Examining readers' mental representations of texts in reading comprehension: The influence of text availability on reading comprehension performance and visual memory

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Abstract

This study aimed to examine the role of mental model formation by examining the effect of text availability on reading comprehension (RC) performance and visual memory in 7th and 8th grade students. Participants were given an RC test in which they answered multiple-choice questions and were subsequently given the text structure and asked to identify information relevant to answering the questions. Participants' eye movements were monitored throughout. One purpose of this study was to examine text availability's impact on RC performance (including accuracy and reading time). A second purpose of this study was to examine the effect of text availability on visual memory (i.e., the ability to identify supporting information in the text). Finally, this study investigated if reading achievement and working memory (WM) are related to the relationship between text availability and RC performance, and between text availability and visual memory, respectively. I found that without-text readers had longer initial reading times than with-text. Additionally, without-text participants were more accurate and precise in their identification of relevant textual information. Next, participants with higher reading achievement levels had faster reading times. Finally, participants with higher WM were more accurate in their visual memory. Unexpectedly, higher-WM participants also had slower times for locating information in the visual memory task. These findings indicate that students should focus on reading strategies that foster strong mental model formation, such as slowing down during the initial read of text. The results also clarify the roles of reading achievement and WM in mental model formation.

Introduction

Reading comprehension is an important skill for educational and career endeavors, as it is involved in students' class placement, screening for reading disabilities, and college and graduate school admissions (Clemens et al., 2020). For young students who are learning how to read, it is necessary to develop robust reading comprehension (RC) skills so these students can understand and make meaning from what they read, rather than simply recognizing words. RC abilities follow students into higher education, where being able to proficiently read and understand texts is required for learning new topics. Good RC continues to be important in the workplace as well, as reading is required for most careers. Even outside of education and the workplace, everyday scenarios such as reading food labels or looking at health documents involve RC skills.

Reading comprehension (RC) is when students read a text and extract meaning from it, making connections between what they are reading and what they already know to gain a greater understanding of the text. During the RC process, readers must visually process each individual idea of a text and connect these units to form a coherent mental representation of the text. This representation includes textual information and relevant prior background knowledge, and it is updated as the reader extracts new information from the text (Kendeou et al., 2014). This mental model has been found to predict good RC, as forming a coherent representation of the text is important for skills such as identifying relevant textual information (Cataldo & Oakhill, 2000).

One way to influence readers' mental model formation is by manipulating whether or not readers have access to the text while answering questions in RC tests, also referred to as text availability. When readers are aware that they will not have the text available while answering RC questions, it may prompt them to read the text more carefully and form a better mental model of the text, leading to better RC (Schroeder, 2011; Stamouli, 2021). Additionally, the

without-text condition may better resemble the real life scenarios readers face when reading a text. After reading a text, readers typically do not have access to that information, and instead rely on the understanding and meaning they have taken away during their initial reading of the text. For example, when students read a chapter from a textbook for one of their classes, it is expected that they have learned that material and can apply that learning to exercises in class. Consequently, it is salient to evaluate how readers perform without text access, as it is most representative of the RC conditions readers are under in the real world.

An important skill connected to mental model formation is being able to find information in the text that is important to the reader's goals, or visual memory of the text. In the context of an RC test, this important information would be text relevant to answering RC questions. In this study, visual memory of the text is defined as the ability to remember where supporting information is in the text that is relevant to answering RC questions. Having a good mental representation of the text can make locating relevant information easier and more efficient, so looking at visual memory can be an index of how robust one's mental understanding of the text is (Cataldo & Oakhill, 2000). The current study aimed to examine the process of mental model formation of the text in readers by studying the impact of text availability on RC performance and visual memory. Following reading the text and answering RC questions, I measured visual memory by presenting participants with the text structure (where the text is replaced by Xs and Os) and having them highlight what they believe is the relevant textual information for each RC question.

Text Availability

Text availability is one method of manipulating readers' mental model formation. In the context of this study, text availability is defined as participants being told prior to taking the RC

test if they will or will not have text access while answering RC questions. When participants have access to the text when answering questions, they know they can reread parts of the text to find or verify answers to questions. While rereading, students rely on techniques such as search skill, reading strategy use, reasoning skill, and motivation, and this processing is largely what determines RC performance (Ozuru et al., 2007). Conversely, in a without-text condition, students will likely read the text more carefully during the initial read and form a stronger mental model of the text. So, text availability is an important variable in the current study because it allows researchers to manipulate mental model formation in readers. RC performance in a without-text condition is primarily determined by processing that occurs during the initial read of the text, so students must rely on their memory of the text when being exposed to questions (Ozuru et al., 2007). Past studies have found that text availability increases RC accuracy on text-based and implicit multiple-choice questions (Guerrero & Wiley, 2018; Marmolejo-Ramos et al., 2014). Implicit multiple-choice questions are based on information not explicitly stated in the text. Text availability also increases accuracy on open-ended questions (Ferrer et al., 2017). These studies attributed the positive correlation between text availability and RC accuracy on these question types to participants being able to rely on the text while answering these RC questions which are based on passage information. Additionally, text access reduces the need for prior background knowledge because readers can rely on the text and remember information that they would otherwise need prior knowledge for (Ozuru et al., 2007). Under without-text conditions, reading skills such as reasoning and decoding abilities and reading strategies such as metacognition predict RC performance to a greater extent (Schaffner & Schiefele, 2013).

Looking at reading time data in addition to RC accuracy may also shed light on RC performance because it allows researchers to make inferences about cognitive processing. For

example, researchers can see what parts of the RC test readers spend more time on, such as on the initial read or rereads of the text, which can help identify what specific parts of RC readers struggle with. In this study, the initial read is the first time a reader looks through the text, while rereading is when a reader returns to the text while answering questions. For the relationship between text access and reading time, previous studies have had different results. In an eye-tracking study by Stamouli (2021), readers had better RC when they spent more time on the initial read of the text compared to question answering. Additionally, within this group of successful readers, readers who did not return to the text while answering questions spent more time on the initial read than all other groups. This finding was attributed to these readers forming a better, more coherent understanding of the text during the initial read, leading to less of a need to revisit the text while answering questions (Stamouli, 2021).

Some research has found that students have overall longer reading times when they have text access and spend more time rereading (Ardoin et al., 2019; Schroeder, 2011). Shroeder et al. (2011) looked at individual word reading times and reading times at clause boundaries and found that reading time measures associated with high-level integration processing were more strongly correlated with RC accuracy scores under without-text conditions. Ardoin et al. (2019), however, looked at rereading by examining the total reading time per word, and found that participants spent more time on higher-level processes (which include inferencing and attention controlling) when they had access to the text. Ardoin et al. (2019) defined rereading as when readers return to the text after the initial reading but before they answer questions. They associated less rereading with readers forming a better mental model of the text, and thus requiring less studying of the text.

Ferrer et al. (2017), however, found that students exhibit more rereading under without-text conditions, and they measured initial reading time and rereading times during the initial reading. They attributed this to readers processing the text more carefully since they knew they would not have text access while answering RC questions. Ferrer et al. (2017) viewed rereading differently than Ardoin et al. (2019), defining it as when readers are initially reading a text and go back to previous text segments during that initial reading. These studies' varying results may be attributed to their different definitions of rereading and the different reading time measures they examined. The current study examined reading time during the initial read for both text conditions and during the reread only for the with-text condition. This is because I am interested in rereading only when participants are answering questions, since this study is examining total reading behavior.

Locating Supporting Information in a Text

The process of forming a mental model of the text involves visual encoding of each individual word at the sentence level and connecting these encodings, requiring the activation of semantic and syntactic information associated with each word. Then, on a larger scale, individual ideas are connected to form a mental representation of the text (Kendeou et al., 2014). According to Ashcraft and Radvansky (2010), a mental representation of the text (which the source also refers to as a situation model) is a mental model that constitutes a simulation of a real or possible world that is described by the text. This mental model is then updated when there are changes to the situation in the text or new information to add (Ashcraft & Radvansky, 2010).

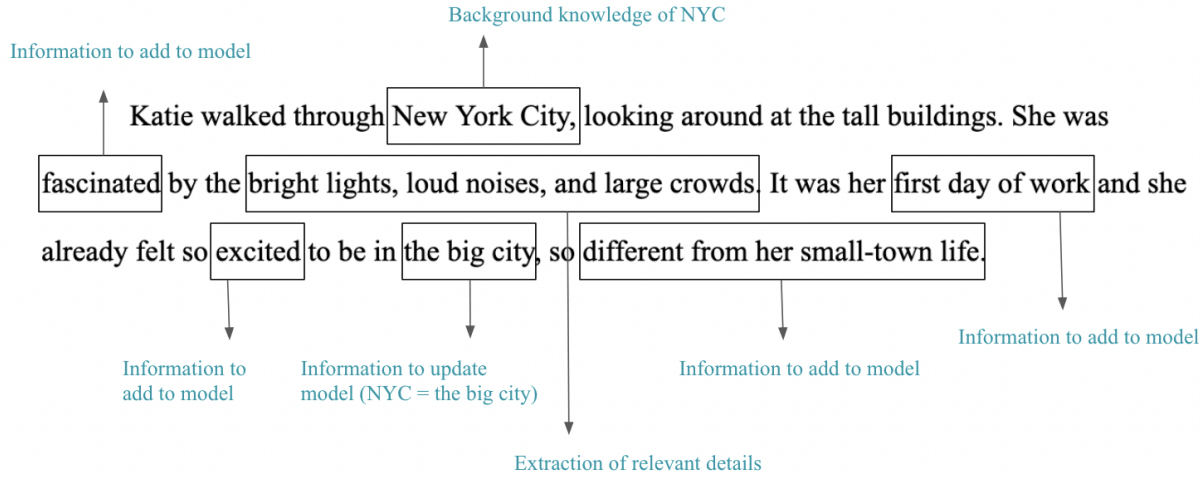


Figure 1: An example of the mental model formation from a section of a passage, displaying aspects such as the application of background knowledge, extraction of relevant details, and information to add to or update the model. Through this process, the main idea is extracted and is what is added to the readers' mental model of the text.

Visual memory of the text, or identifying relevant textual information, is an important component of how readers build a mental representation of a text. According to Guthrie and Mosenthal (1987), locating information in a text involves the following steps: forming a goal, choosing a text category to inspect, extracting relevant details, and recycling to find solutions. The ability to find this information leads to a more strategic reading of the text, helping readers distinguish between significant and less significant textual ideas and building stronger RC (Cataldo & Oakhill, 2000). In a study by Cataldo and Oakhill (2000), searching through the text was found to improve both good and poor readers' RC performance, and good readers were also found to be more efficient in their searching of the text.

Mental model formation of the text has been found to support good RC. Creating mental representations of the text helps readers form inferences through making connections between ideas and drawing conclusions from messages presented in the text (Ashcraft & Radvansky, 2010). Coherent text structures are important to form a good mental representation of the text, and manipulating text coherence is a way to measure the quality of the mental model (Cataldo & Oakhill, 2000). According to Ashcraft and Radvansky (2010), the structure of concepts presented in the text influences how readers process information and construct their mental model. When textual information is presented in a logical, predictable format, readers can process these ideas more easily and build a stronger mental representation. In studies that have examined coherent versus scrambled text representations, readers had better RC performance and increased recall when reading coherent text structures (Cataldo & Oakhill, 2000; Seki, 2001). Additionally, Mangen et al. (2013) investigated RC in different reading mediums and found that RC accuracy was higher for students who read in print compared to screens. The researchers attributed this to participants forming a more coherent mental model when reading in a print medium compared to an online medium. They drew this conclusion because reading on a screen introduces problems of navigation within the document. Readers must scroll through to read through the document, and according to prior studies, scrolling is known to interfere with mental model formation (Baccino, 2004; Eklundh, 1992). Consequently, coherent text structure supports RC due to helping in mental model construction. This finding shows that the formation of strong mental models has an important role in students' RC performance.

The visual aspect of mental model formation is connected to good RC, and this is explored in the current study by examining participants' visual memory. For instance, Casco et al. (1998) looked at the relationship between visual attention and RC in participants with varying

reading levels by giving readers a visual search task which consisted of searching for a target letter within a set of background letters. Accuracy was measured as a function of set size. The researchers found that readers with the poorest performance had a slower reading rate and a higher number of visual errors compared to readers with the highest performance. The researchers attributed this finding to poor readers having a deficit in their visual selective attention. Another study using a visual search task had similar results, finding that visual attention accounted for variance in RC (Liu et al., 2015). Hindmarsh et al. (2021) conducted an eye-tracking study and found that readers with below average reading skills had difficulty controlling horizontal and vertical eye movements while reading a text compared to those with average or above average reading abilities.

Given the importance of mental model formation and how it is connected to visual memory of the text and RC, the current study examined visual memory by having participants locate supporting information when given the structure of the text, composed of XOs instead of the actual words of the text (this structure is shown in Figure 2 and Figure 3 in the Methods). Participants were asked to identify this information in the XOs structure following reading the text and answering RC questions by highlighting what they believe to be the supporting information for each question. Participants with a better mental understanding of the text will have more strongly encoded the relevant textual information, likely making it easier for them to identify this information in the text structure (Kendeou et al., 2014). The current study also measured the time it takes students to locate the supporting information.

Student Characteristics (SCs)

Past research has established the relationship between student skills and reading comprehension. The student characteristics, or SCs, that were examined in this study are reading

achievement and working memory. Reading achievement includes components such as decoding, vocabulary, and fluency (Olson, 1985; Yeari & Lantin, 2021). Poor readers with low reading achievement have adequate reading abilities (i.e. word decoding), but still have significant difficulties with RC (such as poor text comprehension and memory), which may be due to their inability to engage in deep text processing (Yeari & Lantin, 2021). Deep text processing has been found to be linked to the creation of integrated, elaborated text representations by readers, which positively predicts RC performance. Poor readers engage in surface level processing, which entails making fewer connections between textual ideas and creating fewer elaboration and retrieval cues (Yari & Lantin, 2021). In terms of text access and RC accuracy, reading achievement is typically a more significant predictor of RC performance when readers do not have access to the text (Schaffner & Schiefele, 2013). This is likely because when readers cannot return to the text while answering RC questions, reading skills such as decoding and reasoning become more important during the initial read of the text. Under without-text conditions, participants will only be able to have this initial reading of the text, requiring that they rely more heavily on their reading achievement skills.

However, reading achievement is still influential in determining RC performance under with-text conditions. Cerdán et al. (2021) found that skilled readers with text access had higher RC accuracy and had higher recall of ideas compared to poor readers in the with-text condition. The researchers attributed this finding to more skilled readers benefiting more from the ability to return to the text, forming stronger mental models of the text and consequently having better RC performance compared to less skilled readers. Good readers also engage more often in higher-level processes (such as inference making and attention controlling) (Ardoin et al., 2019). Some studies have found that students use more higher-level processing under with-text

conditions (Ardoin et al., 2019), while others have found that students use more higher-level processing when they do not have text access (Shroeder et al. 2011), so there is conflicting information regarding the impact of reading achievement on the relationship between text access and the level of RC processing. Ardoin et al. (2019) argued that more skilled readers also form better mental representations of the text, resulting in participants reading more slowly and exhibiting less rereading of the text under both text conditions.

Ozuru et al. (2007) also present conflicting results regarding the relationship between higher-level processing and text availability. According to the researchers, readers likely have shallow processing during the initial read that relies more on background knowledge and putting together familiar elements in the text rather than constructing a mental model using new information. When readers do not have text access, they only have this processing to rely on while answering questions. Readers with text access can reread the text, however, and employ more deeper, higher-level processing. The researchers conclude that the two different text conditions emphasize different aspects of RC processing. However, accessing prior knowledge and retaining memory of the text are also higher-level processes. Additionally, Ozuru et al. (2007) assumes that readers are conducting a superficial initial read of the text, which may not always be the case, especially under a without-text condition where readers know they will not be able to reread the text.

Reading achievement also influences participants' visual memory of the text. Good readers are more efficient in locating supporting information while answering RC questions and have better recall of the order of words in a text (Cataldo & Oakhill, 2000). Good readers have better metacognitive skills which helps them monitor their understanding of the text (Vidal-Abarca et al., 2010). They also have better control over their horizontal and vertical eye

movements while reading, indicating that they have better visual attention, an important skill for visual memory (Hindmarsh et al., 2021). Additionally, studies using visual search tasks have found that poor readers have a higher number of visual errors and exhibit a deficit in visual selective attention (Casco et al., 1998; Liu et al., 2015). Mental model construction, an important part of visual memory, is also stronger in good readers, as reference and inference processes vary depending on the readers' reading achievement level (Ashcraft & Radvansky, 2010). One example of this variation based on reader skill has been examined in Long and De Ley (2000). According to Long and De Ley (2000), while good and poor readers resolve ambiguous pronouns equally as well, poor readers only do this when they are integrating meanings. More skilled readers are able to resolve ambiguous pronouns earlier on, closer to when they first encounter an ambiguous pronoun.

Working memory (WM) is another important component of RC, and is defined as the amount of information that can be held in the mind and used to execute cognitive tasks (Tang et al., 2019). Previous research has found that more skilled readers typically have higher WM (Daneman & Merikle, 1996) and that WM is closely related to metacognitive skills (Touron et al., 2010). WM has been shown to be associated with mental model formation of the text. In one study, Yeari (2017) found that high WM individuals are better able to incorporate new information into their mental models of the text and discard irrelevant information. Similarly, Daneman and Hannon (2001) found that creating a mental model of the text is more difficult for individuals with low WM, leading to lower RC performance. WM is also relevant for readers' visual memory, as Anmarkrud et al. (2013) found that higher WM individuals are better able to identify relevant sections of the text.

Regarding WM and text availability, research that has examined with-text versus without-text text presentations has found that readers use more higher-level processes in a without-text condition (Schaffner & Schiefele, 2013; Schroeder, 2011), and many of these higher-level processes include abilities that rely on WM (Ardoin et al., 2019). So, readers with higher WM may have better RC in a without-text condition due to utilizing more higher-level processing in their RC. Inference making, a skill connected to mental model construction, is also stronger in readers with higher WM. This is because the greater a reader's WM, the higher the possibility that the information needed for an inference will stay in working memory and can be used (Ashcraft & Radvansky, 2010). Because previous studies have found that reading skills are more important when students have no text access (Schaffner & Schiefele, 2013), it is likely that WM is a more significant predictor of RC performance under no-text conditions.

Current Study

The purpose of this study was to understand students' formation of a mental model of the text during reading by looking at the impact of text availability on RC performance and on the ability to identify supporting information in a text. A second aim of this study was to examine whether RC performance and visual memory are related to SCs. Reading achievement and WM are important skills for mental model formation (Ardoin et al., 2019; Schaffner & Schiefele, 2013; Schroeder, 2011) and may interact with text availability or visual memory.

Participants in 7th and 8th grade were measured on their reading achievement level and WM prior to completing the RC test. Participants read narrative texts and answered multiple choice questions, and were assigned to one of two conditions. In the with-text condition, participants had access to the text while answering RC questions, while participants in the without-text condition did not have the text available to them while answering questions. After

answering the questions, all participants were asked to locate supporting information for each question in the text when presented with the text structure (i.e. XOs replacing the actual words of the passage). Throughout this entire process, participants' eye movements were monitored.

This study consisted of four major questions. The first question was: Does text availability influence participants' RC performance? In the context of this study, text availability is readers' knowledge of whether or not they will have access to the text while answering reading comprehension questions. I hypothesized that having the text available to readers will result in higher RC accuracy because access to the text increases performance on text-based questions and relies less on reading skills, strategies, and prior background knowledge (Guerrero & Wiley, 2018; Ozuru et al., 2007; Schaffner & Schiefele, 2013). I also predicted that text availability will lead to decreased initial reading times, as Ferrer et al. (2017) found that participants spend less time reading the text during the initial reading under a with-text condition. Regarding rereading time in the with-text condition, I used readers' reading achievement and working memory as predictors of how much time they spend rereading the passage while answering questions.

The second question was: Does text access influence participants' ability to identify supporting information in a text, when given the structure of the text as opposed to the actual text? I hypothesized that the without-text condition was a better predictor of participants' ability to find relevant textual information (which involves precision with finding the information and the time it takes to identify the information), as previous research suggests that the without-text condition is a measure of participant's ability to form a mental model of the text, which is a skill associated with locating textual information and RC (Cataldo & Oakhill, 2000; Ozuru et al., 2007). Additionally, under the without-text condition, where participants knew they would not have text access, they may have read more carefully (Schroeder, 2011). Because they read more

carefully, they may have developed a better mental model of the text which would allow them to identify supporting information more easily. They may also have been more likely to better identify textual information relevant to answering the questions and locate less irrelevant information (Kendeou et al., 2014).

The third question was: Is reading achievement related to the relationship between text availability and RC performance, and between text availability and visual memory, respectively? I hypothesized that reading achievement would play a greater role in RC accuracy under without-text conditions than with-text conditions, since most previous research has found that reading skills and strategies are stronger RC predictors under without-text conditions (Schaffner & Schiefele, 2013). Regarding the impact of text availability on reading time, there are mixed results in the previous literature. However, since Ardoin et al. (2019) is most similar to the proposed study's methods and reading time measures, I predicted that more skilled readers would have shorter initial reading times under both no-text and with-text conditions, as good readers form better mental models of the text. In terms of the role of reading achievement in the relationship between text access and visual memory, I predicted that good readers will have a better ability to find relevant information in the text in both accuracy and speed, as they have better visual memory (Cataldo & Oakhill, 2000).

The fourth question was: Is WM related to the relationship between text access and RC performance, and between text access and visual memory, respectively? I hypothesized that WM will have a stronger role in RC accuracy under without-text conditions, as reading achievement and WM are highly correlated (Daneman & Merikle, 1996). Additionally, I predicted that individuals with higher WM will be better able to locate supporting information in the text (which entails the accuracy of identification of information and the speed with which readers

find the information), as WM and the ability to form mental models of the text are closely related, and mental model formation is important for RC visual memory (Daneman & Hannon, 2001).

Methods

Participants

Participants were 7th and 8th grade students attending school districts in the Southern United States. I recruited a total of 57 participants, who were randomly assigned to one of the two experimental conditions discussed above. There were 35 participants in the without-text condition and 22 participants in the with-text condition.

Materials

Woodcock Reading Mastery Test

To measure students' reading achievement, I used the Passage Comprehension subtest of the Woodcock Reading Mastery Test – Third Edition (WRMT-III). The Passage Comprehension subtest required participants to read sentences or short texts of increasing difficulty and identify missing words. It has a split-half reliability of .93-.95 (Woodcock, 2011). Administration of this subtest allowed for calculation of the overall Total Reading Ability standard score.

Test of Silent Reading Efficiency and Comprehension

I used the Test of Silent Reading Efficiency and Comprehension (TOSREC) to measure reading achievement in students. The TOSREC measured silent reading efficiency (the speed and accuracy of reading) and comprehension. Specifically, the TOSREC measured the efficiency with which connected text can be silently read for RC. The TOSREC is a list of simple sentences to which the participants respond true or false. Participants' score was how many of these sentences they got correct in three minutes.

Digit Span Task

To assess students' working memory, I used the Digit Span Task, administered via a computer. Digit span refers to the maximum number of digits correctly recalled in the task. On

each trial of the task, participants were presented with a series of digits on the computer screen, with each number appearing one at a time. There were two forms of the task: forward-span and backward-span. In the forward-span form, participants attempted to recall the list of digits in the order they appeared by typing them via keypress. For example, the participant may see 7 8 4 6, and their response is to type those values back in the order they appeared. In the backward-span form, participants attempted to recall the series of digits in the reverse order that they appeared in. For example, if the participant sees 7 8 4 6, their response would be 6 4 8 7. For both forms, after successfully finishing a trial (i.e. there are no digits missing and the order of digits was recalled correctly), the number of digits increased by one in the subsequent trial. After a failed trial, the number of digits stayed the same for the subsequent trial. Once the participant made errors for two trials in a row for a given digit span, the task ended.

Passage Selection

I first identified potential passages by purchasing standardized RC tests (e.g., Iowa Tests of Basic Skills) and conducting an online search for practice tests and released standardized tests. To be considered for inclusion, passages had to be categorized as 8th grade reading level by the test developer; be narrative; and not require the use of tables or other pictures in answering comprehension questions. A total of 119 passages met these criteria. In this study, I used passages that fit into a medium or long category. To categorize by difficulty, passages were analyzed across multiple readability formulae (e.g., Spache, Flesch Kinkaid) and metrics: decodability, vocabulary frequency, coherence, and lexical diversity. Using this data, two passages were chosen. The passages and question sets are provided in the Appendix.

Each passage had three literal and three inferential multiple-choice questions, and both passages were narrative text types. The passages consisted of 7 paragraphs, 19 - 21 sentences,

and are 362 - 366 words long and 1946 - 2016 characters long. The Spache score of the passages was 5.17 and 5.69, the lexical diversity was 7.69 and 7.17, the Flesch Kinkaid was 6.43 and 8.95, and the CohMetrix score was 11.93 and 9.73, respectively.

Apparatus

Eye movement data was collected using an SR Research Eyelink 1000 system, with a sampling rate of 1000 Hz, resolution of 0.01 degrees of visual angle, and range of 32 degrees horizontally and 25 degrees vertically. By default, eye movements were recorded via the right eye. However, viewing of the students was binocular. Eye-tracking was conducted using a 24-in. Asus VG248 monitor. The monitor measured locations and time on targets at particular locations.

Eye-tracking Program

Programs were designed to present the practice passage to all students first, and then the two assessment passages were presented to students in a randomized order. For the practice passage, the program first had students practice the highlighting function by asking them to highlight a specific part of the text on the screen. In the practice trial, after practicing the highlighting function, students were presented with the passage and answered three questions with or without the text (depending on which condition the student was in). Students did not see the XOs text structure in the practice trial. On the first display screen for each passage, the passage was displayed by itself. On each subsequent display screen for a passage, students under the with-text condition were able to see the passage and one of the six multiple-choice questions. On each subsequent display screen for a passage, students under the without-text condition were able to see one of the six multiple-choice questions, and did not see the passage. “Next” buttons were available for students to move between screens. Students could change answers at any point

and move between questions without answering both questions on a screen but were not allowed to proceed to the next passage until all questions were answered. To answer all six questions for each passage, students had to progress through six screens. After answering the questions for each passage, all students were presented with a screen that displayed the text structure of the passage, where the words of the text were replaced with XOs structure.

Data Collection

Parent permission and student assent was obtained from all participating students. Graduate research assistants administered the WRMT-III, TOSREC, and the Digit Span Task.

At the beginning of the eye-tracking session, students were informed that they would be reading stories from a computer screen and answering questions as a camera tracks their eye. Students were also informed if they would or would not have access to the text while answering the multiple-choice questions. Students sat at a table with their chin on a chinrest and their forehead resting against the top bar of the chinrest. A 24-in. monitor and eye-tracking camera was positioned approximately 93 cm and 65 cm from the student, respectively. Students read a practice passage and answered four multiple-choice questions before moving on to the two assessment passages. Before reading the assessment passages, students' eye movements were calibrated and validated to the eye-tracking camera with a 9-dot grid system. Once assessment began, students were asked to look at a fixation point before each new passage to ensure consistent calibration. Students were given the opportunity to take breaks between passages, and recalibration was conducted when necessary.

Students in the with-text condition had access to the text while answering multiple-choice questions for each passage. Students in the without-text condition had no access to the text while answering multiple-choice questions for each passage. After answering the questions, all

students were provided with the structure of the passage as opposed to the actual text, where XOs replaced the words within the text. Students were asked to highlight the section of the passage they believed provided the supporting information for each question. The time it took students to find the identifying information was measured, as well as their accuracy in locating the identifying information. For students' accuracy in finding the supporting text, we measured both the highlighting of the relevant text and any irrelevant text students highlighted. All students had their RC accuracy and initial reading time measured (i.e. the time it takes to read the passage prior to seeing the questions). Additionally, for students under the with-text condition, we measured the time they spent rereading the passage while answering questions.

The eye-tracking data was cleaned and coded by research assistants working in Dr. Katherine Binder's lab in the Department of Psychology at Mount Holyoke College. The data was coded for participants' precision with their search process for the supporting information in the text structure.

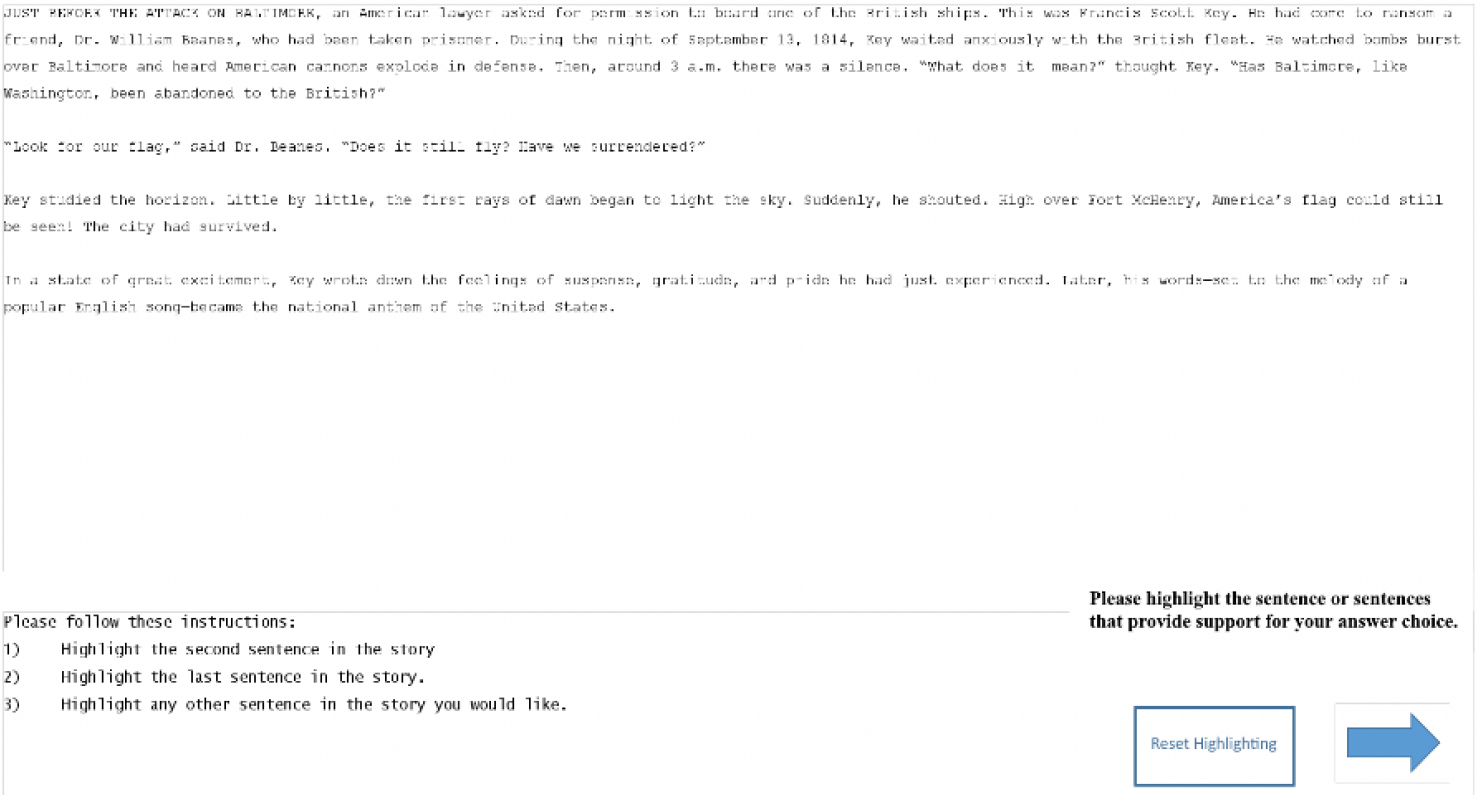
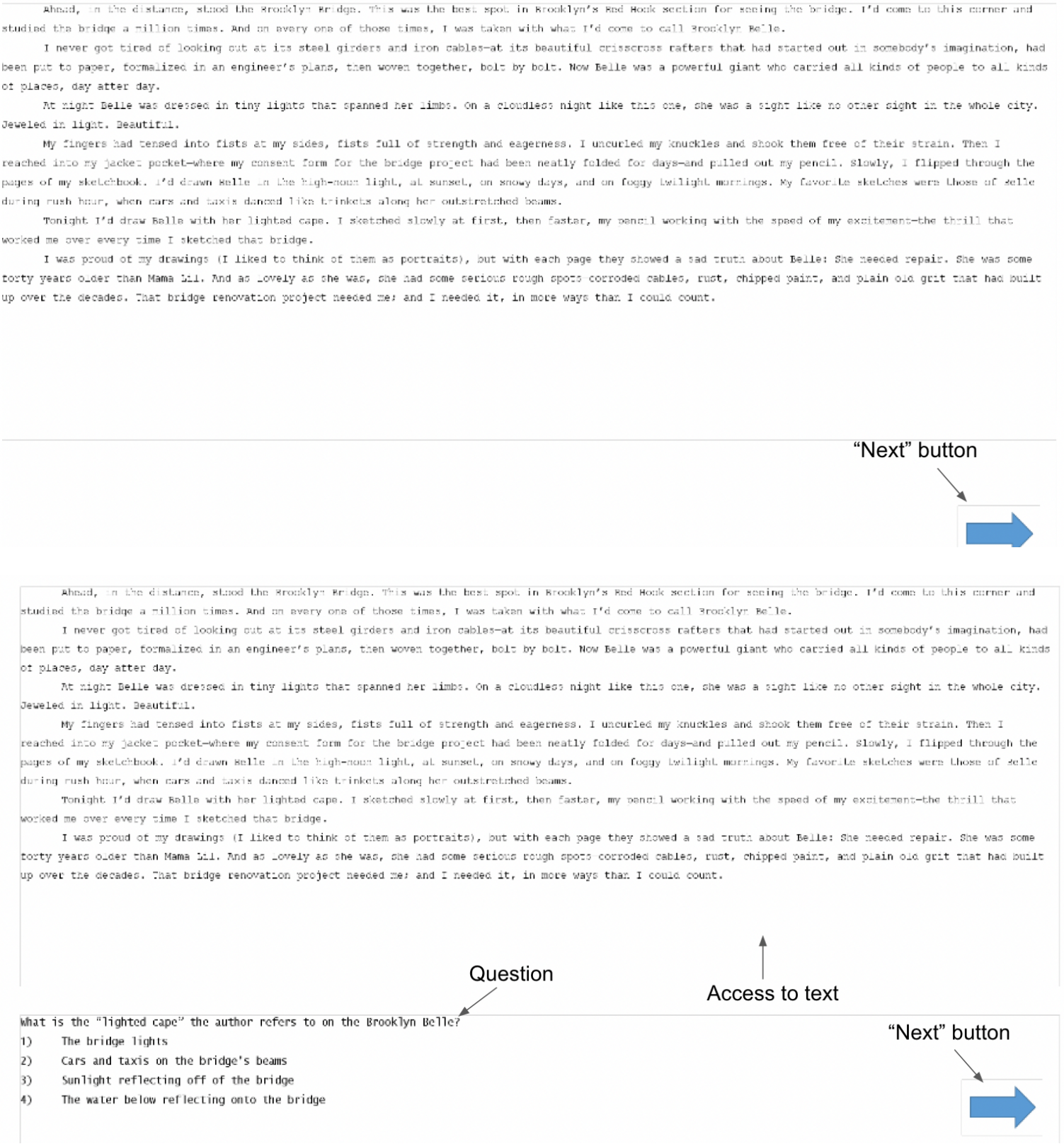


Figure 1: Screen displaying practice of the highlighting function for students in the practice trial.



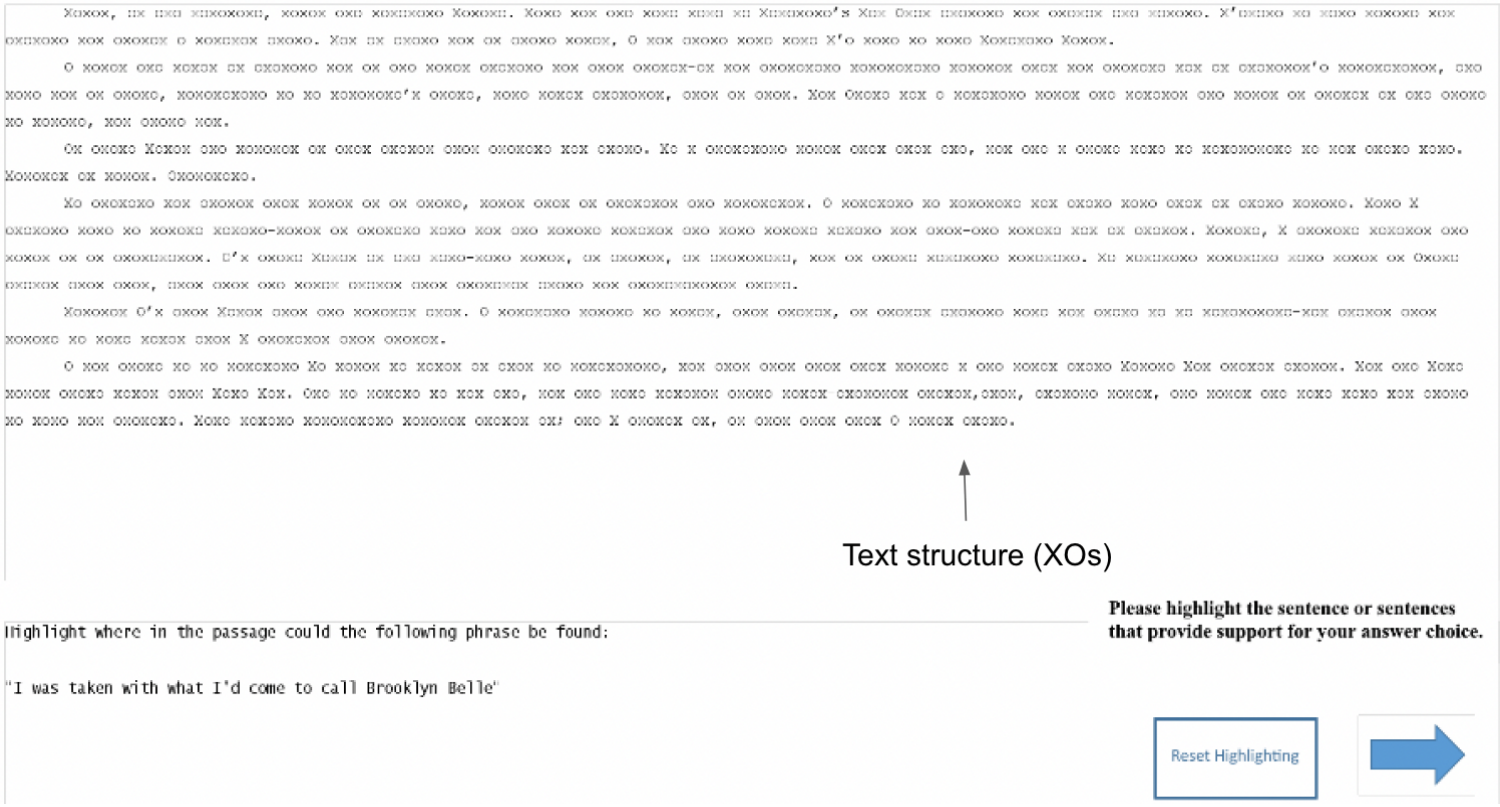


Figure 2: Procedure for the with-text condition. Screen 1 shows the passage, Screen 2 shows the passage and the question, and Screen 3 shows the text structure where participants will highlight the supporting information.

Ahead, in the distance, stood the Brooklyn Bridge. This was the best spot in Brooklyn's Red Hook section for seeing the bridge. I'd come to this corner and studied the bridge a million times. And on every one of those times, I was taken with what I'd come to call Brooklyn Belle.

I never got tired of looking out at its steel girders and iron cables—at its beautiful crisscross rafters that had started out in somebody's imagination, had been put to paper, formalized in an engineer's plans, then woven together, bolt by bolt. Now Belle was a powerful giant who carried all kinds of people to all kinds of places, day after day.

At night Belle was dressed in tiny lights that spanned her limbs. On a cloudless night like this one, she was a sight like no other sight in the whole city. Jeweled in light. Beautiful.

My fingers had tensed into fists at my sides, fists full of strength and eagerness. I uncurled my knuckles and shook them free of their strain. Then I reached into my jacket pocket—where my consent form for the bridge project had been neatly folded for days—and pulled out my pencil. Slowly, I flipped through the pages of my sketchbook. I'd drawn Belle in the high-noon light, at sunset, on snowy days, and on foggy twilight mornings. My favorite sketches were those of Belle during rush hour, when cars and taxis danced like trinkets along her outstretched beams.

Tonight I'd draw Belle with her lighted cape. I sketched slowly at first, then faster, my pencil working with the speed of my excitement—the thrill that worked me over every time I sketched that bridge.

I was proud of my drawings (I liked to think of them as portraits), but with each page they showed a sad truth about Belle: She needed repair. She was some forty years older than Mama Lil. And as lovely as she was, she had some serious rough spots corroded cables, rust, chipped paint, and plain old grit that had built up over the decades. That bridge renovation project needed me; and I needed it, in more ways than I could count.

"Next" button

No access to text

Question

The author refers to the Brooklyn Bridge as "Brooklyn Belle" to help the reader

1) understand that the bridge is very old
2) remember the bridge's history
3) imagine the noise around the bridge
4) appreciate the bridge's beauty

"Next" button

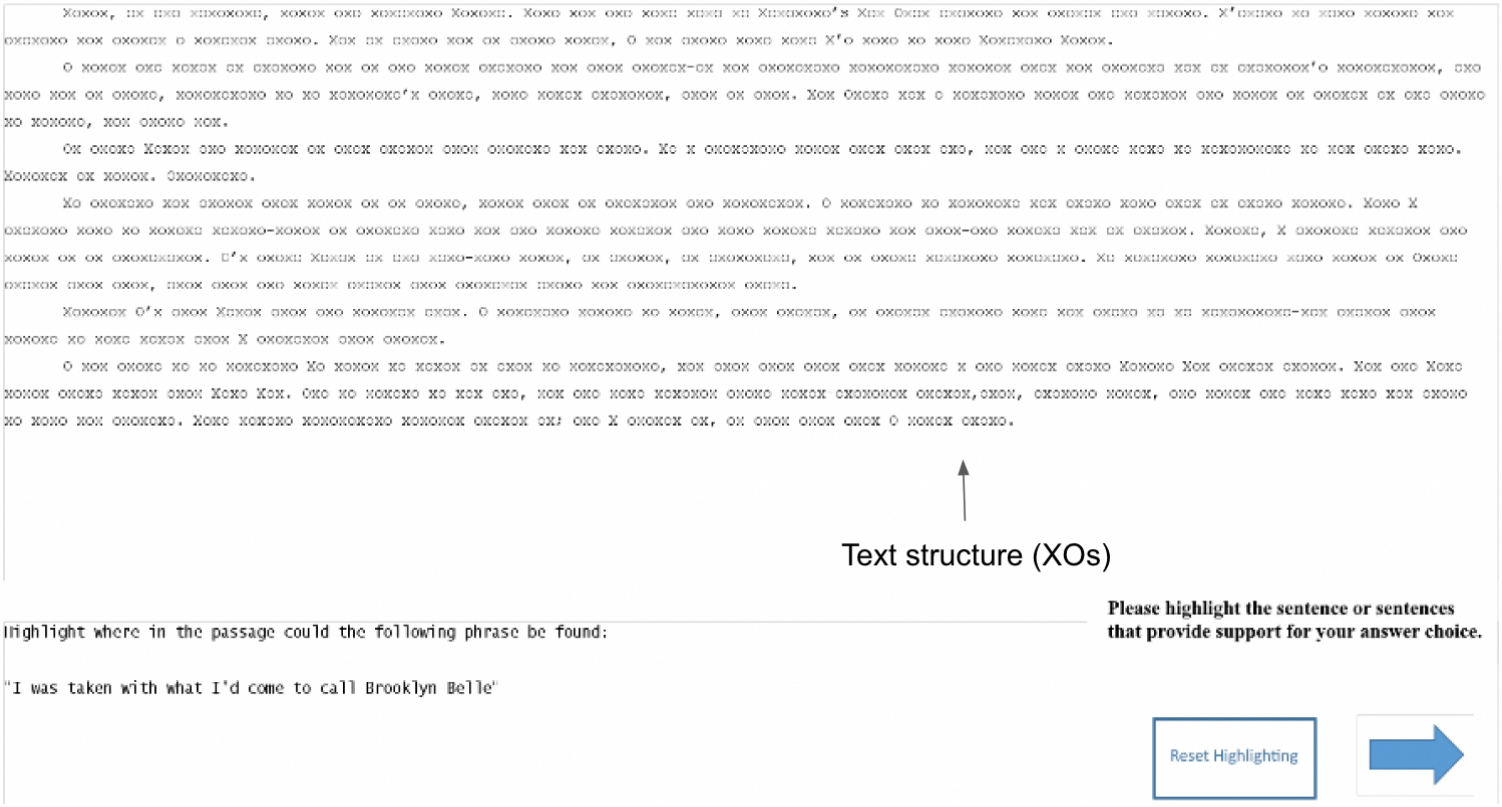


Figure 3: Procedure for the without-text condition. Screen 1 shows the passage, Screen 2 shows the question only, and Screen 3 shows the text structure where participants will highlight the supporting information.

Analytic Strategy

The proposed study intended to assess if text availability was a significant predictor of RC performance and search strategy using linear mixed-effects (LME) regression models. The study also intended to assess if reading achievement and WM are significant predictors of RC performance and search strategy using LME regression models. The appeal of using LME

models to analyze the sizable dataset at hand (i.e. 3,000+ data points) is, in part, due to the ability to incorporate by-subject influences as random effects into the same analysis. Additionally, LME models allow for the inclusion of both categorical and continuous variables in the same model (Baayen, Davidson, & Bates, 2008; Bates, Kliegl, Vasishth, & Baayen, 2018).

The model included the SC variables (reading achievement and WM) as continuous variables and used text availability. For the model, the intercepts for subjects and passage were included as random effects. The data was evaluated for normality prior to analyses.

Results

Response accuracy, several eye-movement measures (first fixation duration, gaze duration, total time, and regressions), the precision in locating supporting textual information, and the time required to identify the supporting textual information were the dependent measures. Linear mixed-effects (LME) regression models were run for each dependent measure, using the MIXED command in SPSS and REML estimation procedures. The alpha level was $p = 0.05$, and Bonferroni corrections were used in posthoc analyses. Reading achievement and working memory scores were centered. This type of regression model has the ability to incorporate by-subject and by-item influences as random effects into the same analysis (Baayen et al., 2008; Bates et al., 2018). The intercepts for subjects and items were included as random effects, while the fixed effects in all models for global analyses included condition (with-text vs. without-text), reading achievement scores, WM scores, the interaction between test format and reading achievement, and the interaction between test format and WM. Condition was a categorical variable, while reading achievement and WM were continuous variables. For the accuracy in identifying supporting textual information, a multinomial linear regression (MLR) was run in SPSS. See Table 1 for means and standard errors for all conditions.

Table 1: Descriptive Statistics for Reading Comprehension Performance Measures

Condition	**RC Performance Measure**	**Mean**	***SE***
Without-Text	Accuracy	66.60%	0.13
	First Fixation Duration	252.10	7.06
	Gaze Duration	351.54	11.22

	Total Time	545.11	21.94
	Regressions In	0.37	0.03
	Regressions Out	0.20	0.01
With-Text	Accuracy	72.40%	0.13
	First Fixation Duration	255.61	8.98
	Gaze Duration	298.18	14.23
	Total Time	386.09	27.91
	Regressions In	0.30	0.20
	Regressions Out	0.14	0.01

Research Question 1: Does text availability affect RC performance?

RC accuracy

A linear mixed-effects regression model was run, and there was no significant difference between the RC accuracy of participants under the without-text condition (M = 66.60%, SE = 0.13) compared to the with-text condition (M = 72.40%, SE = 0.13), F = 1.58, p = 0.22.

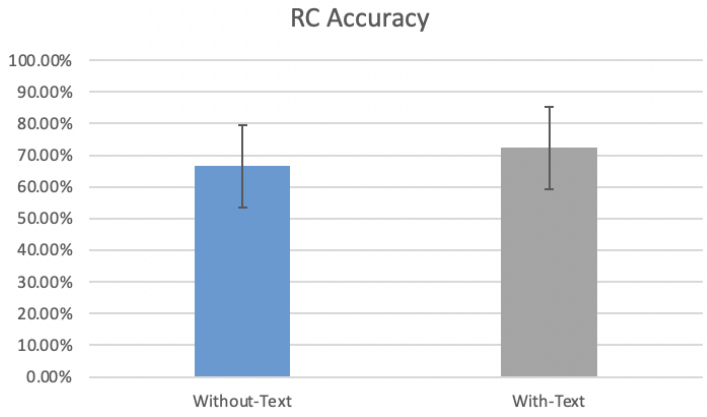


Figure 1: Mean reading comprehension accuracy scores by condition.

Reading time

Regarding reading time, several eye movement measures can be taken from a single participant. Some are thought to reflect lower-level cognitive processing such as word recognition, and others are considered to reflect higher-order processing such as text comprehension. First fixation duration and gaze duration represented the lower-level eye movement measures; total time and regressive eye movements represented the higher-order text processing measures. For all reading measures, an average was obtained across all words per passage.

Average first fixation and gaze duration. First fixation duration is the length of the first fixation on a word, regardless of the number of fixations on the word. Gaze duration is the sum of successive fixations on a word before leaving the word. The first fixation duration between without-text (M = 252.10, SE = 7.06) and with-text participants (M = 255.61, SE = 8.98) was not significantly different, F = 0.09, p = 0.76. However, gaze duration was longer for without-text participants (M = 351.54, SE = 11.22) than with-text participants (M = 298.18, SE = 14.23), F = 8.80, p = 0.005.

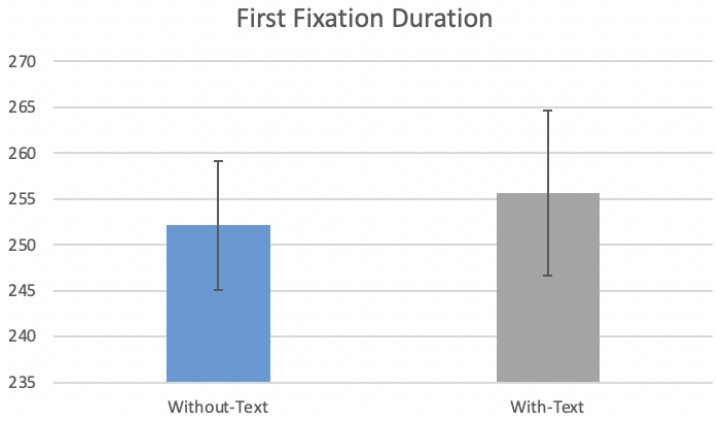


Figure 2: Mean first fixation duration times by condition.

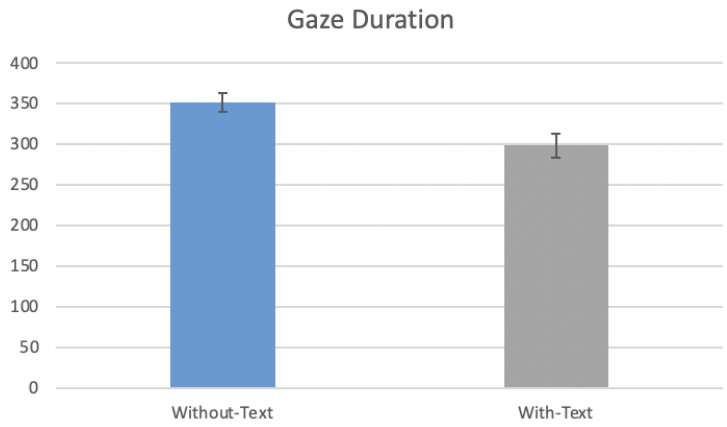


Figure 3: Mean gaze duration times by condition.

Total time spent on a word. Total time spent on a word is the sum of all fixations on a word, including regressions back to a word. The total time spent on a word was longer for without-text participants ($M = 545.11$, $SE = 21.94$) than with-text ($M = 386.09$, $SE = 27.91$), $F = 20.07$, $p < 0.001$.

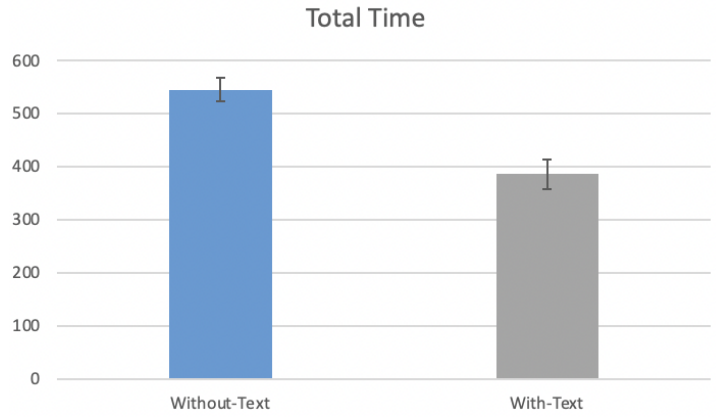


Figure 4: Mean total times spent on a word by condition.

Regressive eye movements. Regressions are the number of times participants return to a word after initially leaving that word. The regressions into words were not significantly different between without-text ($M = 0.37$, $SE = 0.03$) and with-text participants ($M = 0.30$, $SE = 0.03$), $F = 2.57$, $p = 0.12$, but without-text participants ($M = 0.20$, $SE = 0.01$) had more regressions out of words than with-text participants ($M = 0.14$, $SE = 0.01$), $F = 8.51$, $p = 0.005$.

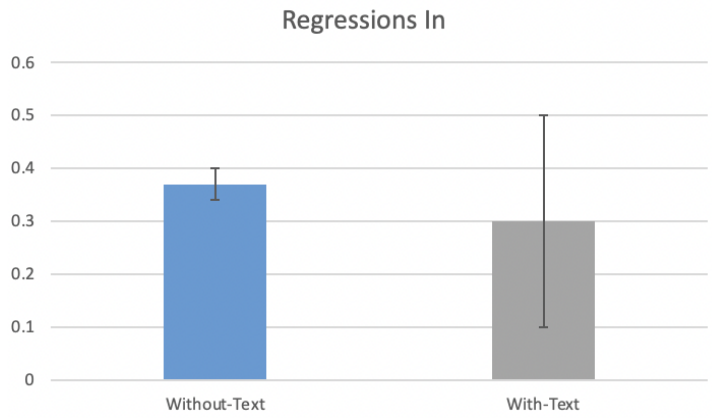


Figure 5: Mean regressions into a word by condition.

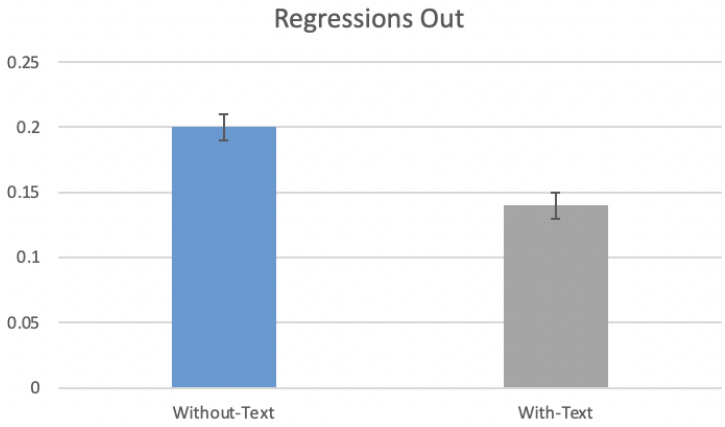


Figure 6: Mean regressions out of a word by condition.

Research Question 2: Does text access affect the ability to identify supporting textual information?

The ability to locate supporting textual information was analyzed using several measures: accuracy in finding the information, the number of words in the participant's highlighted section, and the time taken to identify the information.

The accuracy in locating information was calculated using a precision system based on how far the participant's highlighted section was from the correct section. If the participant's highlighting included any of the correct section, their accuracy was coded as High Precision. If the participant's highlighting did not include any of the correct section but was within two

sentences of the correct section, their accuracy was coded as Low Precision. Lastly, if the participant's highlighting did not include any of the correct section and was more than two sentences away from the correct section, their accuracy was coded as No Precision. The interrater reliability for this coding was 95%.

For the number of words highlighted, two measures were taken. First, the number of words in the participant's highlighted section was measured. Second, the difference between the number of words the participant highlighted and the number of words in the correct section was calculated (number of extra words highlighted).

For the time taken to locate the information, the time between when participants began scanning the passage and when they actually highlighted the information was calculated. "Scanning the passage" was defined as having at least two fixations on the passage when moving from the question to the passage. If participants removed their initial highlighting and highlighted a second time, this was included in their total time taken to identify the information.

Accuracy in locating information. In the without-text condition, 56.40% of the questions were coded as High Precision, 19.3% of the questions were coded as Low Precision, and 24.3% of the questions were coded as No Precision. In the with-text condition, 67.0% of the questions were coded as High Precision, 18.2% of the questions were coded as Low Precision, and 14.8% of the questions were coded as No Precision. A multinomial linear regression was run in which precision category was the outcome variable and predictor variables were condition, passage comp, TOSREC and working memory. The model was significant ($X^2 = 45.432$, $df = 8$, $p < 0.001$). Condition ($X^2 = 11.28$, $df = 2$, $p = 0.004$) and working memory ($X^2 = 7.20$, $df = 2$, $p < 0.001$) were significant predictor variables. Passage comp ($X^2 = 2.51$, $df = 2$, $p = 0.29$) and TOSREC ($X^2 = 7.20$, $df = 2$, $p = 0.03$) were not significant predictor variables. Posthoc follow up

tests were conducted in which No Precision was the reference category. There was a significant difference between the accuracy of without-text and with-text participants for the High Precision category in locating the supporting information (B = -1.01, p = 0.001). Without-text participants had a higher amount of High Precision responses than with-text participants when compared to the amount of No Precision responses between conditions. There was no significant difference between the accuracy of without-text and with-text participants for the Low Precision category in locating the supporting information (B = -0.59, p = 0.11).

Table 2: Descriptive Statistics for Accuracy in Locating Information

Predictor Variable	Precision Category	B	*p*
Condition	High Precision	-1.01	0.001
	Low Precision	-0.59	0.11
Passage Comp	High Precision	-0.04	0.83
	Low Precision	0.26	0.25
TOSREC	High Precision	0.32	0.10
	Low Precision	-0.14	0.53
WM	High Precision	0.61	< 0.001
	Low Precision	0.21	0.24

Number of words highlighted when identifying information. There was no significant difference between the number of words highlighted for without-text (M = 12.82, SE = 2.07) and with-text participants (M = 15.73, SE = 3.22), F = 0.56, p = 0.46. There was a significant

difference between the number of extra words highlighted for without-text ($M = 3.84$, $SE = 1.12$) and with-text participants ($M = 7.84$, $SE = 1.61$), $F = 4.18$, $p = 0.04$.

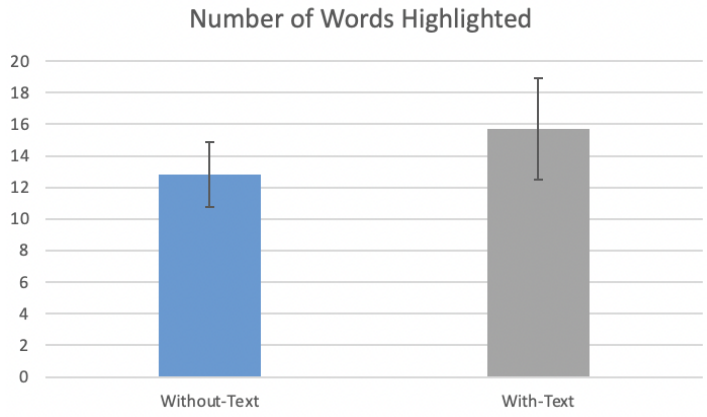


Figure 7: Mean number of words highlighted by condition.

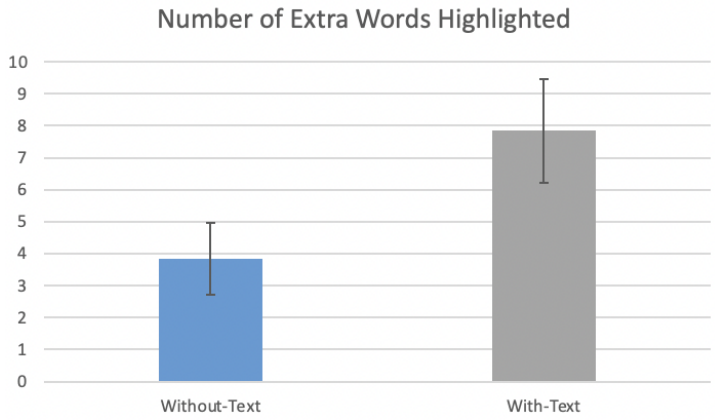


Figure 8: Mean number of extra words highlighted by condition.

Time to locate information. There was no significant difference between the time to locate information for without-text ($M = 29016.36$, $SE = 3946.45$) and with-text participants ($M = 19965.48$, $SE = 5060.55$), $F = 2.19$, $p = 0.15$. A chi-square test of independence showed that there was no significant association between condition and the amount of times a second highlighting occurred, X^2 (1, $N = 57$) = 0.02, $p = 0.89$. A second highlighting was when the participants highlighted a section of information, then removed their initial highlighting and highlighted another section.

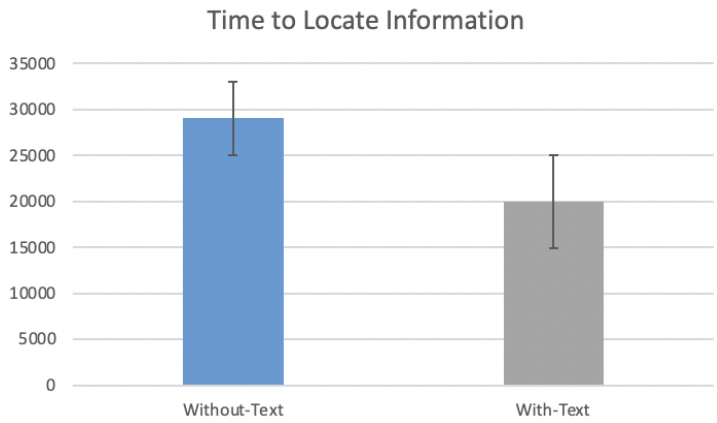


Figure 9: Mean times to locate information by condition.

Research Question 3: Is reading achievement related to the relationship between text availability and RC performance, and between text availability and visual memory, respectively?

Two measures were used to examine reading achievement: the WRMT III Passage Comp Standard Score and the TOSREC Raw Score. The Passage Comp score measured achievement level and the TOSREC score measured decoding skills.

Text availability and RC performance

RC accuracy. The Passage Comp score was not a significant predictor of RC accuracy (F = 1.37, B = 0.04, p = 0.25). The TOSREC score was also not a significant predictor of RC accuracy (F = 1.20, B = 0.03, p = 0.28).

Average first fixation and gaze duration. The Passage Comp score was a significant predictor of first fixation duration (F = 22.20, B = -27.35, $p < 0.001$), and participants with higher Passage Comp scores had lower first fixation durations. The TOSREC score was not a significant predictor of first fixation duration (F = 3.49, B = -7.64, p = 0.07). The Passage Comp score was a significant predictor of gaze duration (F = 4.80, B = -27.36, p = 0.03), and participants with

higher Passage Comp scores had lower gaze durations. The TOSREC score was not a significant predictor of gaze duration ($F = 0.38$, $B = -7.64$, $p = 0.54$).

Total time spent on a word. The Passage Comp score was not a significant predictor of the total time spent on a word ($F = 1.74$, $B = -30.75$, $p = 0.19$). The TOSREC score was also not a significant predictor of the total time spent on a word ($F = 3.97$, $B = -46.11$, $p = 0.05$).

Regressive eye movements. The Passage Comp score was not a significant predictor of regressions in ($F = 1.51$, $B = 0.04$, $p = 0.23$). The TOSREC score was a significant predictor of regressions in ($F = 4.54$, $B = -0.07$, $p = 0.04$), and participants with higher TOSREC scores had a lower amount of regressions in. The Passage Comp score was not a significant predictor of regressions out ($F = 0.38$, $B = 0.01$, $p = 0.54$). The TOSREC score was also not a significant predictor of regressions out ($F = 0.32$, $B = -0.01$, $p = 0.58$).

Text availability and visual memory

Accuracy in locating information. A multinomial linear regression model was run in which the Passage Comp score was not a significant predictor of the accuracy in locating information for the High Precision category ($B = -0.04$, $p = 0.83$) or for the Low Precision category ($B = 0.26$, $p = 0.25$). The TOSREC score was also not a significant predictor of the accuracy in locating information for the High Precision category ($B = 0.32$, $p = 0.09$) or for the Low Precision category ($B = -0.14$, $p = 0.53$).

Number of words highlighted when identifying information. The Passage Comp score was not a significant predictor of the number of words highlighted when identifying information ($F = 0.01$, $B = 0.18$, $p = 0.94$). The TOSREC score was also not a significant predictor of the number of words highlighted ($F = 4.04$, $B = -4.76$, $p = 0.05$).

Time to locate information. The Passage Comp score was not a significant predictor of the time to locate information ($F = 2.61$, $B = -6605.07$, $p = 0.11$). The TOSREC score was also not a significant predictor of the time to locate information ($F = 0.48$, $B = 2774.01$, $p = 0.50$).

Research Question 4: Is WM related to the relationship between text access and RC performance, and between text access and visual memory, respectively?

Text availability and RC performance

RC accuracy. WM was not a significant predictor of RC accuracy ($F = 0.33$, $B = 0.01$, $p = 0.57$).

Average first fixation and gaze duration. WM was not a significant predictor of first fixation duration ($F = 1.78$, $B = 11.39$, $p = 0.19$). WM was not a significant predictor of gaze duration ($F = 1.37$, $B = 11.39$, $p = 0.25$).

Total time spent on a word. WM was not a significant predictor of the total time spent on a word ($F = 0.02$, $B = 2.57$, $p = 0.89$).

Regressive eye movements. WM was not a significant predictor of regressions in ($F = 0.81$, $B = -0.02$, $p = 0.37$). WM was not a significant predictor of regressions out ($F = 0.83$, $B = -0.01$, $p = 0.37$).

Text availability and visual memory

Accuracy in locating information. A multinomial linear regression model was run in which WM was a significant predictor of the accuracy in locating information for the High Precision category ($B = 0.61$, $p < 0.001$), and there was a positive correlation between WM and the amount of High Precision responses. There was no difference between the WM scores of students who had No Precision and Low Precision ($B = 0.21$, $p = 0.24$).

Number of words highlighted when identifying information. WM was not a significant predictor of the number of words highlighted ($F = 0.19$, $B = 0.85$, $p = 0.66$).

Time to locate information. WM was a significant predictor of the time to locate information ($F = 7.13$, $B = 8446.62$, $p = 0.01$), and participants with higher WM took longer to locate the information.

Discussion

The goals of this study were to explore mental model formation during RC by examining the effect of text availability on RC performance and visual memory (i.e., the ability to locate supporting information in the text). A second purpose of this study was to examine the relationship of reading achievement and WM to RC performance and visual memory. Participants were given an RC test in which they answered multiple-choice questions and were subsequently asked to locate supporting textual information for these questions when given the text structure (i.e., the words of the text were replaced with XOs). Using eye-tracking methodology, I monitored participants' eye movements to better understand the cognitive processes behind mental model formation.

There were several interesting findings. First, regarding my first research question, text availability did have an effect on reading time. The average total time spent on words in the passages was longer for without-text participants than with-text participants. Without-text participants also had more regressions out of words than with-text participants. This was expected, as without-text readers would likely spend more time during the initial read since they would not have access to the text while answering questions. Second, for my second research question, there was a relationship between text availability and visual memory in the XOs text structure. The model for the accuracy for visual memory was significant, as were the predictor variables condition and WM. Regarding condition, within High Precision responses, without-text participants had higher accuracy in locating information than with-text participants. When compared to the amount of No Precision responses, without-text participants had a higher amount of High Precision responses than with-text participants. With-text participants also highlighted a greater number of extra words over the correct section compared to without-text participants. Next, regarding my hypothesis on reading achievement, participants with higher

achievement (passage comp) scores had lower first fixation durations and lower gaze durations. Participants with higher decoding (TOSREC) scores had fewer regressions into other words. Finally, for my hypothesis on WM, participants with higher WM had a higher number of High Precision responses in the accuracy for visual memory. However, surprisingly, higher-WM participants also took a greater amount of time to identify the supporting information.

Text Availability and Reading Comprehension

My first hypothesis, that text availability would lead to increased RC accuracy and decreased reading time, was supported for reading time but not for accuracy. There was no significant difference for RC accuracy by condition, but previous studies have found that text access increases performance on multiple-choice questions (Guerrero & Wiley, 2018; Marmolejo-Ramos et al., 2014), which does not align with my results. According to Ozuru et al. (2007), text availability also makes it less necessary for readers to rely on skills such as prior background knowledge, making this finding surprising. However, the means for the conditions do fall in the direction I predicted, with without-text participants having lower accuracy than with-text (66.60% for without-text and 72.40% for with-text), and the means are quite far apart, indicating that the lack of a significant effect may be an issue of low power (which may have come from too few participants or variable data). One factor leading to low power is that there were more without-text participants than with-text participants (35 without-text participants compared to 22 with-text), which may have influenced the results. Because the sample sizes are so different for each condition, this could have introduced more variability in the accuracy scores of the with-text condition, which had fewer participants. Another factor contributing to low power may be that because our study used narrative texts, skills such as prior background knowledge were less necessary for RC, resulting in similar performance between without-text

and with-text participants. In Ozuru et al. (2007)'s study, expository passages were used, making prior background knowledge an important skill for RC. Other studies that found that text availability resulted in increased RC performance also used expository passages (Guerrero & Wiley, 2018; Marmolejo-Ramos et al., 2014).

The reading time measures, however, did show differences across conditions. For example, the average total time spent on a word was longer for without-text participants than with-text participants. Without-text participants also had more regressive eye movements out of a word compared to with-text participants. This demonstrates that without-text participants made a more careful initial read of the passage, which I had expected since without-text readers would anticipate having no text access while answering questions, and would therefore spend more time initially reading the passage. When the text is not available while answering questions, readers are unable to return to the passage to reread, and instead must rely on their memory of the text. This finding is consistent with prior research, as Ferrer et al. (2017) who found that without-text participants had slower reading times during the initial read than with-text participants. Additionally, Schroeder (2011) found that under without-text conditions, readers make a more careful, thorough initial read of the text.

My second hypothesis, that the without-text condition would result in better visual memory compared to the with-text condition, was supported. Without-text participants were more accurate in their identification of the information and more precise with this identification, both in accuracy and the number of words highlighted. This aligns with previous studies, which have found that the without-text condition was a better predictor of visual memory (Cataldo & Oakhill, 2000; Ozuru et al., 2007). According to the supporting literature, without-text readers may also read more carefully and develop a better mental model of the text, aiding them in

locating relevant information (Schroeder, 2011). Studies have also found that without-text readers are less likely to identify irrelevant information, consistent with my finding that without-text participants had higher precision in their highlighting and highlighted fewer extra words (Kendou et al., 2014).

Reading Achievement and Reading Comprehension

My third hypothesis was that reading achievement would correlate with faster reading times and a better ability to locate information in the text, and this hypothesis was partially supported. Higher reading achievement scores resulted in faster first fixation and gaze durations and fewer regressions to the text across both conditions. This aligns with the relevant literature, as Ardoin et al. (2019) found that more skilled readers had faster reading times.

However, reading achievement did not have an effect on participants' visual memory, which does not agree with past studies' findings. According to Cataldo and Oakhill (2000), good readers have better visual memory and have a better recall of the order of words in a text. It may be that while reading achievement is involved in identifying textual information, other skills may be more important and offset lower reading achievement levels. For instance, Schaffner and Schiefele (2013) found that under a without-text condition, skills such as metacognition were more important for RC. Additionally, WM plays a role in searching for textual information as well (Daneman & Hannon, 2001). Consequently, reading achievement may not have led to a significant difference in the location of textual information. A supplementary correlational analysis was run of the two reading achievement measures (achievement and decoding scores) and WM. The correlation between achievement and WM was significant, $r(210) = 0.44$, $p < 0.001$. The correlation between decoding and WM was significant as well, $r(210) = 0.32$, $p < 0.001$. Since WM and reading achievement are related, it may be that reading achievement alone

does not have a significant effect on visual memory, but it does have a significant effect in conjunction with other student characteristics. A second explanation may be that my method of measuring reading achievement was not thorough enough. I used achievement and decoding scores to determine participants' reading achievement level. However, Cataldo and Oakhill (2000) sorted readers into good and poor comprehenders by first giving participants a reading test. Based on their performance, the two groups were divided so that they were matched for age, vocabulary knowledge, and reading accuracy but varied in comprehension skill. This method of determining reading achievement levels is more exhaustive than my method, which may have contributed to my nonsignificant results.

Working Memory and Reading Comprehension

My fourth hypothesis, that WM would be more salient under without-text conditions and result in better identification of relevant textual information, was partially supported. Higher WM did not lead to a difference in RC performance, but past studies have found that WM and RC accuracy are closely related (Daneman & Merikle, 1996). I found our reading achievement measures and WM measure to be significantly correlated as well. It may be that there was an issue of low power due to the unequal number of without-text and with-text participants (35 versus 22), similarly to the issues with the results for text availability and RC accuracy. The B value of this relationship was 0.1, indicating that WM and RC accuracy are positively associated, so the direction of the relationship aligns with what I predicted. Again, the different sample sizes may have led to high variability in the with-text group and affected the results.

Higher WM led to greater accuracy in visual memory, however, which aligns with the literature. Daneman and Hannon (2001), for instance, found that WM and the ability to form mental models of the text are closely related, and mental model formation is important for

locating information in the text. However, higher-WM participants also took a greater amount of time to identify the supporting information, which was an unexpected result and does not match the literature. If, as past research suggests (Daneman & Hannon, 2001), readers with higher WM form better mental models of the text, it would be expected that readers would be able to use these models to more quickly locate information. One possible explanation is that when being asked to find supporting information, a task not typically required by RC tests and one students have less prior experience with, readers may have been distracted by the novelty of the exercise. This may have resulted in slower times to identify textual information despite higher WM. Another explanation may be that readers with higher WM were more motivated to complete the task and spent more time searching for information, while lower WM readers were less driven to complete the task thoroughly.

Limitations and Directions for Future Studies

The results of the present study should be evaluated with its limitations in mind. First, there was a difference in sample size between the without-text and with-text participants, as there were 35 without-text participants compared to 22 with-text participants, which may have impacted the results and resulted in low power. This was due to data loss and issues during data collection. The current study should be repeated in the future with a more equal number of participants between conditions.

This study did not evaluate student characteristics other than reading achievement and WM, but other measures, such as metacognition and prior background knowledge, are important for RC as well (Ozuru et al., 2007; Schaffner & Schiefele, 2013). Given the nonsignificant effects I found of reading achievement on visual memory, and of WM on RC accuracy, future

research should investigate other student characteristics relevant to visual memory, in conjunction with text availability.

Lastly, I unexpectedly found that higher WM resulted in slower times to locate supporting information in the text. This conflicts with past research, which found that WM is an important skill for strong mental model formation, and would lead to more efficient searching of the text. WM did correlate with the accuracy in locating information, however, indicating that WM does influence this task. Possible explanations include readers being distracted by the novelty of the highlighting task or higher WM readers having more motivation to complete the task thoroughly. Future research should explore WM's role in the efficiency of searching for supporting information in a text.

Conclusion

The current study found that text availability does have an important role in RC performance and visual memory, due to its influence on mental model formation. Particularly, the without-text condition was shown to encourage students to read more carefully, resulting in a better mental model of the text. These results support RC studying and test-taking strategies that focus on strong mental model formation, such as making a thorough initial read of the passage prior to question answering. Reading achievement and WM were also shown to be influential factors in RC performance and the ability to identify supporting information. Therefore, these two student characteristics are important for integrating and retrieving information from mental models of the text. Future research should evaluate the role of other student characteristics in mental model formation and should further clarify the effect of WM on building mental models.

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Appendix

Mother – 8MN

In the morning Mother and I travel together to work. Rising at the crack of dawn, I love the adventure of tiptoeing around in the dark living room where we sleep, whispering to each other so as not to wake Aunt Celia and Uncle Martin in the bedroom, then leaving the house soundlessly and making our way to the subway station in semidarkness. By the time we reach Kings Highway, the rising day splatters an eerie light on the deserted [1] avenue ordinarily swarming with human traffic, and on the shuttered storefronts and fruit stands now cozily wrapped in layers of canvas. There is a sense of mystery—a sense of power—in being here before the rest of the world awakens . . as if witnessing the beginning of time.

2 We love traveling together on the subway, Mother and I. It's fun to observe our fellow subway riders, exchange jokes and asides in Hungarian, play guessing games as to their identities, their ages, and their jobs and make bets as to where they'd be getting off.

In a couple of weeks Mother becomes familiar with the train route, and she no longer allows me to accompany her.

"But I'll miss the fun of traveling together in the morning," I protest.

"So will I. [3] But it comes at a sacrifice. In order to accompany me, you must rise an hour earlier, losing an hour's sleep. You need that extra hour of sleep."

Mother is firm, and I have no choice but to comply and regretfully give up on our morning fun.

4 "I hope you'll have time to teach me English. Now that I have a job and travel alone on the subway, I'll need to improve my vocabulary. I don't want to depend on you every time I need to make a phone call in English, or want to take public transport."

5 "Okay, madam," I agree in a happy, jocular tone. "How about today? Let's have our first lesson this evening!"

6 Every evening I grill Mother in vocabulary and grammar, and indeed in a couple of weeks she learns enough English to do marketing on her own and travel freely by subway.

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1. The narrator says the avenue is ordinarily "swarming with human traffic." This means that usually

- The street is crowded with people
- The street is clogged with vehicles
- People are raising their voices on the street
- Drivers are honking their horns on the street

2. What did the narrator and mother not do on the subway together?

- Exchange jokes.
- Make bets.
- Play games.
- Tell stories.

NEXT

3. Why does the narrator's mother say they can no longer travel together in the morning?

- The narrator makes too much noise
- The narrator needs the extra sleep
- The narrator struggles to keep up
- The narrator forgets to lock the door

4. According to information in the passage, it is most important to the mother that she

- Tells jokes in Hungarian
- Rises early in the morning
- Learns to speak in English
- Travels daily on the subway

5. Which word best describes the narrator's behavior toward her mother?

- Disrespectful
- Resentful
- Supportive
- Sympathetic

6. What does the narrator focus on while teaching her mother English?

- Spelling and grammar
- Vocabulary and grammar
- Vocabulary and spelling
- Grammar and spelling

Bridge – MN

Ahead, in the distance, stood the Brooklyn Bridge. This was the best spot in Brooklyn's Red Hook section for seeing the bridge. I'd come to this corner and studied the bridge a million times. And on every one of those times, I was taken with what I'd come to call Brooklyn Belle.

I never got tired of looking out at its steel girders and iron cables – at its beautiful crisscross rafters that had started out in somebody's imagination, had been put to paper, formalized in an engineer's plans, then woven together, bolt by bolt. Now Belle was a powerful giant who carried all kinds of people to all kinds of places, day after day.

At night Belle was dressed in tiny lights that spanned her limbs. On a cloudless night like this one, she was a sight like no other sight in the whole city. Jeweled in light. Beautiful.

My fingers had tensed into fists at my sides, fists full of strength and eagerness. I unclurled my knuckles and shook them free of their strain. Then I reached into my jacket pocket – where my consent form for the bridge project had been neatly folded for days – and pulled out my pencil.

Slowly, I flipped through the pages of my sketchbook. I'd drawn Belle in the high-noon light, at sunset, on snowy days, and on foggy twilight mornings. My favorite sketches were those of Belle during rush hour, when cars and taxis danced like trinkets along her outstretched beams.

Tonight I'd draw Belle with her lighted cape. I sketched slowly at first, then faster, my pencil working with the speed of my excitement – the thrill that worked me over every time I sketched that bridge.

I was proud of my drawings (I liked to think of them as portraits), but with each page they showed a sad truth about Belle: She needed repair. She was some forty years older than Mama Lil. And as lovely as she was, she had some serious rough spots – corroded cables, rust, chipped paint, and plain old grit that had built up over the decades. That bridge renovation project needed me, and I needed it, in more ways than I could count.

1. The author refers to the Brooklyn Bridge as "Brooklyn Belle" to help the reader

- Understand that the bridge is very old
- Remember the bridge's history
- Imagine the noise around the bridge
- Appreciate the bridge's beauty

2. When does this passage take place?

- At night
- At sunset
- On a snowy day
- On a foggy morning

NEXT

3. What are the narrator's favorite sketches?

- The city in lights
- The bridge at twilight
- The bridge at rush hour
- The city in high-noon light

4. What is the "lighted cape" the author refers to on the Brooklyn Belle?

- The bridge lights
- Cars and taxis on the bridge's beams
- Sunlight reflecting off of the bridge
- The water below reflecting onto the bridge

NEXT

BACK

5. In the passage, the narrator refers to the bridge renovation project. Based on the information in the passage, the "renovation" project mostly refers to

- Repairing the bridge
- Removing the bridge
- Remodeling the bridge
- Remembering the bridge

6. How many years older is Brooklyn Belle than Mama Lil?

- Twenty
- Thirty
- One Hundred
- Forty