed and had a right-hemisphere stroke. All participants had received varying amounts of traditional language treatment during the initial months following their stroke.

Screening measures were administered before treatment to determine participant eligibility. The first of these assessed participants' auditory comprehension of both the nouns and verbs included in the treatment and monitoring stimuli (see Stimuli section for details). Participants were shown two depictions of either nouns or verbs and were asked to choose the picture that matched the auditorily presented target; comprehension of nouns and verbs was assessed separately. Accuracy scores on the noun portion of this screener ranged

TABLE 1. Demographic information and pretreatment screener performance for the 15 study participants.

Participant	Age	Sex	Race	Years of education	MPO	Noun test	Verb test	Overall SPM screener (pretesting)	Overall OM screener (pretesting)
BUMA03	67	F	W	16	72	97.8%	91.2%	83.6%	90.0%
BUMA05	54	M	W	12	111	91.3%	100.0%	73.6%	54.5%
BUMA07	29	M	B	12	6	97.8%	87.5%	47.3%	26.4%
BUMA08	62	F	W	16	54	91.3%	89.1%	42.7%	41.8%
BUMA10	65	M	W	18	60	100.0%	92.2%	85.5%	55.5%
BUMA11	59	M	W	16	147	91.3%	79.4%	66.4%	39.1%
BUMA13	63	M	W	16	93	95.7%	90.6%	51.8%	26.4%
BUMA14	63	M	W	18	96	86.9%	73.5%	52.7%	30.9%
BUMA15	59	M	W	18	18	100.0%	89.1%	72.7%	62.7%
BUMA16	56	M	W	18	76	95.7%	92.2%	51.8%	41.8%
BUMA17	73	F	W	14	36	97.8%	90.6%	62.7%	44.6%
BUMA20	45	M	W	20	15	100.0%	95.3%	79.1%	77.3%
BUMA21	39	F	W	20	9	91.3%	92.2%	84.6%	89.1%
BUMA23	65	F	W	12	32	89.1%	68.8%	48.2%	27.3%
BUMA24	59	M	W	14	6	100.0%	92.2%	44.6%	20.0%

Note. MPO = months post onset, SPM = sentence to picture matching, OM = object manipulation, F = female, M = male, W = white, B = black.

from 86.9% to 100% correct (M = 95.1%) and from 68.8% to 100% correct (M = 88.3%) on the verb portion. These scores were considered to be within the range of acceptability for eligibility for the study. Additionally, both an SPM and an OM sentence comprehension screener was administered to assess each participant's comprehension level for both NP-movement and *wh*-movement sentences, as well as other structures. Accuracy scores on the SPM screener ranged from 42.7% to 85.5% correct (M = 63.2%); accuracy scores on the OM screener ranged from 20.0% to 90.0% correct (M = 47.5%) (see Table 2). Eligibility for entrance into the study was performance that was at or below chance on any of the target sentence types.

Stimuli

All stimuli used in the study consisted of reversible sentences that were included in a screening battery, a monitoring battery, and a treatment set. All stimuli were drawn by the same artist and recorded by the same male voice at a consistent pace, and all items were presented using E-prime software. Half of all sentences for each sentence type used animate nouns; the remaining half used inanimate nouns. The animacy of nouns and the lexical frequency of nouns and verbs were balanced across batteries and across versions of each battery.

For 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 drawn for each sentence. The frequency of the position of the target picture on either side of the screen was counterbalanced across trials. For the OM tasks, paper dolls representing the nouns in the sentence were created to be used by the participants. The dolls were laid in front of the participant in random order to control for order effects of agent and theme within and across sentence types.

Screening battery. Two versions of each type of screener (SPM, OM) were developed that included the target sentence types (OR, OC, PA, UNACC), two control sentence types (sentential complement [3NP] and object relative with embedded subject modified by a prepositional phrase [ORCNP]), and a variety of other sentence types (active, reflexive, pronoun-as-object, object control, subject control, and noun phrase raising). Ten tokens of each sentence type were presented, except for the control sentences, which had five tokens each, for a total of 110 items per screener version (see Appendix A for examples of these sentences). The same stimuli were used for each version of the screener, but the order of presentation was reversed between versions one and two.

Monitoring batteries. Four versions of each type of monitoring battery (SPM, OM) were developed that included 15 tokens of each target sentence type (OR, OC, PA) except UNACCs (10 tokens) and 10 tokens of each control sentence type (3NP and ORCNP) for a total of 75 items per version. 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 thematic roles assigned to particular nouns within the stimuli were counterbalanced across the four versions such that the thematic roles of nouns in version 2 and 4 were the reverse of the thematic roles of the same nouns in version 1 and 3. Versions 1 and 2 were differentiated from versions 3 and 4 by placing the target item on a different side of the screen for each sentence. For the OM task, versions 1 and 2 had the same sentences as SPM versions 1 and 2; version 3 contained new sentences with the same verbs; and version 4 contained the same nouns/verbs as version 3, but the roles of agent/theme were reversed.

Treatment materials. Twenty sentences for each sentence type, except UNACCs, which only had 14 sentences, were used in training for both the SPM and OM training methods. These sentences were mostly original, but less than ¼ were copied from the screeners and one (for each sentence type) was copied from the monitoring batteries for all sentence types except UNACC. For the UNACC training sentences, nine of the 14 sentences were taken from the screeners and two were taken from the monitoring batteries. This was unavoidable due to the scarcity of English UNACC verbs and

TABLE 2. Study participants' performance on the SPM and OM screeners before and after treatment.

SPM training	BUMA03		BUMA17		BUMA07		BUMA15		BUMA13		BUMA16		BUMA08		BUMA23	
Structure trained:	OR		OR		OC		OC		PA		PA		UNACC		UNACC	
Sentence type	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
3NP	100.0%	100.0%	20.0%		80.0%		80.0%	80.0%	60.0%	20.0%	40.0%	80.0%	20.0%	80.0%	60.0%	40.0%
Active	90.0%	100.0%	60.0%		30.0%		60.0%	70.0%	60.0%	50.0%	80.0%	80.0%	70.0%	40.0%	40.0%	60.0%
Raising NP	70.0%	100.0%	50.0%		60.0%		70.0%	80.0%	60.0%	80.0%	70.0%	30.0%	60.0%	30.0%	20.0%	30.0%
Object cleft	100.0%	90.0%	50.0%		50.0%		60.0%	70.0%	30.0%	40.0%	40.0%	50.0%	30.0%	60.0%	40.0%	60.0%
Object control	90.0%	90.0%	60.0%		30.0%		**60.0%**	**70.0%**	50.0%	50.0%	50.0%	70.0%	30.0%	50.0%	50.0%	60.0%
Object relative	**50.0%**	**90.0%**	**30.0%**		30.0%		60.0%	80.0%	40.0%	60.0%	40.0%	60.0%	30.0%	60.0%	70.0%	40.0%
OR complex NP	100.0%	100.0%	20.0%		80.0%		20.0%	80.0%	60.0%	60.0%	60.0%	40.0%	40.0%	80.0%	40.0%	60.0%
Passive	70.0%	100.0%	90.0%		60.0%		90.0%	90.0%	**30.0%**	**40.0%**	**10.0%**	**50.0%**	60.0%	50.0%	70.0%	80.0%
Pronoun	90.0%	100.0%	90.0%		40.0%		90.0%	70.0%	60.0%	50.0%	20.0%	50.0%	60.0%	50.0%	50.0%	70.0%
Reflexive	70.0%	100.0%	90.0%		70.0%		90.0%	100.0%	70.0%	100.0%	100.0%	100.0%	10.0%	60.0%	60.0%	90.0%
Subject control	90.0%	100.0%	70.0%		20.0%		80.0%	90.0%	30.0%	80.0%	30.0%	70.0%	30.0%	40.0%	20.0%	70.0%
Unaccusative	100.0%	100.0%	80.0%		50.0%		90.0%	100.0%	80.0%	100.0%	80.0%	100.0%	**60.0%**	**100.0%**	**60.0%**	**100.0%**
Total	83.6%	97.3%	62.7%	ND	47.3%	ND	72.7%	81.8%	51.8%	61.8%	51.8%	65.5%	42.7%	56.4%	48.2%	64.5%

OM training	BUMA10		BUMA21		BUMA05		BUMA20		BUMA11		BUMA14		BUMA24	
Structure trained:	OR		OR		OC		OC		PA		PA		UNACC	
Sentence type	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
3 noun phrase (NP)	20.0%	100.0%	100.0%	100.0%	80.0%	100.0%	100.0%	100.0%	60.0%	20.0%	0.0%	20.0%	0.0%	20.0%
Active	80.0%	100.0%	100.0%	100.0%	100.0%	100.0%	90.0%	50.0%	60.0%	20.0%	70.0%	50.0%	30.0%	10.0%
Raising NP	10.0%	80.0%	100.0%	90.0%	60.0%	0.0%	80.0%	20.0%	10.0%	0.0%	20.0%	50.0%	30.0%	10.0%
Object cleft	100.0%	100.0%	100.0%	90.0%	**40.0%**	**70.0%**	**60.0%**	**100.0%**	40.0%	40.0%	20.0%	70.0%	40.0%	30.0%
Object control	50.0%	100.0%	100.0%	90.0%	60.0%	100.0%	90.0%	80.0%	30.0%	20.0%	10.0%	30.0%	0.0%	30.0%
Object relative	**60.0%**	**40.0%**	**60.0%**	**50.0%**	20.0%	0.0%	0.0%	50.0%	0.0%	10.0%	10.0%	0.0%	0.0%	0.0%
OR complex NP	20.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%
Passive	100.0%	100.0%	100.0%	80.0%	70.0%	80.0%	100.0%	100.0%	**60.0%**	**80.0%**	**40.0%**	**50.0%**	20.0%	20.0%
Pronoun	50.0%	90.0%	80.0%	90.0%	30.0%	80.0%	90.0%	90.0%	10.0%	50.0%	30.0%	60.0%	20.0%	10.0%
Reflexive	0.0%	100.0%	100.0%	90.0%	0.0%	100.0%	100.0%	20.0%	80.0%	60.0%	30.0%	0.0%	10.0%	0.0%
Subject control	40.0%	60.0%	90.0%	90.0%	80.0%	10.0%	90.0%	30.0%	10.0%	10.0%	10.0%	70.0%	20.0%	20.0%
Unaccusative	0.0%	100.0%	100.0%	90.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	**50.0%**	**90.0%**
Total	55.5%	84.5%	89.1%	82.7%	54.5%	62.7%	77.3%	63.6%	39.1%	37.3%	30.9%	44.5%	20.0%	20.9%

Note. The performance level for the trained structure for each participant is bolded. Performance levels above chance are underlined. All other values are at or below chance level comprehension. For SPM, all structures have a chance of 50% accuracy. For OM, depending on the structure, there is either a 50% chance of guessing correctly or a 33% chance. Except ORCNP and 3NP, which have five items, all other structures have 10 items. OR = object relative; OC = object cleft; PA = passive; UNACC = unaccusative; ND indicates no data, as participants did not finish treatment.

because the same verb must be able to be used both unaccusatively and transitively (to allow plausible foils). Because participants were only trained on one sentence type in one modality (SPM or OM), the same sentences for each sentence type were used across each training modality.

Experimental Design

A single-subject multiple-baseline design (Thompson, 2006) was employed to examine the treatment effects. Following three baseline sessions, for each participant, one treatment task was used to train comprehension of one affected sentence structure. The treatment protocol used either an SPM or an OM task, and the treated sentence type was either OR, OC, PA, or UNACC. In addition to the target structures, two untrained control structures (3NP and ORCNP) were included in the monitoring batteries. Treatment was discontinued when the participant exceeded 80% accuracy on three consecutive monitoring batteries or after 10 weeks of treatment, whichever came first. Versions of both the SPM and OM monitoring batteries were administered weekly during the treatment and three additional times after treatment to establish the effect size (ES) of the treatment. Two training session schedules were used. The first consisted of two 1-hr sessions per week. The second consisted of two 2-hr sessions per week.

The criteria for efficacious treatment were deemed to be an increase in the level of performance from the pretreatment baseline probes to posttreatment probes for the treated structure such that accuracy rises from at or below chance to above chance and either (a) accuracy on the treated structure rises by 33% or (b) the ES of training on the treated structure is 2.6. These criteria were selected for the following reasons. First, participants were required to improve from below/at chance to above chance performance rather than normal performance because the 95% confidence interval for normal performance includes chance for OR sentences (Caplan et al., 2006), and we believe that performance must be above chance in order to demonstrate that participants can reliably understand target sentences. The other two criteria were included because it would be possible for a client to meet criterion by increasing the number of correct responses by one sentence, which we believe is too small of an improvement. The level of 33% improvement was selected so that a client performing at the upper range of chance in the pretest period would have to improve by four items—an improvement that seems possible and meaningful. Finally, with regard to the criteria for ESs, existing data suggest that the ES seen in aphasia treatment studies differs depending on the language process under study. Based on an overall review of research on treatment studies in aphasia (Robey, Schultz, Crawford, & Skinner, 1999), Beeson and Robey (2006) suggested that ESs of 2.6, 2.9, and 5.8 be used as initial benchmarks for small, medium, and large, respectively, for single-subject treatment studies in aphasia. Thus, in this study, we considered treatments that result in an ES of at least 2.6 to be successful as a first step in understanding the effectiveness of a treatment for sentence comprehension.

ESs for each participant were calculated by subtracting the average baseline probe scores from the average posttreatment scores and dividing the result by the standard deviation of the baseline scores. Chance performance for the SPM and OM task on each structure was calculated using the binomial test. For SPM, there was a 50% chance of selecting the correct picture for all sentence structures; for the OM task, all structures except OR and ORCNP also had a 50% chance of enacting the thematic roles accurately. For OR and ORCNP structures, there was a 33% chance of enacting the accurate thematic roles.

Treatment Protocol

The treatment used an approach that explicitly demonstrates the thematic role of each constituent of the sentence. Both the SPM and OM treatments were similar in terms of the number of steps as well as the basic procedures involved, but differed in terms of the nature of thematic role mapping. See Appendix B for detailed protocol descriptions. In the SPM task, the clinician used pictures to demonstrate the thematic roles in the trained sentence to the client, whereas in the OM task, the participant enacted the thematic roles using paper dolls. 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 required to facilitate sentence comprehension.

Reliability

All of the baseline, training, and monitoring sessions were digitally video recorded. Responses were scored by the treating clinician, and 30% of these sessions were verified by a student who was trained to code each training step for adherence to the protocol and to code participants' enactment of thematic roles as depicting the target meaning. In terms of the reliability of the dependent variable, responses to SPM tasks were recorded on E-prime and responses to OM were recorded by the clinician. OM has proven to be a highly feasible means of having participants demonstrate comprehension, with hundreds of participants having been tested using this method and interobserver reliability of >90% for interpretation of depicted thematic roles (Caplan et al., 1985). Initial disagreements among the primary and secondary coder were discussed and either were resolved or the trial was eliminated. The overall interobserver reliability on the dependent variable was 99%. Reliability on the independent variable (i.e., administration of treatment) was 89% between the two scorers.

Results

We trained 15 participants, two on each of the target structures. Only one participant entered into the OM–UNACC treatment condition because several other candidate participants improved on this structure during baseline testing. Two participants dropped out of the study before completion of data collection in the SPM phase; hence, we cannot report efficacy data on these two participants. Of the remaining 13 participants, six participants met all three criteria set for treatment (see Table 3 for a summary of results). It should be noted that of the seven participants assigned to the OM

TABLE 3. Participants' performance on the three criteria set for efficacious treatment.

Participant	Trained task	Trained structure	Frequency	Outcome measures	3NP	OC	OR	ORCNP	PA	UNACC
BUMA03	SPM	OR	2 × 2	ES:	2.31	0.00	**2.60**	2.67	0.67	0.58
				change in % acc:	13%	0%	**20%**	27%	4%	3%
				chance:	AC → AC	AC → AC	**AC → AC**	AC → AC	AC → AC	AC → AC
BUMA17	SPM	OR	2 × 1	No effects						
BUMA07	SPM	OC	2 × 1	No effects						
BUMA15	SPM	OC	2 × 2	ES:	0.41	**1.26**	1.09	–0.65	1.83	1.17
				change in % acc:	3%	**11%**	15%	–8%	6%	18%
				chance:	AC → AC	**AC → AC**	C → C	C → C	AC → AC	AC → AC
BUMA13	SPM	PA	2 × 2	ES:	–0.33	0.48	–0.29	0.22	**0.50**	1.15
				change in % acc:	–3%	7%	–2%	3%	**9%**	7%
				chance:	C → C	BC → C	C → C	C → C	**C → C**	AC → AC
BUMA16	SPM	PA	2 × 1	ES:	–8.66	3.27	–3.26	–1.00	**6.34**	1.00
				change in % acc:	–50%	33%	–33%	–20%	**48%**	10%
				chance:	C → BC	BC → AC	C → BC	C → BC	**C → AC**	AC → AC
BUMA08	SPM	UNACC	2 × 1	ES:	6.35	–0.44	2.31	2.31	–1.33	**0.58**
				change in % acc:	37%	–4%	9%	13%	–9%	**3%**
				chance:	BC → C	C → C	C → C	C → C	C → C	**C → C**
BUMA23	SPM	UNACC	2 × 2	ES:	–2.00	–0.30	0.70	–0.40	–2.70	**5.77**
				change in % acc:	–3%	–2%	7%	–13%	–18%	**33%**
				chance:	C → C	C → C	C → C	C → BC	C → C	**C → AC**
BUMA10	OM	OR	2 × 2	ES:	0.00	0.56	**23.00**	4.21	0.00	0.58
				change in % acc:	0%	2%	**91%**	17%	0%	33%
				chance:	AC → AC	AC → AC	**BC → AC**	BC → C	AC → AC	AC → AC
BUMA21	OM	OR	2 × 1	ES:	0.00	0.00	**3.33**	0.00	0.58	0.00
				change in % acc:	0%	0%	**22%**	0%	2%	0%
				chance:	AC → AC	AC → AC	**AC → AC**	C → C	AC → AC	AC → AC
BUMA05	OM	OC	2 × 1	ES:	1.73	**1.37**	0.03	0.00	0.44	0.00
				change in % acc:	10%	**18%**	0%	0%	5%	0%
				chance:	AC → AC	**C → AC**	BC → BC	BC → BC	AC → AC	AC → AC
BUMA20	OM	OC	2 × 2	ES:	–0.43	**4.88**	11.36	5.01	0.00	0.00
				change in % acc:	–3%	**38%**	76%	33%	0%	0%
				chance:	AC → AC	**C → AC**	BC → AC	BC → AC	AC → AC	AC → AC
BUMA11	OM	PA	2 × 2	ES:	–2.79	2.28	–0.96	–0.87	**3.24**	–0.07
				change in % acc:	–48%	23%	–6%	–5%	**47%**	–1%
				chance:	AC → BC	BC → C	BC → BC	C → BC	**C → AC**	AC → BC
BUMA14	OM	PA	2 × 1	ES:	0.58	–2.40	0.22	0.00	**–1.53**	0.67
				change in % acc:	7%	–24%	2%	0%	**–16%**	7%
				chance:	BC → BC	AC → C	BC → BC	BC → BC	**AC → C**	AC → AC
BUMA24	OM	UNACC	2 × 1	ES:	4.62	–1.94	0.00	0.00	1.95	**7.51**
				change in % acc:	27%	–7%	0%	0%	20%	**43%**
				chance:	BC → BC	BC → BC	BC → BC	BC → BC	BC → C	**BC → AC**

Note. In order for treatment to be considered effective for each participant, accuracy should rise from at or below chance to above chance and either (a) accuracy on the treated structure rises by 33% or (b) the effect size (ES) of training on the treated structure is 2.6. ORCNP = objective relative complex noun phrase; BC → AC indicates improvement from below chance (BC) to above chance (AC) and so on. The trained structures are bolded.

treatment, four (BUMA10, BUMA20, BUMA11, BUMA24) met the stringent treatment criteria and two met partial criteria (BUMA21, BUMA05). BUMA14 showed no response to treatment at all; there was a decline in performance as a function of treatment. Results were mixed for participants receiving the SPM treatment. Two participants (BUMA16, BUMA23) met both the criteria, one (BUMA03) met one of two criteria, and three (BUMA08, BUMA13, BUMA15) showed no improvement. Both BUMA15 and BUMA03 were already above chance before treatment (although both participants made gains in treatment). Three participants (BUMA08, BUMA13, BUMA15) showed no change as a function of treatment, and closer inspection of these participants' time-series data revealed great variability on a session-by-session basis.

Recall that we selected two control structures, 3NP and ORCNP, in order to establish experimental control in the study. It was reasoned that ORCNP would not change as a function of treatment as they were significantly more complex than any other sentence type. Although 3NP sentence structures were included to control for the length of the OR sentence structures, these sentences were canonical structures and thus could change as a function of treatment, especially if the treatment was provided to the more complex OR sentence structures. Results from Table 3 show that of the 13 participants who completed treatment, three participants showed changes on the ORCNP structures based on our criteria set for improvement on trained items. BUMA10 and BUMA03 were trained on OR structures, and BUMA20 was trained on OM–OC. Two other participants showed changes on 3NP based on our criteria (BUMA24 and BUMA08); both participants were trained on UNACC. Neither of these two participants showed changes on ORCNP. Isolated improvements in the control structures in some participants do not pose problems for experimental control because for each participant, there were several untrained structures that showed no change in the face of improvements for the trained structure (see Table 3). As an example, participants trained on OR did not improve on PA (BUMA10, BUMA21, BUMA03), and participants trained on PA did not improve on OR or ORCNP (BUMA11, BUMA16).

We performed several statistical tests on the data, which are organized according to (a) statistical tests conducted on the monitoring probe data that examine differences between the two treatment types and the two treatment dosages and (b) statistical tests conducted on the screener probe data that examine differences between the two treatment types. In several analyses, nonparametric statistics were performed due to the relatively small and unequal sample sizes.

A Wilcoxon test examining average percentage change (% change) on the trained structure of the monitoring probes found a significant effect ($z = 2.90$, $p = .0037$) across participants, indicating the overall positive effect of treatment. We then separated the participant data by treatment type (SPM/OM); a Mann–Whitney *U* test examining the effect of treatment type (SPM/OM) revealed no significant effect on treatment ES ($U = 15.0$, $p = .432$; Means: SPM = 2.84, OM = 5.97). Another Mann–Whitney *U* test examining the effect of treatment type (SPM/OM) revealed no significant effect on change in % accuracy ($U = 16.0$, $p = .520$; Means: SPM = 0.252, OM = 0.347). Although there were numerical differences between participants who received 2 hr of treatment each week (Mean ES = 2.9; Mean % change = 20%) and 4 hr of treatment each week (Mean ES = 5.89; Mean % change = 36%), the difference was not statistically significant for ES ($U = 19.0$, $p = .830$) or for average % change ($U = 16.0$, $p = .520$) (see Table 3).

Next, we examined the pre–post screener data (see Table 2). A Wilcoxon test on improvement on all of the 12 structures within the trained task, pre to post screener, across participants, revealed a significant effect of treatment ($z = 3.57$, $p = .0003$). Next, a Wilcoxon test on improvement on the trained structure within the trained task, pre to post screener, across participants, revealed a significant effect of treatment ($z = 2.48$, $p = .013$). A Wilcoxon test on improvement on 3NP within the trained task, pre to post screener, across participants, revealed no significant effect of treatment ($z = 0.652$, $p = .515$). Finally, a Wilcoxon test on improvement on ORCNP within the trained task, pre to post screener, across participants, revealed no significant effect ($z = 1.47$, $p = .142$). In addition, we performed Wilcoxon tests to examine the effect of each treatment on changes on the posttreatment screeners. Participants who received SPM treatment ($n = 6$) improved on their trained SPM structure ($z = 2.20$, $p = .028$), whereas participants who received OM treatment ($n = 7$) did not improve significantly on their trained OM structure ($z = 1.35$, $p = .18$).

Given that some untrained structures showed changes as a function of treatment (see Table 3), we conducted an exploratory cross-correlation analysis using the autoregressive integrated moving average (ARIMA) procedure for each participant to examine if improvements on the untrained structure were associated with improvements on the trained structure/task. ARIMA cross-correlation models are calculated for time-series data as follows: For each time series, a regression line is fit to the actual data and the residuals are calculated for that data. Then, cross-correlations are calculated on the residuals and are averaged over time (Box, Jenkins, & Reinsel, 1994). Therefore, a correlation at a negative lag would indicate that changes in the second structure precede changes in the first structure, a correlation at 0 lag would indicate that changes are concurrent in both structures, and a correlation at a positive lag would indicate that changes in the first structure precede changes in the second structure. In this study, for each participant, we correlated the time series between all possible pairs of structures at 10 lag points (–5 to 5). Correlations >.60 that exceeded two standard errors were deemed statistically significant. In the interest of space, we only report significant correlations (either positive or negative) between the trained structure and specific untrained structures and the corresponding ESs for the untrained structures for each participant.

When combined with the data presented in Table 3, Table 4 reveals several important observations. First, participants such as BUMA14, BUMA07, BUMA13, and BUMA08, who either dropped out or did not show improvements on the trained structure, did not show any generalization to untrained structures. Several other participants showed positive and negative changes on the untrained structures that correspond to the data regarding ES, percentage accuracy (% accuracy), and change to above chance levels presented in Table 3. Specifically, BUMA10 was trained on OR and showed concurrent changes in ES and % accuracy on ORCNP and in % accuracy for UNACC (correlation coefficient was .58). BUMA21 was also trained on OR but did not show generalization to untrained structures because several of the structures were above chance accuracy before treatment. BUMA05 was trained on OC but no other structures showed changes. BUMA20 was trained on OC; positive changes in ES, chance level accuracy, and % accuracy on OR and ORCNP coincided with improvements on OC. BUMA11 was trained on PA; slight improvements in ES, % accuracy, and chance levels were observed in OC that preceded changes on the trained structure. In contrast, ORCNP and 3NP declined relative to positive changes on PA. BUMA24 was trained on UNACC; changes in ES and % accuracy were observed on 3NP that preceded changes on UNACC. Also, slight changes in ES and % accuracy observed on PA coincided with improvements as the trained UNACC (see top of Figure 1).

With regard to participants receiving the SPM treatment, BUMA03 was trained on OR, and changes in ES and % accuracy were observed on 3NP that preceded improvements on OR as well as changes in ES and % accuracy on UNACC and ORCNP that coincided with changes in OR. Additionally, changes in UNACC preceded changes in ORCNP and PA, indicating that several untrained structures improved when OR was trained in this participant. BUMA15 was trained on OC and also showed changes in ES and % accuracy in PA

TABLE 4. Participants' cross-correlation results (*R* values reported in parenthesis) for untrained structures that show a correlation with the trained structure for each participant.

Participant	Trained structure	Positive correlations: Negative lag	Positive correlations: 0 lag	Positive correlations: Positive lag	Negative correlations: Negative lag	Negative correlations: 0 lag	Negative correlations: Positive lag
SPM training							
BUMA03	OR	with 3NP (.900)	with UNACC (.606) with ORCNP (.627)				
BUMA17	OR	No effects					
BUMA07	OC	No effects					
BUMA15	OC		with PA (.594)				
BUMA13	PA						
BUMA16	PA		with UNACC (.740) with OC (.675)			with OR (–.758) with 3NP (–.707)	
BUMA08	UNACC						
BUMA23	UNACC	with OR (.635)					
OM training							
BUMA10	OR		with ORCNP (.839)				
BUMA21	OR						
BUMA05	OC						
BUMA20	OC		with OR (.947) with ORCNP (.630)				
BUMA11	PA	with OC (.665)			with 3NP (–.723) with ORCNP (–.641)		
BUMA14	PA						
BUMA24	UNACC	with 3NP (.751)	with PA (.811)				

Note. Only correlations that exceed .60 and two standard errors are reported. Negative lags indicate lags of –1, –2, –3 sessions; positive lags indicate 1, 2, or 3 sessions; 0 lag indicates a change on the same session. Positive correlations indicate both structures improved; negative correlations indicate that as one structure improved, the other decreased.

concurrent with OC. This participant also showed changes in ES and % accuracy for OR and UNACC, but the cross-correlations were not significant. The lack of congruency between the cross-correlations and the outcome measures for the untrained structures seen in BUMA15 is not problematic because recall that cross-correlations are averaged over time and, thus, the coefficients are reflective of similarities in trend lines between the two structures. BUMA16 was trained on PA; there were coinciding improvements in ES and % accuracy in both UNACC and OC. Also, negative correlations were observed for both 3NP and OR, indicating that as comprehension of PA structures improved, comprehension of OR and 3NP declined (see bottom of Figure 1). BUMA08 was trained on UNACC, which did not improve; however, changes in ES and % accuracy were observed in 3NP, OR, and ORCNP; none of the correlations was significant due to the lack of improvements in UNACC. Lastly, BUMA23 was trained on UNACC and slight changes in ES and % accuracy were observed on OR that lagged changes on UNACC.

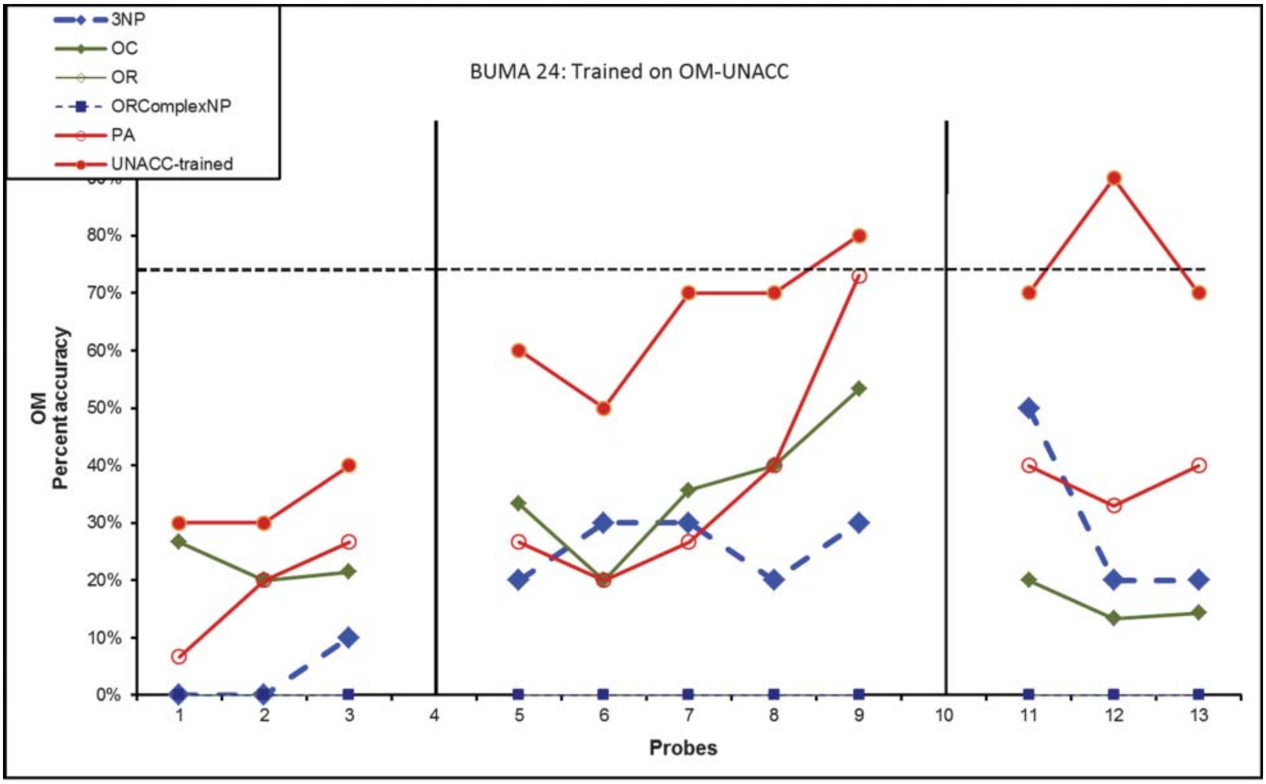
Discussion

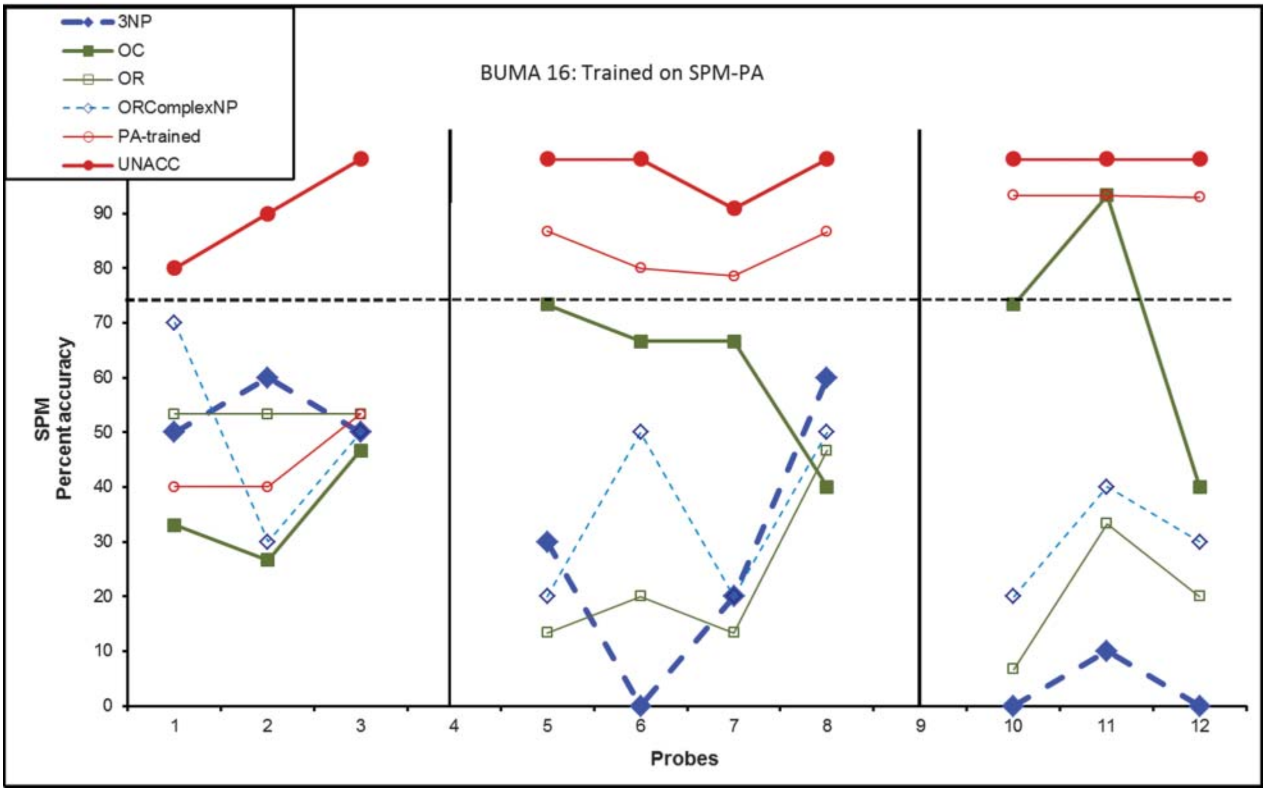
The goal of this project was to develop a theoretically motivated and effective treatment for sentence comprehension deficits in individuals with aphasia. Our basic hypothesis was that a treatment that trained participants on the relationship between syntactic structure and the meanings of sentences by having participants indicate thematic roles on pictures or by manipulating objects may result in an improved ability to use resources in the service of syntactic comprehension.

In general, the results support our hypothesis that the SPM and OM treatments, both based on strengthening thematic role mapping, were generally successful in improving sentence comprehension of noncanonical sentences. Treatment was clearly effective, based on the stringent criteria we set for efficacy using three different metrics. When the combination of the three criteria was taken into account, there were more participants who met our criteria in the OM treatment (4/7) than in the SPM treatment (2/6). Although neither % change nor ES independently captured the nature of the effect of treatment, it could be argued that these criteria are somewhat arbitrary and are not particularly indicative of any psychological aspect of sentence comprehension. In contrast, the third and main criterion—improvement from below/at chance accuracy to above chance accuracy on the trained structure—may be more reflective of the ability of an individual to comprehend syntactically complex sentences. Based on this metric, with the exception of three participants (BUMA14, BUMA13, and BUMA08), all participants comprehended the structure they were respectively trained on reliably above chance at the end of treatment. We should note that even though other participants showed above chance comprehension before treatment, each of them improved to greater levels of accuracy subsequent to treatment: BUMA21 (53% to 88% accuracy) and BUMA03 (75% to 95% accuracy).

Interestingly, even though there were no significant differences between the two treatment dosages (4 hr/week vs. 2 hr/week), four of the seven participants receiving the

FIGURE 1. Results for two participants (BUMA24, BUMA16) showing trends on trained structures and untrained structures within the trained task. Red lines indicate noun phrase movement structures, green lines indicate *wh*-movement structures, and blue dashed lines indicate control structures.





treatment for 4 hr/week met treatment effectiveness criteria, whereas only three of the eight participants receiving the treatment for 2 hr/week met treatment effectiveness criteria. In addition, numerical trends in the data indicated that participants who received treatment 4 hr/week showed mean ESs and % change accuracy that was larger than the mean ESs and % change accuracy for participants receiving treatment 2 hr/week. Therefore, the dosage of treatment arguably has some sort of effect on treatment outcome; however, given the lack of significant findings, any conclusions regarding the optimal treatment dosage for our sentence comprehension treatment are at best speculative at this point. We should note that our initial experimental design aimed to compare treatment provided for 1 hr four times a week with treatment provided for 2 hr two times a week. However, participants did not attend treatment four times a week consistently, requiring us to modify our treatment dosage comparison. This speaks to the tractability of actually prescribing and carrying out daily treatment, at least in a research/clinical setting.

Other than the observation that more participants met our criteria in the OM treatment than in the SPM treatment, differences between SPM and OM treatment were nonsignificant with respect to ES and % change on the trained structure, indicating that both treatments were equally effective in improving comprehension of the trained structure. This result is hardly surprising; participants were trained until they achieved criterion, and the treatment protocols for SPM and OM were identical except for utilization of pictures in SPM and object enactment in OM. There are some initial speculations for why more participants met the criteria on the OM treatment than the SPM treatment. It is possible that enacting the thematic roles during treatment may engage resources that are required for sentence processing differently than while marking thematic roles during picture matching. Consequently, enacting thematic roles with consistent feedback may lend itself to greater accuracy at identifying thematic roles for noncanonical sentences than marking thematic roles for picture matching. Clearly, the notion of a presumed relation between perceptual, motor, and language systems that is equally active in the execution and observation of actions has received extensive support (i.e., embodied communication; Rizzolatti & Arbib, 1998), and the difference between the demands of an enactment-based task and SPM task has been observed by other researchers (Salis & Edwards, 2009). Several recent rehabilitation approaches of aphasia are based on the notion of capitalizing on this interaction between action and language and are mostly geared toward noun and/or verb retrieval (Marangolo et al., 2010; Raymer et al., 2006; Rose & Douglas, 2001). The OM treatment described here provides preliminary evidence for the benefit of enactment in sentence comprehension and an important contribution to therapies for sentence comprehension deficits that have until now mostly used picture or written word stimuli.

It is interesting to note that even though fewer participants receiving SPM treatment met the criteria for improvement on the monitoring probes, when changes on the post- versus pretreatment screeners were compared for participants who were trained on the SPM task relative to participants who were trained on the OM task, the opposite results were found: Participants trained on the SPM task showed significant improvements on their trained and untrained sentences in SPM tasks, whereas participants trained on the OM tasks did not show significant improvements on the OM task screeners. Therefore, it appears that although OM treatment is more effective as a treatment approach, the SPM treatment results in greater overall changes in comprehending a variety of syntactically manipulated sentences. These observations are preliminary and require further careful examination with larger groups of participants receiving both SPM and OM treatments.

Finally, we examined patterns of generalization from the trained structure to untrained structures within the trained task. Results showed that when generalization occurred, structure was not a barrier to generalization; participants showed generalization within and across NP and *wh*-movement structures, specifically between PA and OC (e.g., BUMA16, BUMA11). Other participants showed generalization within movement structures (e.g., BUMA20 from OC to OR; BUMA24 from UNACC to PA), and still other participants showed generalization across movement structures. These results suggest that because participants have resource reductions and not specific deficits, training participants on the relationship between syntactic structure and the meanings of sentences by having participants indicate thematic roles on pictures or by manipulating objects may have resulted in an improved ability to use resources to facilitate comprehension of other noncanonical sentences. Two participants (BUMA 24, BUMA08) showed positive changes on 3NP (canonical sentences), suggesting that the increased sentence length with less complex syntactic structure (such as canonical sentences) requires fewer resources than the sentence with complex syntactic structures (such as noncanonical sentences). Changes on ORCNP were observed in two participants (BUMA10, BUMA03) who received training on OR and one (BUMA20) who received training on OC, again suggesting that improved ability to use resources for noncanonical sentences facilitated comprehension of other noncanonical sentences. With regard to CATE's prediction about generalization only from complex to simple structures, the results are equivocal on this point. Some participants showed generalization from complex to simpler structures, whereas others showed improvements from simple to more complex structures. For instance, BUMA03 was trained on OR and improved on OC, with OR being more complex than OC. BUMA16 was trained on PA and improved on UNACC, with PA being more complex than UNACC. In contrast, BUMA 24 showed improvements from UNACC to PA, and BUMA 20 showed improvements from OC to OR.

Nonetheless, these generalization results provide preliminary but promising evidence for the utility of the treatment program in terms of facilitating improvements to untrained sentence structures. From a theoretical standpoint, if what is trained is an ability to use resources in the service of syntactic comprehension, these results suggest that successful training of the trained structures results in improvements to structures that require the same or fewer resources. Clearly, the next step is to establish the extent to which treatment generalizes to untrained structures and tasks. It is also important to understand if there are savings in further treatment, maintenance, and transfer to discourse in real-world comprehension settings.

Conclusion

We successfully developed and implemented two treatments for syntactic comprehension on 15 participants with sentence comprehension deficits. In participants where treatment was efficacious, a significant increase in the level of performance from pre- to posttreatment probes was observed for the trained structure and resulted in above chance performance. Results also show the efficacy of the treatment approach in training two syntactic structures (*wh*-movement structures: OR and OC. NP-movement structures: PA and UNACC). Our continued work in this area involves a larger group of participants to systematically examine the nature of generalization, maintenance, and transfer resulting from this sentence comprehension treatment.

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Appendix A

Sample Sentence Structures in Treatment

Structure	Number of items	Example
Screeners		
Active	10	The helicopter trapped the airplane.
Noun phrase Raising	10	The niece seemed to the wife to be pushing the boy.
Cleft object	10	It was the bike that the tank chased.
Object control	10	The man convinced the king to follow the wife.
Object relative	10	The daughter who the nephew rescued poked the uncle.
Passive	10	The boy was nudged by the aunt.
Pronoun-as-object	10	The man said that the boy kissed him.
Reflexive	10	The mother said that the girl kicked herself.
Subject control	10	The nephew pledged to the grandmother to hug the niece.
Unaccusative	10	The woman was drowning.
3 noun phrase	5	The girl said that the aunt fed the man.
Object relative w/ complex noun phrase	5	The girl who the husband of the woman kicked touched the boy.
Monitors		
3 noun phrase	10	The father said that the boy hugged the aunt.
Object relative w/ complex noun phrase	10	The train that the door of the car scratched destroyed the helicopter.
Unaccusative	10	The man was spinning.
Passive	15	The bike was dragged by the car.
Cleft object	15	It was the husband who the wife tickled.
Object relative	15	The diamond that the saw cut destroyed the ball.
Therapy items[a]		
Unaccusative	10	The king was healing.
Passive	20	The cannon was scratched by the truck.
Cleft object	20	It was the water that the blanket covered.
Object relative	20	The husband who the girl greeted bit the wife.

[a]Each participant was assigned to *one* of these structures.

Appendix B

Sample Treatment Protocols for Sentence to Picture Matching (SPM) and Object Manipulation (OM) Passive Sentences

SPM treatment protocol	OM treatment protocol
For example, the SPM-PA (e.g., *the aunt was kissed by the man*) treatment protocol included the following steps: (1) Upon hearing the sentence read aloud by the clinician, the patient chose between the target picture depicting that action and a foil picture with reversed thematic roles (i.e. depicting *the man was kissed by the aunt*), and feedback regarding accuracy was provided; (2) The clinician removed the foil picture, placed a strip of paper with the target sentence printed on it beneath the target picture, and further explained the roles of the agent and theme (e.g., "In this sentence, *the aunt was kissed by the man,* the man is kissing the aunt."); (3) The clinician emphasized the agent of the action by placing a version of the target picture in which the agent was bolded/ emphasized and the theme was un-bolded/de-emphasized, as well as a sentence strip in which the agent was bolded/emphasized and the theme was un-bolded/de-emphasized, on the table and saying, "In this part of the sentence, *the aunt was kissed by the man,* the man is doing the action. Ok, now you show me who is doing the action". Feedback regarding accuracy was again provided; (4) The clinician emphasized the theme of the action in a similar manner, using both a picture and sentence strip in which the theme was bolded/emphasized and the agent was un-bolded/ de-emphasized, again provided feedback as to accuracy; (5) The clinician put the original target picture and target sentence strip back on the table and once again read the full sentence and explained the roles of the agent and theme; (6) The clinician read the target sentence aloud and gave the patient the target picture and the foil picture to choose from.	Therefore, for the same sentence, the OM (e.g., *the aunt was kissed by the man*) treatment protocol included the following steps: (1) Upon hearing the sentence read aloud by the clinician, the patient enacted the target sentence using dolls (*aunt, man*) and feedback regarding accuracy was provided; (2) The clinician enacted the sentence using the dolls, placed a strip of paper with the target sentence printed on it beneath the target picture and further explained the roles of the agent and theme (e.g., "In this sentence, *the aunt was kissed by the man,* the man is kissing the aunt."); (3) The clinician emphasized the agent of the action as well as a sentence strip in which the agent was bolded/emphasized and the theme was un-bolded/de-emphasized, on the table and saying, "In this part of the sentence, *the aunt was kissed by the man,* the man is doing the action. Ok, now you show me who is doing the action". Feedback regarding accuracy was again provided; (4) The clinician emphasized the theme of the action in a similar manner (e.g., "In this part of the sentence, *the aunt was kissed by the man,* the woman is being kissed. Ok, now you show me who is receiving the action") and then the theme of the action was emphasized in a similar manner (5) The clinician put the original target picture and target sentence strip back on the table and once again read the full sentence and explained the roles of the agent and theme; (6) The patient enacted the sentence with feedback from the clinician.

Development of a Theoretically Based Treatment for Sentence Comprehension Deficits in Individuals With Aphasia

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