The Competing Role of Knowledge and Working Memory in Reading Comprehension

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Abstract

Though the roles of working memory (WM) and prior knowledge (PK) in reading comprehension have been studied extensively, their effects are rarely studied concurrently. Much of this work has struggled to adequately assess WM or has used insufficient measures of comprehension. The present study simultaneously tested the impact of WM, vocabulary, and domain-specific PK on reading comprehension. Only domain-specific PK predicted unique variance in reading comprehension, emphasizing the importance of PK for building understanding.

Keywords: reading comprehension, working memory, prior knowledge

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Seminal findings have linked working memory (WM) and performance on reading comprehension tasks (Daneman & Carpenter, 1980; Turner & Engle, 1989). However, interpretations of this relationship differ. Daneman and Carpenter's (1980) theory - that differences in reading comprehension arise from differences in the efficiency with which one utilized the restricted capacity of WM - has not been borne out. Rather, evidence corroborates Turner and Engle's (1989) attribution that WM represents domain-general processes which may support successful comprehension.

However, WM's role in reading comprehension remains poorly understood, with methodological differences across research traditions contributing to inconsistent findings. For example, researchers primarily studying text comprehension often rely on: outdated measures of WM like the reading span task (Daneman & Carpenter, 1980) that confound reading ability and WM; outdated theories of WM that focus purely on capacity (Van Dyke et al., 2014); simple span tasks that do not tap into the WM construct (Cain et al., 2004); or self-paced/non-adaptive versions of the task that introduce non-WM variance into performance (Was & Woltz, 2007).

Meanwhile, WM researchers often fail to incorporate theoretical considerations and methodologies from the discourse-processing literature, relying on multiple-choice style comprehension measures, vocabulary-based measures, and rarely including inference-based questions (Martin et al., 2019). Furthermore, vocabulary knowledge is often used as an outcome measure rather than a predictor, despite being shown to explain variance in reading comprehension above and beyond that explained by WM (Van Dyke et al., 2014).

Finally, WM researchers rarely consider the impact of prior knowledge (PK) on comprehension. There is an extensive literature capturing the processes involved in reading comprehension, including the impacts of domain-specific and domain-general knowledge. Kintsch (1988) suggests that incoming text information is integrated with the reader's existing knowledge base as they read, developing a situation model and establishing comprehension. Likewise, experimental work demonstrates that readers' domain-general knowledge aids in *comprehension* (Rizzella & O'Brien, 2002), while individual differences in domain-specific knowledge impacts *learning* from the text (McNamara, 2001).

The present work integrates theoretical and methodological perspectives from the WM and text comprehension literatures. In particular, the roles of WM, vocabulary, and PK in a complex reading comprehension task were assessed. Critically, an adaptive-paced complex span task was used to measure WM; individual differences in domain-specific (i.e., biology) PK were recorded; and deep comprehension was assessed through questions that required bridging inferences.

Method

Participants

Eighty-one undergraduate college students from two universities in the United States participated (28 from New England; 53 from the Southeast) and received partial course credit.

Materials

Reading Comprehension. Participants read a text on the topic of cell mitosis and answered text-based (6 total) and bridging (6 total) comprehension questions (McNamara, 2001). The text contained 650 words in 48 sentences and was presented in 12 paragraphs. All comprehension questions were short answer, and coders demonstrated strong reliability (Kappa=.89).

Biology Prior Knowledge. Participants completed 29 questions about biology, designed to assess their prior knowledge of the text domain (adapted from McNamara, 2001). None of the questions directly tested information that was contained in, or could be inferred from, the text.

Vocabulary Knowledge. Vocabulary knowledge was assessed using the vocabulary section of the Gates-MacGinitie (4^{th} ed.) reading test (form S) level 10/12 (MacGinitie & MacGinitie, 1989). The test consists of 45 simple statements, each with an underlined vocabulary word and a list of five options from which to choose the most closely related associate.

Working Memory. The operation span task measured WM (Unsworth et al., 2005). Participants alternated between mentally solving an algebra equation and remembering a letter. At the end of a trial, participants recalled the letters that they saw in the correct serial order. Trials range between two and seven items, with three iterations of each trial length. The number of items correctly recalled in the correct serial position constituted partial WM scores.

Procedure

Participants completed the tasks in a fixed order, lasting approximately 90 minutes: demographic questionnaire, reading task, reading comprehension assessment, PK test, vocabulary test, and operation span task. All tasks were self-paced, except the adaptively-paced WM task and the vocabulary task.

Results

See Table 1 for descriptive statistics and Table 2 for task correlations. A hierarchical linear regression was conducted predicting overall reading comprehension scores, with WM, vocabulary, and domain-specific PK entered in the first, second, and third steps, respectively (see Table 3). Domain-specific PK was the strongest unique predictor of reading comprehension, subsuming variance from WM and vocabulary. Separately predicting text-based (Table 4) and bridging comprehension (Table 5) yielded similar results.

Table 1. Descriptive Statistics

	Mean	SD	Min	Max	Skew	Kurtosis
ReadingComp	0.36	0.22	0.04	0.88	0.54	-0.67
Ospan	56.98	10.80	25	75	-0.49	-0.25
Vocab	30.77	6.74	11	43	-0.44	-0.09
Bio PK	12.27	3.63	3	23	0.09	0.38

Table 2. Task Correlations

	ReadingComp	Ospan	Vocab	Bio PK
ReadingComp	1	-	-	-
Ospan	0.13	1	-	-
Vocab	0.33**	0.21	1	-
Bio PK	0.40**	-0.07	0.51**	1

Table 3. Predicting Overall Reading Comprehension Scores

		R^2	F	ΔR^2	ΔF	β	SE	$\beta_{Standardized}$	t	p
Step 1		0.02	1.32	0.02	1.32					
	WM					0.003	0.002	0.13	1.15	0.254
Step 2		0.11	4.95	0.10	8.46**					
	WM					0.001	0.002	0.61	0.56	0.580
	Vocab					**0.010**	**0.003**	**0.32**	**2.91**	**0.005**
Step 3		0.19	6.17	0.08	7.75**					
	WM					0.002	0.002	0.13	1.17	0.247
	Vocab					0.004	0.004	0.13	1.06	0.292
	Bio PK					**0.020**	**0.007**	**0.34**	**2.78**	**0.007**

Table 4. Predicting Text-Based Comprehension

		R^2	F	ΔR^2	ΔF	β	SE	$\beta_{Standardized}$	t	p
Step 1		0.02	1.59	0.02	1.59					
	WM					0.003	0.002	0.14	1.26	0.211
Step 2		0.12	5.36	0.10	8.96**					
	WM					0.002	0.002	0.07	0.66	0.514
	Vocab					**0.012**	**0.004**	**0.33**	**2.99**	**0.004**
Step 3		0.20	6.26	0.08	7.21**					
	WM					0.003	0.002	0.13	1.25	0.217
	Vocab					0.005	0.004	0.15	1.18	0.242
	Bio PK					**0.022**	**0.008**	**0.33**	**2.69**	**0.009**

Table 5. Predicting Bridging Comprehension

		R^2	F	ΔR^2	ΔF	β	SE	$\beta_{Standardized}$	t	p
Step 1		0.01	0.67	0.01	0.67					
	WM					0.002	0.002	0.09	0.82	0.415
Step 2		0.07	2.89	0.06	5.07*					
	WM					0.001	0.002	0.04	0.34	0.734
	Vocab					**0.008**	**0.004**	**0.25**	**2.25**	**0.027**
Step 3		0.13	3.80	0.06	5.31*					
	WM					0.002	0.002	0.094	0.84	0.403
	Vocab					0.003	0.004	0.092	2.31	0.479
	Bio PK					**0.018**	**0.008**	**0.292**	**0.84**	**0.024**

Discussion

Across three hierarchical regression models, results demonstrated that WM does not uniquely contribute to reading comprehension, even at the bridging and text-based levels. Vocabulary emerged as a unique predictor of reading comprehension in all three models. However, this variance was completely explained by domain-specific PK, which remained the only unique predictor of reading comprehension.

The present work found that individual differences in reading comprehension are best predicted by knowledge, rather than the resource limitations dictated by WM. These findings align with prior work showing that vocabulary knowledge exceeds WM in predicting sentence-level reading comprehension success (Van Dyke et al., 2014); additionally, the current work demonstrates that domain-specific knowledge explains unique variance in text-level reading comprehension, beyond either WM or vocabulary knowledge. These results are encouraging for the development of reading interventions—because WM is resistant to training (Redick et al., 2015), improving domain-specific knowledge should necessarily improve reading comprehension. However, future work should continue to examine the role of WM during comprehension in other contexts, such as texts in which previous information requires updating or when one must draw conclusions from multiple texts, as these conditions may require further resources for successful understanding. Furthermore, because it is unlikely that WM is a unitary construct, it is worth exploring how the proposed facets of WM, as conceptualized by current WM theories (Unsworth, 2016; Shipstead et al., 2016), can explain individual differences in reading comprehension skill.

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