Working memory is a theoretical construct that refers to the structures and processes used for temporarily storing and manipulating information. Numerous theories exist regarding the theoretical and physiological structure of working memory. Baddeley and Hitch (1974) introduced and made popular the original working memory model. This theory proposes that performance on many tasks relies on a working memory system that helps to keep information active while a task is being performed. In this single resource model theory, a central executive process is ultimately responsible for all language processing. In contrast, Caplan and Waters (1999) theorized a dual resource model that involves an automatic processing component and a conscious processing component, both from a limited resource pool. Similarly, Just and Carpenter (1992) offered a limited resource model that yields comprehension discrepancies and differences across individuals. Despite the unique variations of each theory of working memory, they all implicate a maintenance and processing component that act together during language processing. Thus, in individuals with aphasia (IWA), deficits in the working memory system may contribute to language processing difficulties (Caspari et al., 1998; Friedmann & Gvion, 2003). Indeed, there is some evidence of reduced working memory capacity in IWA (Caspari et al., 1998; Friedmann & Gvion, 2003; Tompkins et al., 1994), although further studies in this area are needed.

To assess working memory ability in IWA, span tasks involving digits, words, letters, and nonwords have been widely used (Wright & Shisler, 2005). Modifications of span tasks, including changing response type from recall to recognition to decreased linguistic burden, have also been made for use with this population (Friedmann & Gvion, 2003; Caspari et al., 1998). In particular, digit span tasks, comprised of forward and backward tasks, have been used extensively to examine working memory capacity in IWA (Friedmann & Gvion, 2003; Ronnberg et al, 1996). Digits Forward has been characterized as a simple span test, and is thought to measure the storage and maintenance components of working memory by de-emphasizing the manipulation of the material. Digits Backward is thought to be a more complex span task, requiring information storage as well as concurrent processing essential to mentally reordering the information (The Psychological Corporation, 2002). The more complex task of recalling digits in the reverse order is assumed to rely more heavily on working memory processing (The Psychological Corporation, 2002); however, studies investigating the sensitivity of forward versus backward digit span conditions in assessing working memory in IWA have yielded inconsistent results (Wilde & Strauss, 2002; Wilde, Strauss, & Tulsky, 2004). Therefore, the literature remains at odds over which measure is *most* appropriate for measuring working memory capacity in this population (Wright & Shisler, 2005).

The purpose of the current study is to further explore working memory skills in IWA by comparing their performance on forward and backward digit span tasks to individuals with right hemisphere stroke without aphasia. Additionally, we sought to determine whether there is a performance difference between two commonly used measures of working memory (forward and backward digit span) in IWA which may indicate greater sensitivity to working memory capacity in this population. The following theoretically and clinically relevant questions will be addressed: 1. Is there a difference in performance on digit span tasks between individuals with right hemisphere CVA and IWA?; 2. Is backward digit span performance equal to forward digit span performance in individuals with right hemisphere CVA and IWA?

Method

Participants. Eleven individuals with left hemisphere CVA and aphasia (8 females, 3 males) and 11 individuals with right hemisphere CVA (4 females, 7 males) participated. Mean age was 53;6 years for individuals with aphasia and 58;10 years for individuals with right hemisphere CVA. Mean months post onset for the group with aphasia was 1.05 months and 2.14 months for the right hemisphere CVA group. Average Western Aphasia Battery Aphasia Quotient for the individuals with aphasia was 68.9. The average score for the Mini-Inventory for Right Brain Injury for the individuals with right hemisphere damage was 5.36.

Procedures. As part of a larger study, all participants completed a forward digit span task and a backward digit span task. The forward digit span task was modeled after Friedmann and Gvion (2003). Eight levels of 7 sequences of digits were orally presented to each participant. Participants were asked to point to the correct order of digits on a written 1-9 digit list or verbally repeat the numbers if the participant was able to do so. Span was defined as the maximum level at which 3 sequences out of 7 were accurate. An additional half point was given if 2 sequences out of 7 were accurate. The backward digit span task followed a similar procedure. Digits were orally presented to the participant. The participant then verbally repeated the numbers or pointed to the numbers in reverse order. Criteria for maximum level of backward digit span were the same as for forward digit span.

Results

See Figures 1 and 2 for average forward and backward digit span for each group. To answer the stated research questions, simple *t* tests were conducted to explore differences within and between groups and tasks. A significant group effect was found for the forward digit span [$t(20) = -3.57$, $p = .02$], but not the backward digit span [$t(20) = -1.10$, $p = .285$). The aphasia group performed much worse on the forward digit span ($M = 4.41$) than the right hemisphere CVA group ($M = 7.32$). Performance on the backward digit span was comparable for each group (aphasia, $M = 2.45$; right hemisphere CVA, $M = 3.32$). The forward digit span was significantly longer than the backward digit span within each group [aphasia, $t(10) = 4.56$, $p < .001$; right hemisphere CVA, $t(10) = 6.85$, $p < .00$]. To determine the presence of a relation between severity and digit span, a post-hoc correlational analysis was performed. Backward digit span was highly correlated with severity as measured by WAB AQ ($r = .627$, $p < .05$) and MIRBI scores ($r = .796$, $p < .05$). Forward digit span was not correlated with severity for either group.

Discussion

This study utilized two commonly used indices of working memory capacity, backward and forward digit span tasks. The measures were modified for use with IWA. Results indicate that IWA performed significantly worse on the Digits Forward condition than the right hemisphere CVA group, which is consistent with previous findings. However, both groups performed comparably on the Digits Backward condition, which was unexpected based on previous findings by Wilde and Strauss (2002), among others. In light of our findings, it is questionable whether Digits Backward is indeed a clinically sensitive measure of working memory in IWA. Further discussion will focus on the clinical and theoretical implications of these findings.

References

Baddeley, A.D., & Hitch, G. J. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 647-667). New York: Academic Press.

Caplan, D., & Waters, G. (1999). Issues regarding general and domain specific resources. *Behavioral Brain Sciences, 22,* 114-126.

Caspari, I., Parkinson, S., LaPointe, L., & Katz, R. (1998). Working memory and aphasia. *Brain and Cognition, 37,* 205-223.

Friedmann, N., & Gvion, A. (2003). Sentence comprehension and working memory limitation in aphasia: A dissociation between semantic-syntactic and phonological reactivation. *Brain and Language*, *86*, 23-39.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, *99*, 1-27.

Ronnberg, J., Larsson, C., Fogelsjoo, A., Nilsson, L. G., Lindberg, M., & Angquist, K. A. (1996). Memory dysfunction in mild aphasics. *Scandinavian Journal of Psychology, 37*(1), 46-61.

The Psychological Corporation. (2002). Updated WAISIII-WMS-III technical manual. San Antonio, TX: Author.

Tompkins, C. A., Bloise, C. G. R., Timko, M. L., & Baumgaertner, A. (1994). Working memory and inference revision in brain-damaged and normally aging adults. *Journal of Speech and Hearing Research, 37,* 896-912.

Wilde, N., & Strauss, E. (2002). Functional equivalence of WAIS-III/WMS-III digit amd spatial span under forward and backward recall conditions. *The Clinical Neuropsychologist*, 16(3), 322-330.

Wilde, N. J., Strauss, E., & Tulsky, D. S. (2004). Memory span on the Wechsler scales. *Journal of Clinical and Experimental Neuropsychology*, *26*(4), 539-549.

Wright, H. H., & Shisler, R. J. (2005). Working memory in aphasia: Theory, measures, and clinical implications. *American Journal of Speech-Language Pathology*, *14*, 107-118.

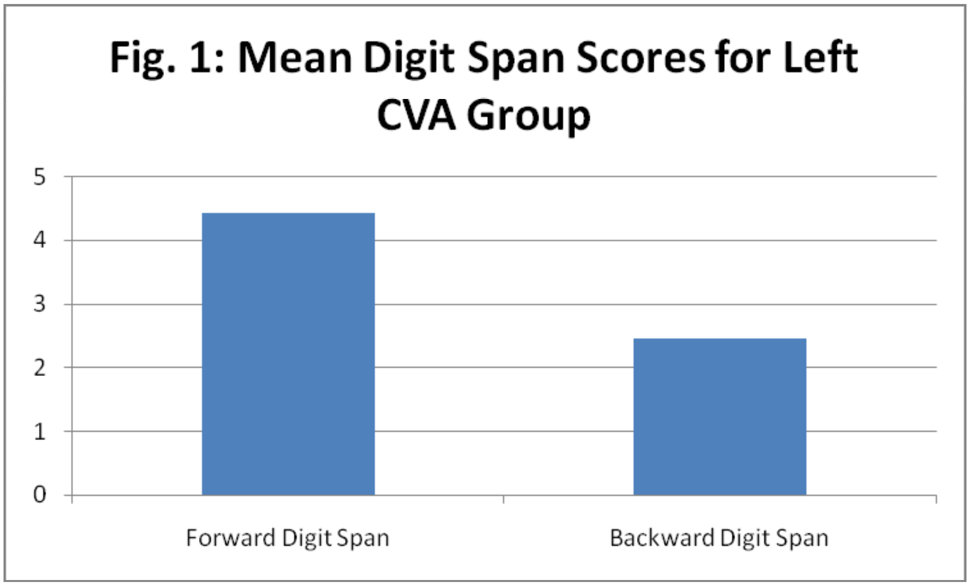
Fig. 1: Mean Digit Span Scores for Left CVA Group
5
4
3
2
1
0
Forward Digit Span
Backward Digit Span

Fig. 2: Mean Digit Span Scores for Right CVA Group