A processing approach to the assessment of language and verbal short-term memory abilities in aphasia

Introduction.

Language processing and verbal short-term memory (STM) are often discussed as separate systems with the latter being a temporary store for phonological representations of utterances longer than a single word. Verbal span tasks exemplify this relationship; a sequence of verbal units is heard, held in STM and repeated in the same serial order. Separation of STM and word processing seems intuitive, as we also store other types of cognitive and sensory information temporarily. Consistent with this model, the verbal STM impairment in aphasia also has been viewed as separate from the language impairment. However, more recent proposals claim that the verbal STM impairment in aphasia is due to an impairment of a process that maintains activation of word representations over the course of language comprehension or production. This can be understood in the context of an interactive activation (IA) model of word processing (Figure 1) that has been used to account for word processing impairment in aphasia (Dell, Schwartz, Martin, Saffran & Gagnon, 1997). Two parameters control the activation of phonological, lexical and semantic representations of words in the lexical network: connection weight and decay rate. Dell et al. (1997) demonstrated that word processing impairments in aphasia could be accounted for as damage to these two processing parameters, leading to a reduction in strength of activation (connection weight impairment), and/or the ability to maintain activation of representations (decay rate impairment).

Figure 1 shows how repetition of even a single word requires maintenance of activated semantic and phonological representations over time. Martin & Saffran (1997) proposed that this temporal aspect of word processing is what links word processing and verbal STM and is active when processing single or multiple word utterances. Severity of the impairment determines whether processing of multiple words is affected (verbal STM impairment) or both single and multiple words (verbal STM impairment and aphasia). Evidence indicating a close relationship between word processing and verbal STM has important clinical implications for approaches to diagnosis and treatment of language disorders in aphasia (Martin, 2001; 2008).

Aims of the study.

This paper reports a study of a comprehensive test battery designed to assess language and verbal STM abilities in aphasia. We introduced this battery and data from a single subject at the *Clinical Aphasiology Conference* in 2008. Here we present new data from thirty individuals with aphasia and ten aged-matched controls on what is now called the *Temple Assessment of Language and Short-term Memory in Aphasia (TALSA)*. We report a summary of the data and discuss ways in which the *TALSA* battery can be used to identify the following:

(1) the linguistic characteristics of language/STM impairment in aphasia at all levels of severity.
(2) the processing nature of the language/STM impairment (weak activation or too-rapid decay of activated semantic and phonological representations),
(3) the ability to activate and maintain activation of language representations in the contexts of increased memory load and verbal interference.

We will also summarize evidence that the battery can:

(1) serve as a pre- and post-treatment measure for a treatment designed to improve the strength and/or short-term maintenance of activation to improve language function and

(2) yield measures of semantic and phonological processing and STM that can be used to predict performance on other language and verbal learning tasks.

Method.

Participants. Thirty individuals with aphasia (a variety of classical aphasia types) resulting from cerebral vascular accident (CVA) and ten controls participated in this study.

Description of the TALSA Battery. The TALSA battery includes some standard tests of language processing, but also has several unique features:

Part 1 includes word processing tasks that probe semantic and phonological abilities. These tasks vary in difficulty and incorporate variations affecting STM and/or executive processing load. Two variations involve inclusion of a 5-second interval between stimulus and response or between two stimuli to be compared. In one variation, the interval is unfilled (silent) allowing assessment of the ability to passively maintain activation of representations (passive STM). The other interval condition is 'filled' (participant names numbers that appear on a computer screen). This variation assesses the ability to maintain activation of representations in the context of verbal interference (STM plus executive processing). Two other subtests vary STM and executive processing requirements in a different way, by increasing the number of items that need to be held in verbal STM (the working memory load) while making a judgment of similarity (synonymy and rhyming judgments).

Part 2 includes span tasks that vary phonological, lexical and semantic characteristics of the stimuli (e.g., frequency, imageability, lexicality).

The memory load conditions in Part 1 and the span tasks in Part 2 enable assessment of the type of language impairment at *all* levels of aphasia severity including individuals with mild aphasia who often score at ceiling on single word processing tasks but still complain of difficulties in functional language situations. The interval conditions of the word processing tasks that include verbal interference and the span tasks that vary semantic and phonological content are sensitive to spared and impaired semantic and phonological abilities in people with mild aphasia and can guide appropriate treatment approaches for this group.

Results.

Tables 1-6 show the results this study, proportions correct on the TALSA battery tasks with and without memory load manipulations:

Part 1. Mean proportions correct in each STM or executive load condition.

Tables 1 and 2: Single word tasks that probe semantic and phonological processing that vary time before a response is made.

Tables 3 and 4: Multiple word tasks (word pairs, word triplets and sentences) that vary time before a response is made.

Table 5: Synonymy and rhyming judgment tasks that vary the number of items in working memory.

On each of these tasks, *mean* performance becomes worse as memory load is increased by inclusion of an interval or increasing the number of items to be held in working memory. *However*, we have observed that while some individuals perform worse when a 5-second interval is imposed, others benefit from the extra processing time. There is also a picture naming test in Part 1. Performance on that task did not vary across interval conditions (means of .69, .63 and .68).

Part 2. Span tasks with language variations.

Table 6. Mean spans and ranges on four span tasks: digit and word, word and nonword, words varied for frequency and imageability, and probe memory (semantic, phonological and identity probes).

Mean spans for the most part are around 2-3 items, but the range is much broader than that. Control data for the full TALSA battery are shown in *Appendix 1* along with data from three participants with aphasia (mild, moderate and severe).

Discussion.

The TALSA battery is proving to be effective in determining both linguistic and processing characteristics of aphasia. Results of the memory load variations indicate two types of processing deficits, slowed activation (need more time to process words) and too-fast decay (cannot maintain activation of representations). We have designed a treatment program that addresses these processing impairments and are using the TALSA battery to measure treatment effects. Additionally, we have used its measures of semantic and phonological STM to predict new word learning success in aphasia. Our future aims include development of a clinically useful version of this comprehensive assessment battery.

<u>References</u>.

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Table 1. Tests of Phonological Processing: Mean proportion correct at each interval condition and range for 1 sec interval.

Subtest			Interval Condition 1-sec UF	5-sec UF	5-sec F
Phoneme Discrimination (n=30)	Words	Mean	**0.95**	**0.93**	**0.87**
		Range	*.80 -1.00*		
	Nonwords	Mean	**0.93**	**0.91**	**0.80**
		Range	*.70 -1.00*		
Rhyme Judgments (n=29)	Words	Mean	**0.88**	**0.87**	**0.79**
		Range	*.60 - 1.00*		
	Nonwords	Mean	**0.84**	**0.82**	**0.76**
		Range	*.35 - 1.00*		
Repetition (n=29)	Words	Mean	**0.80**	**0.83**	**0.68**
		Range	*.33 - 1.00*		
	Nonwords	Mean	**0.48**	**0.42**	**0.17**
		Range	*0 - 1.00*		

Table 2. Tests of lexical-semantic processing: Mean proportion correct at each interval condition and range for 1 sec interval.

Subtest		Interval Condition 1-sec UF	5-sec UF	5-sec F
Lexical Comprehension (n=31)	**Mean**	**0.97**	**0.98**	**0.91**
	Range	*.81 - 1.00*		
Category Judgments - *Pictures (n=28)*	**Mean**	**0.95**	**0.92**	**0.84**
	Range	*.70 - 1.00*		
Category Judgments - *Words* (n=28)	**Mean**	**0.93**	**0.93**	**0.79**
	Range	*.70 - 1.00*		

Table 3. Synonymy and rhyming triplets with memory load variations: Proportion correct with ranges.

Subtest		2-choice Format	3-choice Format
Synonymy Triplet Judgments (n=27)	Mean	**0.87**	**0.77**
	Range	*.68 - 1.00*	*.41 - 1.00*
Rhyming Triplet Judgments (n=28)	Mean	**0.86**	**0.73**
	Range	*.40-1.00*	*.23 - 1.00*

Table 4. Repetition of word pairs and word triplets with interval conditions.

Word Pairs (n=28)		1-sec UF	5-sec UF	5-sec F
Semantically Related	Mean	0.61	0.61	0.45
	Range	*0 - 1.00*		
Phonologically Related	Mean	0.60	0.58	0.34
	Range	*0 - 1.00*		
Unrelated	Mean	0.67	0.64	0.42
	Range	*0 - 1.00*		

Word Triplets (n=28)		1-sec UF	5-sec UF	5-sec F
Semantically Related	Mean	0.46	0.39	0.25
	Range	*0 - 1.00*		
Phonologically Related	Mean	0.32	0.29	0.17
	Range	*0 - 1.00*		
Unrelated	Mean	0.38	0.34	0.16
	Range	*0 - 1.00*		

Table 5. Sentence processing tests with interval conditions: Proportion correct and ranges at 1-sec interval.

Sentence Repetition (n=28)		1-sec UF	5-sec UF	5-sec F
Unpadded	**Mean**	**0.70**	**0.66**	**0.54**
	Range	*0 - 1.00*		
Padded	**Mean**	**0.55**	**0.49**	**0.39**
	Range	*0 - 1.00*		

Sentence Comprehension (n=29)		1-sec UF	5-sec UF	5-sec F
Lexical Distracter	**Mean**	**0.92**	**0.92**	**0.87**
	Range	*.60 - 1.00*		
Reverse Semantic Role Distracter	**Mean**	**0.67**	**0.66**	**0.69**
	Range	*.30 - 1.00*		

Table 6. Span measures with linguistic variations

1. Digit and Word Span (n=30)

	Digits		Words	
	Pointing	**Repetition**	**Pointing**	**Repetition**
Mean Span	**3.31**	**3.54**	**3.01**	**3.09**
Range	*1 - 6.80*	*0 - 6.80*	*1 - 5.50*	*1 - 5.50*

2. Repetition span for words varied for frequency and imageability (n=27)

	Frequency and Imageability Type (n=27)			
	HF/HI	**HF/LI**	**LF/HI**	**LF/LI**
Mean Span	**2.59**	**2.36**	**2.30**	**2.14**
Range	*0 - 4.80*	*0 - 4.80*	*0 - 4.40*	*0 - 4.40*

3. Word and Nonword Repetition Span (n=29)

	Word	**Nonword**
Mean Span	**2.84**	**1.56**
Range	*.50 - 5.00*	*.20 - 4.80*

4. Probe memory Span (n=25)

	Identity	**Semantic**	**Phonological**
Mean Span	**7.86**	**3.14**	**2.94**
Range	*.80 - 12.00*	*0 - 6.93*	*0 - 7.00*

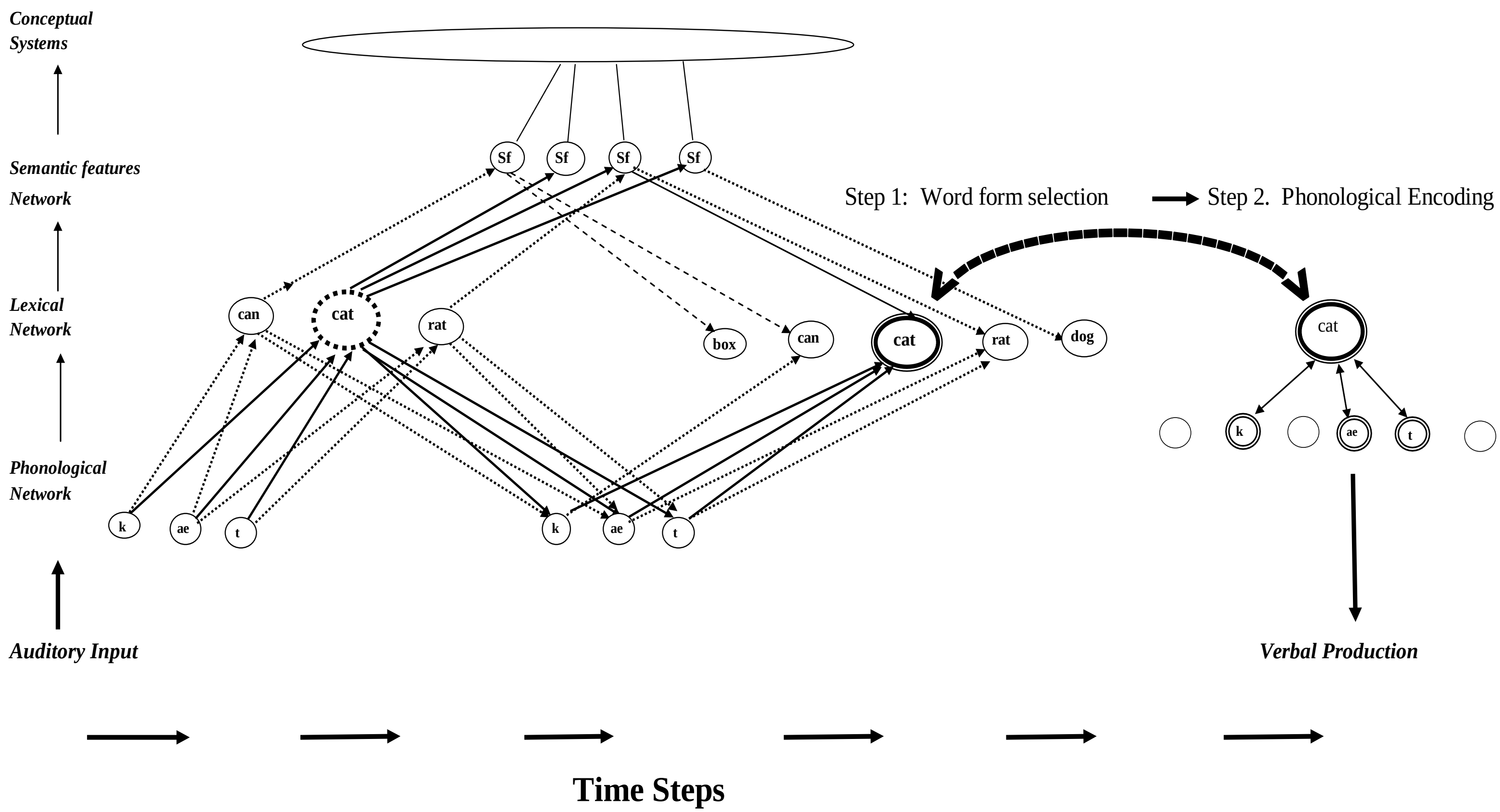

Figure 1. Depiction of spreading activation processes throughout the lexical network over the course of repeating a single word. Activation spreads from phoneme representations to lexical forms and semantic representations. Once activated, a representation begins to decay, but then is refreshed by feedback activation from subsequently activated representations. The feedforward-feedback cycles continue until a word is needed for production, at which time, the most highly activated lexical representation is selected and phonologically encoded.