Title:

Does Memory Contribute to Reading Comprehension in Adults Who Struggle with Reading?

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Abstract

This study explored the relations between reading comprehension and two memory capacities, short-term memory (STM) and working memory (WM), for adults who read between the third and eighth grade levels. With a sample of 407 adults from two countries, we computed correlations among measures and conducted hierarchical regression and commonality analyses for reading comprehension. Reading comprehension had moderate positive correlations with STM and WM. Additionally, STM and WM jointly accounted for approximately 19% of the reading comprehension variance and uniquely contributed approximately 4% and 7% of the variance, respectively. The predictive utility of memory to reading comprehension was greatly reduced after controlling for age, word reading, fluency, and oral vocabulary. WM appears to be a slightly stronger predictor of reading comprehension than STM for struggling adult readers. However, the overall contributions of memory capacities to reading comprehension are much smaller than those of reading-related skills.

Keywords: *adult literacy, reading comprehension, short-term memory, working memory, struggling adult readers*

Highlights

What is already known about this topic

- WM and, to a lesser extent, STM have been examined as predictors of reading comprehension, mostly in studies with children and undergraduates.
- There is a dearth of research on the contributions of STM and WM to reading comprehension in adults who struggle with reading, a population that includes approximately one in six adults in the United Kingdom, the United States, and Canada.

What this paper adds

- This study contributes to the burgeoning research on the cognitive skills of struggling adult readers, specifically adding to the literature on the relations between memory capacities and reading comprehension.
- This is the first study to investigate the joint and unique contributions of STM and WM to reading comprehension in this population.
- This study also examines the predictive utility of STM and WM for reading comprehension in the context of well-established predictors of reading comprehension: word reading, fluency, and oral vocabulary.

Implications for theory, policy, or practice

- For adults who read between the third and eighth grade levels, the relations between memory and reading comprehension are not very strong in the presence of other predictors. Future research should investigate whether these relations are mediated by oral language skills, as suggested by previous findings.

Introduction

The Programme for the International Assessment of Adult Competencies (PIAAC) reported on adult literacy levels in the countries in the Organisation for Economic Co-operation and Development (OECD, 2013). Notably, in the United Kingdom, the United States, and Canada, approximately one in six adults demonstrated low literacy skills. These adults had literacy proficiency at or below Level 1 (OECD, 2013). Adults at Level 1 were only successful at reading simple, short texts and deriving one piece of information that was directly related to the question, while adults below Level 1 had difficulty with these basic tasks.

Many countries have programs where adults can enrol to increase their literacy skills or work toward a high school equivalency diploma. In order to inform and improve such programs, we need a better understanding of the cognitive profiles of adults who struggle with reading. This study is step toward that goal. We focused on reading comprehension, which has been recognised as the ultimate goal of reading (Duke, Pearson, Strachan, & Billman, 2011). In particular, we investigated the role of memory in the reading comprehension of struggling adult readers, because this is an understudied area in adult literacy research. Our participants included adults from two OECD countries who were native speakers of English. Our investigation contributes to the growing body of literature on struggling adult readers' cognitive skills and may eventually inform instructional practices in adult literacy programs.

Reading Comprehension

Reading comprehension is the act of translating text into mental representations. This complex process involves multiple lower-level skills. For skilled adult readers, the ability to recognize the names of literary authors and the ability to read and define written words have emerged as strong predictors of comprehension (Landi, 2010). For struggling adult readers, basic skills seem to be especially important. In Tighe and Schatschneider's (2016) meta-analysis of 16 studies involving struggling adult readers, word reading, fluency, and oral vocabulary exhibited strong relations with reading comprehension (i.e., average *r*s >.50). These three skills have also explained variance in reading comprehension for struggling adult readers (Barnes, Kim, Tighe, & Vorstius, 2017; Braze, Tabor, Shankweiler, & Mencl, 2007; Mellard, Fall, & Woods, 2010; Sabatini, Sawaki, Shore, & Scarborough, 2010).

The predictive utility of these skills can be explained by the Simple View of Reading (SVR). The SVR attributes much of the variance in reading comprehension to skills related to decoding and linguistic comprehension (Gough & Tunmer, 1986) and has been supported empirically (e.g. Kim, 2016). Some evidence suggests that fluency also plays a role in the SVR (Silverman, Speece, Harring, & Ritchey, 2013; Tilstra, McMaster, Broek, Kendeou, & Rapp, 2009). Thus, skills such as word reading, fluency, and oral vocabulary can be considered part of the SVR components; controlling for these skills would account for reading-related predictors that are known to contribute to reading comprehension. Beyond this contribution, any other predictors that explain practically and statistically significant variance in reading comprehension would be worth studying further. Such predictors might include memory capacities, which are considered in the construction-integration (CI) framework (Rayner & Reichle, 2010).

Kintsch's (1988) CI model is an influential theoretical account of the reading comprehension process, which postulates that readers comprehend connected text in two stages. In the construction stage, the reader mines short portions of the text to form a literal interpretation known as the text base. The content of the text base may cue the reader to make connections with existing knowledge. In the integration stage, the reader uses the most salient information to develop a more cohesive representation of the text. The amount of text base information that a reader can maintain at a given time is constrained by memory (Rayner & Reichle, 2010).

Memory

Researchers have examined the impact of memory on reading with other populations, but similar research involving adults with reading difficulties is sparse. For this study, we chose to focus on working memory (WM) and short-term memory (STM), because these are the two memory capacities whose contributions to reading comprehension have been examined the most (e.g., Alloway & Gregory, 2013; Daneman & Carpenter, 1980; Hannon, 2012; Siegel, 1994; Swanson, 1994). STM refers to the capacity to temporarily store information in the mind, and WM refers to the capacity to temporarily store information and manipulate it, as outlined by theorists such as Baddeley and Hitch (1974) and Daneman and Carpenter (1980). Researchers have found that STM and WM assessments measure different latent factors (Cantor, Engle, & Hamilton, 1991; Swanson, 1994), which indicates that despite their overlapping functions, WM and STM should be treated as separate capacities.

Relations between Reading Comprehension and Memory Capacities

In their seminal work, Daneman and Carpenter (1980) found that undergraduates' scores on two WM tasks were positively correlated with their scores on two reading comprehension tasks. More recently, researchers have reported significant direct effects of WM on reading comprehension in the context of reading-related skills for undergraduates (Alloway & Gregory, 2013; Hannon, 2012) and adolescents (Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014). The influence of WM on reading comprehension in conjunction with other reading-related skills is in line with the CI theoretical framework, which points to the role of memory in the retention of textual information (Rayner & Reichle, 2010). However, an important consideration is that these results may have been affected by the types of WM tasks administered. The WM tasks used in these studies included reading a paragraph and recalling the last word of each sentence in the paragraph (Daneman & Carpenter, 1980; Hannon, 2012), recalling a string of letters and numbers after rearranging them in ascending order (Alloway & Gregory, 2013), and recalling a string of numbers in reverse order (Arrington et al., 2014). Since these tasks vary in stimuli and cognitive demands, some of them may be more or less predictive of reading comprehension. For example, tasks involving oral sentence processing may be similar to reading sentences in connected texts and, therefore, have a stronger relation with reading comprehension performance.

Two notable studies have examined the STM, WM, and reading comprehension skills of adults and children diagnosed with reading disabilities. In the first one, Siegel (1994) assessed STM by asking participants to recall sequences of five letters that were visually presented on cards and assessed WM by asking participants to provide missing words to complete sentences and then recall their answers after a set of such sentences. In Siegel's study, WM and STM were positively correlated with reading comprehension for individuals aged 6-49 years both with and without reading disabilities. In the second such study, Swanson (1994) administered a battery of visuo-spatial and verbal tasks to assess STM and WM. For example, an STM task was to draw complex geometric pictures that are presented visually and then removed from sight, and a WM task was to listen to a story, answer a question about it, and then recall all the events from the story. In Swanson's study, the participants were aged 5-58 years and differing trends emerged based on reading disability status. For participants diagnosed with reading disabilities, both STM and WM were positively correlated with reading comprehension, and STM explained more variance than WM in reading comprehension. For participants without reading disabilities, only WM was positively correlated with reading comprehension, and WM explained more variance than STM in reading comprehension. Thus, which of two memory capacities has a greater influence on reading comprehension may depend on the presence of a reading disability, at least when both verbal and visuo-spatial tasks are used to assess memory. Researchers have not yet tested the relative predictive utility of each memory capacity for adults who struggle with reading, a population that includes individuals with and without diagnoses of reading disabilities (Kutner et al., 2007).

Reading Comprehension and Memory in Struggling Adult Readers

In research with struggling adult readers, only a few studies have reported on the relations between STM and reading comprehension (Braze et al., 2007; Thompkins & Binder, 2003) and between WM and reading comprehension (Braze et al., 2007; Mellard et al., 2010; Mellard, Woods, & Md Desa, 2012; Mellard, Woods, Md Desa, & Vuyk, 2015). To assess STM, Thompkins and Binder (2003) asked participants to recall sequences of digits in order. For their sample of adults who were reading on average at the fifth grade level, Thompkins and Binder (2003) found that STM was positively correlated (r = .28) with reading comprehension but did not contribute variance to reading comprehension after controlling for skills related to reading and spelling.

Braze et al. (2007) assessed STM by asking participants to reproduce sequential spatial patterns on touch screens. Their sample comprised adults who had reading difficulties in elementary and secondary school; participants' reading levels were not reported. Braze et al. found that STM performance was correlated with two kinds of comprehension tasks: one that measured participants' understanding of isolated sentences (r = .49) and one that measured participants' understanding of connected text paragraphs (r = .27). Given these differing coefficients within the same sample, it is possible that STM is more important for understanding shorter texts like sentences as opposed to paragraphs, at least for low-skilled adult readers. To assess WM, Braze et al. had participants listen to sentences and, after each sentence, decide whether it is true or false. At the end of a series of two to five such sentences, participants had to verbally recall the last word of each sentence. Braze et al.

reported that WM scores were positively correlated with sentence-level reading comprehension (r = .63) and passage-level reading comprehension (r = .51).

Mellard and colleagues have conducted the remaining three adult literacy studies that measured the relation between WM and reading comprehension (Mellard et al., 2010; Mellard et al., 2012; Mellard et al., 2015). All three of these studies included WJ Auditory Working Memory as a measure of WM; in this task, participants listen to increasingly longer strings of interspersed words and numbers and have to recall first the words in order and then the numbers in order. In the first of these studies, Mellard et al. (2010) presented a path model of reading comprehension based on a representative sample of adult education students at different reading skill levels, with the mean at approximately the fifth grade level. The researchers found a significant indirect effect of WM on reading comprehension mediated through language comprehension, but they did not test a direct effect of WM on reading comprehension. In a later study, Mellard et al. (2012) administered a battery of assessments to adults who read between the second and twelfth grade levels, with the mean at approximately the sixth grade level. Scores on the three WM assessments in this study were positively correlated with reading comprehension scores (rs ranging from .39 to .48).

All of the WM tasks used in the studies reviewed so far involve the storage, manipulation, and recall of information. However, this was not the case for one of the four assessments that were treated as WM tasks in Mellard et al.'s (2015) study. For this sample, which comprised adults in career and technical education programs (reading levels not reported), Mellard et al. (2015) found that as a latent factor, WM explained a significant proportion of variance in reading comprehension. However, one of the four measures that loaded onto this latent factor was WJ Decision Speed, in which participants have to select conceptually matching pairs of pictures from groups within a certain time limit. This task does not satisfy the criteria for a WM task (Daneman & Carpenter, 1980). Thus, working memory ability in this study was not entirely inferred from working memory measures, and it remains unclear what proportion of reading comprehension variance would have been explained by working memory performance alone.

Given this limited literature involving struggling adult readers, it is difficult to pinpoint the mechanisms through which memory capacities might impact reading comprehension. If memory does play a role in comprehension for this population, the CI framework suggests it is through the process of limiting the retention of newly acquired knowledge during connected text reading. Before devoting research resources to investigate this possibility, it is first important to establish the extent of the influence of STM and WM to reading comprehension, both in isolation and in conjunction with reading-related skills.

The Current Study

Together, these studies provide evidence that STM and WM are positive correlates of reading comprehension for struggling adult readers. This evidence, while consistent, is based on a limited number of studies. Moreover, these studies did not examine STM and WM jointly as predictors explaining variance in reading comprehension. Additionally, only verbal tasks were used to assess WM, whereas both verbal and visuospatial tasks were used to assess STM; this variability in stimuli may have influenced results.

In the current study, we assessed the joint and unique contributions of STM and WM to reading comprehension for struggling adult readers. Additionally, we examined the predictive utility of STM and WM for reading comprehension after controlling for word reading, fluency, and oral vocabulary, because these skills are known predictors of reading comprehension for struggling adult readers (Tighe & Schatschneider, 2016). Age was also included as a control variable, because STM and WM have been reported to decline with age (Cowan, Naveh-Benjamin, Kilb, & Staubs, 2006; Luo, Craik, Moreno, & Bialystok, 2013). Furthermore, both memory tasks used in the current study involved verbal stimuli.

The following research questions were addressed:

1. Is reading comprehension related to STM and WM for adults who read between the third and eighth grade levels?
2. What are the joint and unique contributions of STM and WM to reading comprehension?
3. What proportion of the variance in reading comprehension is explained by STM and WM after controlling for age, word reading, fluency, and oral vocabulary?

Method

Participants

As indicated in Table 1, this study included 407 participants from a larger study (Institute of Education Sciences, U.S. Department of Education, Grant R305C120001). Participants were individuals enrolled in adult literacy programs in the United States and Canada. This study included only native speakers of English, defined as individuals who identified English as their primary language or reported that they learned English when they were 1-4 years old and currently speak English most often. All participants read between the third and eighth grade levels, as indicated by their programs. Participants' ages ranged from 16-71 years with a mean of 36.57 years, standard deviation of 14.82, and median of 33 years. Younger adults were highly represented in the sample. For example, 32% of the sample was in the 21-30 years age range, whereas only 16% was in the 41-50 years age range and only 6% was in the 61-70 years age range. Slightly over 60% of the sample was female and about 50% identified as Black or African American. Similar to other studies including adult literacy participants (e.g., Strucker, Yamamoto, & Kirsch, 2007), 37% of this studies' participants indicated that someone had suggested that they have a learning disability, and 28% reported that they had been tested for a learning disability.

All testing was conducted one-on-one in multiple sessions by trained research assistants in quiet rooms at the adult literacy sites where the participants were enrolled. Informed consent was obtained from participants prior to testing, and participants received financial compensation. Although the larger study included a total of 37 assessments, this study included only six assessments.

Measures

This study included performance on measures of WM, STM, reading comprehension, word reading, fluency, and oral vocabulary from the larger assessment battery. All measures are from the Woodcock Johnson (WJ) III Normative Update (Woodcock, McGrew, & Mather, 2007). With the exception of WJ Memory for Words, all of the measures have been used in previous studies with adult literacy students (e.g., Mellard et al., 2010; Mellard et al., 2012; Sabatini et al., 2010). Test manual basal and ceiling rules were followed where applicable.

Working Memory. WM was measured with WJ Auditory Working Memory, in which participants used headphones to listen to audio recordings of strings of interspersed words and numbers. For each item, participants had to first recall all the words in order and then recall all the numbers in order. Correct recall required storage and reordering of auditory stimuli. All participants started at item #1. Unlike some WM tasks used in previous studies (Braze et al., 2007; Daneman & Carpenter, 1980; Hannon, 2012), WJ Auditory Working Memory does not require the participant to process sentences, which markedly distinguishes this task from the sub-processes involved in connected text comprehension and avoids the inflation of the correlation between WM and comprehension performance.

Short-Term Memory. STM was measured with WJ Memory for Words, in which participants used headphones to listen to audio recordings of strings of words and had to repeat the words in the same order. Correct recall required storage of auditory stimuli. Participants started at item #10.

Reading Comprehension. Reading comprehension was measured with WJ Passage Comprehension. Each item was a short connected text comprising one or two sentences and containing a missing word indicated by a blank. Participants had to read each item silently and then verbally provide a word to fill in the blank. Participants started at item #14.

Word Reading. Word reading was measured with WJ Letter-Word Identification. Participants had to read aloud words presented on paper. Participants started at item #33.

Fluency. Fluency was measured with WJ Reading Fluency. Participants had 3 minutes to silently read sentences and circle yes or no depending on whether they are true or false. Participants started at #1.

Oral Vocabulary. Oral vocabulary was measured with WJ Picture Vocabulary. Participants were shown pictures of objects and had to name each object. Participants started at item #15.

Results

Table 2 describes participants' performance on all six measures. Participants performed approximately between the second and fifth grade levels. The age-based standard scores demonstrate that the mean performance of the sample was below average on each measure. (However, it should be noted that approximately 16% of participants scored at or above average on the WM measure, approximately 12% scored at or above average on the STM measure, and fewer than 3% scored at or above average on measures of reading comprehension, word reading, fluency, and oral vocabulary.)

Research Question 1: Is reading comprehension related to short-term memory and working memory?

To address the first research question, correlations were computed among all variables (see Table 3). Scores on the reading comprehension measure, WJ Passage comprehension, had a moderate positive correlation with scores on the WM measure, WJ Auditory Working Memory (r = .385, p < .001), and with scores on the STM measure, WJ Memory for Words (r = .338, p < .001). Additionally, there was a positive correlation between STM and WM (r = .406, p < .001).

Research Question 2: What are the joint and unique contributions of short-term memory and working memory to reading comprehension?

To address the second research question, we first conducted hierarchical regression analyses with the two memory capacities as the independent variables and reading comprehension as the dependent variable. To isolate the contributions of each memory predictor, we tested different orderings of the predictors in separate regression models, following Swanson’s (1994) methodology.

Together, STM and WM explained 18.9% of variance in reading comprehension. In the first regression model, STM was entered as a predictor in the first step, which explained a significant proportion of variance in reading comprehension, $F(1,371) = 48.85$, $p < .001$, accounting for 11.6% of the variance. WM was further added in the second step, which explained an additional 7.3% of the variance in reading comprehension, $F(2,370) = 43.05$, $p < .001$. This model is summarized as Model 1(a) in Table 4.

In the second regression model, WM was entered as a predictor in the first step, which explained a significant proportion of variance in reading comprehension, $F(1,371) = 64.73$, $p < .001$, accounting for 14.9% of the variance. STM was further added in the second step, which explained an additional 4% of the variance in reading comprehension, $F(2,370) = 43.05$, $p < .001$. This model is summarized as Model 1(b) in Table 4.

One concern with these models was the significant positive correlation between STM and WM. Ray-Mukherjee et al. (2014) recommend commonality analysis as a method to decompose the effects of correlated predictors. We conducted a commonality analysis using the 'yhat' package (Nimon, Oswald, & Roberts, 2013) in R (R Core Team, 2016), with reading comprehension as the dependent variable and the two memory capacities as the independent variables. The results, summarized in Table 5, confirm the pattern observed in the regression models that WM uniquely contributed a slightly greater proportion of variance (7.24%) to reading comprehension than STM (4.02%). Additionally, 7.61% of variance explained in reading comprehension was shared by the two memory predictors.

Research Question 3: What proportion of the variance in reading comprehension is explained by short-term memory and working memory after controlling for age, word reading, fluency, and oral vocabulary?

To address the third research question, we conducted further hierarchical regression analyses, summarized as Models 2(a) and 2(b) in Table 4. Age, word reading, fluency, and oral vocabulary served as control variables in these models. These four variables were entered in the first step in both models, which significantly explained 57.3% of variance in reading comprehension, $F(4,345) = 115.604$, $p < .001$.

In Model 2(a), STM was added in the second step, which significantly accounted for an additional 1.2% of variance, $F(5,344) = 96.787$, $p < .001$. WM was further added in the third step, accounting for an additional 0.2% of variance, $F(6,343) = 81.413$, $p < .001$. In the final model, when age, word reading, fluency, and oral vocabulary were controlled for, STM was a statistically significant predictor of reading comprehension, but WM was not.

The order of the memory predictors was reversed in Model 2(b). WM was added in the second step, accounting for an additional 0.7% of variance in reading comprehension, $F(5,344) = 95.064$, $p < .001$. STM was further added in the third step, accounting for an additional 0.7% of variance, $F(6,343) = 81.413$, $p < .001$. Since the final model was the same as Model 2(a), when age, word reading, fluency, and oral vocabulary were controlled for, STM was once again a statistically significant predictor of reading comprehension, whereas WM was not.

Discussion

Relations between Memory Capacities and Reading Comprehension

The current study contributes to previous studies documenting the correlation between STM and reading comprehension for struggling adult readers (Braze et al., 2007; Thompkins & Binder, 2003). For our sample, reading comprehension was positively correlated with STM, which echoes the findings of the previous studies. The correlation coefficient was slightly higher than the ones reported by Thompkins and Binder (2003) and Braze et al. (2007) for passage-level comprehension, which may be due to the nature of the STM task included in the current study. While the stimuli in our task consisted of auditory isolated words, the tasks used in the previous studies involved auditory numbers (Thompkins & Binder, 2003) or visual shapes (Braze et al., 2007); therefore, our STM task may have a higher content match with text comprehension tasks. In addition, Swanson (1994) reported a positive correlation between STM and reading comprehension for individuals with reading disabilities, but did not find a significant correlation for individuals without reading disabilities. It is possible that STM plays a larger role in comprehension for individuals with reading difficulties, such as struggling adult readers in the current study and Swanson's participants with reading disabilities.

In general, more studies have measured the WM-comprehension relation than the STM-comprehension relation, possibly because WM is considered a stronger predictor of cognitive aptitudes (Cowan, 2008). To succeed in a WM task, the individual has to rely on attentional, processing, and storage resources and cannot merely rehearse information covertly; this complex feat seems to be more directly related to aptitudes such as fluid intelligence (Cowan, 2008). For the struggling adult readers in our study, reading comprehension was positively correlated with WM. Positive correlations between reading comprehension and WM have also been reported in three other adult literacy studies (Braze et al., 2007; Mellard et al., 2010; Mellard et al., 2012), in studies with undergraduates (Daneman & Carpenter, 1980; Hannon, 2012) and adolescents (Arrington et al., 2014) as well as a mixed sample of children and adults with and without reading disabilities (Swanson, 1994).

Joint and Unique Contributions of Memory Capacities to Reading Comprehension

Further insight into the relation between memory and reading comprehension for struggling adult readers comes from our regression and commonality analyses. Both STM and WM were significant predictors of reading comprehension, jointly accounting for a considerable proportion of variance in reading comprehension, which matches Swanson's (1994) findings. In the current study, STM and WM also made significant unique contributions to reading comprehension. In isolation, WM explained a greater proportion of variance in reading comprehension than did STM, as indicated by the first steps of Models 1(a) and 1(b). The commonality analysis demonstrated that beyond the shared contributions of the two memory predictors to reading comprehension, WM made a relatively greater unique contribution than STM.

The relative importance of WM and STM to reading comprehension in our sample is similar to the pattern observed for the typical readers in Swanson's (1994) sample but not for those with reading disabilities. Unfortunately, we cannot speculate on the role of learning disability status in our sample. The sample was drawn from adult literacy programs and, as is typical in other adult literacy studies (e.g., Strucker, Yamamoto, & Kirsch, 2007), we only have self-reported data (see Table 1). It is likely that the adults in our study have different cognitive strengths and weaknesses than Swanson's participants, since previous research suggests that struggling adult readers differ from other populations in their reading-related skills and techniques (Greenberg, Ehri, & Perin, 1997; Nanda, Greenberg, & Morris, 2010; Thompkins & Binder, 2003; To, Tighe, & Binder, 2016).

Contributions of Memory Capacities to Reading Comprehension Controlling for Age and Reading-Related Skills

When the contributions of STM and WM to reading comprehension were investigated in conjunction with other predictors, the memory capacities diminished in importance. Word reading, fluency, and oral vocabulary accounted for a large proportion of variance in reading comprehension in our sample. We expected these predictors to make a substantial contribution to the reading comprehension variance. There is considerable evidence for relations between these skills and reading comprehension in struggling adult readers (e.g., Barnes et al., 2017; Braze et al., 2007; Mellard, Fall, & Woods, 2010; Tighe & Schatschneider, 2016). Additionally, the SVR emphasizes the predictive utility of decoding and linguistic comprehension for reading comprehension.

As Model 2 shows, after controlling for age, word reading, fluency, and oral vocabulary, STM and WM accounted for a very small proportion of variance in reading comprehension, with STM emerging as statistically significant and only very slightly more important than WM in this larger model. This result is in line with Thompkins and Binder's (2003) findings. Specifically, they tested a simultaneous regression model for reading comprehension on their sample of adult education students. The predictor variables in this model included STM and lower-level skills related to reading and spelling. STM was not found to be a significant predictor of reading comprehension, which adds support to our finding that, for struggling adult readers, memory capacities have much lower predictive utility for reading comprehension than other skills. Even in research with university students, there is some evidence to suggest that memory capacities make very small unique contributions to reading comprehension in the context of other predictors (Alloway & Gregory, 2013; Hannon, 2012). The main role of memory in the CI framework is to restrict the information actively held by the reader (Rayner & Reichle, 2010). It is possible that adults who have literacy deficits may already be limited in their text processing speeds. Thus, memory may not place a substantial additional constraint on the amount of information gleaned from the text.

Furthermore, it has been argued that verbal WM is indicative of a broader oral language comprehension construct (Lervag, Hulme, & Melby-Lervag, 2017; Nation, Adams, Bowyer-Crane, & Snowling, 1999). This view suggests that the effect of WM on reading comprehension observed in our sample could be at least partially attributed to language comprehension, which has been shown to mediate the link between WM and text comprehension for struggling adult readers (Mellard et al., 2010).

Implications for Research

Most studies examining the relation between memory and reading comprehension seemed to have focused on WM instead of STM (Cowan, 2008). However, this approach may not be appropriate for struggling adult readers. Even if WM is a stronger predictor of achievement for children, reading models based on research with children may not easily apply to the adult literacy context (Mellard et al., 2010; Nanda et al., 2010; Sabatini et al., 2010). For our sample of adults reading below the high school level, both memory capacities were positively correlated with reading comprehension, with similar correlation coefficients. Additionally, in the absence of any controls, both memory predictors explained unique variance in reading comprehension, with WM uniquely capturing a slightly larger proportion of variance. Researchers interested in struggling adult readers may find it meaningful to measure both STM and WM when studying a construct as complex as reading comprehension. If only one of the two memory capacities is included in a reading comprehension model, its contributions may be inflated, as demonstrated by the orderings of predictors in Model 1. Researchers who assess both WM and STM should also be wary of the shared variance these constructs contribute to reading comprehension; commonality analyses or similar methods should be undertaken to identify the unique contributions of the two predictors.

Researchers have explored the possibility that children's reading comprehension can benefit from interventions aimed at improving WM. In such interventions, children work individually with adult trainers on tasks that purportedly build their capacity to temporarily store and manipulate information. Although some positive comprehension outcomes have been reported (Dahlin, 2011; Henry, Messer, & Nash, 2014), no clear causal link has been established between WM training and reading comprehension gains (Dunning, Holmes, & Gathercole, 2013; Melby-Lervag & Hulme, 2013). Among adults, WM training interventions have been largely limited to those with neurological impairments (Netto et al., 2010). The effects of implementing a WM training program in the adult literacy context are currently unknown. Our findings suggest that the predictive utility of memory for reading comprehension diminishes in the presence of stronger predictors. Additionally, prior research has demonstrated the memory capacities peak in young adulthood and then continue to decline throughout the lifespan (Cowan et al., 2006; Luo et al., 2013). This suggests that WM may not be as malleable in adults and may be more important for children. Thus, it is possible that WM training may not impact adults' reading comprehension as much as extensive instruction in foundational reading skills, such as word reading and oral vocabulary knowledge. More research is needed to explore the effects of adult literacy interventions on reading comprehension.

Limitations

It is important to consider the potential limitations of the WM and reading comprehension measures we used in this study. Researchers have previously used the WJ Auditory Working Memory task with struggling adult readers (Mellard et al., 2010; Mellard et al., 2012). This task has both storage and processing components; for a correct response, a participant must remember a string of numbers and words, rearrange the items in each string, and then verbally recall this rearranged string. However, it can be argued that this measure is less complex than another WM measure previously used (Braze et al., 2007) with struggling adult readers: the listening span task developed by Daneman and Carpenter (1980). In the listening span task, participants listen to series of sentences that gradually increase in length, from two to five sentences. Participants have to decide whether each sentence is true or false. At the end of each series, participants have to recall the first word of each sentence in the series (in any order). Thus, the listening span task may seem more demanding than the WJ Auditory Working Memory task, and the possibility exists that participants' WM performance might have been different and might have had a stronger or weaker correlation with STM had the listening span task been used in this study.

The reading comprehension measure used in this study, WJ Passage Comprehension, is a cloze test with items ranging from one to two sentences. This was the only reading comprehension measure administered in the larger study. There is evidence to suggest that cloze tests may measure other skills in addition to comprehension, especially decoding (Francis, Fletcher, Catts, & Tomblin, 2005; Keenan, Betjemann, & Olson, 2008). Moreover, Keenan et al. (2008) found that WJ Passage Comprehension scores were only moderately correlated with comprehension performance on the Gray Oral Reading Test (GORT; Wiederholt & Bryant, 2001), which involves longer text stimuli and open-ended questions. These potential limitations of cloze tests should be considered when interpreting the relations between memory and reading comprehension in this study. It should be noted that researchers have found issues with the validity of reading comprehension assessments other than WJ Passage Comprehension (Coleman et al., 2010; Cutting & Scarborough, 2006; Greenberg, Pae, Morris, Calhoon, & Nanda, 2009). Reading comprehension is clearly a difficult construct to measure, and future adult literacy studies should investigate whether STM and WM contribute similarly to reading comprehension when different measures are used.

There is also a larger concern with the use of the WJ III Normative Update in this study. The standardization work was based on the United States population (Woodcock et al., 2007). Due to the lack of Canadian representation in the development process, it is difficult to comment on the validity of these measures for the Canadian population, which is represented in our sample. However, the WJ III Normative Update is largely considered suitable for school-age Canadian students (Ford et al., 2010), likely because of the cultural and linguistic similarities between the United States and Canada. In addition, other researchers have also used previous versions of this test battery with Canadian samples (Lovett et al., 2017; Morris et al., 2012).

Finally, it is important to consider the characteristics of the sample in this study. Adults with low literacy skills comprise a heterogeneous population, with diverse backgrounds (Lesgold & Welch-Ross, 2012). Our sample may reflect these differences and additionally included adults from two countries. We did not control for these characteristics in our analyses, instead choosing to control only for age because of its theoretical link to memory performance (Cowan et al., 2006; Luo et al., 2013). Moreover, we could not treat learning disability as a covariate in our analyses; while participants' self-reported history of learning disability testing is useful for the contextualization of the sample, it cannot be used as a proxy for learning disability diagnosis. We also recognize that our sample represents a limited range of literacy skills. The larger study purposefully sampled adults who were in classes targeting reading levels between the third and eighth grades. Thus, the findings from the current study should not be generalized to more or less skilled adult readers. It should be noted that despite this restriction, the size and reading skill range of the sample is relatively large compared to some other studies involving struggling adult readers (e.g., Mellard et al., 2010; Nanda et al., 2010; Tighe & Binder, 2015).

Future Directions

Future research can investigate the role of memory in more complex models of reading comprehension specifically for adults who struggle with reading. In Mellard et al.'s (2010) path model for adult literacy students, WM had a direct effect on language comprehension, which in turn had a direct effect on reading comprehension. Braze et al. (2007) found that WM predicted oral vocabulary, and oral vocabulary predicted reading comprehension for their sample of adults with self-reported reading difficulties. Informed by these studies, researchers could examine whether language comprehension and oral vocabulary mediate the relation between memory and reading comprehension for struggling adult readers.

Another direction for future research in adult literacy is to provide measurement evidence to establish the independence of STM and WM. Despite the overlap of functions in the two memory capacities (Cowan, 2008), performance on STM and WM measures was only moderately correlated in our sample. Using confirmatory factor analyses, some researchers have observed that separate latent factors underlie performance on STM and WM measures (Cantor et al., 1991; Swanson, 1994). A similar study with struggling adult readers could indicate whether STM and WM should be treated as separate constructs in the adult literacy context.

The participants in this study demonstrated a wide range of reading skill levels as indicated by the ranges of standard scores reported in Table 2. With the minimum scores in these ranges falling more two standard deviations below the expected mean, it is conceivable that some adults may have an underlying reading disorder. Future investigations with larger samples could explore whether standardized reading measures can be used to diagnose reading disorders among adult literacy students and whether the findings of the current study can be replicated for a sample of adults with such diagnoses.

In general, more research is needed on predictors of reading comprehension in this population. Our findings reiterate the importance of word reading, fluency, and oral vocabulary (Barnes et al, 2017; Braze et al, 2007; Mellard et al., 2010; Sabatini et al., 2010). Beyond these basic skills, text comprehension also involves higher-level skills that help the reader make meaning from the text (Perfetti & Stafura, 2014). Some of these domains, such as reasoning ability and general knowledge, are currently understudied with struggling adult readers and should be investigated further in the context of reading comprehension (Greenberg, Ginsburg, & Wrigley, 2017).

Conclusion

Although the contributions of memory capacities to reading abilities have been explored with typical readers, there is a paucity of similar work with adults who struggle with reading. The aim of this study was to examine the effects of WM and STM on reading comprehension for struggling adult readers. In isolation, WM exhibited a stronger relation with reading comprehension than STM. However, the memory capacities did not make significant contributions to comprehension in the context of known reading predictors. These results suggest that instructional interventions in adult literacy classes should focus on strengthening foundational reading skills and include WM training only as an additional component, if at all. Future research should explore the role of language comprehension as a mediator of the relation between memory and reading comprehension.

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Table 1

Participants' Demographic Background

Characteristics	*n*	%
Country		
United States	226	55.5
Canada	181	44.5
Gender		
Female	250	61.4
Male	150	36.9
Unreported	7	1.7
Age		
16 – 20 years	53	13.0
21 – 30 years	131	32.2
31 – 40 years	62	15.2
41 – 50 years	65	16.0
51 – 60 years	67	16.5
61 – 70 years	24	5.9
71 and over	2	0.5
Unreported	3	0.7
Racial/Ethnic Identity		
Black or African American	209	51.4
White	99	24.3
African, Caribbean, or Black Canadian	72	17.7
First Nations, Metis, or Inuit	8	2.0
Asian or Other	11	2.7
Unreported	8	2.0
Identified as Hispanic or Latino	18	4.4
Identified as belonging to more than one racial/ethnic group	61	15.0
Learning Disability History		
Responded "yes" to "Has anyone ever suggested to you that you have a learning disability?"	151	37.1
Responded "yes" to "Have you ever been tested, as a child or as an adult, for a learning disability?	114	28.0

Table 2

Performance on Measures

Measure	Raw Scores			Standard Scores			Mean Grade Equivalency	Median Reliability
	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range		
WJ Auditory Working Memory	19.24	6.566	0-38	89.75	11.085	46-129	5.4	.80
WJ Memory for Words	15.29	2.269	6-22	87.71	11.273	58-128	2.4	.74
WJ Passage Comprehension	29.28	4.417	16-42	84.23	8.916	51-111	4.0	.73
WJ Letter Word Identification	55.12	8.455	33-72	82.64	10.312	42-106	5.3	.88
WJ Reading Fluency	44.33	14.256	7-84	82.89	7.775	64-111	5.0	.95
WJ Picture Vocabulary	26.15	4.252	15-39	82.93	7.545	56-107	5.7	.76

Note. All measures are from the Woodcock Johnson (WJ) III Normative Update (Woodcock, McGrew, & Mather, 2007). Standard scores refers to age-based standard scores that are on a normalized scale with a mean of 100 and standard deviation of 15. Median reliability refers to the median of the internal reliability coefficients provided in the test manual for adults in the age range represented in the sample.

Table 3

Correlation Matrix for All Measures

Variable	1	2	3	4	5	6
1. WJ Passage Comprehension	—					
2. WJ Auditory Working Memory	.385***	—				
3. WJ Memory for Words	.338***	.406***	—			
4. WJ Letter Word Identification	.595***	.311***	.388***	—		
5. WJ Reading Fluency	.522***	.426***	.273***	.542**	—	
6. WJ Picture Vocabulary	.599***	.292***	.097	.331**	.352***	—
7. Age	-.042	-.195***	-.180***	-.169**	-.271***	.087

Note. *** p < .001. All measures are from the Woodcock Johnson (WJ) III Normative Update (Woodcock, McGrew, & Mather, 2007).

Table 4

Summary of Hierarchical Regression Analyses for Reading Comprehension

Step	Predictor and Control Variables	Increase in R^2	B	SEB	β	*t*	*F*
Model 1 (R^2 full model = .189)							
(a) 1	STM	.116	.667	.095	.341	6.989***	48.847***
2	WM	.073	.199	.035	.295	5.748***	43.052***
(b) 1	WM	.149	.260	.032	.385	8.045***	64.730***
2	STM	.040	.430	.100	.220	4.283***	43.052***
Model 2 (R^2 full model = .587)							
(a) 1		.573					115.604***
	Age		.016	.011	.052	1.403	
	Word Reading		.193	.022	.366	8.649***	
	Fluency		.063	.014	.204	4.641***	
	Oral Vocabulary		.418	.040	.408	10.426***	
2		.012					96.787***
	STM		.233	.074	.120	3.125**	
3		.002					81.413***
	STM		.194	.078	.100	2.471*	
	WM		.044	.028	.065	1.572	
(b) 1		.573					115.604***
	Age		.016	.011	.052	1.403	
	Word Reading		.193	.022	.366	8.649***	
	Fluency		.063	.014	.204	4.641***	
	Oral Vocabulary		.418	.040	.408	10.426***	
2		.007					95.064***
	WM		.066	.027	.098	2.467*	
3		.007					81.413***
	WM		.044	.028	.065	1.572	
	STM		.194	.078	.100	2.471*	

Note. *$p < .05$, **$p < .01$, ***$p < .001$. Coefficients are reported from the final steps of each model. All measures are from the Woodcock Johnson (WJ) III Normative Update (Woodcock, McGrew, & Mather, 2007). Reading comprehension was measured with WJ Passage Comprehension. Word reading was measured with WJ Letter-Word Identification. Fluency was measured with WJ Reading Fluency. Oral vocabulary was measured with WJ Picture Vocabulary. Working memory (WM) was measured with WJ Auditory Working Memory. Short-term memory (STM) was measured with WJ Memory for Words.

Table 5

Commonality Analysis for the Variance Explained in Reading Comprehension by Memory Capacities

	R^2 Coefficient	%Total
Unique to STM	0.0402	21.31
Unique to WM	0.0724	38.37
Common to STM and WM	0.0761	40.32
Total	0.1888	100.00

Note. STM, short-term memory; WM, working memory.