Improving the maintenance of word representations in short-term memory to improve language function: Acquisition and generaliization effects.

The hallmark of a successful rehabilitation program for aphasia is generalization. We report a treatment program for word processing impairment in aphasia that incorporates methods to promote acquisition and response generalization, as well as generalization of treatment effects to language tasks other than those used in treatment (Kalinyak-Fliszar, Kohen, & Martin, 2011). The program also includes a second feature to promote generalization based on the complexity account of treatment efficacy (*CATE*; Thompson, Shapiro, Kiran, & Sobecks, 2003; Kiran, 2008).

The treatment program is based on principles of an interactive activation (IA) model of word processing (Dell & O'Seaghdha, 1992), which postulates specific processes responsible for activating and maintaining activation of a word's semantic and phonological representations during comprehension and production of language. It has been proposed that impairment to this ability to maintain activation of linguistic representations is the source of co-occurring word processing and verbal STM impairments in aphasia (Martin & Saffran, 1997). This relationship is supported by a large body of empirical evidence demonstrating linguistic influences on verbal STM span in speakers with and without aphasia, statistical association of the presence of word processing and verbal STM impairment in aphasia, and co-occurring improvements of word processing and verbal span following recovery from aphasia (Martin, 2009).

This model predicts that treatment of the activation maintenance ability will promote acquisition and response generalization effects, as well as generalization effects to language tasks not used in treatment. Recently, treatments have targeted the co-occurring impairments of language and STM memory in aphasia by varying length and complexity of stimuli or imposing a delay before a response (e.g., Koenig-Bruhin & Studer-Eichenberger, 2007; Kalinyak-Fliszar, et al., 2011). These manipulations have resulted in generalization effects to untrained items and tasks not used in training, providing stronger evidence for this model.

The second feature of our treatment program to promote generalization is based on evidence provided by *CATE* (Thompson et al., 2003). Specifically, treatment of more complex structures (e.g., sentences with objective relative clauses) or less typical category members (e.g., peacock) results in generalization of performance to less complex structures (e.g., wh-questions) and more typical category members (e.g., robin) if the trained and untrained stimuli share a common relationship (Thompson et al, 2003; Kiran, 2008).

In the present study, we replicated our language and STM treatment with a second individual with conduction aphasia. Similarly, we predicted that improvements in language ability, evinced as improved ability to maintain activation of phonological representations in STM, would be evident in acquisition and response generalization effects of treatment and would generalize to better performance on language tasks other than those used in treatment. Motivated by *CATE* we examined whether training more complex stimuli enhanced generalization effects to untrained less complex stimuli if the trained and untrained items shared a common relationship.

Method

Participant. TB, a 54-year old right-handed male, experienced a left posterior temporal lobe infarct extending into the parietal lobe in July, 2006. He was 52 months post onset at the time of enrollment.

Language evaluation (Table 1). TB's language profile was consistent with a conduction aphasia. Results of the Revised Token Test (*RTT*; McNeil& Prescott 1978) revealed a severe auditory processing deficit. Other measures indicated relatively spared input semantic processing compared to input phonological processing.

Pretreatment measures.

Temple Assessment of Language and Short Term Memory in Aphasia (TALSA; Kalinyak-Fliszar et al., 2011). The *TALSA* includes measures of language processing that incorporate (1) STM variations into language measures and (2) linguistic variations into span measures. Results (Tables 2, 3 and 4) revealed impairments of output phonological processing and input and output lexical semantic processing. Lower span scores were observed when span manipulated phonological characteristics of the items to be recalled. In general, TB's performance declined with increasing temporal interval and for tasks that manipulated memory load.

Narrative discourse. Narrative discourse measures (Nicholas & Brookshire, 1993) were administered to assess content information units (CIUs). TB produced .33 CIUs in a 1781 word language sample.

Experimental stimuli. These were selected from a 420-item pretest of 2- and 3-syllable words and nonwords. Four experimental sets (30 items/set) were formed from 2-and 3-syllable nonwords: 10 items each to assess acquisition, response generalization and "cross generalization" (CG). (*Note*: Excellent repetition of word stimuli precluded their use in treatment.)

Treatment program. The treatment program (Kalinyak-Fliszar et al., 2011; Appendix A) is designed to improve activation and maintenance of increasingly more complex semantic and phonological representations at increasing temporal intervals. Participants are assigned to a specific module, level and interval based upon their performance on the *TALSA*. TB was enrolled in Phonological Module, Level 1, 1-sec UF interval condition.

Treatment. A hierarchical cueing procedure (e.g., Wambaugh, Cameron, Kalinyak-Fliszar, Nessler, & Wright, 2004; Appendix B) was used to elicit repetition responses. Treatment continued until $\geq$ .80 was achieved for two consecutive probe sessions or until a minimum of 12 treatment sessions was completed.

Experimental design. This is detailed in Table 4.

Post treatment measures. See Table 4.

Results

Acquisition and maintenance. Figure 1. shows acquisition and maintenance data for treatment, response generalization and CG items for 2- and 3-syllable nonwords (Sets 1-4) at 1-sec and 5-sec UF intervals. Shewart chart trend lines (Robey, Schultz, Crawford & Sinner, 1999) were used to assist in visual interpretation of treatment and maintenance effects. Results are summarized below.

1-second UF interval condition.

Set 1: 3-syllable treatment and 2-syllable untrained CG items improved rapidly from baseline.

Behavioral and Shewart chart criteria met for treatment items (probes 11-12) and for CG items (probes 10-11).

Limited generalization to untrained 3-syllable response generalization items.

Maintenance of treatment effects specific to 3-syllable treatment items.

Set 2: Behavioral criteria met for 2-syllable treatment and response generalization items, probes 12 -14.

No generalization to 3-syllable CG items.

Set 3: Robust acquisition and maintenance effects limited to 2-syllable treatment items.

Set 4: Pattern of performance similar to that observed in Set 1 with one exception: maintenance of treatment effects for treatment items *and* untrained CG items.

5-sec UF interval condition. Similar patterns of repetition were observed for treatment, response generalization and CG items with some exceptions.

Set 1 and Set 4: Behavioral and/or Shewart criteria met in baseline (treatment and response generalization items). Behavioral criteria met for 2-syllable CG items (*Set 4*).

Set 2: Acquisition limited to 2-syllable treatment items but achieved in baseline.

Pre- and post-treatment assessments (Tables 1-3). Preliminarily, improvements were evident on the following *TALSA* subtests: synonymy triplet judgments (3-item), word pair repetition (semantically- and phonologically-related pairs), word repetition span, and spans varied for frequency and imageability.

Discussion

Replication of this treatment with a second individual with conduction aphasia has provided additional evidence for directly treating the activation maintenance deficit as a rehabilitation approach for aphasia. Specifically, the treatment program produced not only acquisition and generalization effects to target stimuli, but also improvement on standardized language and *TALSA* measures (completed thus far), especially those measures that require increased STM support (e.g., *RTT*, span measures). Also, this study provides additional evidence for the principles of the complexity account of treatment efficacy for aphasia (Thompson et al., 2003): Robust generalization effects to untrained “less complex 2-syllable cross generalization” nonword stimuli were observed when “more complex” 3-syllable nonword stimuli were targeted in treatment, but the reverse pattern was not observed.

Table 1. Pretreatment standardized language evaluation.

Measure	*Pretreatment*	*Posttreatment*
Western Aphasia Battery		
Information content	9/10	
Fluency	8/10	
Comprehension		
Yes/no questions	57/60	
Auditory word recognition	55/60	
Sequential commands	56/80	
Repetition	58/100	
Naming		
Object naming	34/60	
Word fluency	2/20	
Sentence completion	6/10	
Responsive speech	6/10	
Aphasia Quotient	68	
Aphasia Classification	Conduction	
Boston Naming Test	8/60	TBA
Peabody Picture Vocabulary Test IIIA		
Raw Score	142	149
Standard Score	73	75
Pyramid and Palm Trees		
Picture	48/52 (.92)	
Word	47/52 (.90)	
Auditory Lexical Decision		
Words	38/40	
Nonwords	32/40	
Revised Token Test	9.90 (9th %ile)	10.38 (15th %ile)
Corsi Block (ISO)		
Forward	4.33	4.33
Reverse	3.00	

Table 2. TALSA Part 1. STM variation 1: Single and multiple word processing tasks with two interval conditions: 1-second unfilled (1-sec UF) and 5-second unfilled (5-sec UF).

	Pretreatment		Post treatment	
	Interval Condition		**Interval Condition**	
Input phonological and lexical-semantic tasks	1-sec UF	5-sec UF	1-sec UF	5-sec UF
Phoneme discrimination				
Word (n=44)	0.98	0.98	NA	NA
Nonword (n=44)	1.00	0.98	NA	NA
Rhyme judgments				
Word (n=60)	0.98	0.93	NA	NA
Nonword (n=60)	0.90	0.90	TBA	TBA
Lexical comprehension (n=48)	1.00	0.98	NA	NA
Category judgments - pictures (n=60)	0.95	0.63		
Sentence comprehension (n=20)				
Reversible	0.60	0.50		0.30
Lexical	1.00	0.80		0.80
Output phonological and lexical-semantic tasks				
I. Single word processing tasks				
Word-nonword repetition				
Word (n=45)	1.00	0.98	0.96	
Nonword (n=45)	0.47	0.56		0.58
II. Multiple word processing tasks				
Word pair repetition				
Semantically Related (n=10)	0.70	0.50	0.90	0.60
Phonologically Related (n=10)	0.20	0.30	0.50	0.30
Unrelated (n=10)	0.80	0.30	0.50	0.40
Sentence repetition				
Unpadded (n=50)	0.34	0.38		
Padded (n=80) / Post Tx (n=70)	0.26	0.19		
Picture naming (n=90)	0.30	0.32	0.25	0.34
Semantic*	0.02	0.07	0.01	0.04
Mixed*	0.02	0.06	0.00	0.01
Nonword*	0.02	0.01	0.00	0.01

*Picture Naming Errors

Table 3. TALSA Part 1. STM variation 2: Increasing memory load for for word judgment tasks.

	Pretreatment		Post	
	2-item version	**3-item version**	**2-item version**	**3-item version**
Synonymy Triplet Judgments (n=40)*	0.85	0.80	TBA	0.85
Rhyming Triplet Judgments (n=30)**	1.00	0.87	NA	0.83

*Words

**Pictures

Table 4. TALSA Part 2. Span measures with language variations.

	Pretreatment	Post treatment
Digit and Word Span*		
Digits (ISO)		
pointing	3.00	2.80
repetition	3.00	3.40
Words (ISO)		
pointing	2.20	TBA
repetition	3.00	TBA
Word and Nonword Repetition Span*		
Word	1.40	2.20
Nonword	1.20	1.20
Repetition span for words varied for frequency (F) and imageability (I)*		
HiF-HiI	2.00	2.33
HiF-LoI	1.67	2.00
LoF-HiI	1.67	2.67
LoF-LoI	1.33	2.00
Probe memory Span**		
Semantic	4.13	TBA
Phonological	5.47	TBA

*Maximum string length = 7 items

**Maximum string lengths: Identity = 12, Semantic = 7, Phonological = 7

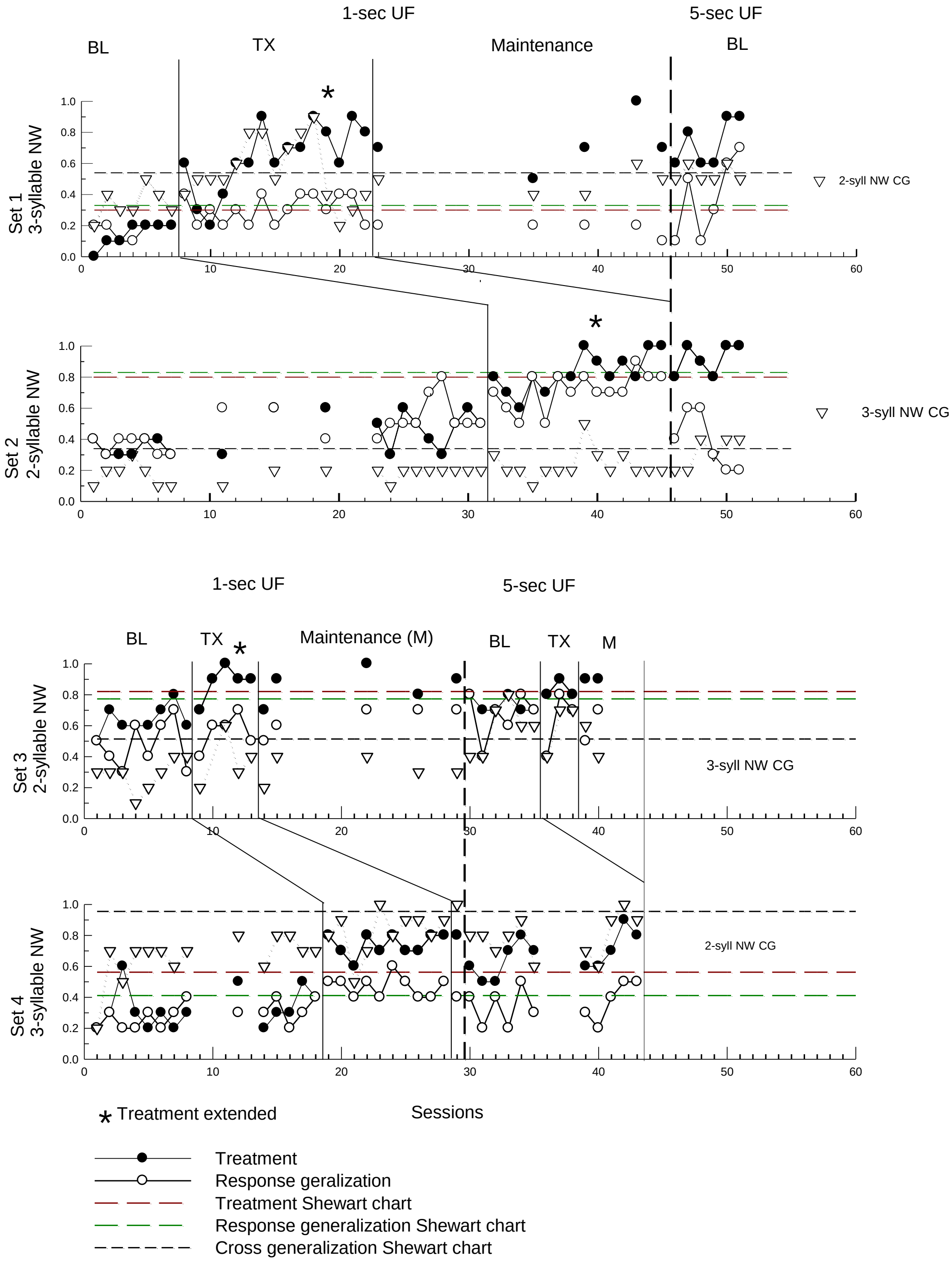

Figure1. Proportion correct nonword (NW) repetition responses during probe sessions for treatment, response generalization and cross generalization items, Phonological Module , Level 1.

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Appendix A

Protocol for treatment of short-term word activation and maintenance impairments:
1-second unfilled (1-sec UF), 5-second unfilled (5-sec UF).

Phonological Module	**Interval condition**	
Variations	1-sec UF	5-sec UF
Level 1		
Hi Image- 2-syllable words	1	1
Hi Image - 3-syllable words	2	2
2-syllable nonwords	3	3
3-syllable nonwords	4	4
Level 2		
Phonologically unrelated/related word pairs	1	1
Phonolgoically unrelated/related word triplets	2	2

Phonological + Semantic Module		
Variations	1-sec UF	5-sec UF
Level 1		
Hi Image- Hi Freq 2-syllable words	1	1
Hi Image-Lo Freq 2-syllable words	2	2
Level 2		
Categorically related word pairs		
Hi Image-Hi Freq word pairs	1	1
Hi Image-Lo Freq word pairs	2	2

Appendix B

Treatment cueing hierarchy

The application of the steps of the hierarchy was response-contingent. The steps were applied sequentially until a correct repetition response was elicited. Then the order of the steps was reversed to elicit correct responses at each of the preceding steps. In the event that an incorrect response occurred during the hierarchy reversal, the order of the hierarchy steps was again reversed until a correct response was obtained (Note: Step 1 is identical to probe. No visual cues are given. Visual cues are given for steps 2 through 5 of the cueing hierarchy).

1. Word/nonword is presented for repetition and delay is imposed (i.e., 1-sec UF, 5-sec UF). Repetition is requested after delay: "Repeat the word." Feedback is given for correct/incorrect response. If correct, next word/nonword present. If incorrect, Step 2 is presented.
2. Word/nonword is presented for repetition. Delay is imposed. Repetition is requested: "Repeat the word/nonword." Feedback given for correct/incorrect response. Step 3 is presented.
3. Participant's error is reproduced followed by correct production of the stimulus (e.g., "You are saying breakwis. It is not breakwis. It is breakwis."). Delay is imposed. Repetition requested: "Repeat the word." Feedback is given for correct/incorrect response. Step 4 is presented.

4. Each syllable is targeted in the stimulus at the interval condition at which treatment is applied. Post-it notes are placed in front of the participant as visual cues to represent syllable boundaries. Each syllable is produced. Delay is imposed. Repetition is requested: **"Repeat the syllable."** This procedure is followed for each syllable. If all syllables are correct, the word/nonword is presented for repetition. Delay is imposed. Repetition is requested: **"Repeat the word/nonword."** If word/nonword is incorrect, syllable procedure is presented again. If any syllable is incorrect, Step 5 is presented.
5. Stimulus is produced. No repetition is requested. Next stimulus is presented.