WORKING MEMORY AND APHASIA

By

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Abstract

The working memory capacity of individuals with aphasia has been investigated on numerous occasions. One major problem with the previous testing procedures was that they required the individuals with aphasia to verbally produce target words in order for their working memory capacity to be scored. Since verbal expression is frequently impaired in individuals with aphasia, five new working memory tasks were created to limit the need for the participant to speak, in order to test their working memory capacity more accurately. The five new tasks include forward picture span, backward picture span, forward square span, backward square span, and listening span. This study tested seven college age participants. The participants were tested using new and old working memory tasks. Preliminary results showed that one of the new tasks, backward picture identification, was significantly and positively correlated with the working memory composite score. This result indicates that this test could be a good measure of working memory for individuals with aphasia.

Introduction

The occurrence of cognitive deficits in people with aphasia has received increasing attention over the past several years (Wright & Shisler, 2005; Wright, Downey, Gravier, Love, & Shapiro, 2007; Christensen & Wright, 2010). In particular, working memory deficits have been suggested as a possible cause of language deficits in people with aphasia. The purpose of this study was to create a working memory task with limited language production requirements. These new working memory tasks would help distinguish which deficits are due to language production issues and which are due to cognitive deficits.

The term working memory has been used in a variety of contexts. There are two well-known and commonly used definitions of working memory. One definition of working memory is temporarily retained information that is used to accomplish work (Miller, Galanter, & Pribram, 1960). According to the second definition, working memory is a multi-component system that manipulates and provisionally maintains information in order to complete cognitive tasks (Baddeley & Hitch, 1974). The two definitions vary mainly in the amount of detail. The first definition does not mention what kind of work is accomplished nor does it mention how working memory is accomplished. The second definition extends the first by adding that the system of working memory has three components. The multi-component system has the ability to perform a range of cognitive activities and features combined processing and storage (Baddeley, 2003). The two storage components or slave systems of this system are the phonological loop for verbal working memory and the visual-spatial sketchpad for spatial working memory. The central executive allocates resources to the two slave systems and helps with inhibition (Smith & Jonides 1998; Caplan & Waters, 1999).

Each part of the multi-component system has an important role in working memory. The phonological loop is based on language and sound and plays a key role in verbal working memory (Baddeley, 2003). Sub-vocal speech or the articulation rehearsal process takes place within the phonological loop (Baddeley, 2003). Studies on the phonological loop indicate that immediate memory span declines as the word increases in length. This word length effect is evident because articulation takes place in real time; sub-vocally rehearsing long words takes more time and energy than rehearsing shorter words (Baddeley, 2003). The phonological similarity effect is observed when recall of items with similar phonology is poorer than items with dissimilar phonology (Baddeley, 1992). The word lists “man, cap, can, map, mad” and “pit, day, cow, pen, rig” exemplify the phonological similarity effect (Baddeley, 1992). Recall would be better for the second set than the first set because there are higher memory spans for words that are phonologically dissimilar (Caspari, Parkinson, LaPointe, & Katz, 1998). This is because there are fewer cues to differentiate the items from one another, which makes these items easier to forget (Baddeley, 1992). The visual-spatial sketchpad is based on visual and spatial relationships of items. It has a limited capacity of about three to four objects for most people (Baddeley, 2003). The color, dimension, shape, and location are all important indicators for the visual-spatial sketchpad because it works along with “visual semantics” (Baddeley, 2003).

The central executive’s ability to inhibit insignificant information is important (Baddeley, 2003). Anytime someone is in a noisy environment, such as a restaurant, the ability to listen to their partner’s conversation relies on the ability of the central executive to inhibit unimportant information such as dishes clanging, music playing, and other conversations going on around them. It allows more information to be maintained and modified by controlling a person’s focus of attention. When there are many distractions in an environment, the supervisory activating system intervenes to help control your attention (Baddeley, 2003). The central executive also coordinates information from the phonological loop and the visual-spatial sketchpad (Baddeley, 1992).

Working memory capacity is a measure of the total amount of activation available for processing and storage (Just & Carpenter, 1992; Caspari, Parkinson, LaPointe, & Katz, 1998). Working memory tasks require both processing and storage components (Waters & Caplan, 2003). Some working memory span tasks incorporate the processing and storage components by requiring the participant to perform an operation on each item or on the entire list and then repeating the list back to the experimenter (Waters & Caplan, 2003). An example of this is Subtract 2 span. When the participant is presented with a list of numbers, he/she has to repeat that same list back after first subtracting 2 from each digit. Other working memory tasks require participants to hold onto a list of items and then recall a previously presented item that is related to the current item. N-back tasks are an example of this type of working memory test. For an n-back test (n=1) participants must push a button that indicates whether the picture that they are currently viewing is the same as the previous picture (i.e. "1" back). Finally, some tasks require participants to perform a function while concurrently storing unrelated items (Waters & Caplan, 2003). These are all considered working memory tasks because they require simultaneous storage and processing of to-be-remembered information (Caspari, Parkinson, LaPointe, & Katz, 1998; Daneman & Carpenter, 1980).

Working memory contributes to cognitive tasks by allowing the individual to hold information while manipulating and processing it in a variety of ways. This allows us to think about problems and solve them (Ricker, AuBuchon, & Cowan, 2010). Working memory is also of vital importance for reasoning and language comprehension (Just & Carpenter, 1992). It seems obvious that some kind of memory is involved in language comprehension (Friedman & Gvion, 2003). In 1999, Just and Carpenter reported that individual variation in working memory capacity accounted for quantitative and qualitative differences in language comprehension of college students. The students with higher working memory capacities had faster reading times, which made them "better" readers. Comprehension of language involves processing a series of words that are produced and perceived over a period of time (Just & Carpenter, 1992; Friedman & Gvion, 2003). When ambiguity occurs in a sentence, greater working memory capacities allow the individual to hold multiple interpretations of that sentence (Just & Carpenter, 1992). Another possibility is that working memory plays a role in assigning syntactic structure of sentences, which helps in determining the meaning of the ambiguous sentence (Caplan & Waters, 1999; Just & Carpenter 1992). Overall, several possible roles of working memory in language comprehension have been proposed, but the exact nature of the relation between these systems is an ongoing debate.

Numerous studies have examined the relation between working memory and language processing through studies on aging and sentence comprehension. Older and younger adults' performance on sentence comprehension measures has been shown to correlate with their verbal working memory capacity (DeDe, Caplan, Kemtes & Waters 2004). These data suggest that the age related changes in sentence and paragraph comprehension may be due to declining working memory. Individuals with high verbal working memory spans process sentences more quickly than their peers with lower verbal working memory capacities. This is demonstrated during measures of comprehension taken at the end of the sentence. However, individuals with high and low verbal working memory do not show different patterns of proficiency in real time (online) sentence processing (DeDe, Caplan, Kemtes & Waters 2004). Nonetheless, individuals with higher working memory capacities are able to comprehend more complex sentences with greater ease than those with lower working memory capacities. These results indicate that working memory is related to sentence comprehension.

The relation between working memory and language comprehension has led researchers to investigate whether working memory deficits are the underlying cause of sentence comprehension impairments in people with acquired language disorders, such as aphasia. Aphasia is customarily considered a language-based impairment (Benson, 1994; Grodzinsky, 1990). Nonetheless, some researchers have attributed the language processing difficulties seen in individuals with aphasia to deficits in working memory capacity (Caspari, Parkinson, LaPointe & Katz, 1998; Friedman & Gvion, 2003).

Individuals with aphasia have difficulty processing linguistic information. These difficulties appear in the areas of phonology, semantics, and syntax (Wright, Downey, Gravier, Love, & Shapiro, 2007). The severity of the deficit of verbal working memory on sentence comprehension depends on the type of processing necessary in the sentence, whether it be phonology, semantics, syntax, or a combination of the three (Friedmann & Gvion, 2003). The category of syntax is essential for resolving structural ambiguity in sentences. Semantics is essential for resolving lexical ambiguity in sentences (Wright & Shisler, 2005). Deficits in these areas are likely to negatively influence comprehension. Therefore, working memory capacity deficits may contribute to the language comprehension impairments seen in individuals with aphasia (Caspari, Parkinson, LaPointe, & Katz, 1998).

It makes sense that individuals with aphasia would also experience working memory deficits because some of the regions of the brain that are involved in working memory are typically lesioned in this population. Some of the areas implicated in working memory are the dorsolateral prefrontal cortex, Broca's area, posterior parietal cortex, and the pathways running between these areas (Ricker, AuBuchon, & Cowan, 2010). The left hemisphere speech areas such as Broca's area and the pre-motor and supplementary motor areas are activated during sub-vocal rehearsal (Smith & Jonides, 1998). Some of these areas also play key roles in language processing. Broca's area has the ability to use syntactic information to determine meanings of sentences, which is important for processing of complex sentences (Ricker, AuBuchon, & Cowan, 2010). Broca's area is also important for the phonological loop in the multi-component system of working memory.

The close relationship between working memory and language processing makes it difficult to test verbal working memory in people with aphasia. Determining whether the deficit is due to limitations in speech production or due to limitations in working memory is a significant challenge. The measurement and assessment of working memory in individuals with aphasia can establish the resources available for storing, processing, and incorporating information (Wright & Shisler, 2005). Numerous researchers have tested verbal working memory in individuals with aphasia.

In 1998, Caspari, Parkinson, LaPointe, and Katz examined the relation between working memory capacity and reading comprehension in individuals with aphasia. In a modified version of Daneman and Carpenter's (1980) reading span task, participants either listened to or read the sentences depending upon their reading ability. The sentences were shorter than the original Daneman and Carpenter sentences, which contained thirteen to sixteen words. The modified version had sentences with five to six words, with the final words being high frequency, picturable, and monosyllabic (Caspari, Parkinson, LaPointe, & Katz, 1998). Instead of repeating the words after each group of sentences, participants were required to recognize a picture of the terminal words among foils (Caspari, Parkinson, LaPointe, & Katz, 1998). Each of these modifications lessened the possibility that language impairments would interfere with the measurement of working memory. The researchers found positive correlations between working memory capacity, language function, and reading comprehension (Caspari, Parkinson, LaPointe, & Katz, 1998). The results of this study support the concept that working memory capacity predicts the capability of individuals with aphasia to comprehend written sentences and paragraphs (Caspari, Parkinson, LaPointe, & Katz, 1998). Individuals with smaller working memory capacities had more difficulty comprehending more complex sentences than the individuals with larger working memory capacities. The study concluded that working memory capacity and silent reading comprehension were related in the people with aphasia (Caspari, Parkinson, LaPointe, & Katz, 1998).

In 2003, Friedman and Gvion conducted a study on the relationship of working memory and sentence comprehension in individuals with aphasia. The researchers selected Hebrew speaking individuals with either Broca's or conduction aphasia. Working memory deficits are common in individuals with Broca's and conduction aphasia (Friedman & Gvion, 2003). A battery of tests was used to measure working memory capacity in individuals with aphasia and age and education matched control participants. The tests included digit span, word span, non-word span, listening span, recognition span, and n-back tasks. Digit span required participants to point to the digits that were orally presented to them by the tester. Word span required participants to verbally recall a sequence of phonologically similar and dissimilar words. Non-word span required participants to verbally recall lists of two syllable length non-words. Listening span required participants to make true/false judgments about groups of sentences and then recall the terminal words of the previous sentences during a recognition task.

Recognition span was a simple word recognition task. Three n-back (n=2) tasks were also tested. They required the participant to push a button when the item was the same as the stimulus presented 2 back. None of the tasks used required the participants to vocalize. This is important given the prevalence of expressive language disorders in the individuals with aphasia. There were variations between the control group and the individuals with the two different aphasia types. For example, in the digit span task the controls averaged 7.25; the conduction aphasia group averaged 3.2; and the Broca's aphasia group averaged 2.6 (Friedman & Gvion, 2003). These working memory capacity results are inconsistent with theories that describe the deficit in aphasia as resource reduction because the two aphasia groups did not differ. These theories predict that individuals with different types of aphasia would perform differently on the working memory tasks because their reduction in resources differs (Friedman & Gvion, 2003).

Freidman and Gvion also compared working memory capacity to the results of a measure of sentence comprehension. Comprehension was tested using sentences with lexical ambiguity and relative clauses. The relative clauses required syntactic-semantic reactivation and the lexical ambiguity required form/phonological reactivation (Friedman & Gvion, 2003). The researchers found that the type of memory overload (phonological, syntax, semantic) and the type of reactivation made necessary by the sentence were essential to identifying the effect of working memory deficits on sentence comprehension (Friedman & Gvion, 2003).

In 2007, Wright, Downey, Gravier, Love, and Shapiro tested individuals with aphasia using three different n-back tests. Each task focused on a specific area of linguistic information phonology, semantics, or syntax (Wright, Downey, Gravier, Love, & Shapiro, 2007). The n-back tasks required participants to bush a button when the word that they heard was the same as the one they heard *n*-back (where n=1 or 2). For phonology n-back tests, the button was pushed when a word rhymed with the one heard n-back. For semantic n-back tests, the button is pushed when the word matches the same category (animals, tools, clothing, etc.) as the one they heard n-back. The syntactic n-back test requires the participant to push the button when they hear the same sentence (Wright, Downey, Gravier, Love, & Shapiro, 2007). An example for the semantics n back (n=2) test is “cat, drill, wolf, apple, shirt” (Wright, Downey, Gravier, Love, & Shapiro, 2007). Since cat and wolf both belong to the category of “animals”, the button would be pressed once the word “wolf” was heard. As the difficulty of the n-back task increased, the participants’ performance decreased. The 2-back test was more difficult than the 1-back task because participants were required to remember more items. Participants with aphasia performed better on the semantic test than on the phonology or syntax tests. Those who did badly on syntax n-back tasks had more trouble comprehending the more complex sentence structures. This difficulty was probably because they were not able to build mental representations of the complex syntactic structures to help them interpret the sentence (Wright, Downey, Gravier, Love, & Shapiro, 2007). Since the adults with aphasia were able to execute the working memory task, the n-back testing procedure is considered appropriate for measuring the working memory capacity of this group. The differences in the ability of each category (phonology, syntax, semantics) may contribute to the general troubles with language for individuals with aphasia (Wright, Downey, Gravier, Love, & Shapiro, 2007).

Christensen and Wright (2010) noted that numerous studies of the cognitive abilitities of people with aphasia have an inherent language component. This study used three different n-back tasks that differed in "linguistic load" (Christensen & Wright, 2010). The term linguistic load was defined as the consistency with which an object could quickly be named in a confrontation naming task (Christensen & Wright, 2010). Fruit had the highest linguistic load because it was easiest to name. It was followed by fribbles (semi-linguistic stimuli) and blocks (non-linguistic stimuli) (Christensen & Wright, 2010). Each n-back task was tested at two levels of difficulty, 1-back and 2-back. Individuals with aphasia and individuals who were neurologically intact were tested. The researchers concluded that there was a significant influence of language ability upon working memory tasks. As predicted, the individuals with aphasia were less accurate than the individuals who were neurologically intact on both 1-back and 2-back tasks. All participants performed better on the stimuli with higher linguistic loads (Christensen & Wright, 2010). The individuals with aphasia performed similarly on the fribbles and block n-back task, unlike the neurologically intact individuals who did better on the fribbles as compared to the blocks. This demonstrates that the ability to "name" an object makes it easier to recall the object later on. This influence is an important consideration when examining cognitive deficits in individuals with aphasia (Christensen & Wright, 2010).

The emphasis on reception and production of language in standard working memory tasks severely limits their usefulness with individuals with aphasia. For example, one traditional working memory measure is reading span. It required participants to read groups of sentences and recognize the final word of each sentence in the same order that they read them. Some of these words are plural, which can make it difficult for an individual with aphasia to produce. The individual may say "can" instead of "cans," which would be marked as an incorrect answer. It is impossible to know whether they produced the incorrect word because that is how they memorized it or if it was produced incorrectly due to difficulty with speech production. One study on working memory and individuals with aphasia used a modified version of the reading span task which did not require speech production (Caspari, Parkinson, LaPointe & Katz, 1998). Instead, researchers implemented a recognition task. Participants were required to recognize the terminal words of sentences among foils (Caspari, Parkinson, LaPointe & Katz, 1998). The use of the recognition task may not be the best measure because it can result in ceiling effects for the control group. Nevertheless, some researchers think that the language difficulties experienced by those with aphasia are due to working memory deficits (Caspari, Parkinson, LaPointe & Katz, 1998; Friedman & Gvion, 2003; Wright, Downey, Gravier, Love, & Shapiro, 2007). So the problem becomes more complicated. Individuals with aphasia may have low working memory capacity for at least two reasons: their language inhibits them from performing well on the tasks or their working memory capacity is reduced due to their lesion site and therefore inhibits language. Most testing procedures make this distinction difficult to make.

The purpose of this pilot study was to validate materials designed to measure working memory in people with aphasia by testing college aged students. The materials will be tested and compared to known working memory tests such as alphabet span, subtract 2 span, reading span and n-back tasks. Correlations between new and old working memory tests will be used to examine the validity of the newly developed tasks.

This experiment features three new working memory tasks, which were created to test individuals with aphasia. One task limits the effect of restricted language production. The task will feature picture identification. The test examiner reads words aloud and the participant points to the corresponding pictures. A forward and backwards version of this task will be administered to each participant. The forward version is a measure of short term memory capacity, whereas the backwards version is a measure of working memory capacity. It will be scored in two ways: the total score (total number of items correct), and the span (largest number of items where three or more trials are repeated back correctly).

A second working memory task aims to test spatial working memory. The picture identification task provides both semantic and spatial cues to the participant. The square span task was included to measure the effect of spatial recall. This task requires the participant to mimic the pattern of the tester pointing to squares. Each square is identical in size and color to remove any additional cues as to the proper order of pointing. This was also administered in both forward pointing and backward pointing versions.

The third test is a modified Daneman and Carpenter task, which eliminates the need for the participant to read. The listening span task will require the participant to listen to sentences (rather than read them) and recall the final word of each sentence. Individuals with aphasia can be tested more accurately by eliminating the need to orally read the sentences. While this task takes away the necessity to read, it still requires verbalization of the final words of each sentence.

Controls are expected to perform similarly to other working memory span tasks such as alphabet span, subtract two span, and reading span. Some participants may have higher spans and total scores due to the additional semantic and visual information presented by the pictures in front of them. Individuals with aphasia will likely perform better on the picture identification task than other verbal working memory tasks because no language production is required. Although their span is predicted to be higher, it would still be significantly lower than the controls due to the lesion(s) in areas that are important to working memory.

Methods

Participants

Seven college age adults (19-22 years) were tested on all measures of working memory during two sessions. The participant's years of education ranged from 13 to 15 years and the average number of years of education was 13.4. Participant 6 did not complete backward picture span and forward square span. Participant 7 did not complete forward picture span and backward square span.

Experimental Tasks

Working memory was assessed using a battery of ten tests. Five of the tests have been used in other studies. Alphabet span, Subtract-two span and a modified version of Daneman and Carpenter's Reading span were tested because they are known to have high test/retest reliability (Waters & Caplan, 2003; DeDe, Caplan, Kemtes & Waters 2004). The n-back tasks (n=1 and n=2) were also used. These tasks were chosen because they were used to test individuals with aphasia in a previous study (Christensen & Wright, 2010). The other five tasks were newly developed to test individuals with aphasia. These tasks included forward and backward picture identification, forward and backward square span, and listening span. Appendix A presents the score sheets that were used for each task.

The picture identification task was developed to remove the need to verbalize during working memory tasks. Forty-five monosyllabic, concrete nouns were selected due to their high frequency and high image-ability. Frequencies ranged from 42 per million to 557 per million using the SUBTLEXus frequency database. Only monosyllabic words were used to control the word length effect.

The picture identification task tested spans of two through eight words. Each span size had a total of five trials. No one word was repeated during a span. Each trial had its own page of pictures. The pictures were arranged so that semantically related terms and items with similar phonology (rhymes) did not occur on the same page. This separation of rhyming words was used to reduce the phonological similarity effect. There were nine pictures on each page arranged in three rows of three. Each picture was approximately two inches tall. The pictures were color photographs printed on an 8 ½ by 11 sheet of white paper. Preliminary pilot studies showed that participants could use spatial cues to assist them in remembering the proper order of pictures, so each page of pictures was separated by a blank sheet of paper.

Two versions of this task were administered to participants: forward picture identification and backward picture identification. For the forward version, participants were instructed to listen to the tester and then point to the corresponding pictures in the same order that they heard them. For example, in span two the tester stated, "*boy*, *house*" and the participant was required to point to the picture of the boy and then the house. Once span two was completed, the tester continued on to span eight. For the backward version, participants were instructed to listen to the tester and then point to the corresponding pictures in the reverse order that they heard them. For example, during span three, if the tester stated "*foot, dog, plane*," the participant would point to plane, dog, and then foot. The backward version also progressed from span two to span eight.

Square span was included in the working memory battery in order to separate the effects of spatial cues in the picture identification task. There were forward and backward versions of the task. In the square span task, a white sheet of paper with nine black boxes on it was placed in front of the participant. The boxes were arranged in three rows of three, similar to the set up of the picture span. The boxes were placed evenly apart on the sheet. On the scoring sheet the tester has a small diagram of the black boxes that are labeled numbers one through nine. This labeled diagram assisted the tester in maintaining the accuracy and order of the trials. The tester instructed the participant to point to the boxes in the same order (or reverse order) that he or she pointed to them. For example, the tester pointed to box 1, box 5, and box 7 and scored the participant according to their accuracy in imitating the tester. Unlike the picture identification task, the square span was able to repeat within the trials. For example, on span 6, the order of the boxes may appear as *5, 7, 4, 8, 5, and 1*. There was only one instance of repetition on any given trial. The repetition in trials was to minimize the usefulness of strategies based on process of elimination.

Listening span is a modified version of the Daneman and Carpenter reading span. It is similar to the reading span task, but eliminates the need for the participants to read the sentences orally or to themselves for comprehension. This is important for individuals with aphasia who may have deficits in verbal expression that affect reading. If a participant required a prolonged period of time to orally read the sentences, he or she might perform poorly because of the increased time between items. The sentences used in listening span were controlled to reduce demands associated with complex sentence structure. Each sentence in the task was comprised of eight words and ten syllables. The final word of each sentence was a high frequency, picture-able, single syllable noun. The final words of the sentences were all singular to eliminate the possibility of missing a word because the participant omitted a plural /s/.

During listening span, participants listened to sets of sentences. Upon completion of each set the participant was asked to verbally recall the final words of each sentence while maintaining order. Once they recalled the words, the participant answered a yes or no question about one of the sentences in the group that he or she just completed. The participant was required to answer the yes or no question verbally. This was done for all five trials of each span. Spans two through six were tested on the listening span task.

Alphabet span, subtract two span, and reading span were tested because of their high test/retest reliability (Waters & Caplan, 2003; DeDe, Caplan, Kemtes & Waters 2004). These three tests are often used as a working memory battery because they produce good correlations between one another. Once the results from all tests are collected, the correlations between the alphabet span, subtract two span, and reading span and the newly developed tests; picture identification, square span, and listening span, will be examined.

Alphabet span required the participant to listen to a series of words and repeat them back to the tester after first having rearranged the words in alphabetical order. An example is the tester states “girl, couch, frog” and the participant repeats “couch, frog, girl” back. Alphabet span started out with a set of two words and ended with a set of eight words.

Subtract 2 span required the participant to listen to a group of numbers and repeat them back to the tester after first subtracting two from each digit. For example, if the tester said “5, 3, 7, 6”, then the participant would say “3, 1, 5, 4”.

Reading span called for the participant to read sentences silently to themselves and make judgments of the plausibility of the sentence. Immediately after reading and making judgments on a set of sentences the participant was asked to recall the final words of each sentence in the set. A set with two sentences would be “It was the girl that met the stapler – BAD; It was the girl that met the boy – GOOD”. Then the participant would say “stapler & boy”. Reading span began with sets of two sentences and ends with sets of six sentences.

The n-back tasks required the participant to push a button when the word that he or she heard was the same as the one they heard *n* back (where n=1 or 2). In the Christensen and Wright (2010) n-back task, participants sit in front of a computer screen, which displays color pictures of fruit for 750 ms with a 2750 ms interval between the stimuli (Christensen & Wright, 2010). In the 1-back task, the participant is asked to push the button when he or she sees the same picture as he or she saw one picture back. An example would be “grapes, apple, pear, pear”. 2-back is exactly the same, but requires the participant to react when he or she see the same picture as two pictures back. For example, in this series “pear, apple, grapes, apple, grapes” the participant would have to push the button twice because both the second apple and the second grapes appear two back. For 1-back task, there were 100 trials, 33 of which were targets.   For 2-back task, there were 100 trials, 32 of which were targets.

In all of the working memory tasks, with the exception of the n-back task, participants were scored on their total item score (the number of items correct), and their span.   Upon completion of the eighth span (or the sixth span for reading and listening span) the tester tallied up all of the correct answers and indicates this number as their total score. Span was the longest set size at which the participant is able to recall at least three out of five of the trials correctly, regardless of performance on previous spans. If the participant was able to remember two out of five on the following span then an additional 0.5 was added to their span score. N-back was scored for percent accuracy and reaction time. E-Prime recorded reaction time data for all targets, regardless of whether or not the participant responded. When participants missed a target, the reaction time was recorded as zero. The zero reaction times were omitted from the calculation of reaction time.

Procedures

Each session lasted 60-90 minutes and had an equal number of working memory tasks. The tasks were separated so that the forward and reverse orders of picture identification and square span were never completed on the same day. Reading span and listening span were also separated between sessions because of their similarity as were the n-back tasks.

Results

TABLE 1: N-back scores, averages, standard deviations

Subject	N-Back 1 % ACC	N-Back 1 RT	N-Back 2 % ACC	N-Back 2 RT
1	100	524.6	97	448.8
2	100	592.8	95	727.8
3	99	564.3	97	978.6
4	100	411.4	97	615.9
5	100	442.6	95	444.3
6	99	465.0	99	788.0
7	100	607.9	95	629.4
Average	99.7	515.5	96.4	661.8
Standard Deviation	0.5	77.1	1.5	189.9

Table 1 displays the individual percent accuracy and reaction times for both n-back tasks (n=1, n=2). The average reaction time and percent were calculated using the data from the E-Prime program.

The n-back (n=1) average individual reaction times ranged from 411.4 ms to 607.9 ms and percent accuracy ranged from 99 to 100. The average percent accuracy for 1-back was 99.7 with a standard deviation of 0.5. The average reaction time for 1-back was 515.5ms with a standard deviation of 77.1. The n-back (n=2) average individual reaction times ranged from 444.3 ms to 978.6 ms and percent accuracy ranged from 95 to 99. The average percent accuracy for 2-back was 96.4 with a standard deviation of 1.5. The average reaction time for 2-back was 661.8 with a standard deviation of 189.9.

TABLE 2: Alphabet, subtract 2, reading, listening spans and working memory composite score

Subject	Alphabet Span	Subtract 2 Span	Reading Span	Listening Span	WM Composite Score
1	4	6.5	5.5	4.5	16
2	3.5	5	2.5	5	11
3	5	4	3	4	12
4	4.5	5	6	4	15.5
5	5	5	3.5	4	13.5
6	5	6	4	5	15
7	4	4	3.5	3.5	11.5
Average	4.4	5.1	4.0	4.3	13.5
Standard Deviation	0.6	0.9	1.3	0.6	2.0

Table 2 displays the individual span scores for each participant along with the average span score for each task. Alphabet span scores ranged from 3.5 to 5 with an average of 4.4 and a standard deviation of 0.6. Subtract 2 span scores ranged from 4 to 6.5 with an average of 5.1 and a standard deviation of 0.9. Reading span scores ranged from 2.5 to 6 with an average of 4.0 and a standard deviation of 1.3. Listening span scores ranged from 3.5 to 5 with an average of 4.3 and a standard deviation of 0.6. The working memory composite score was calculated by summing the span scores for alphabet span, subtract 2 span, and reading span. Composite scores provide a more reliable measure of working memory capacity (Caplan & Waters, 2004). The working memory composite scores ranged from 11 to 16 with an average of 13.5 and a standard deviation of 2.

TABLE 3: Picture and square spans, averages, and standard deviations

Subject	Forward Picture Span	Backward Picture Span	Forward Square Span	Backward Square Span
1	7	7	4	4.5
2	6	4	5	6
3	6	4.5	7	4
4	7.5	6.5	7	6
5	6.5	4	5.5	4.5
6	5.5			4
7		4	6.5	
Average	6.4	5.0	5.8	4.8
Standard Deviation	0.7	1.4	1.2	0.9

Table 3 shows the span scores for both picture spans (forward & backward) and square spans (forward & backward). The picture and square span tasks had to be video scored because it was too difficult to score it on-line. The tasks were video scored by two people in order to make comparisons at the end of the scoring session. Because it was possible to pause and go back to recordings of certain sequences, the scores are very accurate. Forward picture span ranged from 5.5 to 7.5 with an average of 6.4 and a standard deviation of 0.7. Backward picture span ranged from 4 to 7 with an average of 5.0 and a standard deviation of 1.4. Forward square span ranged from 4 to 7 with an average of 5.8 and a standard deviation of 1.2. Backward square span ranged from 4 to 6 with an average of 4.8 and a standard deviation of 0.9.

TABLE 4: Correlation between n-back tasks and other span measures

	N-Back 1 RT	N-Back 2 RT
WM Comp	-0.75*	-0.43
Listening Span	-0.06	0.16
Picture Forward Span	-0.45	-0.61
Picture Backward Span	-0.47	-0.34
Square Forward Span	-0.12	0.58
Square Backward Span	-0.03	-0.21

* $p < .05$

TABLE 5: Correlation between working memory composite score and other span measures

	WM Comp
Listening Span	0.18
Picture Forward Span	0.528
Picture Backward Span	0.909*
Square Forward Span	-0.254
Square Backward Span	-0.151

* $p < .05$

Waters and Caplan (2004) reported that a composite working memory score had better test-retest reliability then any individual span score. The working memory composite score was calculated by adding the span scores of alphabet span, subtract 2 span, and reading span.

Correlational analyses were used to investigate the relation between performance on the working memory composite score and the experimental measures. Given the small number of participants, the correlations should be interpreted with caution. Pairwise deletion of missing data was used to maximize the number of data points in each cell. There was a significant positive correlation between backwards picture span and the working memory composite score ($r=.91$, $p<.01$). The listening span, forwards square span, and backwards square span revealed low to moderate correlations with the working memory composite score, which were not significant. Reaction times for the n-Back (n=1) test were negatively correlated with the working memory composite score ($r=-.75$, $p=.05$). However, reaction times on the n-back tasks were not significantly correlated with performance on any of the listening span, picture span, or square span tasks.

Discussion

In this study we developed new tasks to be used for examining the working memory capacity of individuals with aphasia. We investigated the ability of the new tasks to measure working memory as compared to alphabet span, subtract 2 span, and reading span. To determine how well the new tasks worked, we conducted correlational analyses of the new tasks against the working memory composite scores. The listening span, forwards square span, and backwards square span revealed low to moderate correlations with the working memory composite score, which were not significant. It is possible that with more participants, higher correlations between listening span, forwards square span, and backwards square span and the working memory composite score would occur. Backward picture span and the working memory composite score were significantly correlated. This could show that the backward picture span a good measure of working memory. Correlational analyses were also conducted with the n-back tasks and the working memory composite scores. Reaction times for the n-Back (n=1) test were negatively correlated with the working memory composite score. This implies that individuals with larger working memory capacity had quicker responses on the 1-back task. The results should be taken with some skepticism since there were so few participants tested.

The limited number of participants was due to time constraints. Human Subjects Research and Institutional Review Board (IRB) approval was required before testing participants and it was necessary to complete data collection with enough time to analyze the data. In order to obtain more conclusive data more testing needs to be conducted. More college age participants should be tested to replicate the data in the current study. Older adults should also be tested to examine the effect of age on the working memory task scores on the newly developed tasks. Finally, individuals with aphasia should be tested on all tasks and correlations should be used to examine the relation between the new working memory tasks and the older tasks with high test/retest reliability.

If the individuals with aphasia achieve higher span and item scores on the newer working memory tasks compared to the old working memory tasks, it may be possible to assume that the higher scores resulted from the limited need to verbalize. If this is true, the study would be considered a success, because the purpose of the study was to create working memory tasks that reduce the need to verbalize in order to provide more accurate depictions of an individual with aphasia's working memory capacity. Of course, more testing that limits the need to verbalize would need to occur before these results could be considered conclusive. It is necessary to ensure that the tasks without verbalization are not easier, which would yield higher scores.

Conclusion

These preliminary results indicate that we are on the right track for developing a more efficient working memory task for individuals with aphasia. The backwards picture span may be a good measure of working memory because it correlates with the alphabet span, subtract 2 span, and reading span. Reaction times during the n-back (n=1) task indicate that individuals with larger working memory capacity responded more quickly on the 1-back task. The data presented in this study are preliminary and more testing needs to be done in order to achieve conclusive results.

Appendix A

Subject__________ Experimenter_____________ Date_____________ Span________ Items_________

PICTURE SPAN-FORWARD

Instructions: Read aloud to participant while having the notebook open to the directions page. "In this memory test, I will read you some words. After I read you the words I want you to point to the corresponding pictures while maintaining the same word order. For example, if I say boy, ball, foot, what would you do? (Wait for correct response.) Remember that order is important, so if you did not remember the second word you would point to the boy say blank and then point to the foot. Please do not repeat the list of words out loud. We will start with two words and then work our way up to eight words. Let me know if you need a break between trials."

Span 2

1. Bag Girl ___________ ___________
   (bag) (girl)
2. Dress Car ___________ ___________
   (dress) (car)
3. Hand Star ___________ ___________
   (hand) (star)
4. Dog Plane ___________ ___________
   (dog) (plane)
5. Film Earth ___________ ___________
   (film) (earth)

Span 3

1. Wine Rock Fire ___________ ___________ ___________
   (wine) (rock) (fire)
2. Store Ball Sun ___________ ___________ ___________
   (store) (ball) (sun)
3. Bus Card Tree ___________ ___________ ___________
   (bus) (card) (tree)
4. Ring Clock Hat ___________ ___________ ___________
   (ring) (clock) (hat)
5. Bed Rose Train ___________ ___________ ___________
   (bed) (rose) (train)

Span 4

1. Suit Desk House Cake ___________ ___________ ___________ ___________
   (suit) (desk) (house) (cake)
2. Lock Fish Heart Chair ___________ ___________ ___________ ___________
   (lock) (fish) (heart) (chair)
3. Phone Knife Bear Milk ___________ ___________ ___________ ___________
   (phone) (knife) (bear) (milk)
4. Cash Foot Boy Tea ___________ ___________ ___________ ___________
   (cash) (foot) (boy) (tea)
5. Coat Key Horse Book ___________ ___________ ___________ ___________
   (coat) (key) (horse) (book)

Subject__________ Experimenter_____________ Date_____________ Span________ Items_________

PICTURE SPAN-FORWARD

Span 5

1.	Fire Girl Rock Bag Wine	(fire)	(girl)	(rock)	(bag)	(wine)
2.	Dress Ball Car Sun Store	(dress)	(ball)	(car)	(sun)	(store)
3.	Hand Card Tree Bus Star	(hand)	(card)	(tree)	(bus)	(star)
4.	Dog Plane Ring Clock Hat	(dog)	(plane)	(ring)	(clock)	(hat)
5.	Bed Earth Film Rose Train	(bed)	(earth)	(film)	(rose)	(train)

Span 6

1.	Fire Suit Wine Rock Desk Cake	(fire)	(suit)	(wine)	(rock)	(desk)	(cake)
2.	Fish Store Lock Chair Heart Car	(fish)	(store)	(lock)	(chair)	(heart)	(car)
3.	Milk Star Bear Phone Tree Knife	(milk)	(star)	(bear)	(phone)	(tree)	(knife)
4.	Boy Ring Tea Foot Hat Cash	(boy)	(ring)	(tea)	(foot)	(hat)	(cash)
5.	Coat Film Horse Train Book Earth	(coat)	(film)	(horse)	(train)	(book)	(earth)

Span 7

1.	Rock Bag House Suit Wine Girl Fire	(rock)	(bag)	(house)	(suit)	(wine)	(girl)	(fire)
2.	Sun Heart Dress Lock Ball Fish Store	(sun)	(heart)	(dress)	(lock)	(ball)	(fish)	(store)
3.	Bus Card Star Tree Knife Hand Phone	(bus)	(card)	(star)	(tree)	(knife)	(hand)	(phone)
4.	Plane Clock Dog Ring Boy Hat Tea	(plane)	(clock)	(dog)	(ring)	(boy)	(hat)	(tea)
5.	Book Key Horse Film Earth Rose Bed	(book)	(key)	(horse)	(film)	(earth)	(rose)	(bed)

Span 8

1.	Desk Wine Suit Rock Cake House Fire Bag	(desk)	(wine)	(suit)	(rock)	(cake)	(house)	(fire)	(bag)
2.	Chair Ball Dress Heart Store Car Fish Lock	(chair)	(ball)	(dress)	(heart)	(store)	(car)	(fish)	(lock)
3.	Milk Bus Tree Bear Star Card Phone Knife	(milk)	(bus)	(tree)	(bear)	(star)	(card)	(phone)	(knife)
4.	Tea Foot Dog Cash Clock Hat Plane Ring	(tea)	(foot)	(dog)	(cash)	(clock)	(hat)	(plane)	(ring)
5.	Train Coat Horse Book Rose Key Bed Film	(train)	(coat)	(horse)	(book)	(rose)	(key)	(bed)	(film)

Subject_________ Experimenter____________ Date____________ Span_______ Items________

PICTURE SPAN-REVERSE ORDER

Instructions: Read aloud to participant while having the notebook open to the directions page. “In this memory test, I will read you some words. After I read you the words I want you to point to the pictures that match the words in the reverse order. For example, if I say boy, ball, foot, what would you do? (Wait for correct response.) Remember that order is important, so if you did not remember the second word you would point to the foot, point to the box that says “blank,” and then point to the boy. Please do not repeat the list of words out loud. We will start with two words and then work our way up to eight words. Let me know if you need a break between trials.”

Span 2

Wine Girl _______ _______
(Girl) (Wine)

Ball Lock _______ _______
(Lock) (Ball)

Bear Hand _______ _______
(Hand) (Bear)

Clock Dog _______ _______
(Dog) (Clock)

Train Film _______ _______
(Film) (Train)

Span 3

Bag Desk Fire _______ _______ _______
(Fire) (Desk) (Bag)

Sun Fish Chair _______ _______ _______
(Chair) (Fish) (Sun)

Bus Tree Phone _______ _______ _______
(Phone) (Tree) (Bus)

Boy Plane Foot _______ _______ _______
(Foot) (Plane) (Boy)

Rose Key Horse _______ _______ _______
(Horse) (Key) (Rose)

Span 4

House Cake Rock Suit _______ _______ _______ _______
(Suit) (Rock) (Cake) (House)

Heart Store Car Dress _______ _______ _______ _______
(Dress) (Car) (Store) (Heart)

Bear Milk Star Knife _______ _______ _______ _______
(Knife) (Star) (Milk) (Bear)

Ring Hat Cash Tea _______ _______ _______ _______
(Tea) (Cash) (Hat) (Ring)

Book Coat Bed Earth _______ _______ _______ _______
(Earth) (Bed) (Coat) (Book)

Subject__________ Experimenter_____________ Date_____________ Span________ Items_________

PICTURE SPAN-REVERSE ORDER

Span 5

Girl Suit Wine Cake Fire _______ _______ _______ _______ _______
(Fire) (Cake) (Wine) (Suit) (Girl)

Chair Lock Car Sun Fish _______ _______ _______ _______ _______
(Fish) (Sun) (Car) (Lock) (Chair)

Tree Card Phone Hand Bear _______ _______ _______ _______ _______
(Bear) (Hand) (Phone) (Card) (Tree)

Foot Plane Hat Clock Boy _______ _______ _______ _______ _______
(Boy) (Clock) (Hat) (Plane) (Foot)

Horse Key Rose Film Train _______ _______ _______ _______ _______
(Train) (Film) (Rose) (Key) (Horse)

Span 6

Bag Desk Rock Fire House Suit _______ _______ _______ _______ _______ _______
(Suit) (House) (Fire) (Rock) (Desk) (Bag)

Chair Fish Dress Store Heart Ball _______ _______ _______ _______ _______ _______
(Ball) (Heart) (Store) (Dress) (Fish) (Chair)

Phone Milk Star Hand Bus Tree _______ _______ _______ _______ _______ _______
(Tree) (Bus) (Hand) (Star) (Milk) (Phone)

Hat Ring Tea Cash Dog Boy _______ _______ _______ _______ _______ _______
(Boy) (Dog) (Cash) (Tea) (Ring) (Hat)

Key Bed Coat Earth Book Film _______ _______ _______ _______ _______ _______
(Film) (Book) (Earth) (Coat) (Bed) (Key)

Span 7

House Rock Fire Desk Wine Girl Cake _____ _____ _____ _____ _____ _____ _____
(Cake) (Girl) (Wine) (Desk) (Fire) (Rock) (House)

Lock Store Car Ball Sun Chair Dress _____ _____ _____ _____ _____ _____ _____
(Dress) (Chair) (Sun) (Ball) (Car) (Store) (Lock)

Milk Star Phone Knife Tree Bus Hand _____ _____ _____ _____ _____ _____ _____
(Hand) (Bus) (Tree) (Knife) (Phone) (Star) (Milk)

Hat Cash Boy Tea Foot Ring Clock _____ _____ _____ _____ _____ _____ _____
(Clock) (Ring) (Foot) (Tea) (Boy) (Cash) (Hat)

Coat Rose Key Earth Train Book Horse _____ _____ _____ _____ _____ _____ _____
(Horse) (Book) (Train) (Earth) (Key) (Rose) (Coat)

Span 8

Fire Girl Wine Rock Bag Desk Cake House _____ _____ _____ _____ _____ _____ _____ _____
(House) (Cake) (Desk) (Bag) (Rock) (Wine) (Girl) (Fire)

Car Dress Heart Chair Ball Store Sun Fish _____ _____ _____ _____ _____ _____ _____ _____
(Fish) (Sun) (Store) (Ball) (Chair) (Heart) (Dress) (Car)

Card Knife Tree Milk Bear Phone Star Hand _____ _____ _____ _____ _____ _____ _____ _____
(Hand) (Star) (Phone) (Bear) (Milk) (Tree) (Knife) (Card)

Plane Ring Foot Dog Boy Cash Hat Clock _____ _____ _____ _____ _____ _____ _____ _____
(Clock) (Hat) (Cash) (Boy) (Dog) (Foot) (Ring) (Plane)

Earth Bed Train Film Horse Book Rose Key _____ _____ _____ _____ _____ _____ _____ _____
(Key) (Rose) (Book) (Horse) (Film) (Train) (Bed) (Earth)

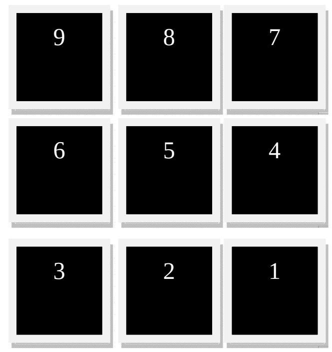
Subject_________ Experimenter____________ Date____________ Span_______ Items________

Working Memory Square Span- Forward

In this memory task I am going to point to some of the boxes on this sheet in a certain order. After I am done I want you to point to them in the same order as I did. I will start with a series of two boxes and end with a series of eight boxes. Note that order is important. If you forget one box of the series point to the sheet that says BLANK and then continue with the rest of the series. For example: Point to 6 2

Span 2

1) 1 9 __________ __________
2) 1 4 __________ __________
3) 5 9 __________ __________
4) 3 6 __________ __________
5) 4 2 __________ __________



Span 3

1) 7 6 9 __________ __________ __________
2) 2 3 1 __________ __________ __________
3) 1 5 9 __________ __________ __________
4) 6 3 1 __________ __________ __________
5) 9 5 2 __________ __________ __________

Span 4

1) 9 7 5 1 __________ __________ __________ __________
2) 1 2 4 6 __________ __________ __________ __________
3) 5 7 2 5 __________ __________ __________ __________
4) 4 6 7 8 __________ __________ __________ __________
5) 2 9 6 2 __________ __________ __________ __________

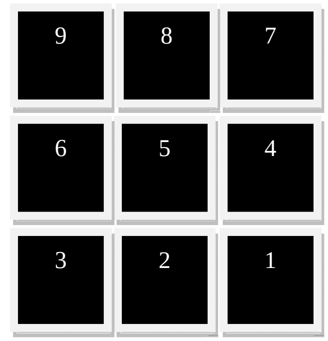
Span 5

1) 1 8 4 6 7 __________ __________ __________ __________ __________
2) 6 8 7 3 6 __________ __________ __________ __________ __________
3) 9 1 4 2 8 __________ __________ __________ __________ __________
4) 7 2 9 6 1 __________ __________ __________ __________ __________
5) 2 5 1 8 6 __________ __________ __________ __________ __________

Subject__________ Experimenter_____________ Date_____________ Span________ Items_________

Span 6

1) 4 2 8 6 9 8 ______ ______ ______ ______ ______ ______
2) 2 3 4 1 5 2 ______ ______ ______ ______ ______ ______
3) 1 8 7 5 4 8 ______ ______ ______ ______ ______ ______
4) 2 4 9 1 4 6 ______ ______ ______ ______ ______ ______
5) 8 9 5 3 7 5 ______ ______ ______ ______ ______ ______



Span 7

1) 3 2 1 9 7 8 3 ______ ______ ______ ______ ______ ______ ______
2) 2 6 8 2 5 1 6 ______ ______ ______ ______ ______ ______ ______
3) 3 1 2 4 8 5 4 ______ ______ ______ ______ ______ ______ ______
4) 1 4 5 6 8 2 7 ______ ______ ______ ______ ______ ______ ______
5) 9 6 5 4 8 3 4 ______ ______ ______ ______ ______ ______ ______

Span 8

1) 1 3 2 6 4 7 5 9 ______ ______ ______ ______ ______ ______ ______ ______
2) 2 6 7 3 9 8 1 7 ______ ______ ______ ______ ______ ______ ______ ______
3) 8 5 1 2 7 3 9 2 ______ ______ ______ ______ ______ ______ ______ ______
4) 3 1 2 6 4 8 7 3 ______ ______ ______ ______ ______ ______ ______ ______
5) 6 3 1 8 7 5 2 6 ______ ______ ______ ______ ______ ______ ______ ______

Subject__________ Experimenter_____________ Date_____________ Span________ Items_________

Working Memory Square Span-Reverse

In this memory task I am going to point to some of the boxes on this sheet in a certain order. After I am done I want you to point to them in reverse order. I will start with a series of two boxes and end with a series of eight boxes. Note that order is important. If you forget one box of the series point to the sheet that says BLANK and then continue with the rest of the series. For example: 5 1 (1 5)

9	8	7
6	5	4
3	2	1

Span 2

6)	**9 5**	________	________	
		5	9	
7)	**4 5**	________	________	
		5	4	
8)	**8 2**	________	________	
		2	8	
9)	**4 1**	________	________	
		1	4	
10)	**3 8**	________	________	
		8	3	

Span 3

6)	**8 5 7**	________	________	________
		7	5	8
7)	**3 5 9**	________	________	________
		9	5	3
8)	**6 7 1**	________	________	________
		1	7	6
9)	**4 9 3**	________	________	________
		3	9	4
10)	**2 9 4**	________	________	________
		4	9	2

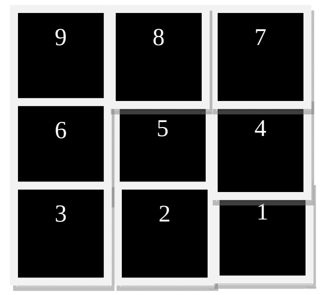
Span 4

6)	**1 8 4 9**	________	________	________	________
		9	4	8	1
7)	**7 4 1 7**	________	________	________	________
		7	1	4	7
8)	**2 5 9 7**	________	________	________	________
		7	9	5	2
9)	**9 8 2 4**	________	________	________	________
		4	2	8	9
10)	**6 3 4 8**	________	________	________	________
		8	4	3	6

Subject__________ Experimenter_____________ Date_____________ Span________ Items_________

Span 5

6)	**8 9 1 8 6**	6	8	1	9	8
7)	**5 3 1 8 5**	5	8	1	3	5
8)	**5 1 8 4 1**	1	4	8	1	5
9)	**2 9 3 8 9**	9	8	3	9	2
10)	**7 9 5 7 6**	6	7	5	9	7



Span 6

6)	**6 4 3 9 7 6**	6	7	9	3	4	6
7)	**4 7 6 9 3 4**	4	3	9	6	7	4
8)	**4 6 3 1 6 7**	7	6	1	3	6	4
9)	**4 5 3 8 5 1**	1	5	8	3	5	4
10)	**7 8 5 2 3 5**	5	3	2	5	8	7

Span 7

6)	**9 8 7 3 5 2 8**	8	2	5	3	7	8	9
7)	**5 9 1 8 2 3 6**	6	3	2	8	1	9	5
8)	**1 6 8 5 2 3 9**	9	3	2	5	8	6	1
9)	**8 5 3 4 2 1 9**	9	1	2	4	3	5	8
10)	**8 7 1 5 2 3 7**	7	3	2	5	1	7	8

Span 8

6)	**4 5 8 7 6 1 2 6**	6	2	1	6	7	8	5	4
7)	**3 2 1 9 5 3 8 2**	2	8	3	5	9	1	2	3
8)	**8 7 3 4 5 2 1 8**	8	1	2	5	4	3	7	8
9)	**8 3 7 2 3 9 6 1**	1	6	9	3	2	7	3	8
10)	**4 5 3 2 9 1 6 8**	8	6	1	9	2	3	5	4

Subject__________ Experimenter_____________ Date_____________ Span________ Items_________

Working Memory Listening Span

Instructions: In this memory test, you will be listening to sets of sentences. After each set of sentences, you will see an asterisk in the middle of the screen. At that point, tell me the last word of each sentence in the order that they appeared. After you have repeated the last words of each previous sentence there will be a YES NO question. Please say the answer out loud.

Note to experimenter: Be sure to mark whether the participant responds "yes" or "no" to each question.

Scoring: Span is the highest set at which the person gets 3/5 trials correct. Add .5 if 2/5 trials were correct on the next span.

Practice Answer: 1.Clock, Bench Y 2.Street, Game N 3.Box, Gift N

SPAN 1 (/5)

1. bell ______________ **Y** N
2. store ______________ Y **N**
3. work ______________ **Y** N
4. glass ______________ Y **N**
5. suit ______________ Y **N**

SPAN 2 (/5)

1. cloud ______________
2. couch ______________ **Y** N

3. film ______________
4. brush ______________ Y **N**

5. train ______________
6. room ______________ Y **N**

7. plane ______________
8. watch ______________ **Y** N

9. ball ______________
10. knife ______________ Y **N**

SPAN 3 (/5)

1. door ______________
2. doll ______________
3. wine ______________ Y **N**

4. lamp ______________
5. board ______________
6. flag ______________ **Y** N

7. dock ______________
8. lock ______________
9. prom ______________ **Y** N

10. coat ______________
11. beer ______________
12. bus ______________ **Y** N

13. mouse ______________
14. zoo ______________
15. truck ______________ Y **N**

SPAN 4 (/5)

1. heart ______________
2. bag ______________
3. beach ______________
4. tent ______________ **Y** N

5. chair ______________
6. purse ______________
7. light ______________
8. phone ______________ Y **N**

9. trash ______________
10. lake ______________
11. key ______________
12. crowd ______________ **Y** N

13. nurse ______________
14. brush ______________
15. tail ______________
16. belt ______________ Y **N**

17. field ______________
18. swing ______________
19. shoe ______________
20. dance ______________ **Y** N

SPAN 5 (/5)

1. hand ______________
2. back ______________
3. roof ______________
4. egg ______________
5. pan ______________ **Y** N

6. rock ______________
7. ring ______________
8. plate______________
9. shark______________
10. dress______________ Y **N**

11. cat ______________
12. paint ______________
13. tree ______________
14. prize ______________
15. golf ______________ Y **N**

16. town ______________
17. king ______________
18. horn ______________
19. juice ______________
20. piece ______________ **Y** N

21. hill ______________
22. horse ______________
23. shirt ______________
24. bowl ______________
25. ear ______________ Y **N**

SPAN 6 (/5)

1. sea ______________
2. rose ______________
3. cheese ______________
4. hat ______________
5. pen ______________
6. beer ______________ **Y** N

7. bike ______________
8. fish ______________
9. chest ______________
10. boy ______________
11. house ______________
12. tie ______________ Y **N**

13. child ______________
14. desk ______________
15. guard ______________
16. tooth ______________
17. tea ______________
18. base ______________ Y **N**

19. card ______________
20. prince ______________
21. bread ______________
22. girl ______________
23. rice ______________
24. trunk ______________ **Y** N

25. job ______________
26. mail ______________
27. cake ______________
28. milk ______________
29. car ______________
30. boat ______________ **Y** N

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