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Abstract

This study tested how instructional visuals affects students' judgments of learning. Participants studied four texts with or without visualizations. For each text, students rated how well they would perform on a test of the material, how well they could explain the material, how well they could draw the material, and completed comprehension tests. The presence of visuals did not affect comprehension performance; however, it did significantly hinder relative monitoring accuracy, specifically for judgments of drawing.

Keywords: science text, metacomprehension, drawing, visualizations

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Instructional visuals, such as diagrams or illustrations, are often used to supplement science texts. Visuals are powerful tools because they can display complex, dynamic, and imperceptible phenomena in more efficient and meaningful ways than text alone (Mayer, 2020). However, many students study provided visuals passively or struggle to build appropriate relationships between the visuals and corresponding parts of the text (Renkl & Scheiter, 2017; Schnotz & Wagner, 2018). The presence of visuals may also interfere with students' ability to effectively *monitor* their own learning (Jaeger & Wiley, 2014; Serra & Dunlosky, 2010; Wiley, 2019; Wiley, et al., 2017), or distinguish between topics that are better or less well-understood. Students' monitoring judgments are important because they inform subsequent study choices.

According to the cue-utilization framework, readers use cues available to them during learning to make metacognitive judgments (Koriat, 1997). For example, cues may include the perceived familiarity or fluency of the text, or whether the information described in text conflicts with one's existing knowledge. Visuals provide additional cues, such as the perceived familiarity or complexity of the visuals, which may affect students' judgments. The accuracy of one's judgments depends on whether the chosen cues are consistent with factors that affect test performance. According to the situation-model approach to metacomprehension (Wiley, Thiede, & Griffin, 2016), accurate comprehension monitoring depends on the use of *situation-model-based* cues—those most aligned with comprehension questions that require understanding relations among ideas. Although instructional visuals are intended to help students build a situation model, students may focus on superficial features of visuals that negatively affect their monitoring accuracy.

The current study explored how the presence of visuals affects students' monitoring accuracy for *different types* of metacognitive judgments. Prior research has typically focused on students' judgments concerning how well they will perform on a test or their ability to explain key concepts (Griffin, Mielicki, & Wiley, 2019). However, in science, one's ability to *draw* key concepts may be a unique indicator of one's understanding (Ainsworth et al., 2011). Research suggests generating drawings of key concepts can improve student understanding and support self-monitoring (Fiorella & Zhang, 2018), yet little is known about students' *judgments of drawing* and its relationship to students' actual level of understanding. In the present study we hypothesized that students' judgments of drawing may be especially affected by the presence of instructional visuals. Specifically, it was hypothesized that students may exhibit lower monitoring accuracy if they focus on superficial cues from the visuals, or if the availability of the visuals inflates the sense that they would be able to create the visuals on their own. Thus, we predicted that students in the text-and-image group would demonstrate lower levels of metacomprehension accuracy than students in the text-only condition. Further, we predicted that students' judgments of drawing would be especially inaccurate when images were presented alongside the text.

Method

Participants and design

Participants were 226 undergraduates recruited from St. John's University (n=182) and the University of Georgia (n=44). Four participants were dropped for taking over 24 hours to complete the study, 53 were dropped for spending fewer than 20 minutes completing the study, and 6 were dropped for having no variance in their judgments. The final sample consisted of 163 participants. Students were randomly assigned to the text-and-image condition (n=92) or the text-only condition (n=71).

Materials

Learning materials included six texts (approximately 600-900 words) on human organ systems: digestive, respiratory, circulatory, renal, lymphatic, and nervous. For the text-and-image condition, the text was supplemented with 2-3 labeled diagrams depicting key structures and processes. For each text, students completed an 8-item multiple choice comprehension test (e.g., “Which of the following best describes what happens to lymph fluid that is removed from the interstitial spaces of the body and taken up by the lymphatic system?”).

Students made three judgments of learning for each text: test performance (e.g., If you were to take a test on the material that you just read, how many questions out of 5 would you answer correctly on the test?), explanation performance (e.g., On a scale from 1 to 10, how well would you be able to explain to a friend the lymphatic system and how it helps to maintain balance between the blood and tissue fluid?), and drawing performance (e.g., On a scale from 1 to 10, how well would you be able to draw the lymphatic system and how it helps to maintain balance between the blood and tissue fluid?). We calculated *absolute accuracy* by computing the mean absolute deviation between each judgment and performance on the multiple-choice test. We calculated *relative accuracy* by computing an intra-individual correlation between readers' judgments for each text relative to the other texts, and their actual performance on each test relative to other tests.

Procedure

Participants completed the study online via Qualtrics. Each participant was randomly assigned to read four of the six texts. After each text, students completed the three judgments of learning (test, explain, and drawing judgments). Then students completed the inference tests for each of the texts they read. Finally, students completed demographics measures and self-reported their prior experience with each of the topics from the texts.

Results

Comprehension and judgment magnitude

Independent samples t-tests indicated the text-and-picture group and the text-only group did not significantly differ on comprehension test performance, $t < 1$ (see Table 1). The text-and-picture group and the text-only group also did not differ in terms of judgment magnitude for test performance judgments ($t(161) = 1.90$, $p = .06$) or explanation judgments ($t(161) < 1$, *ns*). However, for drawing judgments, students in the text-and-picture group made higher judgments than students in the text-only group ($t(161) = 2.02$, $p = .045$).

Monitoring Accuracy

To examine differences in relative metacomprehension accuracy as a function of image condition and judgment type, a 2x3 repeated measures ANOVA was conducted. This analysis revealed no main effect of judgment type, $F(2, 129) < 1$. The main effect of image condition was significant and indicated that metacomprehension was more accurate in the text-only group compared to the text-and-image group, $F(1, 129) = 4.38$, $p = .038$, $\eta_p^2 = .033$. The interaction between judgment type and image condition did not reach significance, $F(2, 129) = 2.04$, $p = .13$, $\eta_p^2 = .02$. However, to test the a priori prediction that images would be especially harmful for judgments of drawing, an independent samples t-test was conducted comparing drawing judgment accuracy for the text-and-image group to the text-only group. This analysis revealed that students in the text-and-image group showed significantly worse relative accuracy for drawing judgments than the text-only condition, $t(147)=3.10$, $p<.002$ (see Figure 1).

A 2x3 repeated measures ANOVA was also conducted to examine the impact of judgment type and image condition on absolute judgment accuracy. This analysis revealed a significant main effect of judgment type, $F(2, 161) = 4.19$, $p < .02$, $\eta_p^2 = .03$. Follow up pairwise comparisons with Bonferroni correction indicated drawing judgments were less accurate than test judgments ($p = .03$), but there were no differences between drawing and explanation judgments or between test and explanation judgments. There was no main effect of image condition and no interaction between image condition and judgment type, *F*s < 1.

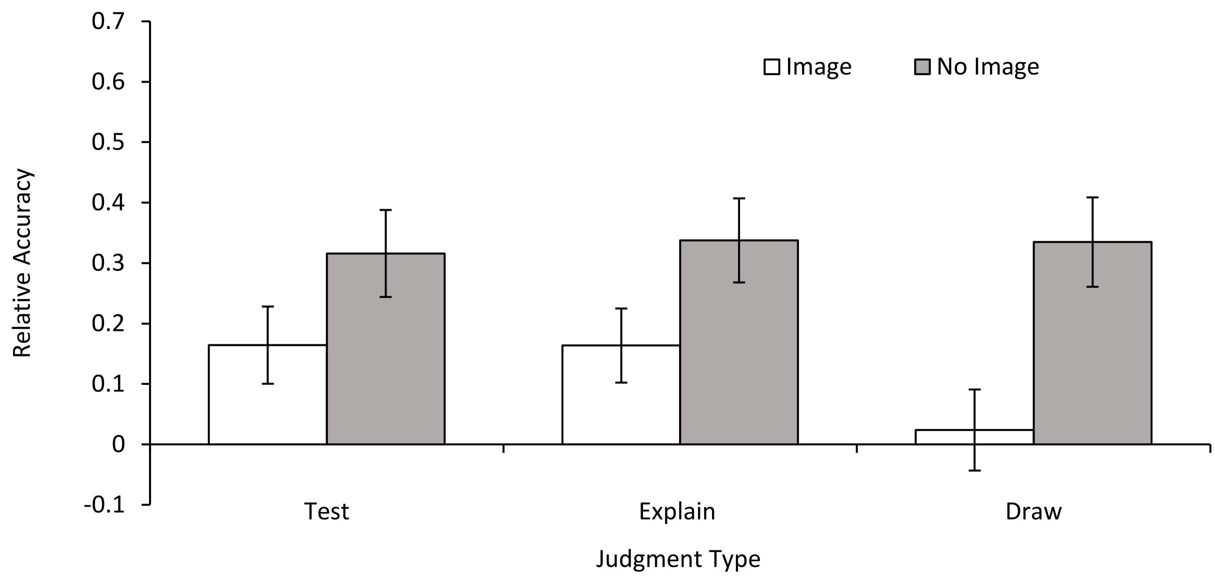
Table 1

Means and standard deviations for test score, judgments, and monitoring accuracy measure as a function of image condition

	Text Only M (SD)	Text-and-Image M (SD)
Test Score	16.13 (5.30)	16.08 (4.30)
Explain Judgment	4.59 (1.55)	4.80 (1.76)
Test Judgment	2.50 (.73)	2.73 (.79)
Draw Judgment	4.12 (1.58)	4.68 (1.89)
Explain Relative Accuracy	.34 (.58)	.16 (.56)
Test Relative Accuracy	.32 (.57)	.16 (.56)
Draw Relative Accuracy	.33 (.60)	.02 (.61)
Explain Absolute Accuracy	.22 (.10)	.21 (.09)
Test Absolute Accuracy	.21 (.10)	.21 (.09)
Draw Absolute Accuracy	.23 (.10)	.23 (.09)

Figure 1

Mean Metacomprehension Accuracy as a Function of Image Condition and Judgment Type



Note. Error bars represent standard error of the mean.

Discussion

This study yielded two main findings. First, the presence of images did not affect comprehension performance. This is consistent with prior research suggesting students do not actively process visuals spontaneously. Second, the presence of images interfered with students' relative accuracy, most notably when making judgments about their ability to draw key concepts as opposed to their test performance or their ability to explain key concepts. This suggests students may rely on cues from the images when making drawing judgments despite that these cues may not be diagnostic of their understanding. We are currently conducting a follow-up study to directly examine the types of cues students use to make their judgments of drawing with and without the presence of images. One limitation of this study is that we associated students' judgments of drawing with comprehension performance (rather than drawing performance) to calculate relative accuracy. However, prior research shows that the quality of students' *actual* drawings are strongly predictive of their subsequent comprehension performance. Nonetheless, future research should also examine how judgements of drawing relate to actual drawing performance when learning with or without images.

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