The Effect of Short-Term Memory on Measures of Semantic Knowledge

Introduction. When individuals with aphasia fail on tests that involve semantic processing of information, it is not certain whether they have lost access to semantic representations that are presumably intact or whether semantic knowledge is impaired. Here, we investigated the possibility that poor performance on measurements of semantic knowledge can be attributed to impaired access to and maintenance of semantic representations in verbal short-term memory (STM). To test this hypothesis, we examined performance on two semantic judgment tasks that manipulate the number of items to be held in STM but keep constant the semantic associations to be judged.

Performance on semantic judgment tasks requires **accessing** semantic concepts from some stimulus, **maintaining** activation of those words and concepts for the time it takes to make the judgment, and **making judgments** about semantic similarity or associations between two or more concepts. This task description emphasizes the processes needed to support activation, maintenance and retrieval of representations rather than the types of representations that are affected (e.g., semantic, phonological). This model postulates close links between impairments of short-term memory and word processing, and predicts that performance on semantic judgment tasks will be impaired when STM load is beyond the capacity of the individual with aphasia.

Understanding the role of short-term memory processes in performance of language tasks has implications for treatment of word processing disorders. A recent study of performance by individuals with aphasia on the *Pyramid and Palm Trees Test* (Howard & Patterson, 1992), a measure of semantic knowledge, supports this idea. Martin (2005) observed seven participants who performed poorly on both written and picture versions of this measure, a pattern that departs from typical performance in aphasia (better performance with pictures than words) and is interpreted as indication of impaired semantic knowledge. These same seven subjects demonstrated semantic knowledge in other tasks that were less taxing to short-term memory. Additionally, the word spans were significantly lower than participants who showed the typical pattern in aphasia, suggesting that impaired STM played a role in their poor performance on pictures and words. This hypothesis is explored further here.

Subjects: Four adults with aphasia, resulting from left hemisphere stroke, were tested. All demonstrated word-processing deficits as part of their aphasia. At the time of testing, they were all at least 3.5 years post-onset of their stroke. Table 1 reports the lesion location, age, education, time post-onset, and aphasia classification (WAB).

Methods: The participants were administered two semantic judgment tasks; a noun- verb synonymy task and a category membership judgment task. The Noun-Verb Synonymy task is presented in two formats that vary the number of distracters. In the first condition, three words are presented both visually and auditorily. The task is to select the two words that are closest in meaning (e.g., *to scream, to shout*, to threaten). In the second condition, the participant is still presented three words visually and auditorily, but the task changes. One word becomes the target word (e.g., *to scream*) and the participant chooses between one of two additional words most similar in meaning to the target word

(e.g., *to shout*, to threaten). (Figure 1) In the first condition three possible pairs are held in STM and compared. In the second condition, only two possible pairs are held in STM and compared. These two formats also differ with respect to the probability of getting a correct response by chance (.33 vs. .50). In our data analysis, we correct for this by comparing the patients' performances to chance. (see Table 2 and discussion below)

The second task, The Categories Test, a category membership judgment task developed in our laboaratory, keeps chance performance constant over two conditions that vary the number of items that need to be maintained in STM. For both conditions only a yes/no response is required. The task is to determine whether a word presented in Set 1 is from the same category as a different word presented in Set 2. Set size varies from 1 to 2 items, but only 1 item in each set can potentially be from the same category. (See Figure 2 for examples of these stimuli.) In the first condition the participant must hold 2 words and their meanings in STM, in the second condition 4 words and their meanings need to be held in STM to make the judgment.

Data Analysis: Performances on the different format conditions of each semantic judgment task were compared. For the Noun-Verb Synonmy Test, the probability that correct responses were produced by chance was factored into the comparison by using the binomial distribution test. (Table 2). We also obtained word span measures and and calculated z-scores in reference to a larger sample of aphasic individuals to determine if our participants spans were unusually low, as the activation-maintenance deficit hypothesis would predict.

Results.

Noun-Verb Synonymy Test. All participants scored noticeably better when only two comparisons needed to be activated and maintained compared to the condition where three word pairs were needed (Table 3). These improved percentages were all shown to be significantly better than chance alone would predict.

Categories Test. Here, chance is controlled but the number of words to be held in STM changes from Condition 1 to Condition 2, all participants demonstrated lower scores when the comparison involved maintaining activation of four words rather than two. This pattern was even more pronounced for the items that were from the same category, as the participants often made false rejections (Table 4). None of our controls showed this pattern of decline from the comparison of 1 word to 2 words.

Verbal STM span. In order to determine whether restricted STM span played a role in the performance of these tasks, we established z scores for the spans of the participants relative to a large sample of individuals with aphasia. (Martin &Ayala, 2002). Compared to that sample, three of the four particiants had z-scores below the mean for aphasic individuals and the fourth participant's span was less than 1 standard deviation above the mean (see Tables 3 and 4).

This overall pattern of results is compatible with our prediction that increasing the number of semantic concepts to be impaired will impair performance in a semantic judgement task. It supports the proposal that the semantic impairment in aphasia may be due to impaired ability to access and maintain representations in short-term memory.

Conclusions: Evidence thus far, suggests that the 'semantic' impairment in for these four participants is related to accessing and maintaining semantic representations and not degradation of the semantic representations themselves. This finding may have important implications for the treatment of semantic deficits in aphasia.
Recent treatments that target auditory-verbal STM deficits support this idea. For example, studies by Francis, Clark and Humpreys (2003) and Majerus, van der Kaa, Renard, Vander Linden and Poncelet, M. (2005) demonstrated improved comprehension after treating auditory-verbal STM. These studies suggest that methods to improve the ability to maintain activation of linguistic representations during language production and analysis may better improve performance on language tasks.

References

Francis, D.R., Clark, Nina, Humphrey G.W. (2003), The treatment of an auditory working memory deficit and the implications for sentence comprehension abilities in mild "receptive" aphasia. *Aphasiology, 17*, 723-750.

Howard, D. & Patterson, K. (1992). *The Pyramids and Palm Trees Test*. Thames Valley Test Company.

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Table 1. Patient Biographical Information.

Participant	Age	Education	TPO (months)	Type of Aphasia	Lesion Location
CC	57	16	54	Broca's	Left frontal parietal
DBU	56	17	129	Anomic	Left temporal
BS	44	10	56	Broca's	Left fronto-parietal
WW	62	10	40	Wernicke's	LMCA, sylvian fissure

Table 2. Binomial Test Comparing Results of Noun-Verb Synonymy with Chance Performance.

Participant	P value of chance Noun-Verb Synonymy 3	P value of chance Noun-Verb Synonymy 2
CC	.0067*	.00003*
DBu	.0549*	.0139*
BS	.1148	.0005*
WW	.0014*	.0005*

Table 3. Noun-Verb Synonymy Results: Percent Correct.

Participant	Noun-Verb Synonymy 2 Choices	Noun-Verb Synonymy 3 Choices	Verb Synonymy 2 Choices	Verb Synonymy 3 Choices	Span-Word Repetition	z Score Word Repetition
CC	0.93	0.80	1.00	0.67	2.40	-0.63
Dbu	0.87	0.67	0.80	0.53	3.30	0.27
BS	0.93	0.57	0.93	0.47	3.00	-0.03
WW	0.90	0.70	0.93	0.73	2.10	-1.43

Table 4. Categories Test Results: Percent Correct

Participant	Category Test 1 Item	Category Test 2 Items	Category Test 1 Item Same Judgments	Category Test 2 Item Same Judgments	Word Repetition Span	Word Repetition Span z Score
CC	1.00	0.78	1.00	0.55	2.40	-0.63
Dbu	0.98	0.78	0.95	0.65	3.30	0.27
BS	1.00	0.95	1.00	0.90	3.00	-0.03
WW	0.88	0.53	0.8	0.35	2.10	-1.43

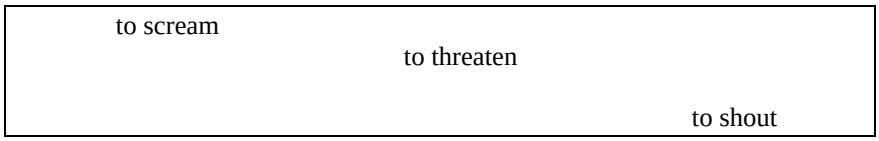
Figure Captions**.**

Figure 1. Formats for Noun -Verb Synonymy Task.

Figure 2. Categories Test: Two conditions that vary number of items to be held in STM.

Figure 1.

Format 1: 3 choices
Participant is asked to select the two words most similar in meaning.
Must hold 3 items in STM to make the judgment.



Format 2: 2 choices
Participant is asked to select the word most similar in meaning to the target word.
Must hold 2 choices in STM to make the judgment.

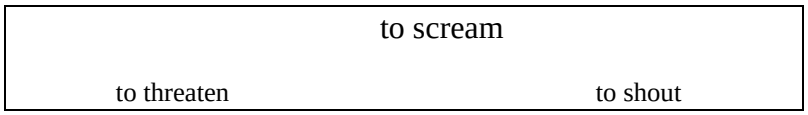


Figure 2. Categories Test: Two conditions that vary number of items to be held in STM.

Condition 1: 1 item

Participant is asked to make a yes/no judgment if the item in Set A is from the same category as the item in Set B.
Requires holding 2 items in STM.

Example 1

Set A	DOG
Set B	WOLF

(response = yes)

Example 2

Set A	CAT
Set B	HAMMER

(response = no)

Condition 2: 2 items

Participant is asked to make a yes/no judgment if any of the items in Set A are from the same category as any of the items in Set B.
Requires holding 4 items in STM.

Example 1

Set A	DOG SKIRT
Set B	COW APPLE

(response = yes)

Example 2

Set A	FORK CAR
Set B	DRESS PIANO

(response = no)