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Angel Long is now at the department of psychology, Georgia Southern University.

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Abstract

We explored whether self-explanation strategies influence the "screen inferiority effect." Participants read a text on paper or a computer monitor and received instructions to self-explain or to read for comprehension. On a subsequent comprehension test, we observed a screen inferiority effect, but only in the self-explanation condition. Analyses of processing times, metacognitive judgments, and constructed responses are presented to help explain these results.

Keywords: science text comprehension, self-explanation, digital reading

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Comprehension of expository texts tends to be superior in a printed medium when compared with reading via digital displays such as a computer screen or e-reader (Clinton, 2019; Singer & Alexander, 2017). This phenomenon is known as the "screen inferiority effect." The current study attempts to replicate the screen inferiority effect and explores whether this effect is influenced by prompting students to engage in active reading strategies.

Considerations of reading strategies are important in this context because differences in reading strategies may underlie the issues with digital reading. When reading on a screen, research participants tend to be overconfident in their understanding of the text (Ackerman & Goldsmith, 2011). Consequently, readers spend less time processing the text, and process it less deeply, when compared to reading on paper (Singer-Trakhman, et al., 2019). This may be because readers apply different goals, expectations, or strategies to reading via different media.

Based on these previous accounts, reading strategy interventions that encourage readers to accurately monitor their understanding, and to process information deeply for comprehension, should moderate the discrepancy between screen and paper texts (Lauterman & Ackerman, 2014). In this study, we explore one such intervention: self-explanation. Self-explanation involves readers describing and elaborating upon content to themselves while they read. Skilled readers spontaneously self-explain -- they monitor their comprehension as they read, connect information across the text, and integrate information from prior knowledge (Wolfe & Goldman, 2005). In addition, prompting students to self-explain can help less skilled readers leverage these same benefits (McNamara & Magliano, 2009).

As outlined above, the benefits of self-explanation (comprehension monitoring and deep processing) align with factors thought to underlie the screen inferiority effect. Thus, we assigned participants to either read from paper or a computer monitor, and either included or excluded prompts to self-explain. Participants then completed a test on the text content.

Our primary hypotheses related to test performance. We predicted main effects such that paper reading would outperform screen reading (a screen inferiority effect), and that self-explanation prompts would enhance performance (a self-explanation effect). We also predicted an interaction such that the self-explanation prompts would reduce the negative effects of screen reading by prompting both groups of readers to engage in similar effective reading strategies. We also analyzed processing time and confidence to replicate previous findings.

Method

Materials and Procedure

Participants (n = 103, 67 female) completed the study in a computer lab classroom. All participants read a 454-word text on the topic of Vision (from Hinze, et al., 2013), which was relevant to their coursework. Participants were randomly assigned to a medium condition. Half read the text presented digitally on 22” computer monitors (screen condition), and the other half were prompted to open a printed reading packet to read the same text on paper (paper condition). In both medium conditions, participants completed the tasks at their own pace, with processing time recorded by a computer when the participants advanced to the next task.

In addition to the medium manipulation, participants were randomly assigned to a reading strategy condition. Control participants were instructed to read the text for comprehension, with the text appearing on a single printed or digital page without the need to turn pages or scroll. Participants in the self-explanation condition, in contrast, received instructions to write an explanation for each of nine targeted sentences from the text. Sections of the text were presented across nine printed or digital pages, and participants' explanations were either hand-written or typed in a textbox prior to proceeding to the next page.

After finishing the text, all participants made judgements of learning (JOLs) where they predicted their performance on a 10-item test. Finally, participants completed a 10-item short answer test on the computer, which included 5 detail and 5 inference items (modified from Hinze et al., 2013).

Coding

All SA test responses were scored by a single rater. A second rater scored responses for 26 (25.24%) participants (a total of 260 scores), with agreement on all but one score. After resolving the disputed score, the scores from the initial rater were maintained for all test responses.

Self-explanation responses (9 per participant in the SE conditions) were scored on a 0-3 scale. A score of 0 reflected a response that was too short, or completely off topic. A score of 1 reflected a paraphrase of the target text content. A score of 2 reflected a bridging inference, connecting the target content to previous text content. Finally, a score of 3 reflected an elaboration (e.g., by connecting to multiple pieces of previous content, making a prediction, or connecting information to real-world applications or examples). Two raters scored all SEs, with good inter-rater reliability (Weighted Kappa = .87). All disagreements were resolved by a third rater.

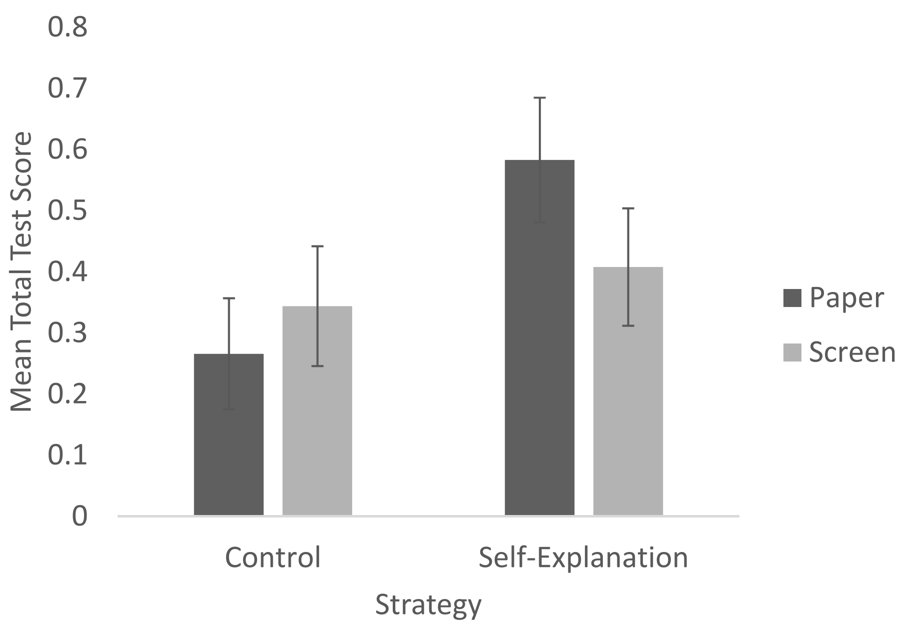
Results

Test Scores

First, we analyzed the effects of medium and strategy on test scores using 2 X 2 analysis of variance (ANOVA; see Figure 1). While the tests consisted of 5 detail and 5 inference items, question-type did not significantly interact with any other factor, so we have collapsed across this variable to create a total test score DV for the analyses below.

Figure 1

Effects of medium and strategy on Total Test Scores.



Note. Error bars on all figures represent 95% confidence intervals.

Participants prompted to self-explain scored significantly higher on the test (*M* = .49, *SD* = .29) than control participants (*M* = .30, *SD* = .23), as indicated by a main effect of strategy, $F(1, 99) = 15.20$, $p < .001$, $\eta^2 = .13$. This finding replicates the typical advantage for self-explanation, as compared to a self-regulated reading control.

There was no main effect of medium, with similar scores after reading on screen (*M* = .37, *SD* = .25) and on paper (*M* = .39, *SD* = .29), $F < 1$. This finding does not replicate the screen inferiority effect.

There was a significant medium by strategy interaction, $F(1, 99) = 6.73$, $p = .01$, $\eta^2 = .06$. Analysis of Figure 1, and simple effects, demonstrates that a significant screen inferiority effect *was* observed in the self-explanation condition ($p = .02$). The simple effect of medium was reversed, though not significant, in the control condition ($p = .262$).

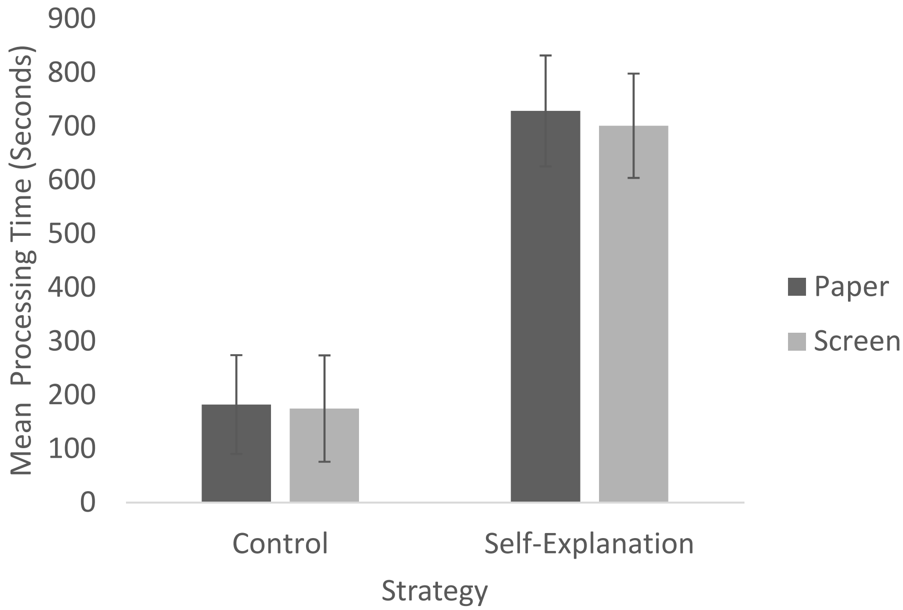
In sum, the results demonstrated an overall benefit of self-explanation over the control strategy, and higher performance after self-explaining on paper, as compared to self-explaining on screen.

Processing Time

Next, we considered processing time using a similar 2 X 2 ANOVA (see Figure 2). Processing times were unsurprisingly longer in the self-explanation conditions ($M = 714.12$s, $SD = 353.99$) than control ($M = 179.12$s, $SD = 53.93$), as indicated by a main effect of strategy, $F(1, 99) = 118.15$, $p < .001$, $\eta^2 = .54$.

Figure 2

Effects of medium and strategy on processing time.



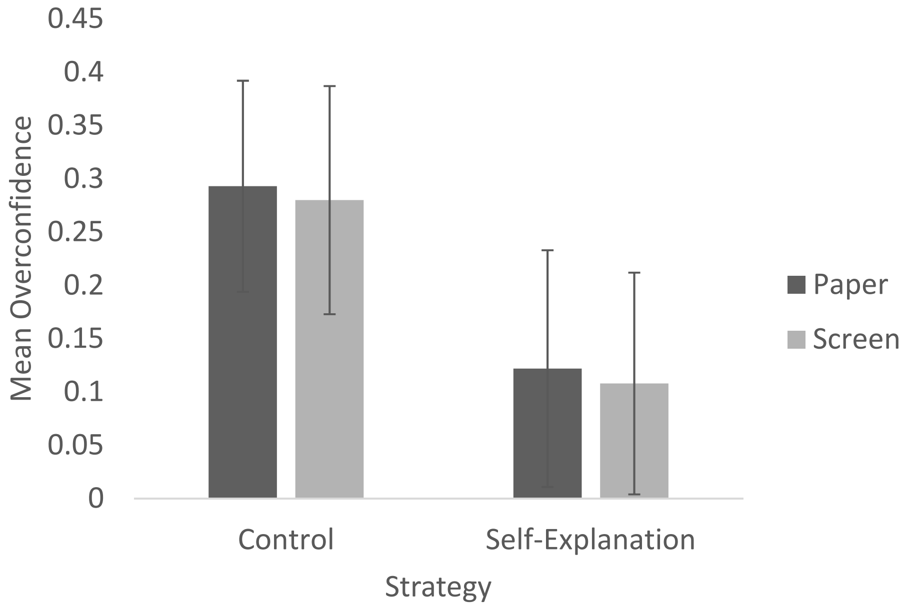
There was no main effect of medium, nor a significant medium by strategy interaction (*Fs* < 1). As such, we did not replicate the finding that readers spend longer on paper compared to digital reading.

Overconfidence

Next, we considered a similar 2 X 2 ANOVA for overconfidence, operationalized as the difference between JOLs and test scores (see Figure 3). Participants were generally overconfident, as indicated by a mean overconfidence scores ($M = .21$, $SD = .28$) higher than zero.

Figure 3

Effects of medium and strategy on overconfidence (JOL – Total Test Score).



Overconfidence was overall lower in the self-explanation (*M* = .11, *SD* = .28) compared to the control condition (*M* = .29, *SD* =.25) as indicated by a significant main effect of strategy, $F(1, 99) = 10.45$, $p = .002$, $\eta^2 = .10$.

There was no main effect of medium, and no interaction (*F*s < 1), indicating that reading on a screen did not seem to exacerbate overconfidence.

Self-Explanation Quality

Given that we observed a screen inferiority effect specifically in the SE condition, we finally considered whether the quality of SE protocols was superior when SEs were completed on paper as compared to on screen. For the DV in this analysis, each participant in the SE conditions received an overall SE quality score by calculating the mean of all nine SE scores.

Average SE quality was nominally higher in the paper condition (*M* = 1.71, *SD* = .45), than the screen condition (*M* = 1.51, *SD* = .57), but this difference did not reach significance, $t(47) = 1.34$, $p = .09$, $d = .38$.

Discussion

Based on the current results, the screen inferiority effect was moderated by reading strategies, but in a manner we did not predict. Below, we consider (1) the null effect of medium in the control condition, (2) the general benefits of self-explanation, and (3) the screen inferiority effect in the self-explanation condition.

Control participants, who self-regulated their reading times and strategies, demonstrated no screen inferiority effect in terms of performance. This finding is inconsistent with previous research findings of a screen inferiority effect in self-regulated reading (Clinton, 2019). The performance similarities in the control condition may be best explained based on the similar processing times and overconfidence across media. Previous research demonstrates that the screen inferiority effect is mediated by reading times (Singer-Trakham et al., 2019), and characterized by overconfidence in screen conditions (Lauterman & Ackerman, 2014), presumably due to varying expectations or strategies adopted for different media. As control participants did not demonstrate these differences, it may not be surprising that their comprehension performance was similar.

An alternative explanation for the null screen inferiority effect in the control condition is that all participants took the test on screen. This may have proven somewhat problematic for participants in the paper reading condition, as they were required to shift media from reading to test. However, this account does not explain why no differences were observed for the reading time or overconfidence measures, which occurred prior to the test phase. It also does not explain why the screen inferiority effect *was* observed in the self-explanation condition.

We next consider the main effects of self-explanation. Participants prompted to self-explain not only scored higher on the final tests, but also spent longer on the task, and demonstrated less overconfidence in comparison with the control group. These overall effects are consistent with previous research demonstrating benefits of self-explanation on comprehension (Bisra et al., 2018) and metacognitive accuracy (Griffin, et al., 2008). However, the design of our manipulation does not allow us to isolate the specific mechanism responsible for these benefits. In addition to explaining the content, which elicits inferential processing (McNamara & Magliano, 2009), self-explanation participants clearly demonstrated longer processing times, regardless of medium. In addition, the self-explanation condition may have benefitted from segmentation of the text, awareness of metacognitive cues (Griffin et al., 2008), or simply from producing a response. Any of these features could have led to increased test performance or reduced overconfidence. Because we did not set out to *explain* the SE effect, but rather to compare the screen inferiority effect under different strategies, we make no strong claims as to the mechanism responsible for these main effects.

Perhaps most interestingly, participants asked to self-explain *did* demonstrate a screen inferiority effect. As such, the beneficial aspects of self-explanation on test scores seem to have been more effective for participants explaining on paper, compared to on screen. Participants may have adopted different approaches to the self-explanation tasks across media (e.g., elaboration vs. paraphrasing; McNamara & Magliano, 2009), but any differences in these approaches were not significant in our analysis of the quality of self-explanations. Other advantages of writing explanations by hand may include activation of kinesthetic information that enhances contextual memory (Mangen, et al., 2019), differences in editing responses prior to production, or issues with typing proficiency. Further research may be warranted to investigate the differences between typed and hand-written self-explanations.

In conclusion, we demonstrated that self-explanation reading strategies are a potentially important moderator of the screen inferiority effect. This has implications for the study of digital reading, as it implies that the effect of medium may depend on readers engaging in certain active reading strategies. It also has potential implications for the implementation of explanation-based reading strategies. While typed explanations make automated feedback and adaptive training easier, there may be some immediate advantages to constructing explanations on paper.

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