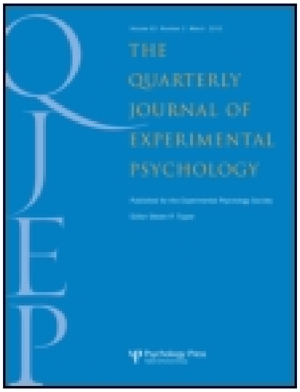

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The influence of story context on a working memory span task

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The purpose of the present study was to examine factors that could influence whether recall performance in the reading span task (Daneman & Carpenter, 1980) would benefit from the contextual information from the sentences in the processing component of the task. More specifically, we investigated whether people would benefit from sentence sets that formed short stories or when the entire span task was one continuous story. Overall, there was a clear benefit for contextually related sentence sets (i.e., the story span tasks) compared to the traditional reading span task. However, the benefit was eliminated when the entire set formed one continuous story. These results support the recall reconstruction hypothesis for working memory (Towse, Cowan, Hitch, & Horton, 2008), which suggests that people may strategically use the content of the sentences from the processing component of the reading span task as memorial cues to reconstruct the target words of the storage component. However, this benefit is constrained to scenarios when the contextual cues are unique to a specific set.

Keywords: Working memory; Context; Reading span; Narrative; Recall reconstruction.

Working memory is a short-term, limited-capacity memory system responsible for the processing and storage of information, and the capacity of working memory is typically assessed by working memory span tasks (see Conway et al., 2005). Span tasks measure processing and storage abilities by having users engage in one task (e.g., reading sentences or solving simple maths problems) while being simultaneously engaged in a different task (e.g., temporarily retaining a list of words or letters for later recall). There are many different types of span tasks, with one of the earliest being the reading span task (Daneman & Carpenter, 1980). The reading span task requires people to read sets of unique sentences out loud (processing) while concurrently holding the last word of each sentence in memory for subsequent recall (storage). The goal of the present study was to examine the recall reconstruction hypothesis for working memory using contextually supportive reading span tasks (Towse, Cowan, Hitch, & Horton, 2008; Towse, Hitch, Horton, & Harvey,

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2010). According to this view, people can improve working memory span by using contextual information to help reconstruct degraded information from working memory. The current study explored whether people use the contextual information from the sentences in a reading span task to aid recall of the target words. Specifically, in this study, we considered whether people's span scores could benefit from the sentences in the reading span forming narratives, or whether too much contextual information would lead to interference that would counteract any benefits.

Cowan (2010) stated that an important component to measuring the true capacity of working memory is to ensure that there is an adequate processing component to prevent the use of strategies to aid recall, such as rehearsal or chunking. Most complex working memory span tasks, such as the reading span task, include a processing component that results in a capacity of approximately 3 to 5 items that can be maintained in working memory. Although the reading span task has been shown to adequately measure immediate processing and storage abilities, some theorists have posited that the limited capacity of working memory may be overcome by the coordination of long-term memory resources (e.g., long-term working memory; Ericsson & Kintsch, 1995). The basic idea of long-term working memory is that if information that is stored in working memory is highly related to knowledge held in long-term memory, then people can use their long-term memory to aid their limited-capacity working memory (e.g., Kintsch, Patel, & Ericsson, 1999). For example, individuals who are highly knowledgeable about baseball outperform others on a reading span task in which the target words of the sentences were baseball related (Fincher-Kiefer, Post, Greene, & Voss, 1988; Ricks & Wiley, 2009). Those with highly developed long-term storage strategies are more efficient at managing and retrieving domain-relevant information than those with less developed memory schemes.

One of the early assumptions of complex working memory span tasks was that the processing and storage components of the task were independent (Miyake & Shah, 1999) and that one of the main goals of the processing task was that it should be difficult enough that people could not rehearse target words during that part of the task (Turner & Engle, 1989). For example, Turner and Engle showed that correlations between working memory span and other cognitive measures were stronger when the processing task was more difficult. Additionally, Waters and Caplan (1996) showed that increasing syntactic complexity can decrease span scores. Also, recent work by Jarrold, Tam, Baddeley, and Harvey (2011) demonstrated that the processing component impaired memory performance, typically by preventing rehearsal or causing interference. However, there is some research that contradicts this idea of there always being competition between the processing and storage components and instead suggests that span scores (i.e., the memory component) may be positively affected by the information in the processing component of the task. This idea has led to the development of the recall reconstruction hypothesis for working memory (Towse et al., 2008; Towse et al., 2010), which states that people not only retrieve the target words in a working memory task, but can also use context from the processing component to aid in the retrieval of target words that may be degraded. In the case of the reading span, the context of the sentences could potentially be used to reconstruct target words that were degraded. Thus, the processing component seems to be able to either compete or help the storage component of the span task, depending on the materials that are used.

Evidence supporting the recall reconstruction hypothesis on a reading span performance was observed by Copeland and Radvansky (2001) in a study examining phonological similarity effects. In contrast to the typical phonological similarity decrement (Conrad & Hull, 1964), Copeland and Radvansky reported that participants exhibited better memory for reading span target items that were phonologically similar than for target items that did not sound the same. They suggested that participants were able to avert the phonological similarity decrement for the reading span task by using their knowledge of phonological similarity along with their mental representation of the sentence content. That is, people were possibly using the context of the sentences to aid their retention of the target words. This seemed to be a plausible explanation because when less contextually supportive information was available for either the word span (no additional context) or the operation span task (only mathematical context; Turner & Engle, 1989), the memory advantage was not observed.

Other more recent studies that have supported the idea of the recall reconstruction hypothesis have examined the timing of recall efforts for span tasks. For example, studies by Towse et al. (2008) and Cowan et al. (2003) used chronometric analyses of recall to examine the duration of recall for target words in span tasks. The Cowan et al. study showed that recall duration was longer for the reading span than simple span tasks. Towse et al. (2008) showed that pauses during recall were longer for a reading span task when the target words were integrated with the sentence content than when the target words were not integrated. These results were interpreted to mean that for the traditional reading span task (i.e., the target words are the final word of a sentence and fit the context of the sentence), people were slower to respond because they were using the sentence content to aid in the retention of the target words.

In another example, Guida, Tardieu, and Nicolas (2009) showed that prior knowledge of information included in the processing component can improve reading span scores. In their experiments, reading span sentences were manipulated as to whether the sentence content included a familiar or unfamiliar location. Guida et al. argued that improved performance in the familiar condition suggests that people were able to use the knowledge of these locations in long-term working memory to aid recollection of the target information. While this study showed that people can benefit from information in the processing task, it should be noted that in this task the benefit seems to greatly depend on prior knowledge that was brought to the task (e.g., Ricks & Wiley, 2009), as opposed to simply using the information presented.

This idea of context possibly influencing span performance was explored in a recent study by Macnamara, Moore, and Conway (2011) examining phonological similarity and working memory span. In some conditions, a story span task was used, in which the sentences within a set were written to be related as a short story to provide even richer contextual information than the traditional reading span task, where the sentences within a set are unrelated. Their results showed no significant benefit to performance for the story span task relative to the traditional reading span task. However, it should be noted that the mean scores showed a pattern of slightly better performance for the story span version. While Macnamara et al. (2011) were focusing on the effects of phonological similarity, it is possible that an effect for the story span was not observed due to a lack of power, or possibly because the sentences were not as easy to integrate as a typical narrative.

The goal of the present study was to further examine the recall reconstruction hypothesis for working memory (Towse et al., 2008) and the use of contextual cues by presenting related sentences in a reading span task. In the current study we examined whether providing usable context in the processing and storage components of the reading span task would always lead to facilitation. For example, when Towse and colleagues (Towse et al., 2008; Towse et al., 2010) used target words that integrated with the sentences, facilitation was observed. However, is too much context, or context that is not uniquely associated with target words, still beneficial? According to Unsworth and Engle (2007), the capacity of working memory is shared between an attention-controlling primary memory and secondary memory. For complex span tasks, such as the reading span task (or variations used in the current study), because the processing component of the task uses primary memory, the target words are stored in secondary memory. Based on this explanation, retrieval from secondary memory can be easier if the information is stored with unique contextual cues because people can use indicators from the original stimulus, such as sentence context, to access items that have been stored in secondary memory. However, too much context could result in the cues no longer being unique, which may limit the cooperative relationship between the sentence context and target words.

These ideas were examined across two experiments in which participants completed two versions of the reading span task: a traditional reading span task consisting of sets of unrelated sentences and a contextually supportive reading span task (i.e., story span) consisting of related sentence sets that formed a short story. Although the methods used in the present study were similar to those used by Macnamara et al. (2011), in the current study we did not use phonologically similar target words (i.e., the current study was not examining phonological similarity effects). In Experiment 1, people completed a traditional version of the reading span as well as a story span task in which each set was a different, unique story. In Experiment 2, participants once again completed two versions of the reading span task: a traditional version of the reading span task and a contextually supportive reading span task in which the entire task comprised one long continuous story. If, according to the recall reconstruction hypothesis, participants benefit from greater contextual support on working memory measures, then recall for target items when the sentences form a story should be better than when the sentences are unrelated because the contextual information would produce stronger memory representations, such as a situation model representation (Zwaan & Radvansky, 1998). Alternatively, it is possible that rich context is not useful in a reading span task, or, possibly, that previously learned thematic sentence content might interfere with new sentence material and produce greater recall errors (e.g., Keppel & Underwood, 1962). This last point is particularly relevant for Experiment 2, when the context is similar across sets because they form one continuous story. In this scenario, based on Unsworth and Engle's (2007) proposal that contextual cues should be unique, the benefit of the context may be overridden by the fact that it is not unique to any particular set, which could lead to intrusions from an earlier set rather than correctly recalled words from the current set.

EXPERIMENT 1

The goal of Experiment 1 was to test a prediction of the recall reconstruction hypothesis as to whether contextual information, with sentences presented as short narratives, would enhance performance on a reading span task. Specifically, Experiment 1 compared two versions of a reading span task: a traditional span task consisting of unrelated sentence sets and a short-story span task consisting of related sentence sets. As stated earlier, the materials and design was somewhat similar to the one used by Macnamara et al. (2011), but phonologically similar words were not used here. Also, compared to that study, we used a repeated measures design to increase the likelihood of detecting a context effect if it was present. The short-story span was constructed so that each set was a different short story, unique from the other sets. The recall reconstruction hypothesis (Towse et al., 2008) predicts that related context should lead to improved performance. An alternative possibility was that the similar story content available from the related sentences would create interference, which would worsen performance for that condition (e.g., Keppel & Underwood, 1962); however, because each set was a different, unique, story, the build-up of proactive interference should be less likely (e.g., Wickens, Born, & Allen, 1963).

In Experiment 1a, the short-story span task sentences were created first and were then randomized to create the ordering of the materials for the traditional span task; thus, the same sentences were used in both span tasks. In the short-story span tasks the sentences were organized so that each set formed short (independent) stories, and in the traditional span task those sentences were randomly ordered so that the sets did not form short stories. One potential problem with this method was that the combinations of target words for each set would be different in the conditions. It is possible that the specific word combinations in one condition would be easier to remember (e.g., Carpenter & Just, 1989). To correct for this, in Experiment 1b, the short-story and traditional span tasks used the same combinations of target words in the sets. To do this, the traditional span task in Experiment 1b was created by rewriting the sentences used for the short-story span task so that each sentence in a set was unrelated (i.e., did not create a short story), but the combinations of the target words were the same as those used in the short-story span task.

Method

Participants

Sixty undergraduates, 30 in Experiment 1a (15 males and 15 females, mean age = 19.7 years) and 30 in Experiment 1b (11 males and 19 females, mean age = 19.4 years), were recruited from the student population at the University of Nevada, Las Vegas via the Department of Psychology's subject pool. For their participation, students were compensated with partial course credit. The only restrictions for participation were that one must be at least 18 years of age and be able to fluently speak and understand English.

Materials

Two reading span tasks were created for Experiment 1a. To create these tasks, 120 single-syllable words with high frequency (50–100) and concreteness (400–700) were taken from the MRC Psycholinguistic Database with the Kucera and Francis (1967) word list to create a list of target words (i.e., to-be-remembered words) for the reading span tasks. The list of target words was randomly separated into two lists, List A and List B, containing 60 words each. Both lists were then randomly separated into 15 sets. The sets ranged from a set size of two to six sentences, with 3 sets of each size. Next, sentences were written to create a short-story span task (i.e., sentences in each set created a story) using each list. The sentences were between 12 and 15 words in length and were written so that the target words were the last word of the sentences. The sentences creating a story were written to focus on the same event and/or characters and were written in a way that they flowed together as sentences do in a typical narrative. Also, even though these sentences focused on the same events and characters, they were written so that the target words were not repeated in a later sentence. This is important because repeating the words would give an obvious advantage to this story span task over the traditional span task, where the sentences are unrelated, and, thus, target words are never repeated in later sentences in a particular set. It should be noted that each set was a different short story, unrelated to the stories in the other sets. While a story consisting of two to six sentences is not very long, the use of a small number of sentences has been used in previous research examining narrative comprehension and memory; for example, Jahn (2004) used two sentence descriptions, and Radvansky and Copeland (2001) used short stories that were three to five sentences in length. Finally, to create the traditional span task, the sentences from the short-story span task were randomized to form sets containing random, unrelated sentences; this was done for both List A and List B. Example sets from the span tasks are in the Appendix.

The two versions of the short-story reading span task from Experiment 1a were used in Experiment 1b; however, the two versions of the traditional reading span task used in Experiment 1b were different from those in Experiment 1a. For both lists, new sentences were written to create a traditional span task that contained unrelated sentences but maintained the combinations of target words (i.e., which target words were in each set) from the short-story span task. As was the case in Experiment 1a, sentences were written to be between 12 and 15 words in length with the target words being the last word of the sentences.

Procedure

For both Experiments 1a and 1b, participants were told that the basic procedure of the experiment was to read sentences and then later remember information from the sentences. Participants were seated at a computer, and the experimenter read the specific instructions to the participant. After completing a practice reading span set consisting of three sentences, participants completed two reading span tasks: a traditional span task (i.e., sentences in each set were unrelated) and a short-story span task (i.e., sentences in each set created a short story). The order in which participants completed the span tasks was randomized, and list order was counterbalanced. The procedure for the two different span tasks was identical. The only difference between the traditional and short-story span tasks was whether the sentences were unrelated or created a short story in each set. The presentation order of the set sizes was randomized so that each participant saw the sets in a different random order for a list. For each set, sentences were presented one at a time, and participants read each sentence aloud without taking breaks between sentences in a set. After reading all sentences in a set, participants were then instructed to recall the last word of each sentence in the order they were presented. During recall, participants attempted to recall the words one at a time, and the experimenter typed in the participants' responses. If participants did not know a response, they were told to guess or respond that they did not remember. After participants finished recalling the words for a set, the experimenter advanced to the first sentence for the next set.

Results and discussion

For both Experiments 1a and 1b, a one-way (span task: short story vs. traditional span task) repeated measures analysis of variance (ANOVA) was conducted with working memory span scores as the dependent measure. Working memory span scores were computed using the partial-credit load method (Conway et al., 2005). With the partial-credit load method, a score for each set is computed by summing the number of items recalled in the correct serial order, which are then added together and divided by the total number of memoranda (i. e., 60) to obtain the span score or proportion of items recalled in the correct serial order. For Experiment 1a, a significant difference was found between the short-story ($M = .54$, $SE = .03$) and traditional span tasks ($M = .48$, $SE = .02$), $F(1, 29) = 9.81$, $p < .01$, $\eta_p^2 = .25$. The results for Experiment 1b replicated this pattern with a significant difference between the short-story ($M = .57$, $SE = .03$) and traditional span tasks ($M = .47$, $SE = .03$), $F(1, 29) = 23.77$, $p < .001$, $\eta_p^2 = .45$.

Thus, in both Experiments 1a and 1b, participants had significantly higher working memory span scores for the short-story span task than for the traditional span task. These results demonstrate that people can increase span scores by using the contextual information from the sentences in a reading span task (Copeland & Radvansky, 2001). When the sentences in the span task provided greater contextual information, as was the case with the short-story span task, people were able to create stronger memory representations for the critical information required for recall. These results support the recall reconstruction hypothesis for working memory and demonstrate that unique contextual cues (i.e., the stories from each set) can aid memory performance.

EXPERIMENT 2

In Experiment 2, we explored whether people would benefit from a larger amount of context by creating a story span task where all 60 sentences formed one continuous story. Here, the sentences are still presented in sets of 2 to 6, but as each new set is encountered the story continues from where it left off in the previous set. Thus, every participant saw the same randomized ordering of the words and sets because that ordering created one long continuous story. In Experiment 1, where each set of sentences formed a different, unique story, performance was better than when using unrelated sentences, as are used in a traditional reading span task. If, according to the recall reconstruction hypothesis, context can aid performance, then in Experiment 2 people would greatly benefit from reading the entire set of sentences as a single continuous story because they would form richer and more coherent mental representations for the story content. This is because, while people can construct rich memory representations (e.g., situation models) from brief stories, most narratives are much longer than 2 to 6 sentences. If people are truly going to be transported into the events of a story, then additional context (i.e., longer text) would help facilitate the immersion of the reader into the events of the story (Zwaan, 1999). However, it was also possible that the benefits of connecting the sets as one continuous story may be counteracted by proactive interference effects (e.g., Keppel & Underwood, 1962). That is, as more and more sets are encountered in the continuous-story span task, the benefit of the story may diminish because previous sets, which are based on the same story, may interfere with recall of the current set. According to Unsworth and Engle (2007), context cues should be unique in order to aid recall. However, in Experiment 2, if people remember the story context, this could increase the number of intrusions from previous sets because those sets were also based on the same story. If this is the case, it is unclear whether the outcome would be a smaller benefit for the continuous-story span (i.e., the benefit of the story would still outweigh the proactive interference) or a null effect (i.e., the benefit of the story would be completely eliminated by proactive interference). As a preview, because the effects in Experiment 2 were much smaller than those observed in Experiments 1a and 1b, a much larger sample was used.

Method

Participants

Sixty undergraduates (17 males and 43 females, mean age = 19.4 years) were recruited for Experiment 2 from the student population at the University of Nevada, Las Vegas via the Department of Psychology's subject pool. For their participation, students were compensated with partial course credit. The only restrictions for participation were that one must be at least 18 years of age and be able to fluently speak and understand English. None of these people participated in Experiments 1a or 1b.

Materials

Lists A and B from Experiment 1 were used again in Experiment 2. For each list, the sets were randomized to create a new presentation order for the sets. For the traditional span task, the same sentences from Experiment 1b were used in these new random orders. However, for the continuous-story span task, the sentences were rewritten so that the entire list formed one continuous story. In other words, for this condition, all of the sets in a list were part of the same story. Once again, sentences were between 12 and 15 words in length with the target words being the last word of the sentences. Example sets from the continuous-story span task are in the Appendix.

Procedure

The procedure used in Experiment 2 was almost identical to that in Experiments 1a and 1b except that a continuous-story span task was used instead of a short-story span task. The continuous-story span task differed from the short-story span task previously used in that the entire span task was written to create a continuous story, whereas for the short-story span task, each set had been written to be a unique short story. Because of this change, the sets were presented in a sequential (i.e., not random) order for the continuous-story span task so that the sentences would create a sensible story. The traditional span task was also presented in the same sequential order as the continuous-story span task. Besides this change, the procedure for Experiment 2 was the same as that for Experiment 1.

Results and discussion

A one-way (span task: continuous-story vs. traditional span task) repeated measures ANOVA was conducted with working memory span scores (computed using the partial-credit load method; Conway et al., 2005) as the dependent measure. No significant difference was found between the continuous-story ($M = .51$, $SE = .02$) and traditional span tasks ($M = .49$, $SE = .02$), $F(1, 59) = 2.40$, $p = .13$, $\eta_p^2 = .04$. Thus, unlike Experiments 1a and 1b, the continuous-story span task led to no improvement in performance relative to the traditional span task, even when a larger sample was used.

To more closely examine these results, an analysis was conducted to compare the results from

Experiment 2 to those observed in Experiment 1 (data from Experiments 1a and 1b were combined so that there would be equal sample sizes). A 2 (span task: story vs. traditional span task) × 2 (experiment: short story vs. continuous story) mixed ANOVA was conducted. Span task was a within-subjects factor, and experiment was a between-subjects factor with span scores as the dependent measure. A main effect of span task was found, $F(1, 118) = 25.32$, $p < .001$, $\eta_p^2 = .18$. Participants had significantly higher scores with a story span task than with a traditional span task, regardless of whether the story span task consisted of short stories for each set or a continuous story for the entire task. The main effect of experiment was not significant, $F(1, 118) = 0.39$, $p = .54$, $\eta_p^2 = .00$. Importantly, though, an interaction between span task and experiment was found, $F(1, 118) = 7.80$, $p < .01$, $\eta_p^2 = .06$. This showed that the story effect was greater in Experiment 1 than in Experiment 2. This demonstrates that while contextual information can aid working memory, the benefit is not as strong when the sentences in the entire span task are related in a continuous story. This is probably the case because of a build-up of proactive interference due to the fact that all of the sets are centred around the same events and/or characters in a single narrative (i.e., memory for the information from the previous sets is interfering with memory for the current set). In other words, consistent with Unsworth and Engle (2007), the additional context of the continuous story did not provide a unique contextual cue for any set and, thus, did not lead to improved memory performance.

To examine the possibility of proactive interference, the percentage of trials with intrusions was examined for the story and traditional span tasks for Experiments 1 and 2. Intrusions were target words from a previous set that were mistakenly recalled for a later set. A 2 (span task: story vs. traditional span task) × 2 (experiment: short story vs. continuous story) mixed ANOVA was conducted, where the data from Experiments 1a and 1b were combined to compare to Experiment 2. Overall, there was a main effect of span task, $F(1, 118) = 6.86$, $p < .05$, $\eta_p^2 = .06$, with more intrusions for the traditional span task ($M = 2.17\%$, $SE = 0.24$) than the story span task ($M = 1.56\%$, $SE = 0.18$). There was no main effect when comparing Experiments 1 ($M = 2.00\%$, $SE = 0.20$) and 2 ($M = 1.80\%$, $SE = 0.20$), $F(1, 118) = 0.42$, $p = .52$, $\eta_p^2 = .00$; however, there was a significant interaction, $F(1, 118) = 9.59$, $p < .01$, $\eta_p^2 = .08$. Because the short-story and continuous-story span tasks were conducted with different participants (i.e., experiment was a between-subjects factor), it makes sense to compare participants' performance in the story span condition to that in their control condition, the traditional span task (t-tests with a Bonferroni adjustment). For Experiment 1, participants had significantly fewer intrusions in the short-story span task ($M = 1.31\%$, $SE = 0.23$) than in the traditional span task ($M = 2.64\%$, $SE = 0.37$), $t(59) = 3.42$, $p < .01$, but in Experiment 2, there was no difference in the number of intrusions for the continuous-story span task ($M = 1.81\%$, $SE = 0.27$) and the traditional span task ($M = 1.69\%$, $SE = 0.29$), $t < 1$.

To further examine the possibility of proactive interference in Experiment 2, we broke the continuous and traditional span tasks into thirds based on set order (the first 5, middle 5, and final 5 sets; 18–22 trials in each section). If proactive interference is occurring in the continuous span task, then there should be a higher percentage of intrusions toward the end of the task than what is observed for the traditional span task. A 2 (span task: continuous-story span vs. traditional span) × 3 (set: beginning vs. middle vs. end) within-subjects ANOVA was conducted. The main effects of span task ($M_{CSS} = 1.96\%$, $SE_{CSS} = 0.25$, $M_{TS} = 1.72\%$, $SE_{TS} = 0.25$), $F(1, 59) = 0.69$, $p = .41$, $\eta_p^2 = .01$, and set ($M_B = 1.73\%$, $SE_B = 0.28$, $M_M = 1.55\%$, $SE_M = 0.31$, $M_E = 2.23\%$, $SE_E = 0.32$), $F(1, 59) = 1.70$, $p = .20$, $\eta_p^2 = .03$, were not significant (CSS = continuous-story span, TS = traditional span, B = beginning, M = middle, and E = end). However, the interaction was significant, $F(1, 59) = 7.02$, $p < .05$, $\eta_p^2 = .11$, and follow-up t tests were conducted using a Bonferroni adjustment. For the beginning sets, there was no difference between the continuous-story ($M = 1.81\%$, $SE = 0.41$)

and traditional ($M = 1.65\%$, $SE = 0.38$) span tasks, $t < 1$. There was also no difference between the continuous-story ($M = 1.13\%$, $SE = 0.37$) and traditional ($M = 1.97\%$, $SE = 0.49$) span tasks for the middle sets, $t(59) = 1.75$, $p = .26$. However, for the end sets, the difference in intrusions for the continuous-story ($M = 2.93\%$, $SE = 0.50$) and for the traditional ($M = 1.53\%$, $SE = 0.40$) span task was marginally significant, $t(59) = 2.44$, $p = .054$.

These results are consistent with the idea that proactive interference led to a smaller benefit for the continuous-story span task. In Experiment 1, people benefited from the short-story span task because each trial was based on a unique short story, and the sets did not interfere with one another because the context in the previous sets was clearly unrelated to that in the current set. In contrast, in Experiment 2, there was less of a benefit from the continuous-story span task because all sets were based on the same story, and that seemed to produce comparable interference as was observed with the traditional span task. In the short-story span task, it is easier to determine whether a remembered word fits with the current set because its story is unique relative to the other sets; however, in both the continuous-story and traditional span tasks, when an intrusion enters a person's mind it is not as easy to determine that it does not belong with the current set. Thus, this pattern is consistent with the idea that proactive interference led to a smaller benefit for the continuous-story span task[1] than for the short-story span task that was used in Experiment 1.

GENERAL DISCUSSION

The goal of this study was to test predictions made by the recall reconstruction hypothesis for working memory (Towse et al., 2008; Towse et al., 2010), which emphasizes the notion of a cooperative relationship between the processing and storage components of working memory span tasks. In the current study, the traditional reading span task (Daneman & Carpenter, 1980) was compared to a modified version in which the sentences were written to form a story. In Experiment 1, where each set of sentences formed a unique story, a clear benefit in performance was observed relative to the traditional version. In Experiment 2, where the entire list of sentences formed a single continuous story, there was no benefit compared to the traditional task. The results of these experiments suggest that people can use contextual information from the processing component of a complex span task to aid in the retention of target items, as long as the context is a unique cue (Unsworth & Engle, 2007).

The outcomes of the experiments presented here indicate that people encode and store the contents of the reading span task in a manner that is consistent with the long-term working memory theory proposed by Ericsson and Kintsch (1995). Individuals are able to circumvent working memory capacity limitations by accessing and using long-term memory resources, such as comprehension or storage of information that a person is highly knowledgeable about (Ricks & Wiley, 2009; Fincher-Kiefer et al., 1988). These results are also consistent with the recall reconstruction hypothesis for working memory (Towse et al., 2008). As described by Cowan and Chen (2009), when information is in the focus of attention, such as when people are reading sentences during the reading span task, strong associations can be formed between elements; in the short-story span task from the current study, this would be between the target word and both the current sentence context as well as the story theme from the current set. Because these associations are then stored in long-term working memory (or as Cowan and Chen refer to it, the activated portion of long-term memory), people have additional cues to help them remember the target words. If memory for a particular word is degraded, making recall difficult, people can then use the context of

[1] We use the phrase "smaller benefit" because, in contrast to the reported analysis, this comparison was significant when using a more lenient scoring procedure that scored words as correct even if they were not recalled in the appropriate serial position (e.g., Friedman & Miyake, 2005), $F(1, 59) = 5.04$, $p < .05$, $\eta_p^2 = .08$.

the sentence, or possibly the story from the current set, to help reconstruct that target word.

However, this study also showed that there are limits to the extent to which context can help with reconstruction (Towse et al., 2008). For example, the results of Experiment 2 are consistent with previous studies that have shown proactive interference effects for working memory span tasks (Lustig, May, & Hasher, 2001; May, Hasher & Kane, 1999). Unsworth and Engle (2007) explained that proactive interference is due to a lack of unique contextual cues for the to-be-remembered information, and this seems to have been a factor in Experiment 2 when a continuous-story span task was used. At first glance, the interference effects may be slightly puzzling in that a small amount of related context helps performance (i.e., the short-story span task), whereas more context shows evidence of proactive interference (i.e., the continuous-story span task). A closer look at the current study shows that in the short-story span task, a story theme served as a unique contextual cue for that particular set. Because other sets were based on completely different stories, each set had the target words associated with different contextual cues. If a target word was degraded, people could use the unique context from that current set to reconstruct the target word. However, for the continuous-story task with the common story theme, the contextual cue for the present set is no longer unique. In this case, the same story context is associated with all of the target words from the present and earlier sets. In this scenario, if in the present set, target words are degraded, and people attempt to reconstruct them, they are relying on the same contextual cues as those that are associated with previous sets, which could lead to intrusions, or proactive interference, as people try to reconstruct target words from that common context. Thus, this shows that the recall reconstruction hypothesis could be improved by directly incorporating the ideas of Unsworth and Engle regarding unique contextual cues. That is, the presence of usable context in the processing component is not enough to lead to a cooperative relationship between processing context and the target words; the target words must be associated with specific, unique, context to aid recall reconstruction.

The results of the current study may also contribute to possible explanations of phonological similarity effects with working memory. Both Copeland and Radvansky (2001) and Macnamara et al. (2011) have shown that the typically observed phonological similarity decrement for simple span tasks (e.g., word span) is reversed for the reading span task so that there is actually a phonological similarity benefit. Because this benefit was observed for the reading span but not for the operation span, it seemed that the sentence context may have led to the benefit in performance.

Finally, the findings that the contextual information from the processing component can influence recall performance have implications for how to conduct working memory span tasks (Conway et al., 2005). On the one hand, individual differences in the ability to reconstruct information based on cues could be an important distinction. Individual differences in the use of context to aid recall in a span task, such as the reading span, could be related to other complex cognitive tasks where people have to manage a lot of contextual information, such as narrative comprehension. On the other hand, if the goal of a working memory span task is to have independent processing and storage components, or for the processing component to simply prevent rehearsal of the target items, methods of administering the reading span that includes the presentation of an additional, unrelated, target word or letter following each sentence may be more appropriate (e.g., Engle, Tuholski, Laughlin, & Conway, 1999; Kane et al., 2004). Because the target words would be unrelated to the content of the sentences, the contribution of the sentence context could be minimized using this method. This is important because, despite the fact that the separate target word/letter has been recommended (Conway et al., 2005) and that some researchers have used this method for many years (e.g., LaPointe & Engle, 1990), some research studies still use the traditional version of the reading span test with the sentence-final word as the target word (e.g., van den Noort, Bosch, Haverkort, & Hugdahl, 2008). Along this line, there would also be a need to reassess the predictive relationship between traditional reading span performance and other cognitive processes (e.g., see Daneman & Merikle, 1996, for a meta-analysis of studies that used the reading span in this way). Critically, previous studies that have used the reading span as a measure of working memory may have been tapping both working and long-term memory resources when the intent was to only measure working memory. While it is possible that the inclusion of useable contextual cues in the traditional reading span simply inflates scores, leaving the relationships with other cognitive tasks relatively unaffected, future studies would need to explore this idea further.

CONCLUSION

Complex working memory span task measures, such as the reading (Daneman & Carpenter, 1980) and operation span tasks (Turner & Engle, 1989), are the standard for measuring the amount of information a person is able to simultaneously process and store in working memory. However, the reliability and validity of span tasks has been a subject of controversy among memory researchers because it is uncertain to what extent people employ mental strategies to circumvent capacity limitations imposed by the task requirements. This study showed that the information in the processing component of a reading span task can be used to increase span score by using richer mental representations in secondary memory. This study also showed that rich contextual information, if it does not serve as a unique contextual cue, does not significantly increase span performance. Understanding how people use and store information from span tasks can provide a greater understanding of how this information can both hurt and help performance.

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APPENDIX

Example sets used for the traditional span task

As a parting gift, the company bought the loyal retiree an expensive watch.
The fortunes of many wealthy families began with the discovery of oil.
It took courage for the young man to ask the popular girl to the dance.
The butcher placed the expensive ham onto the meat scale.
He knew that the sword was useless as he rubbed his fingers along its dull edge.

Despite her best efforts, the teacher could not keep the hyper student on task.
Although the church had many remarkable features, it was best known for its large cross.

The angry mother scolded her disobedient son for playing with the sharp knife.
After a day of hiking in the jungle, he decided to find shelter when it began to rain.
The picky women preferred to shop for groceries at the neighborhood store.

Example sets used for the short-story span task

He walked into the courtroom and right in front of him was the judge.
He was on trial today because last night he was involved in a fight.

The man kissed his beautiful wife on the back of her neck.
When she felt his kiss a shiver went up her spine and made her smile.
She threw her arms around him and thanked him again for adopting the small dog.
Things like this made her proclaim, “I have married the right guy!”
They watched together as it playfully romped around outside in the snow.

The football player hit the ground and slid across the wet grass.
He crashed into the coach who was standing in front of the equipment box.
The collision was hard; it felt like he had been hit by a train.

Example sets used for the continuous-story span task

It was a nice day, so Anthony decided he’d take a walk to the bank.
There, standing ahead of him in line, was a beautiful woman in a green dress.
Anthony was visibly shy, swallowing hard to the bottom of his throat.
He thought about making a move, instead of standing there collecting dust.

He owed it to himself to talk to her, it was only fair.
To relax, he closed his eyes and breathed deeply through his nose.

He approached in a way that, though not direct, made his romantic intentions frank.
“Your shoes are nice, but don’t you find that walking in them makes you trip?”
“Oh yes”, Sonya replied, “this morning I lost my footing and fell on my rear”.
She winced visibly, as if to express that she could still feel the pain.