Background

A paucity of diagnostic instruments to assess the role of short-term memory (STM) in language processing necessitates the development of a test battery to evaluate STM and language processing in aphasia. Investigators have been increasingly interested in the role of STM in language processing. Language production and comprehension occur over time, implying that some short-term maintenance of activated linguistic representations is needed during language processing. Evidence from typical adult and developmental populations indicates close ties between STM and language processes. Span capacity varies depending on characteristics of the items to be recalled (Brener, 1940) and is differentially influenced by phonological (Conrad & Hull, 1964), lexical (Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997) and semantic factors (Poirier & Saint Aubin, 1995).

Verbal STM deficits are pervasive in aphasia. The 19th century neurologist, Grashey (1885), once postulated that short-term decay of linguistic representations was a possible cause of aphasia. This view was controversial in its day (Bartels & Wallesch, 1996) but has gained support from more recent evidence of associations between recovery of STM and language deficits in aphasia (N. Martin, Saffran & Dell, 1996) and severity of STM language deficits in aphasia (Martin & Ayala, 1997). These and other studies of language and STM deficits in aphasia have provided evidence for a multi-level model of verbal STM that includes both phonological and semantic STM stores (R. Martin, Shelton & Yaffee, 1994). Additionally, recent studies have shown that increased memory demands can affect performance on semantic and phonological judgment tasks (Kohen, Martin, & Kalinyak-Fliszar, 2006; Martin. 2006) supporting the idea that aphasia does not reflect degradation of semantic and phonological representations of words, but rather is an impairment of the ability to activate and maintain activation of these representations.

Although the theoretical implications of these studies of STM and language processing remain controversial, they have important clinical implications. The consistent evidence of associations between impairments of STM and language processing suggests a need to incorporate this relationship into diagnosis and treatment approaches for aphasia. Current test batteries offer a thorough assessment of the ability to access and retrieve linguistic representations (e.g., Psycholinguistic Assessments of Language Processing in Aphasia (PALPA), Kay, Lesser & Coltheart, 1992; Comprehensive Aphasia Test (CAT), Swinburn, Porter & Howard, 2004) but do not address the ability to maintain activation of these representations for brief time periods or in contexts that stress short-term memory. However, the integrity of this ability to maintain verbal information in STM is vital for functional communication.

We present a diagnostic battery for aphasia that evaluates the ability to activate and maintain activation of phonological and semantic representations of single and multiple word utterances. This battery is unique in that it (1) incorporates a short-term memory component into measures of language processing and (2) includes a comprehensive set of span measures that probe phonological and semantic abilities. This enables us to more effectively identify the locus of word processing impairment (semantic or phonological) in a full range of aphasia severity from mild to severe. Additionally, this test battery provides a complete profile of semantic and phonological abilities that will serve as the guide to a treatment protocol designed to improve the ability to maintain activation of semantic and/or phonological representations of words and thus improve overall language function (Kalinyak-Fliszar, Kohen & Martin, in preparation).

Overview of Diagnostic Battery.

The test battery includes multiple in-depth measures of phonological and semantic processing that incorporate a STM component in one of three ways:

(1) A timed interval between two stimuli is used for four input measures: phoneme discrimination, rhyming judgments, word-to-picture matching, and category judgments.

(2) A timed interval between stimulus and cue to respond is used for four output measures: picture naming, repetition of words and nonwords, word strings, and sentences.

Time intervals for each test are: 1 second Unfilled Interval, 5-second Unfilled Interval and 5-second Filled Interval (participant and examiner simultaneously naming randomly presented single digits on the computer screen). The Unfilled Interval will reveal whether someone can rehearse effectively to maintain activation of the stimulus and complete the task. The Filled Interval prevents the opportunity to rehearse.

(3) Increasing STM load is used for two similarity judgment tasks by varying the number of items to be held in STM: rhyming and synonymy judgments.

Two formats are used to test the ability to make judgments of rhyming or similarity of meaning: the 3-choice paradigm in which the participant chooses two of three words that are either most similar or rhyme (three pairs are held in STM) and in the 2-choice paradigm in which the participant chooses one of two words that is either most similar to or rhymes with a third word (two pairs are held in STM). Thus, for these two measures, rather than increase the amount of time language representations need to be maintained in STM, we increase the number of items to be held in STM in order to complete the task.

The test battery also consists of four measures of verbal span that vary the content of items to be recalled: digit and word span, span for words varied by frequency and imageability, word and nonword span and probe span for semantically-related, phonologically-related or identical words (see R. Martin et al., 1994 for this paradigm). These measures of span will be used to further reveal the relationship between STM and language processing and how these systems operate together in tasks that require processing and temporal maintenance of linguistic representations.

In addition to these measures of language and STM processing, we include several measures of narrative production (e.g., Narrative Discourse, Nicholas & Brookshire, 1993) and measures of executive function (e.g., Comprehensive Trail-Making Test, Reynolds, 2002).

Preliminary results.

We are currently collecting data from 12 persons with various types and severity levels of aphasia and 12 non-brain damaged persons matched for age, education and gender. Data from one participant with aphasia (TUFS-2) are shown in Table 1. TUFS-2's profile indicates primarily a phonological impairment affecting both input and output phonological processing. In all phonological tasks, all repetition tasks, and semantic tasks that require comparisons of several concepts, there is a decline in performance in the interval conditions and when memory load is increased. Data from another participant (TUKL-12) demonstrates few errors on most tasks during the 1-second Unfilled Interval, but has more difficulty with phonological tasks (e.g., nonword repetition) when a 5-second delay is imposed. In semantic tasks that do not require comparisons (picture naming, word-to-picture matching), performance for both of these participants is not affected by imposing an interval between stimulus and response.

Discussion.

The data from these participants and others we are currently testing indicate the usefulness of this test battery for determining the locus of language processing. Additionally, unique to this test battery is that it is proving to be sensitive to milder impairments. Most importantly, results of this diagnostic battery can be used to pinpoint the specific type of language processing deficit (semantic or phonologic) and the extent to which verbal STM is impaired. This information can then be used to guide and test the efficacy of a treatment program focused on improving the ability to access and maintain activation of semantic and phonological representations of words and sentences.

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Table 1. Summary of Performance on Language and STM Diagnostic Battery: TUFS 2

1. Input Tasks

Phonological			**Semantic Tasks**			
Interval Condition	Phoneme Discrimination	Rhyming Judgments	Interval Condition	Word-to-Picture Matching	Category Judgments	Sentence Comprehension
1-sec Unfilled	0.85	0.90	1-sec Unfilled	0.94	0.90	0.80
5-sec Unfilled	0.90	0.88	5-sec Unfilled	1.00	0.90	0.70
5-sec Filled	0.75	0.80	5-sec Filled	0.94	0.65	0.80

2. Output Tasks

				Word String Repetition			**Sentence Repetition**	
Interval Condition	Picture Naming	Word Repetition	Nonword Repetition	Semantic	Phonological	Unrelated	Simple	Padded
1-sec Unfilled	0.80	0.80	0.13	0.50	0.30	0.10	0.62	0.36
5-sec Unfilled	0.80	0.73	0.07	0.20	0.10	0.10	0.56	0.30
5-sec Filled	0.80	0.40	0.07	0.30	0.20	0.10	0.54	0.30

3. Tasks that vary number of items to be held in STM

Rhyming Judgments		Synonymy Judgments	
2-item	3-item	2-item	3-item
0.87	0.77	0.85	0.73

4. Verbal Span Tasks

Digit Span		Word Span		Word-Nonword Span		Probe Memory Span		
Repetition	Pointing	Repetition	Pointing	Word	Nonword	Semantic	Phonological	Identity
3.15	3.05	2.1	3	2	0.8	3.57	4.88	10.50

Hi-Lo Frequency/Imageability Word Span			
Hi Freq	Lo Freq	Hi Image	Lo Image
1.2	0.8	1.6	0.8