Does Combining Study Strategies Support Comprehension on Immediate Tests?

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Abstract

Both online and offline explanation strategies have been shown to support comprehension. However, little work has examined how combining these strategies might help or hinder their effects. This study used a 2(online: think-aloud, self-explain) x 3(offline: reread, free recall, explanatory retrieval) design to examine how different strategies affect science text comprehension. Analyses revealed a main effect of online strategy, but no effect of offline strategy on an immediate comprehension test.

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Despite the growing need for STEM professionals, national reports indicate most college students are underprepared for the science comprehension tasks they encounter in their STEM courses (NAEP, 2015). Researchers have identified several strategies that can support deeper comprehension of science content. Based on text and discourse research, *self- explanation*, which occurs during reading (online) can help readers to actively engage with text and integrate information from the text with their prior knowledge (e.g., Chi et al., 1994; McNamara, 2004). Based on applied memory research, offline activities after reading like retrieving information from memory and explaining from memory can increase comprehension and long-term retention (Hinze et al., 2013; Roediger & Karpicke, 2006). Although science students are likely to use combinations of these strategies, few studies have examined how combinations of online and offline strategies impact learning (McCrudden & McNamara, 2017). One hypothesis is that these strategies will interact insofar that the quality of an offline recall or explanation is likely to be dependent on the quality of the mental model constructed during reading. Alternatively, combining strategies may prove redundant if the benefits of online and offline strategies rely on similar mechanisms (cf. McDaniel & Einstein, 1989)

Background

Theories of discourse comprehension and applied memory undergird this study (e.g., Bjork & Bjork, 1992; Kintsch, 1988). The former posits that learners create an elaborated mental model that includes information from the text integrated with information from prior knowledge (e.g., Kintsch, 1988). Self-explaining the text as you read (e.g., Chi et al., 1994) encourages the generation of inferences that support a more elaborated mental model. The benefits of this process, should be demonstrable on immediate tests, and in fact have rarely been tested at long delays (Bisra et al., 2018).

Theories of applied memory assume that long-term memory retention is enhanced when readers successfully retrieve information from memory. Retrieval requires cognitive effort that may have costs to immediate performance, but is essential for long-term retention. In the case of free recall retrieval practice, a common post-reading strategy, not all information can be effectively retrieved after reading. This provides an immediate advantage to a rereading control condition, which is re-exposed to all content. As such, retrieval practice benefits are typically only demonstrated after a delay, as the reread information is more likely to be forgotten (Congleton & Rajaram, 2012; Roediger & Karpicke, 2006). Only under conditions where practice test performance is quite strong do we see the benefits of retrieval practice on immediate tests (Rowland & DeLosh, 2015). Thus, one potential method of enhancing the effects of retrieval is to prompt readers to *explain* from memory (e.g., Hinze et al., 2013), given that prompts to explain or elaborate during retrieval seem to enhance the quality of retrieval practice attempts (Endres et al., 2017; McCarthy et al., 2020).

The Current Study

The purpose of this study is to examine the effect of both online and offline strategies on college readers' comprehension of science texts. In addition, we explore the extent to which these effects are influenced by learners' individual differences in science prior knowledge and general reading skill.

The current study manipulated prompts to encourage explanation during online processes (self-explanation vs. think-aloud control) alongside offline retrieval processes after reading (free recall, explanatory retrieval, rereading control). Here we explore these effects on an immediate test, while another ongoing study explores these effects at a delay (Authors, 2021).

Based on prior work (e.g., Chi et al., 1994; Hinze et al., 2013), we predicted (1) a main effect of the online task, such that participants asked to self-explain would outperform participants asked to think-aloud and (2) a main effect of offline task, such that participants in the rereading condition would outperform participants in the free recall condition and that explanatory retrieval (writing a coherent explanation during retrieval practice) would improve retrieval quality and mitigate the advantage of the reread condition. Finally, we predicted an interaction between online and offline strategies. Specifically, explanation at either online or offline stage should attenuate the negative effects of retrieval at immediate test, given the comprehension advantages experienced after explaining. However, it was unclear whether self-explaining and explanatory retrieval would have an additive effect or would be redundant.

Method

Participants were 210 Prolific workers (M_{age} = 21.56*, SD* = 2.78*; Female* = 50.9%; all self-reported Fluent English speakers). Participants were recruited from Prolific, and randomly assigned to a 2(online: think-aloud, self-explain) x 3(offline: reread, recall, explanatory retrieval) between-subjects design. Participants were prompted to think-aloud or self-explain as they read two science texts. The order of texts was counterbalanced across participants. After reading, participants were given 10 minutes (5 minutes per text) to complete the offline task (reread, recall, explanatory retrieval). In the recall condition, participants were told they would be scored on how much of the text they could recall. Participants assigned the task of explanatory retrieval were informed that their responses would be scored according to quality of their explanation.

Participants then completed multiple-choice comprehension tests that included both textbase and inference items (Hinze et al., 2013). Finally, participants completed a series of individual difference measures for vocabulary (Gates-MacGinitie Vocabulary Test) and science prior knowledge (O'Reilly & McNamara, 2007).

Results

Preliminary analyses revealed positive correlations across all measures (Table 1). Analysis of variance tests also demonstrated no systematic difference in vocabulary or prior knowledge test scores across the manipulation conditions (*F*s < 2.50, *p*s > .35). Comprehension test performance as a function of item type, online condition, and offline condition is shown in Figure 1.

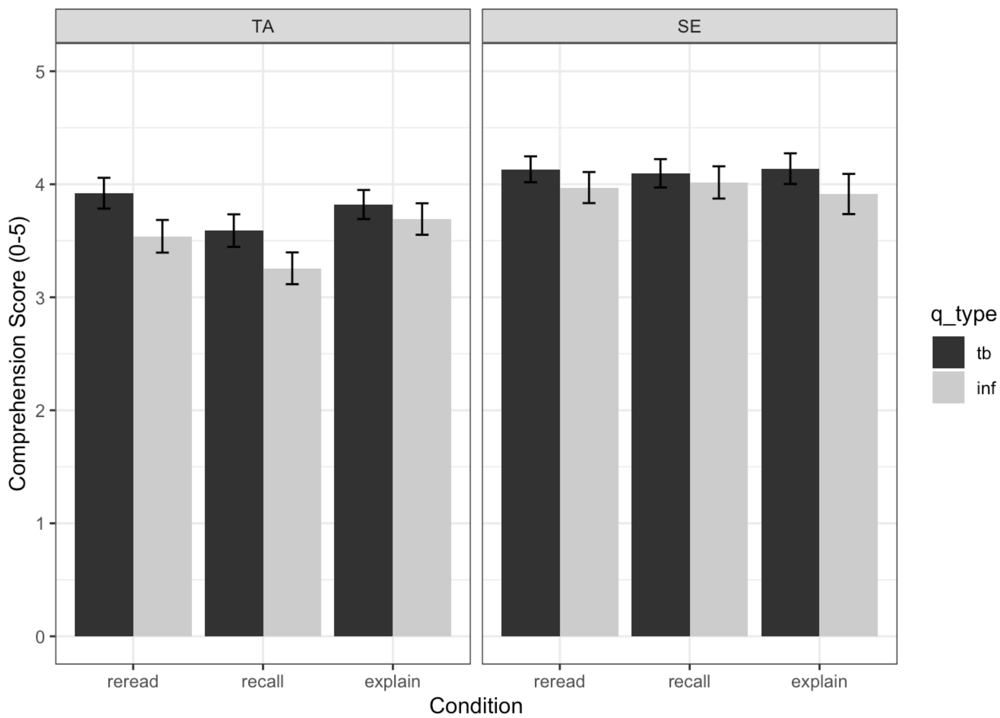
Table 1

Means, Standard Deviations, and Bivariate Correlations for Measures

	M	***SD***	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Vocabulary	37.97	5.93							
2. Prior Knowledge	17.32	2.54	.58**						
3. Vision Memory	4.05	1.20	.39**	.35**					
4. Vision Inference	3.84	1.22	.41**	.47**	.65**				
5. Vision Total	7.89	2.20	.44**	.45**	.91**	.91**			
6. Fight Memory	3.80	1.03	.36**	.43**	.39**	.40**	.43**		
7. Fight Inference	3.57	1.26	.40**	.42**	.43**	.47**	.49**	.48**	
8. Fight Total	7.37	1.98	.44**	.49**	.48**	.51**	.54**	.83**	.89**

Figure 1

Comprehension Test Score as a Function of Item Type, Online Condition, and Offline Condition



We conducted a series of binomial generalized linear mixed effects models (GLMMs) to examine the effects of online and offline strategy prompts on comprehension test score. In the baseline model, participant and item were included as random effects. In subsequent models, we added fixed effects in the following order: item type (memory, inference; m1), text (Vision, Fight or Flight, m2), online condition (think-aloud, self-explain, m3), offline condition (reread, recall, explain; m4); and the online × offline interaction term (m5). Likelihood ratio tests revealed that the best fit model was m3, which included item type, text, and online condition.

This model accounted for 39% of variance in comprehension test score, with only online condition as a significant predictor (Table 3).

Table 2

Model Comparisons

Model	AIC	BIC	χ^2	p
m1	3926.20	3951.50	0.00	0.99
m2	3927.70	3959.40	0.52	0.47
m3	3917.60	3955.70	12.02	0.00
m4	3920.30	3971.00	1.34	0.51
m5	3922.60	3986.10	1.65	0.44

Table 3

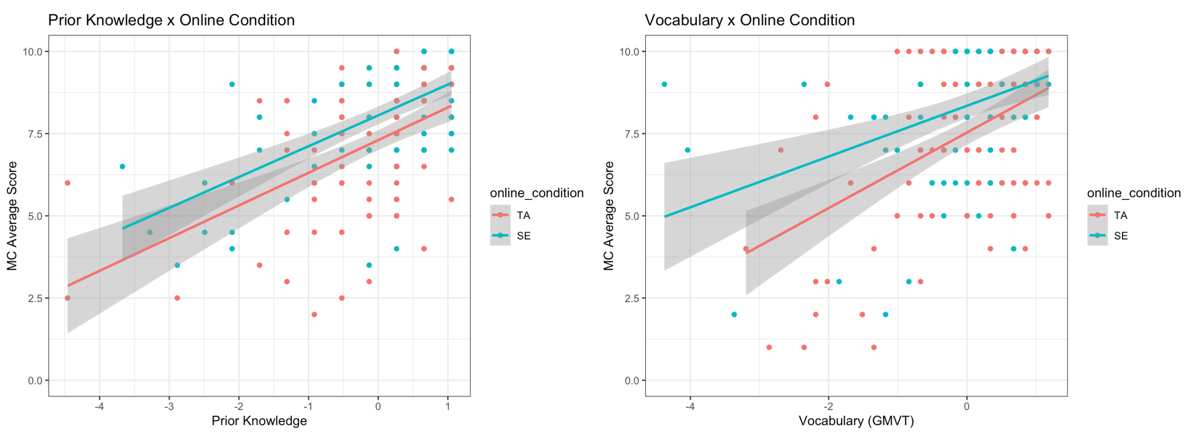
Fixed Effects of Best Fit Model (m3)

Fixed Effects	Odds Ratios	*SE*	*p*
(Intercept)	3.29	1.30	0.00
Item Type (memory)	1.00	0.41	0.10
Text (Vision)	1.34	0.54	0.47
Online Condition (SE)	1.87	0.33	**<0.01**

As exploratory analyses, we examined how individual differences in vocabulary and prior knowledge affected comprehension test score. We added prior knowledge z-score (m3b) and the prior knowledge × online condition term (m3c) to the best fit model. In a separate analysis we added vocabulary test z-score (m3d) and the vocabulary × online condition term (m3e) to the best fit model. While the two individual differences variables increased model fit (prior knowledge: $\chi^2 = 66.33$, $p < .001$; vocabulary = $\chi^2 = 57.68$, $p < .001$), the interaction terms did not (χ^2s < 1.00). These effects are shown in Figure 2.

Figure 2

Correlation Between Prior Knowledge and Comprehension Test Score as a Function of Online Condition



Discussion

This study explored the independent and combined effects of an online study strategy (self-explanation) and offline study strategies (retrieval practice, explanatory retrieval), as compared to standard control conditions (think aloud, reread). Analyses reveal a benefit of self-explanation on immediate test performance. This finding adds to the existing literature demonstrating that self-explanation during reading can enhance comprehension (Bisra et al., 2018).

The data show no overall benefit of retrieval practice or explanatory retrieval, but also showed no obvious advantage for the reread condition on this immediate test, contrary to previous research (e.g., Congleton & Rajaram, 2012; Roediger & Karpicke, 2006). Ultimately, these results support the suggestion that retrieval practice benefits may only arise after a delay. They further demonstrate that explanatory or elaborative retrieval prompts, regardless of any additional benefits at delay (Endres et al., 2017; Hinze et al., 2013), were not sufficient to enhance performance on an immediate test. To further explore this issue, we are in the process of conducting a preregistered test of these manipulations using a delayed comprehension test (McCarthy & Hinze, 2021).

Although only exploratory, our analysis of individual differences suggest no interactions between vocabulary knowledge or general science knowledge and the online strategy manipulation. This is somewhat surprising given existing research demonstrating that self-explanation is particularly beneficial for less skilled and less knowledgeable readers (e.g., McNamara & Kintsch, 1996; O'Reilly & McNamara, 2007; Ozuru et al., 2009). A limitation of this individual differences analysis is that scores on the vocabulary and prior knowledge tests were generally high, potentially reducing our ability to detect differences among lower skilled individuals.

We are in the process of analyzing the constructed responses (think-aloud, self-explanation, recall, explanations) to examine how the quality of these responses relates to comprehension performance and the extent to which online processing might impact the quality of offline responses. Based on this research, we hope to provide recommendations for enhancing performance on immediate tests. It may also help to differentiate the benefits of self-explanation, which are immediately available as a result of enhanced comprehension, from the benefits of retrieval practice, which may be moderated by the quality of a mental model, and become available after a delay.

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