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RESEARCH REPORT

The Influence of Levels of Processing on Recall From Working Memory and Delayed Recall Tasks

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Recent research in working memory has highlighted the similarities involved in retrieval from complex span tasks and episodic memory tasks, suggesting that these tasks are influenced by similar memory processes. In the present article, the authors manipulated the level of processing engaged when studying to-be-remembered words during a reading span task (Experiment 1) and an operation span task (Experiment 2) in order to assess the role of retrieval from secondary memory during complex span tasks. Immediate recall from both span tasks was greater for items studied under deep processing instructions compared with items studied under shallow processing instructions regardless of trial length. Recall was better for deep than for shallow levels of processing on delayed recall tests as well. These data are consistent with the primary-secondary memory framework, which suggests that to-be-remembered items are displaced from primary memory (i.e., the focus of attention) during the processing phases of complex span tasks and therefore must be retrieved from secondary memory.

Keywords: working memory, secondary memory, episodic memory, levels of processing

Considerable research has been devoted to understanding the role of attention in immediate memory (Engle & Kane, 2004). In recent years, immediate memory typically has been studied under the rubric of working memory (WM; Miyake & Shah, 1999). Although many definitions of WM exist, most suggest that WM is involved in the maintenance and processing of information over brief periods of time (Miyake & Shah, 1999). WM has become central to understanding cognition, partly because there is a strong relationship between performance on WM span tasks and measures of higher level cognition (e.g., Engle, Tuholski, Laughlin, & Conway, 1999; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010).

Although many tasks have been used to measure the efficiency of WM, perhaps the most widely used measures of WM capacity are complex span tasks. For example, the operation span task typically involves the presentation of between two and six to-be-remembered words per trial, each preceded by an arithmetic problem that participants must decide is either true or false ($5 \times 7 = 40$?; Conway et al., 2005). These tasks originally were believed to measure WM capacity by requiring concurrent maintenance and manipulation of information (Turner & Engle, 1989). A recent, alternative interpretation of complex span tasks focuses more directly on their retrieval demands rather than on distinct storage and processing components (Cowan et al., 2005; McCabe, 2008; Unsworth & Engle, 2006). Unsworth and Engle (2006, 2007) suggested that primary memory (PM) can maintain up to approximately four items (similar to the *focus of attention*; Cowan et al., 2005). However, when items are displaced from PM, they must be retrieved from secondary memory (SM). On a complex span task, the processing component of the task (e.g., the arithmetic problems in the case of operation span) causes to-be-remembered items to become displaced from PM due to the processing task consuming resources that would otherwise be used for maintenance of to-be-remembered items. When to-be-remembered items are displaced from PM they must be retrieved from SM, which relies on an error-prone search and retrieval process. Thus, according to the primary-secondary memory framework, complex span tasks principally measure SM retrieval. Consequently, variables that affect traditional SM, or episodic memory tasks, should affect complex span tasks in a similar manner.

In the present study, we investigated whether retrieval from typical complex span tasks (i.e., reading and operation span) and typical episodic memory tasks (i.e., delayed free recall) would be similarly affected by levels-of-processing manipulations (Craik & Tulving, 1975). Indeed, hundreds of studies have demonstrated

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In memory of our beloved friend and colleague, David P. McCabe, who died January 11, 2011.

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that deeper levels of processing (e.g., semantic processing) benefit episodic recall more than shallower (e.g., phonological or orthographic) levels of processing, whereas immediate recall (e.g., word span) depends greatly on phonological or even orthographic cues (Baddeley, 1986). Thus, examining levels-of-processing (LoP) effects on complex span tasks and delayed free-recall tasks provides a method of examining whether the memory processes involved in these tasks are similar or distinct. Indeed, findings of LoP effects (i.e., benefits of deeper as compared with shallower processing) on both complex span tasks and delayed free-recall tasks would suggest that the quality of processing involved in the tasks is similar and that complex span tasks rely on the same cue-dependent search mechanism involved in traditional episodic retrieval tasks.

To date, little empirical research has investigated the influence of LoP on retrieval from simple or complex span tasks. A notable exception is an early study motivated by the LoP framework in which simple and complex span type tasks were administered to participants, followed by immediate and delayed free-recall tests (Mazuryk & Lockhart, 1974). Five-item lists were processed under different encoding conditions: shallow (i.e., overt or internal rehearsal), intermediate (generating rhymes), and deep (generating semantic associates). Immediate recall following shallow processing at encoding was greater than both intermediate and deep processing, but for delayed recall, deep processing led to reliably better recall performance than shallow and intermediate processing. However, because this task did not include a demanding concurrent processing task to displace items from PM, and participants had several seconds to encode each item, it differed considerably from contemporary complex span tasks.

More recently, the influence of LoP on a novel span task—the LoP span task—was reported by Rose, Myerson, Roediger, and Hale (2010). In this task, a target to-be-remembered word was presented, with one of two "matching" words presented immediately afterward. The target word could be matched on the basis of the color of the font (shallow, orthographic processing), rhyming with the target word (medium, phonological processing), or the meaning of the target word (deep, semantic processing). After processing between two and eight of these target matches per trial, participants were asked to immediately recall the target words in serial order. Results indicated no influence of LoP on immediate recall, regardless of trial length, but the typical LoP effect was found on a later recognition test, such that items processed semantically were better recognized than items processed phonologically, which were in turn better recognized than items that were processed orthographically. Rose et al. concluded that the effects of LoP on episodic memory tasks and WM tasks, such as the LoP span task and the tasks used by Mazuryk and Lockhart (1974), were dissociable.

One question left unanswered by these previous studies concerns whether LoP effects would occur for traditional complex span tasks such as the reading span (Daneman & Carpenter, 1980) and operation span (Turner & Engle, 1989) tasks, which are arguably the most widely used WM span tasks (see Conway et al., 2005, for a review). It is possible that the novel demands of the LoP span task differ in some important respects from the demands of a traditional complex span task. For example, the difficulty of the decisions on the LoP span task may not be great enough to completely displace items from PM, thus placing less demand on retrieval from SM as compared with traditional complex span tasks. Indeed, some researchers have argued that the processing component in a complex span task must be of considerable difficulty in order to effectively measure WM capacity (Conway et al., 2005). Thus, the lack of an LoP effect for immediate recall from the LoP span task does not rule out the possibility that LoP effects would be found for immediate recall from traditional complex span tasks, like reading or operation span. Finding LoP effects for traditional complex span tasks would be consistent with the contention of the primary-secondary memory framework (Unsworth & Engle, 2007) that such tasks require retrieval from SM.

In Experiment 1, we examined the effect of an LoP manipulation on the reading span task. For the typical reading span task, to-be-remembered items are integrated with the processing component of the task, and some researchers have speculated that this integration provides effective semantic cues for long-term memory retrieval (Towse, Cowan, Hitch, & Horton, 2008). In a typical sentence-word presentation on a reading span task, a sentence such as "A four-footed animal that barks is a DOG" is presented, and the participant must determine whether the statement was true or false. Participants must also encode the final word of each sentence and recall these words in serial order after several sentences have been presented. In Experiment 1, we incorporated an LoP manipulation during a reading span task by including sentences that were either orthographically (shallowly) or semantically (deeply) related to the to-be-remembered word at the end of each sentence. This characteristic of the task is also advantageous because traditional LoP manipulations in episodic memory studies have used similar sentence stimuli to engage shallow or deep processing (e.g., Craik & Tulving, 1975).

If integrating to-be-remembered words within sentences provides effective retrieval cues for recall (Towse et al., 2008), then participants should favor a semantic retrieval strategy for recall following reading span, such that the sentence stems would be used as retrieval cues for immediate recall. Consequently, an LoP effect should emerge for recall from the reading span task. However, such rich retrieval cues are not characteristic of the Rose et al. (2010) LoP span task or of some other traditional complex span tasks (e.g., operation span). Thus, in Experiment 2, we examined whether LoP effects would be obtained for immediate recall from an operation span task that requires participants to solve an arithmetic problem before studying to-be-remembered words that is unrelated to the processing operation.

In both experiments, after participants completed blocks of shallow and deep span task trials, a delayed recall test was given to assess the retrieval of those items from episodic memory. This delayed recall test provides an assessment of LoP effects for a typical episodic memory task, which exclusively involves retrieval from SM according to the primary-secondary memory framework. We also sought to provide converging evidence with Rose et al. (2010) using a different episodic memory task (i.e., recall instead of recognition). Thus, several outcomes are possible in the present study: (a) Traditional complex span tasks may not show an LoP effect, similar to the results reported by Rose et al., which would challenge the notion that complex span tasks involve similar retrieval processes as SM tasks; (b) alternatively, LoP effects may be found for complex span tasks, supporting the primary-secondary memory framework hypothesis that these tasks depend on SM retrieval. (c) Finally, it is possible that LoP effects will only be found for reading span, which provides rich semantic retrieval cues (i.e., sentence stems), but not for operation span, which does not provide rich semantic retrieval cues.

Experiment 1

Method

Participants and design. Ninety-six participants were included in this study (68 women, age $M = 19.27$, $SD = 2.07$). Half were assigned to a condition requiring immediate serial recall during span task recall, and the other half were allowed to recall the items from the trials in any order they wished (immediate free recall). This manipulation of recall instructions was included in order to ascertain whether any potential LoP effects on immediate recall were due to recall instructions. Two participants from each condition were dropped due to experimenter error.

Materials and procedure. Two blocks of reading span were administered, with a brief intervening task separating the blocks. Each block consisted of trials of two to five to-be-remembered words, with two trials of each list length (eight trials per block). The trial lengths were randomly presented within each block. The sentences of both processing types were all equated for number of words ($M = 8.93$, $SD = 1.13$) and syllables ($M = 11.56$, $SD = 1.18$) in each. All to-be-remembered words were concrete, high-frequency nouns: the Log HAL frequency ratings ranged from 8.25 to 12.02 ($M = 10.09$, $SD = 0.77$). Words were counterbalanced for block, processing type, and affirmative or negative response.

Each block included both "deep" and "shallow" sentences, which prompted participants to respond to either the semantic or the orthographic characteristics of the to-be-remembered word, respectively. Half of the sentences in either block were deeply oriented to the to-be-remembered word in capital letters at the end of the sentence (e.g., "The brother of one of your parents is an UNCLE"; "A tool for making clothes is a sewing MACHINE"), and the other half of the sentences were shallowly oriented toward the to-be-remembered word (e.g., "A word made up of five letters is UNCLE"; "There are three different vowels in the world MACHINE"). For each type of sentence, half of the sentences were true and half were false, with false sentences composed by including a to-be-remembered word that did not make sense in the sentence (e.g., "The brother of one of your parents is a LETTER"). Sentences of both types were distinct from the others. The type of processing elicited by the sentences was constant within the trial (i.e., no shallow sentences appeared in the same trial as a deep sentence, and vice versa), but the presentation of deep and shallow trials was random. Prior to the administration of the two blocks, participants completed one practice trial of List Length 2 of both types of sentences. Participants were asked to read the entire sentence aloud and respond to the veracity of each statement. After receiving two to five sentences, half the participants were prompted to recall in the original order that the words were presented (in the serial recall condition), and the other half recalled in any order they wished (in the free-recall condition).

Participants completed a short distractor task for approximately 2 min following each block: a demographics questionnaire following the first block and a short word search following the second. The distractor task was followed by a surprise delayed recall test on which they were asked to recall any words that they had tried to recall during the preceding block of span task trials. Although participants may have anticipated a delayed recall test following the second block, block order did not significantly interact with LoP on delayed recall in either Experiment 1 or Experiment 2 (Fs < 1.48).

Results and Discussion

All significant results reported reached a criterion of $p < .05$ unless otherwise indicated. Although free-recall instructions led to better memory performance compared with serial recall instructions, immediate recall instruction (free vs. serial) did not interact with any of the other independent variables (all Fs < 2.65), and therefore we collapsed across recall instructions for the following analyses. There were also no significant differences in response times or error rates on the processing task of the reading span between recall conditions (Fs < 1) (see Table 1). In addition, for the processing component (i.e., the sentence decisions), response times were slower, $t(91) = 6.71$, $d = 0.22$, and error rates were higher, $t(91) = 3.79$, $d = 0.79$, for shallow as compared with deep processing at encoding (see Table 1). Free- and serial recall scoring methods yielded the same pattern of results. Thus, free-recall scoring was used for the following analyses (see Table 2).

The recall data for Experiment 1 are shown in Figure 1. A 2 (time of recall: immediate, delayed) × 2 (LoP: deep, shallow) repeated measures analysis of variance (ANOVA) yielded a significant main effect of time of recall, $F(1, 91) = 2494.38$, $MSE = 15.38$, $\eta_p^2 = .97$, with recall being greater during the span task as compared with the delayed recall test. There was also a significant main effect of LoP, $F(1, 91) = 32.59$, $MSE = 0.28$, $\eta_p^2 = .26$, such that deeper items were better recalled than shallow items. More

Table 1
Response Times and Number of Errors for Processing Components of the Complex Span Tasks in Experiment 1 and Experiment 2

	Experiment 1				Experiment 2		
	Serial recall condition		Free-recall condition				
Level of processing	Response time	Error rate	Response time	Error rate	Judgment accuracy	Response time	Error rate
Deep	5190.27 (1823.52)	0.76 (0.99)	5172.60 (1686.04)	1.13 (1.31)	0.97 (0.04)	3518.08 (574.25)	1.95 (1.82)
Shallow	5569.76 (1656.17)	1.65 (1.27)	5349.28 (1448.72)	1.35 (1.32)	0.96 (0.07)	3529.80 (550.10)	1.71 (2.01)
Total	5383.43 (841.52)	2.41 (1.89)	5313.26 (834.08)	2.48 (2.19)	0.97 (0.06)	3523.22 (1076.76)	1.83 (1.91)

Note. Standard deviations are in parentheses.

Table 2
Immediate Recall Performance Scored According to Strict Serial Order and Free-Recall Order for Experiments 1 and 2

	Experiment 1				Experiment 2	
	Serial recall condition		Free-recall condition		Serial recall condition	
Scoring method	Deep	Shallow	Deep	Shallow	Deep	Shallow
Serial recall scoring	.39 (0.16)	.32 (0.07)	.17 (0.11)	.13 (0.04)	.35 (0.21)	.31 (0.20)
Free-recall scoring	.62 (0.12)	.58 (0.05)	.69 (0.10)	.63 (0.05)	.62 (0.13)	.57 (0.14)

Note. Standard deviations are in parentheses.

important, the interaction between the LoP and time of recall was not significant ($F < 1$).

Because longer trials of complex span tasks may engage SM more than shorter lists (Rose et al., 2010; Unsworth & Engle, 2006), we examined whether the LoP effect in immediate recall differed as a function of list length. A 2 (LoP: deep, shallow) × 4 (list length: 2, 3, 4, 5) repeated measures ANOVA on immediate recall revealed main effects of LoP, $F(1, 91) = 32.81$, $MSE = 0.79$, $\eta_p^2 = .26$, and list length, $F(1, 91) = 267.10$, $MSE = 5.70$, $\eta_p^2 = .74$, but no interaction ($F < 1$) (see Table 3). Thus, the LoP effect was evident at immediate recall regardless of the trial's list length.

The findings from Experiment 1, in which LoP affected recall from reading span, differed from Rose et al.'s (2010) finding that LoP did not affect recall on their novel LoP span task. Procedural differences between these tasks were likely responsible for the inconsistent results. These issues are discussed in detail in the General Discussion section, but one methodological difference between these tasks addressed in Experiment 2 concerns the extent to which the to-be-remembered items are integrated with the processing component of the span task. The reading span task used in Experiment 1 integrated the to-be-remembered items with the processing task, which likely provided rich semantic retrieval cues for recall both immediately and after a delay (cf. Towse et al., 2008). Indeed, in their "user's guide" to WM span tasks, Conway et al. (2005) suggested that if the to-be-remembered items are not integrated with the processing task, then participants will be less able to use the sentence stems strategically to retrieve the items.

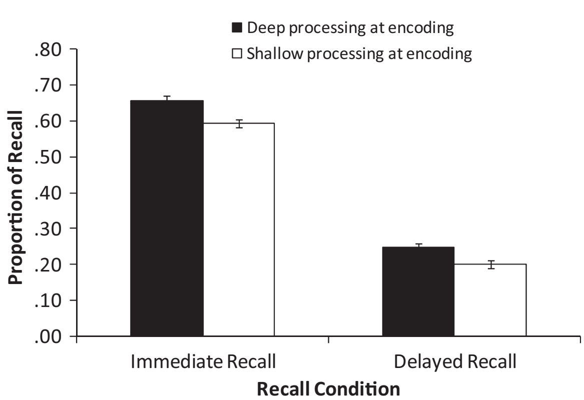

Figure 1. Performance at immediate and delayed recall as a type of processing at encoding for Experiment 1, using reading span task.

In Experiment 2, we examined LoP effects on a typical WM task—operation span—that does not integrate the to-be-remembered items within the processing task and therefore does not provide rich semantic cues at retrieval. If there is no LoP effect for immediate recall from operation span, then this would suggest that the LoP effect found for reading span (Experiment 1) was likely due to the provision of semantic cues. Alternatively, if the LoP effect found for reading span in Experiment 1 were to be replicated using operation span in Experiment 2, then it would provide strong support for the proposal that complex span tasks require retrieval from SM (Unsworth & Engle, 2007).

Experiment 2

Method

Participants and design. Fifty-six participants were included in this experiment (35 women, age $M = 18.94$, $SD = 1.28$). Because recall condition (free vs. serial) did not interact with other variables in Experiment 1, only serial recall was required in Experiment 2.

Materials and procedure. After completing 30 practice arithmetic problems, each participant completed two blocks of operation span. Before each block, participants were told that they should make a judgment for each to-be-remembered word. These judgments were either deep (i.e., "Please decide whether the words in the following trials are living things or nonliving things by responding 'yes' [living] or 'no' [not living] to each word that appears on screen") or shallow (i.e., "Please decide whether the words in the following trials have at least 2 vowels [a, e, i, o, u] by saying 'yes' [at least 2 vowels] or 'no [only 1 vowel] to each word that appears on the screen"). The type of judgment was constant

Table 3
Immediate Recall Performance as a Function of List Length for Experiment 1 and Experiment 2

	Experiment 1		Experiment 2	
List length	Deep	Shallow	Deep	Shallow
List Length 2	.93 (0.13)	.86 (0.17)	.84 (0.18)	.78 (0.17)
List Length 3	.76 (0.19)	.70 (0.18)	.68 (0.20)	.64 (0.21)
List Length 4	.61 (0.18)	.54 (0.17)	.56 (0.18)	.54 (0.18)
List Length 5	.54 (0.16)	.48 (0.15)	.55 (0.16)	.47 (0.17)

Note. Standard deviations are in parentheses.

within the same block (e.g., deep judgments for the first block and shallow judgments for the second block), and the order of the blocks was counterbalanced. Participants completed one practice trial of each type of judgment before starting the task.

During both blocks of operation span, an arithmetic problem (e.g., 7 × 4 = 28?) preceded each to-be-remembered word. Participants read each problem aloud and responded true or false. The experimenter then advanced the screen to the to-be-remembered word, which was displayed for 2 s. Participants read the word silently and said "yes" or "no" aloud. Two trials of each list length (two to five words) were included in each block. The procedure for the distractor tasks and delayed recall tests was identical to Experiment 1.

Results and Discussion

The accuracy of the deep versus shallow judgments, $t(55) = 1.68$, $d = 0.18$, as well as the response times, $t(55) = 0.24$, $d = 0.02$, and error rates, $t(55) = 1.11$, $d = 0.13$, on the processing task did not differ between the two processing conditions (see Table 1). Although serial recall was required during the task, we analyzed overall recall regardless of original serial order to allow for a more direct comparison between immediate and delayed recall. Note that all analyses were consistent between the free- and serial recall scoring methods (see Table 2).

The recall results for Experiment 2 are shown in Figure 2. A 2 (time of recall: immediate, delayed) × 2 (LoP: deep, shallow) repeated measures ANOVA revealed a main effect of time of test, $F(1, 55) = 547.26$, $MSE = 6.83$, $\eta_p^2 = .91$; a main effect of LoP, $F(1, 55) = 42.90$, $MSE = 0.27$, $\eta_p^2 = .44$; and a Time of Recall × LoP interaction, $F(1, 55) = 4.14$, $MSE = 0.02$, $\eta_p^2 = .07$. Planned comparisons indicated an LoP effect for immediate recall, $F(1, 55) = 12.35$, $MSE = 0.08$, $\eta_p^2 = .18$, and for delayed recall, $F(1, 55) = 48.35$, $MSE = 0.21$, $\eta_p^2 = .47$. Thus, the interaction was driven by a larger LoP effect (as measured by effect size) for delayed recall as compared with immediate recall.

As in Experiment 1, in order to examine whether the LoP effect differed as a function of trial length, we conducted a 2 (LoP: deep, shallow) × 4 (list length: 2, 3, 4, 5) repeated measures ANOVA, with immediate free recall as the dependent measure. We found a main effect of LoP, $F(1, 55) = 11.49$, $MSE = 0.31$, $\eta_p^2 = .17$, and a main effect of list length, $F(3, 165) = 95.10$, $MSE = 2.02$, $\eta_p^2 = .63$, but there was no significant interaction between the two variables, $F(3, 165) = 1.24$, *ns*.

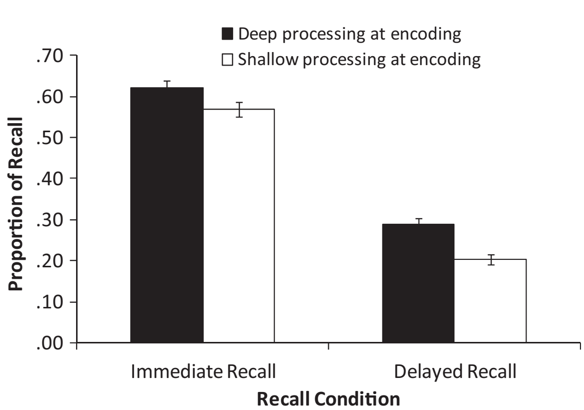

Figure 2. Immediate and delayed recall performance as a function of type of processing at encoding for Experiment 2, using the operation span task.

General Discussion

Deeper LoP led to better performance than shallow LoP for recall from a reading span task (Experiment 1) and an operation span task (Experiment 2). Similarly, deeper LoP led to better memory performance on a delayed recall test in both experiments. This pattern of results was obtained regardless of whether free or serial recall was required during the span task, and regardless of whether immediate recall was scored using serial or free-recall criteria. The only inconsistency between the two experiments was that there was a nonordinal interaction between LoP (deep or shallow) and time of recall (immediate or delayed) in Experiment 2 (operation span), but not Experiment 1 (reading span). The interaction in Experiment 2 using operation span resulted from a larger LoP effect for delayed recall than for immediate (span task) recall. In contrast, we found similar LoP effects for immediate and delayed recall in Experiment 1 using reading span.

Although the finding of an LoP effect in immediate recall in the present study differed from the null LoP effect of Rose et al. (2010), this is likely the result of differences in task demands and the types of cues available in the two studies. On the LoP span task, for example, to-be-remembered items were required to be read aloud, which may have resulted in a reliance on phonological cues for immediate retrieval. Furthermore, the correct answer for the processing decisions in the LoP span task often shared two associations with the to-be-remembered items, which could have caused interference on many levels (e.g., semantic, phonological). The processing decisions may have also been too easy to disrupt maintenance in WM (cf. Conway et al., 2005, for discussion of this issue). Indeed, the response times for the processing components of the tasks in the present study were two to four times longer than on the LoP span task. To the extent that processing times are a proxy for difficulty, which may decrease cognitive load and allow increased time devoted to maintaining to-be-remembered items (Barrouillet, Bernardin, & Camos, 2004), it is possible that the LoP span task did not disrupt maintenance to the same extent as reading or operation span. As a result, it is possible that the to-be-remembered items were not completely displaced from PM in the LoP span task. In contrast, greater cognitive load during the traditional span tasks may have displaced to-be-remembered items completely from PM. Although this explanation is speculative, there is obviously some important difference in the type of processing engendered by the LoP span task and traditional span tasks, given that LoP effects were found for the traditional span tasks but not for the LoP span task.

The data we report have important implications regarding whether distinct principles govern retrieval from WM and episodic memory. First, our results are consistent with the primary-secondary memory framework (McCabe, 2008; Unsworth & Engle, 2006, 2007), which posits that complex span tasks and delayed recall tests are primarily dependent on retrieval from SM. Specifically, because items retrieved during complex span tasks and delayed recall tasks had been displaced from PM, they require an error-prone search and retrieval process in order to recall them. By this rationale, complex span task recall and delayed recall should be similarly affected by experimental manipulations (e.g., LoP) that influence episodic memory tests. These results are also consistent with embedded-processes models (Cowan et al., 2005; Oberauer, 2002), which contend that WM is a subset of activated representations within a broader long-term memory. Although the present study cannot delineate between specific aspects of different versions of embedded-processes models (e.g., the capacity of the focus of attention), the data support the idea that maintenance of information in WM occurs through a focus-switching process (Zhang & Verhaeghen, 2009). Specifically, deeper LoP may provide more robust representations to retrieve from SM into the focus of attention, thereby making the representation more available for retrieval than representations that have been shallowly processed.

If the WM tasks used in the present study rely on perceptual (e.g., phonological) cues during retrieval to a greater degree than delayed recall tasks, then this could potentially explain why an interaction was found for the operation span task in Experiment 2 but not for the reading span task in Experiment 1. Specifically, Rose et al. (2010) suggested that span task recall may rely more on shallow, perceptual (phonological) cues, whereas episodic memory tasks likely rely more on conceptual (semantic) cues or recollection of temporal context (i.e., constraining retrieval to specific episodes). Because the processing component of operation span tasks is not integrated with the to-be-remembered items, participants may rely more on phonological cues, rather than semantic cues, as compared with the reading span task, which provides rich semantic retrieval cues. Specifically, the reading span task may allow for the recovery of sentence stems that can be used as cues for recall for both span tasks and delayed tests (Towse et al., 2008). Thus, versions of reading span in which the to-be-remembered items are not integrated within the processing sentence should yield results similar to the slightly diminished LoP effect in immediate operation span recall. Regardless of factors that might moderate the strength of the LoP effect in WM (e.g., practice, proactive interference, the specificity of potential retrieval cues), the important point is that the LoP effect was evident for two of the most often used WM span tasks, for trials of all lengths.

In summary, although LoP effects had previously been reported as being absent in short-term recall (Mazuryk & Lockhart, 1974; Rose et al., 2010), the experiments reported here provide clear evidence of LoP effects on complex span tasks. Thus, these data are consistent with the hypothesis that the processes engaged by traditional complex span tasks and episodic memory tasks are similar, as postulated by the primary-secondary memory framework (McCabe, 2008; Unsworth & Engle, 2006, 2007).

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