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Individual differences in updating information during reading

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INDIVIDUAL DIFFERENCES IN UPDATING INFORMATION DURING READING

BY

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ABSTRACT

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Causal information has been shown to help readers update outdated information (Rapp and Kendeou, 2007, 2009). Outdating occurs when integrating new information produces a conflict with encoded information that was encountered earlier in the text. There are also a number of individual differences among readers that influence how successful they will be at encoding, integrating, and outdating information including their reading skill, working memory capacity, and domain knowledge. This thesis examines how these individual differences impact how readers utilize causal information during updating. Across three experiments, participants were indexed as less-skilled or skilled readers using the Gates-MacGinitie Reading Test. Experiments 1 and 2 showed that skilled readers used causal information to update their representation of the text while less-skilled readers continued to show disruption from outdated information. The findings are examined in the discussion section.

INTRODUCTION

Reading comprehension requires readers to continually integrate incoming textual information with the information that came before it. To do this, readers must be able to update their representation of the text as it forms. Along with integrating incoming information, this updating process can also involve outdating information from earlier in the text that has been discounted or changed (Kendeou & van den Broek, 2007; Rapp & Kendeou, 2007, 2009). Outdating occurs when integrating new information produces a conflict with encoded information that was encountered earlier in the text.

Causal information has shown to be good at helping readers update outdated information (Rapp and Kendeou, 2007, 2009), but there are also a number of individual differences among readers that influence how successful they will be at encoding, integrating, and outdating information. Some readers are more skilled than others. These skilled readers tend to have more working memory capacity, which enables them to store and process incoming text more efficiently. Additionally, higher working memory capacity allows skilled readers to maintain activation of task relevant goals while inhibiting inappropriate information (McNamara & McDaniel, 2004). Domain knowledge also plays an important part in reading skill because it allows readers to easily make connections between concepts in the text. Readers use domain knowledge to help integrate incoming information with what is already available in long-term memory, strengthening those memory traces (McNamara & O'Reilly, 2009). This thesis examines how these individual differences in reading skill and working memory capacity impact how readers utilize causal information to update information. Chapter I describes early models of text comprehension that have heavily influenced current models. Chapter II reviews the current models of text comprehension like the explanation-based view and the memory-based view and resonance model. Chapter III discusses the processes

involved in updating and outdating information in texts. Chapter IV discusses working memory and working memory measures, while Chapter V reviews components of reading skill and reading skill measures. Chapter VI outlines the experimenters that were designed to investigate the individual differences in ability to update with causal information. The results and implications from the experiments are discussed in Chapter VII.

CHAPTER I

EARLY MODELS OF READING COMPREHENSION

Perhaps the most influential model of reading comprehension was developed by Kintsch and Van Dijk (1978). This buffer model describes how idea units, represented by propositions, are processed in memory during reading. The first assumption of this model is that propositions are connected via argument overlap. The second assumption is that memory has a limited attention capacity with only a certain amount of resources available at a time, so propositions are processed in cycles with only a proportion of the propositions being activated in each cycle.

First, a number of the propositions enter working memory. From this set, a proposition is selected to represent the general idea conveyed by the text. Based upon their amount of argument overlap, the remaining propositions are joined together. When this process has finished, a small subset of the propositions is maintained in the short-term memory buffer. This buffer keeps the subset activated from cycle to cycle, so on the subsequent cycles, the propositions entering working memory can be integrated into the growing representation of the text. The probability that subsets of the propositions will enter long-term memory is based on the number of cycles they were maintained in the short-term memory buffer. The buffer empties so that new propositions can enter. The longer they were activated, the more likely the propositions become encoded in long-term memory.

In summary, readers have a limited capacity to maintain textual information, so they only hold a small subset active in working memory. The subset has connections to the more elaborate text representation stored in long-term memory. These connections allow the reader to join new information with what was read earlier. Readers develop a

representation of the text through a number of cycles. To describe how readers focus on the textual information that is needed for the evolving representation of the discourse, Kintsch and Van Dijk (1978) proposed the leading edge strategy. This strategy predicts that the most recent as well as the most important propositions are stored in the short-term memory buffer. Kintsch and Vipond (1979) described this cyclical procedure in terms of a hierarchy, with the most important propositions at the top of the hierarchy and the less important but still relevant propositions in subordinate positions.

Kintsch and Van Dijk's (1978) model was influential; essentially all the models that were developed afterward follow the same basic assumptions. However, it was not a perfect theory. It failed to address how readers draw inferences, and instead of focusing on what the text was about, or its semantic meaning, the model was too heavily focused on the text representations in and of themselves: the text structure.

To address this weakness, Trabasso and Sperry (1985) theorized that text representations include the causal links between ideas, and that readers account for these links while developing the representation. When deciding the idea's place in the integrated network of the discourse, readers consider the implications and consequences of a sentence and its relation to other propositions within a text. If a proposition is part of a causal chain, it receives a higher place in the hierarchy and is more actively maintained compared to propositions that are not linked in a causal chain. Connections are based on argument overlap and membership in causal chains.

Yet this model does not address *how* a reader forms a text representation using causal links. The capacity of working memory is limited, so readers cannot identify all possible causal relations in a text. It is not clear how readers choose which links to form. The Current State Selection Strategy (Fletcher & Bloom, 1988) was developed in response. In this process model, readers find causal links by identifying the proposition that is the end result of a causal chain. A reader accomplishes this by first finding the

closest link in the causal chain: an antecedent in the preceding text that has no concluding event. The reader then maintains that proposition in short-term memory until the next causal proposition in the chain is identified. This system also has a limited capacity. Causal links can only be identified if the most recent antecedent is available in active memory.

Trabasso and Sperry's (1985) model and the Current State Selection Theory do not clearly identify the number of causal chains that can be made by a reader, leading van den Broek et al. (2002) to theorize that the reader's standard of coherence determines the number. Standards of coherence vary among readers, depending on their reading goals and their idea of full comprehension. Standards can vary for a number of other reasons including working memory capacity and the genre of the text (van den Broek et al. 2001; van den Broek, Fletcher, & Risden 1993). A reader with the highest standards of coherence should attempt to make the greatest number of causal connections, while a reader with the lowest standards should attempt to make the least.

Situation Models

The first section of chapter 1 discussed text-based models. Current models, however, posit that readers develop text-based representations as well as a situation model. Text-based representations include information about the text itself, while situation models are representations of what information the text contains. For good comprehension, readers have to continuously integrate information previously stated in the text with what they are currently reading. This allows readers to maintain a representation of the full text, regardless of whether it is a paragraph or a full length novel. Like the previously mentioned text-based models, situation models allow for this.

Van Dijk and Kintsch (1983) extended their theory to discuss situation models. Situation models include all the inferences that the text does not explicitly state as well as actions, characters, and events.

Researchers became interested in defining exactly what is represented at the level of the situation model. Bransford, Barclay, & Franks (1972) found evidence that readers create representations of the text that are different from the actual words. Participants read two sentences that had nearly identical syntactic structure but differed in their semantic meaning:

1. Three turtles rested beside a floating log, and a fish swam beneath them.
2. Three turtles rested on a floating log, and a fish swam beneath them.

In one, the fish swims under the turtles, and in the other, the fish swims under the log. When participants were asked if they had read the following sentence previously:

1. Three turtles were sitting on a log, and a fish swam under it.

They responded yes, even though they had not seen that sentence. The participants mistakenly identified a syntactically different sentence because it was semantically very similar to one they had seen before, showing that they had created a situation model for the text that represented the meaning the sentence conveyed and not its actual structure.

Another study assessed whether readers keep track of spatial information in their situation models (Morrow, Greenspan, Bower 1987). Participants in this study first memorized the spatial locations of rooms within a particular building layout and then read passages about protagonists walking throughout those rooms. In the passages, the protagonist moved through three rooms: the original room where the story began, called the source room; the room that the protagonist subsequently walked through, called the path room; and finally the protagonist's end location, called the goal room. After they had read the passages, participants were presented with an object and asked if that

object came from the room where the protagonist was at the end of the passage. The researchers found that participants were faster to respond when the object came from the goal room as well as the path room as opposed to when the object came from the source room. This led Morrow, Greenspan, and Bower (1987) to conclude that the structure of the text is not as important as the reader's situation model of the text.

Focus Model

References allow readers to form coherent representations of a text because they facilitate the process of linking the current text with what occurred earlier. For this reason, the focus model (Garrod & Sanford 1990) theorizes that the referential processes that occur in reading are necessary for good comprehension. The situation model of a text changes rapidly as protagonists experience events and progress through situations. Comprehension requires that a reader be able to identify the protagonist and the situation despite dynamic changes in both; they must focus attention on those two important aspects of the text.

Readers accomplish this necessity by using explicit and implicit focus; two systems that work in parallel (Sanford & Garrod 1981). These two systems control the reader's comprehension and representation of the text. Information that is in working memory is in explicit focus, so its capacity is limited. Information that is not in working memory, but is still relevant to the text is considered to be in implicit focus. This system does not have capacity limits.

Readers maintain comprehension by keeping the protagonist in explicit focus (Garrod & Sanford, 1988). Other information from the text like the setting or the characteristics of the protagonist is kept activated in implicit focus. The two systems have access to each other. When readers encounter new information, it is mapped onto the information already in explicit and implicit focus. Only relevant background information

can be activated and sent to working memory (Garrod et al. 1990). Glenberg and Langston (1992) added to the focus model the theory that discourse pointers allow tokens of the information about the protagonist in explicit focus to connect with the overarching characteristics of the protagonist that are held in implicit focus. These discourse pointers make related background information available so that it can be reactivated. A richer, more elaborate representation of the protagonist is primed any time the text references the character, and that information becomes active and available to the reader through a resonance-like process (e.g. Myers & O'Brien, 1998; O'Brien & Myers 1999).

Event-Indexing Model

Similarly to the focus model, the event-indexing model proposes that the protagonist's actions are at the focus of a situation model (Zwaan, Langston, & Graesser 1995). In their situation models, readers keep track of the protagonist, as well as a number of other indexes like temporal, spatial, causal, and intentional information. The situation model is updated if incoming information is inconsistent with any of the information in the current model. For example, if the time changes, the location shifts, or a new character appears, those indexes must be updated. To do this, readers activate new nodes or reactivate older nodes. For this reason, inconsistent or discontinuous information requires an increase in effort to process. The more discontinuities in the five types of situational dimensions, the longer it takes for the reader to parse the sentence.

In this model, the strength of the link between two nodes varies depending on the amount of situational dimensions they have in common. Furthermore, the situation model that the reader creates for a text is dependent on the amount that events share situational dimensions. Readers do not actively monitor these situational dimensions because the occurrences of temporal, spatial, causal, intentional, and protagonist

references are too numerous to track. This view does not make clear whether readers maintain activation of all this information or only access it when necessary.

That question led to the development of two competing and essentially mutually exclusive views about reading comprehension: the explanation-based and the memory-based text processing views. In the explanation-based view, readers constantly maintain their representation of the text, actively searching for meaning and updating their model to account for any inconsistencies or discontinuities, while the memory-based view holds that readers maintain only a small portion of the representation active in memory. Cues from the discourse allow information to be reactivated in a fast, automatic process that is outside of the reader's conscious control.

CHAPTER II

CURRENT THEORIES OF TEXT PROCESSING

The Explanation-Based View of Text Processing

Previous experiences and general world knowledge vary among individuals. Readers begin passages with a whole store of experience-based expectations already available in memory. This led researchers to question how general world knowledge impacts comprehension (McKoon & Ratcliff, 1988; Singer, Graesser, & Trabasso 1994). The explanation-based and memory-based text processing views were developed to help answer that question.

The explanation-based view posits that readers take an active role in the reading process. They purposefully search the text for meaning, matching incoming information with what occurred previously. When there are discontinuities or inconsistencies, readers update their situation models to fix them. Readers consciously search their memory, maintaining local and global coherence within the text. Local coherence requires that the information in each incoming sentence can be integrated with what came just before it in the text, while global coherence requires that the incoming information can be integrated with earlier events in the text as well as the reader's general world knowledge. Trabasso and other researchers found support for this view (Graesser, Singer, Trabasso, 1994; Singer, Graesser, Trabasso 1994).

Search after meaning and the active construction of inferential information are two of the most important process that happen during reading, according to this view. Search for meaning is a memory retrieval mechanism that can be explained by the "need to know node" (Graesser et al. 1994). In other words, readers make such an effortful search of memory because they want to understand the motives of the protagonist and the causes of the events or outcomes in the text so that they can make

appropriate connections. The reader actively searchers their memory for general world knowledge as well as the information active in their working memory in order to maintain coherence, generating inferences where necessary and using strategic, top-down processing.

Three main assumptions of this model explain why readers would use such effortful search and integration processes (Graesser et al. 1994). First, readers are motivated by their own goals for comprehension. Second, readers are motivated to maintain global and local coherence, and third, readers are motivated to explain the information in the text.

Text becomes excessively redundant when all the information is explicitly stated for the reader. Because most texts avoid this, readers have to make inferences during reading to maintain coherence and make sense of the information that appeared previously in the text. Driven by the "need to know node", readers use a resource-demanding search of short-term and long-term memory, using strategic processes to create inferences from the information stated in the text. Thus, information from long-term memory should only be activated and accessed when the reader requires it to make sense of the text.

The explanation-based view theorizes that readers actively search memory for information that is necessary for comprehension, using strategic processes to create inferences that facilitate the maintenance of coherence. In stark contrast, the memory-based view of text processing theorizes that basic memory processes can account for comprehension; strategic processes are not used by readers. Instead, passive activation of memory traces can account for inferential processes.

The Memory-Based View

The memory-based view of text processing does not allow that readers use strategic, active search processes to make meaning of a text. Instead, basic memory

processes account for what takes place during reading. Information that is available in working memory or long-term memory can influence comprehension as long as that information shows relatedness to what the reader is currently processing from the text as part of a resonance process.

The resonance process is essential for explaining the memory based text processing view, and it was first published by Ratcliff (1978). In this model, the more a concept is activated in memory, the more likely it can be retrieved. This reactivation in memory works as a function of how much concept "resonates" or is activated by the incoming information from the text. If a concept in memory shares many of its features with the current information, it has a greater chance of becoming reactivated.

Using this model as a base, Myers and O'Brien (1998) developed a resonance model to explain the mechanisms involved in reading comprehension (also O'Brien and Myers, 1999). The resonance process is fast, passive, and "dumb": dumb meaning that information can be reactivated regardless of its current relevance to the text as long as it shares enough features with the incoming information. The main assumption of the memory-based view is that the information available in working memory that was derived from the earlier portions of the text act as signals to all of memory, including general world knowledge. The attention given to the current information from the text and its recency determines the strength of that signal. The signal is fast, automatic, and unrestricted. General world knowledge, as well as encoded information from earlier portions of the text, resonates in response to the signal if it shares sufficient semantic features. The traces in memory that receive activation from the signal activate other related concepts in turn, allowing even the concepts in long-term memory to become activated. Traces in memory that share the most features are the most likely to be returned to working memory. This process is insensitive to whether the concepts are

relevant or irrelevant to the current text; the most active concepts enter working memory.

Evidence that all of memory can be accessed during the resonance process was provided by a study by O'Brien and Albrecht (1991). They demonstrated that any concept that shares enough features with what is available in working memory can be activated via the resonance process, even concepts from long-term memory that are a part of the reader's general world knowledge. Passages in two conditions of the study had either low or high supporting context (see Table 1). The information in the high context condition elaborated on a concept so that only one antecedent was likely to be inferred by the reader (e.g. "skunk"). The information in the low context condition gave less specific elaborations so that other antecedents could also be inferred (e.g. "skunk" or "cat"). After reading a passage, the participant then named either the highly elaborated target aloud (e.g. "skunk") or the other possible target (e.g. "cat").

O'Brien and Albrecht (1991) found that participants who read the highly elaborated condition were faster to name "skunk" than "cat". Importantly, "cat" was still named faster than a neutral, unrelated word. This shows that both the high context target word and the alternative context word were active in memory, even though only one was relevant. Because "cat" was related to the concepts in the passage, it resonated in response to the signals from the text. When participants read the low context version of the passage, the time they took to say "skunk" or "cat" was equally fast. The text did not constrain the activation toward either target, so both remained highly available.

In a subsequent experiment, participants read passages where skunk was never mentioned. Yet in a speeded recall task, they still responded with "skunk", showing that even when concepts are not mentioned in a text, if they are related enough to the theme, they can become activated. This is strong evidence for the fact that the

Table 1.
Sample Passage used by O'Brien and Albrecht (1991)

High-Context Version:
Mary was driving in the country one day when she smelled a terrible odor. Suddenly a small black (skunk/cat) with a white stripe down its back ran in front of her car. Mary knew she couldn't stop in time. However, she hoped she had managed to miss the animal and continued on her way. After a while, she noticed she was low on gas. While at the gas station, the attendant asked her what had run in front of her car.

Low-Context Version:
Mary was driving in the country one day and she gazed at the setting sun as she went. Suddenly, a small black (skunk/cat) with a long furry tail ran in front of her car. Mary knew she couldn't stop in time. However, she hoped she had managed to miss the animal and continued on her way. After a while, she noticed she was low on gas. While at the gas station, the attendant asked her what had run in front of her car.

resonance process is automatic and "dumb" or unrestricted. General world knowledge can be accessed as well as episodic memory traces, leading a reader to believe they read something in a passage that they never actually saw.

Good comprehension of a text requires a reader to maintain both global and local coherence. Readers must be able to integrate the information from the current sentences with what was read just before it in the text, as well as integrate the incoming information with earlier events in the text and their general world knowledge. Early evidence for this came from a study by Albrecht and O'Brien (1993) which demonstrated that readers have access to backgrounded information and that they maintain global and local coherence. Participants read a passage that introduced a protagonist and then elaborated on their characteristics (see Table 2). Following this, participants read information about the protagonist that was consistent, inconsistent, or unrelated to a target sentence they encountered later. The local coherence of the passage was not disrupted by the target sentence.

For example, the target sentence that said Mary ordered a cheeseburger was consistent with the elaboration that she loved junk food and was inconsistent with the elaboration characterizing her as a vegetarian. The participants showed slower reading times when the target was inconsistent, indicating that they were aware of the global coherence break. Despite the fact that there was no local coherence break, the incoming information about Mary ordering a cheeseburger sent a signal to all of memory, activating traces that were related to her eating habits, which then returned to working memory, slowing responses to the inconsistent target because it did not match with the reader's situation model.

Table 2.
Sample Passage Used by Albrecht and O'Brien (1993)

Introduction:
Today, Mary was meeting a friend Joan for lunch. She arrived early at the restaurant and decided to get a table. After she sat down, she started looking at the menu.

Consistent Elaboration:
This was Mary's favorite restaurant because it had fantastic junk food. Mary enjoyed eating anything that was quick and easy to fix. In fact, she ate at McDonald's at least three times a week. Mary never worried about her diet and saw no reason to eat nutritious foods.

Inconsistent Elaboration:
This was Mary's favorite restaurant because it had fantastic heath food. Mary, a health nut, had been a strict vegetarian for 10 years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything that was fried or cooked in grease.

Neutral Elaboration:
This was Mary's favorite restaurant because it had a nice and quiet atmosphere. Mary frequently ate at the restaurant and had recommended it to all of her friends. She especially liked the cute tables and the country style cloths on them. It made her feel right at home.

Filler:
After about 10 minutes, Mary's friend Joan arrived. It had been a few months since they had seen each other. Because of this, Mary and Joan had a lot to talk about and chatted for over a half hour. Finally, they signaled the waiter to come and take their orders. They checked the menu one more time. Mary and Joan had a hard time deciding what to have for lunch.

Target Sentences:
Mary ordered a cheeseburger and fries.
She handed the menu back to the waiter.

Conclusion:
Her friend didn't have as much trouble deciding what she wanted. She ordered and they began to chat again. They didn't realize there was so much for them to catch up on.

CHAPTER III

UPDATING INFORMATION

For good comprehension, incoming information has to be continually integrated into the reader's situation model, and sometimes this involves outdating previous information (Kendeou & van den Broek, 2007; Rapp & Kendeou, 2007, 2009). Outdating describes a process where new information changes the state of affairs for a character or an object in the passage. Outdated information decays, leaving the active portion of the discourse, however, traces of the outdated information that were encoded remain in long-term memory, where they are less accessible (Zwaan & Radvansky, 1998). Nonetheless, the outdated information can still be activated during the resonance process and return to disrupt comprehension for readers (Gueraud, Harmon, & Peracchi, 2005; O'Brien et al. 1998, 2010; Rapp & Kendeou, 2007, 2009).

O'Brien et al. (1998) extended the findings from Albrecht and O'Brien (1993) to show that readers maintain access to information that has been backgrounded as well as outdated, and that this outdated information can return to the active portion of the discourse to disrupt comprehension. The researchers expanded the conditions from Albrecht and O'Brien (1993) to include a qualified condition which made clear that the inconsistent elaborations were no longer true (See Table 3). For example, this qualifying information stated that Mary had been a vegetarian, but was not any longer, or even stronger: that she had never been a vegetarian and that her friend had made it up as a joke. The explanation-based view predicts that readers should actively update their situation model to include this new information, preventing any comprehension difficulty or slow down in reading times. The memory-based view, on the other hand, predicts that despite being outdated, the false information should resonate in response to the signal from the target sentence because it relates to Mary's eating habits. Because of the

Table 3.
Sample Passage Used by O'Brien et al. (1998)

Introduction:
Today, Mary was meeting a friend Joan for lunch. She arrived early at the restaurant and decided to get a table. After she sat down, she started looking at the menu.

Consistent Elaboration:
This was Mary's favorite restaurant because it had fantastic junk food. Mary enjoyed eating anything that was quick and easy to fix. In fact, she ate at McDonald's at least three times a week. Mary never worried about her diet and saw no reason to eat nutritious foods.

Inconsistent Elaboration:
This was Mary's favorite restaurant because it had fantastic heath food. Mary, a health nut, had been a strict vegetarian for 10 years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything that was fried or cooked in grease.

Qualified Elaboration:
Mary remembered that at a recent party, Joan played a joke by telling people that Mary had been a strict vegetarian for 10 years. Joan told everyone that Mary's favorite restaurant had fantastic health food. She said that Mary was a health nut and wouldn't eat anything that was fried or cooked in grease. She also claimed that Mary's favorite food was cauliflower.

Filler:
After about 10 minutes, Mary's friend Joan arrived. It had been a few months since they had seen each other. Because of this, Mary and Joan had a lot to talk about and chatted for over a half hour. Finally, they signaled the waiter to come and take their orders. They checked the menu one more time. Mary and Joan had a hard time deciding what to have for lunch.

Target Sentences:
Mary ordered a cheeseburger and fries.
She handed the menu back to the waiter.

Conclusion:
Her friend didn't have as much trouble deciding what she wanted. She ordered and they began to chat again. They didn't realize there was so much for them to catch up on.

signal, the outdated information is reactivated and becomes a part of the integration process, disrupting comprehension.

Consistent with this prediction, reading times for the inconsistent condition were significantly slower than for the qualified or the consistent conditions. Importantly, reading times were also significantly slower for the qualified condition than for the consistent condition, giving evidence that the resonance process is "dumb". Information that had been outdated for no longer being true was still activated and influenced comprehension.

Additional evidence was provided by a recent study (O'Brien, Cook, Gueraud, 2010) which also used inconsistent, consistent, and qualified elaborations (See Table 4). This study showed that even after creating an irreversible change of state in the main character or object, outdated information still has a significant impact. In these passages, the main character or object was introduced, followed by elaborations that were consistent, qualified, or inconsistent with a target sentence. In one passage, the main object was a tree that two characters were thinking about cutting down. In the consistent condition, they decide to cut down the tree. In the inconsistent condition, they decide against cutting down the tree, and in the qualified condition, they decide against cutting down the tree, but the tree is struck by lightning and has to be chopped down anyway. The target sentence then states that all that remained of the tree was a stump.

The researchers found that reading times were significantly slower in the inconsistent condition than for the consistent or qualified conditions. However, the qualified condition was still significantly slower than the consistent condition. The fact that the change in state was irreversible did not matter because the resonance process is unrestricted and automatic. All the information that was related to the target sentence resonated and returned to working memory, even though it was completely inconsistent

Table 4.
Sample Passage Used by O'Brien, Gueraud, and Cook (2010)

Introduction:
Susan was writing her first novel from her study at home.

Consistent Condition:
Her study was on the second floor and she had a beautiful view from one of the windows facing the backyard. She loved to sit and think about what she wanted to write while looking out the window at a graceful old oak tree. When her husband wanted to cut it down, she reluctantly agreed with him. They both thought it was a tragedy that such a beautiful tree had to be taken down. Still, they had it cut down and removed.

Inconsistent Condition:
Her study was on the second floor and she had a beautiful view from one of the windows facing the backyard. She loved to sit and think about what she wanted to write while looking out the window at a graceful old oak tree. Once her husband wanted to cut it down, but she stopped him. She thought it would be a tragedy if such a beautiful tree were taken down. He agreed and decided not to have it cut down and removed.

Qualified Condition:
Her study was on the second floor and she had a beautiful view from one of the windows facing the backyard. She loved to sit and think about what she wanted to write while looking out the window at a graceful old oak tree. Once, she husband wanted to cut it down, but she stopped him. She thought it would be a tragedy if such a beautiful tree were taken down. He agreed and decided not to have it cut down and removed. Soon afterwards, however, the tree was struck by lightning and had to be cut down.

Filler:
Susan really wanted to focus on working on her novel. She had already outlined the plot and developed her characters. Today, though, she was suffering from a bad case of writer's block. She just could not decide what she wanted to write next. While she was thinking, she got up and went over to look out the window.

Target Sentences:
All that remained of the tree was a stump.
Susan missed seeing the tree in her yard.

Conclusion:
She decided to plant a new tree in the same spot in the spring.

with the current text, which caused difficulty and a slowdown in reading times in both the inconsistent and qualified conditions.

Outdated information need not always disrupt comprehension. Gueraud, Harmon, and Peracchi (2005) adapted the passages from O'Brien et al. (1998) and added several elaborative sentences to the qualified condition so that there were an equal number of sentences in those passages for character traits that were inconsistent and consistent with the target sentence (see Table 5). For example, there were three sentences describing how Mary was a vegetarian followed by three sentences about why she was not any longer. The researchers found that with enough consistent elaborations, the readers were no longer disrupted by the outdated information. The outdated information was still activated by the signal sent from the target sentence, but the readers had a sufficient amount of consistent information and so they had no difficulty integrating the information from the target sentence into their situation model.

The results from the previous study seemed to indicate that readers need several sentences of consistent information to keep their comprehension from being disrupted by irrelevant outdated information. However, Rapp and Kendeou (2007, 2009) found that in certain circumstances, only one sentence was enough. They presented their readers with behavioral evidence about a protagonist that implied a certain kind of trait (see Table 6). These traits were then outdated with one sentence by either a simple refutation or a causal refutation. Unlike the simple refutation, which only stated that something was no longer true, the causal refutation gave an explicit reason why the outdated information was incorrect. For example, the readers learned that Albert was looking for his shoes and he found them under a pile of dirty laundry and candy wrappers, from which they were supposed to infer that Albert is a sloppy individual. The simple refutation for this passage was that Albert cared about the condition of his room, even though it currently was not up to par, while the causal refutation stated that he cared about the

Table 5.
Sample Passage from Gueraud, Harmon, and Peracchi (2005)

Introduction:
Carol had always wanted to be a construction worker. It was hard getting started, but she found this job two years ago. It was exciting for her and she couldn't have been happier.

Consistent Elaboration:
Carol especially enjoyed working on the beams of skyscrapers, high above the city. Even as a young child. Carol had been a thrill seeker and very adventurous. That is exactly why Carol decided to do construction work on large scale projects. She was thrilled by the high winds and the view from high places. She felt exhilarated watching the activity on the street far below. In fact, she volunteered to work on the highest beams where many people refused to work. Carol loved her job and couldn't imagine doing anything else.

Inconsistent Elaboration:
Carol was extremely scared of heights and would only work on the ground level. She even refused to climb anything much higher than a step ladder. While her colleagues worked on the upper levels, she would only do ground projects where she felt safe and secure. Many workers enjoyed working high above the city and even volunteered to work on the high beams. They were proud they had the courage to work on the highest levels. They were thrilled by the high winds and felt exhilarated watching the activity on the streets below.

Qualified Elaboration:
Carol used to be extremely scared of heights and would only work on the ground level. She remembered that she even refused to climb anything higher than a step ladder. While her colleagues worked on the upper levels, she would only do ground projects. Now Carol enjoyed working high above the city and even volunteered to work on the high beams. Carol was proud she had the courage to work on the highest levels. She was thrilled by the high winds and felt exhilarated watching the activity on the street below.

Backgrounding section:
Carol always ate lunch with her fellow workers. She was well liked and felt that she belonged. They were a friendly group of people she could depend on. Carol was happy to have such a great group of friends. She thought of them as a family and had developed several close friendships. In fact, one of her co-workers, Lori, invited Carol to join her on a trip. As Lori described the weekend adventure, Carol became very excited.

Target Sentences:
She had always wanted to go skydiving.
Carol immediately accepted the offer.

Conclusion:
To celebrate, she offered to take Lori out to dinner. Over dinner, they finalized the plans for the trip. They would leave Lori's house the following Saturday at 6 a.m.

Table 6.
Sample Passage Used by Rapp and Kendeou (2007)

Episode 1:
(Sloppy)
Albert was listening to the radio. He had finished getting ready to meet his friends at the movies. They were going to see a new comedy that was getting rave reviews. He pulled a sweater over his head. Then he began to look for his shoes.

Trait Context:
They were buried under old candy wrappers, crumpled magazines, and some dirty laundry. Albert didn't care about keeping his room clean, and this is how it usually would look.

Simple Refutation:
They were buried under old candy wrappers, crumpled magazines, and some dirty laundry. Albert cared about the condition of his room, even though it currently wasn't up to par.

Causal Refutation:
They were buried under old candy wrappers, crumpled magazines, and some dirty laundry. Albert cared about the condition of his room, but had only moved into the apartment yesterday.

Control Context:
Albert's friends had suggested meeting outside the pizzeria adjacent to the movie theater. The pizzeria was one of their favorite spots in town, and the movie theater was too.

Episode 2:
Albert had to take the bus to go to the movies. He bought a newspaper to read during the ride to the theater. Albert had finished leafing through the paper when his stop was announced. Albert put the newspaper on the seat next to him. As he waited for the bus to stop, he noticed a sign asking riders not to leave garbage on the bus.

Outcomes:
Albert ignored the sign and got off the bus. (Trait-Consistent)
Albert picked up the newspaper to throw away later. (Trait-Inconsistent)

condition of his room, but he had only moved in yesterday, giving the reader a concrete reason for the protagonist's inconsistent behavior. Similar to the results from O'Brien et al. (1998), when readers only received the simple refutation, they were still disrupted by the outdated information. Importantly, when they received the causal refutation, they were no longer disrupted by the outdated information.

The explanation for this mirrors that from Gueraud, Harmon, and Peracchi (2005). With enough consistent information, readers no longer show disruption from outdated information. Causal information is semantically rich and creates a whole, elaborate network for the reader (O'Brien & Myers, 1987; Trabasso & Suh, 1993). Therefore, one causal sentence that contained a large amount of semantic information was able to produce the same results as several elaborative sentences. The causal sentence gave the reader enough consistent information to prevent disruption.

There are a number of limitations to Rapp and Kendeou's (2007) study. The traits of the protagonist were never explicitly mentioned in the passage; it was assumed that the readers would infer them. There is no way to know if the readers made that inference. If the reader never inferred that Albert was sloppy, then the experiment is not measuring anything that it claims to measure. Because the traits were not mentioned, there was also no control over when the readers made the intended trait inference and when they revised them. It is questionable whether the readers inferred the trait at the beginning, as intended, and then revised that trait after the refutation, or if they only inferred the trait at the end, in which case the experiment was not measuring active reading processes. This limitation was addressed in Rapp and Kendeou's (2009) study which found that readers revised their representations when they were presented with causal information. However, the passages still made no explicit mention of the character trait, which was the most serious limitation of Rapp and Kendeou (2007).

To address this problem, a recent series of experiments examined the effect of causal information in passages where the trait of the protagonist was explicitly mentioned (Kendeou, Smith, Steiner, & O'Brien, 2010). The passages were adapted from O'Brien et al. (1998) and the qualified elaboration section was modified so that it contained one sentence of causal information that outdated the inconsistent information from earlier in the section (see Table 7). Using these highly reliable passages, the researchers replicated the results of Rapp and Kendeou (2007, 2009); a single sentence of causal information eliminated disruption of the outdated information for readers. Subsequent experiments showed that this outdated information was still available, despite showing no effect on comprehension, similar to the results of Gueraud et al. (2005). However, the addition of two extra explanatory sentences related to the causal information was able to eliminate the reactivation of the outdated information (Kendeou et al. 2010).

One of the goals of this thesis is to examine what effect differences in reading skill and working memory capacity have on how readers use causal information to update their representation of the text. Previous studies have shown that less-skilled readers have difficulty maintaining global coherence (Long & Chong, 2001; McNamara & O'Reilly, 2009; Stiegler & O'Brien, 2009). Both less-skilled and skilled readers can encode and integrate information about the protagonist into their representation at the local level; they are both able to activate memory traces from earlier portions of the text (Stiegler & O'Brien, 2009). However, only skilled readers seem to be able to encode and integrate at the global level. Less-skilled readers cannot integrate information or update their representation at the global level, and they fail to notice textual inconsistencies (Stiegler & O'Brien, 2009). The experiments in this thesis investigate whether this trend is also true for skilled and less-skilled readers updating with causal information, as well as readers with

Table 7.
Sample Passage Used by Kendeou, Smith, Steiner, & O'Brien (2010) in Experiment 1

Introduction:
Today, Mary was meeting a friend for lunch. She arrived early at the restaurant and decided to get a table. After she sat down, she started looking at the menu.

Consistent Elaboration:
This was Mary's favorite restaurant because it had fantastic junk food. Mary enjoyed eating anything that was quick and easy to fix. In fact, she ate McDonald's at least three times a week. Mary never worried about her diet and saw no reason to eat nutritious foods.

Inconsistent Elaboration:
This was Mary's favorite restaurant because it had fantastic health food. Mary, a health nut, has been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease.

Causal-Explanation Elaboration:
This was Mary's favorite restaurant because it had fantastic health food. Mary, a health nut, has been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease. She wasn't getting enough vitamins because of her diet, so her doctor said she had to start eating meat.

Filler:
After about ten minutes, Mary's friend arrived. It had been a few months since they had seen each other. Because of this they had a lot to talk about and chatted for over a half hour. Finally, Mary signaled the waiter to come take their orders. Mary checked the menu one more time. She had a hard time deciding what to have for lunch.

Target Sentences:
Mary ordered a cheeseburger and fries.
She handed the menu back to the waiter.

Conclusion:
Her friend didn't have as much trouble deciding what she wanted. She ordered and they began to chat again. They didn't realize there was so much for them to catch up on.

high or low working memory spans. The following chapters will cover working memory capacity and reading skill.

CHAPTER IV

WORKING MEMORY

The Multi-component Model

Human beings have the unique ability to solve complex problems, read information, learn different languages, and use reason and abstract thought to make intricate plans. Success in daily living depends on the mastery of these skills, and yet there is great variation between individuals in how well they are able to complete these tasks. Working memory, and specifically working memory capacity, appears to be part of the answer. This belief is essentially ubiquitous among researchers that working memory represents the common underlying feature of these abilities and higher-order cognition, and is one of the sources of the variation between individuals (Engle, 2002; Baddeley, Gathercole, Papagno, 1998; Daneman & Carpenter, 1980; Kyllonen & Christal, 1990).

Although there are multiple competing theories that explain how working memory operates, (see Cowan, 1995; Nairne, 2002 for review) the most popular and widely researched theory was developed by Baddeley and Hitch (1974, 1994). This multi-component model of working memory posits that working memory is flexible and resource limited, with both storage and processing abilities that can be used depending upon the requirements of the situation. Working memory allows important information to be kept active and available for use in memory while simultaneously processing new, incoming information. Working memory is composed of a number of structures with different functions that work together to accomplish these storage and processing demands. One structure, called the central executive, has supervisory control over the other subsystems, called the phonological loop,

the visuo-spatial sketch pad, and the episodic buffer (Baddeley, 1986, 1992, 2000, 2003).

Along with the ability to regulate the subsystems, the central executive has the capacity to switch or divide attention, depending on the task. It controls the flow of information between the subsystems, allowing for inhibition, selective attention, and strategic retrieval. The central executive is also proposed to be domain general, working with verbal, visual, and spatial information alike, binding the pieces of information it receives from the subsystems into a coherent whole.

The phonological loop (formerly the articulatory loop) is one of the subsystems controlled by the central executive, and unlike the domain-general central executive, it is domain specific, dealing with verbal information. It can be divided further into two subsystems which serve several functions. The phonological store maintains auditory memory traces for a very short period of time; memory traces that are not rehearsed can decay after two seconds (Baddeley & Hitch, 1994). It acts like an inner ear, allowing sounds to be remembered in the correct temporal order.

Auditory verbal information enters the phonological store automatically. Written language also can be transformed into auditory verbal information, or a phonological code, by the silent rehearsal that takes place in the articulatory rehearsal system, which is the second subsystem of the phonological loop. This articulatory rehearsal system allows memory traces to be refreshed or reactivated using subvocalization. It acts like an inner voice; the memory traces from elements of speech can be subvocally repeated on a loop, which stops them from rapidly decaying. Evolutionarily, the phonological loop is thought to have been necessary for the acquisition of language in humans.

The multi-component model states that working memory has another domain-specific subsystem called the visuo-spatial sketch pad. While the phonological loop works with auditory stimuli, the visuo-spatial sketch pad deals with visual and spatial information. It works as a short-term store for information like shape, location, movement,

and color. Along with its storage function, the visuo-spatial sketch pad also allows spatial and visual information to be mentally manipulated.

Logie (1995) added to the multi-component model of working memory, theorizing that the visuo-spatial sketch pad can be broken down farther into two subsystems. One subcomponent, called the visual cache, stores information specifically about color and shape, while the other subcomponent, called the inner scribe, stores information about spatial location and movement. The inner scribe is also responsible for communicating with the visual cache, rehearsing the information it contains to prevent decay, and communicating this information to the central executive.

More recently, Baddeley added a third subsystem to the working memory model called the episodic buffer (2000). The phonological loop and the visuo-spatial sketch pad are domain-specific stores, so they cannot communicate with one another. However, like the central executive, the episodic buffer is domain-general and acts as a go-between for the other two subsystems. It is able to receive information from both stores, integrating the verbal, spatial, and visual information together in the correct temporal order to form a coherent representation. Finally, the episodic buffer can transmit and receive information to and from the central executive and long-term memory.

Complex Working Memory Span Tasks

After the multi-component model of working memory was developed (Baddeley & Hitch, 1974; Baddeley, 2000), researchers became interested in testing its validity as a theory. In order to do this, an experimental task that directly measured working memory capacity needed to be created. In earlier research, simple tasks like the digit or word span task had been used to study short-term memory capacity, but they have not been shown to be related to higher order cognitive abilities like reading comprehension

(Perfetti & Goldman, 1976; Perfetti & Lesgold, 1977). In these tasks, the participant is shown or read a random list of numbers or words and must later recall the items in the correct order. Simple span tasks test only the storage capacity of memory, but researchers were looking for a memory span task that assessed both the storage *and* the processing component proposed by Baddeley and Hitch (1974).

For this purpose, Daneman and Carpenter invented the reading span task (1980). In this task, participants read a series of sentences aloud and are asked to verify that the sentence is true or false and also to remember the last word of each sentence. After they finish reading the last sentence in the series, they are asked to recall the final words from all of the sentences in the series. The number of sentences in a series increases incrementally until the participant can no longer recall all of the final words correctly. Thus, a participant's reading span is the maximum number of last-words they can remember correctly. Unlike the simple span tasks, the reading span task was highly correlated with several measures of reading comprehension, listening comprehension, and verbal SAT scores, which are thought to be heavily influenced by working memory ability (Daneman & Carpenter 1980, 1983, Daneman & Merikle, 1996).

Other versions of the reading span task have been developed since 1980, but they are fundamentally the same as Daneman and Carpenter's (1980) original. The procedure is the same in other reading span tasks, but participants have to verify that the sentences are semantically or syntactically correct instead of true or false, or remember an unrelated word that never appeared in the sentence instead of one that did, or they must recall a single letter at the end of the sentences instead of a word (Turner & Engle, 1989; Engle, Tuholski et al. 1999; Kane et al. 2004).

A number of non-verbal complex span tasks have also been developed like the Operation Span task (Turner & Engle, 1989), the Memory Updating Numerical task (Salthouse, Babcock, Shaw, 1991), and the Spatial Short-term memory task (Oberauer,

1993). Daneman and Carpenter (1980) believed that the reading component of their complex span task was necessary in order for the task to be able to predict reading and listening comprehension abilities. In other words, the working memory component of reading comprehension could only be predicted if the processing task that measured it was in the same domain. However, the operation span task (Turner & Engle, 1989), which replaced the sentences in the reading span task with mathematical equations, showed that working memory capacity measures are not dependent on the specific domain of the processing task they use. This non-verbal task was highly correlated with reading skill (Turner & Engle, 1989).

The operation span task is very similar to the reading span task, except that instead of verifying sentences, the participants must verify that simple mathematical equations are true or false. Participants progress through a series of equations one at a time, followed by a word to be remembered for later recall. After the participant has seen all of the equations in the series, they are asked to recall the words. Like the reading span task, the number of equations in the series increases incrementally until the subject can no longer correctly remember the target words. This is their operation span. Turner and Engle (1989) found that the operation span task correlated as well with measures of reading comprehension and the verbal SAT as the reading span tasks did, proving the domain-specific theory held by Daneman and Carpenter (1980) incorrect.

Other non-verbal complex span tasks include the memory updating numerical task (Salthouse, Babcock, Shaw, 1991), in which participants must perform a series of simple mental arithmetic manipulations, and the spatial short-term memory task (Oberauer, 1993), in which participants have to remember the spatial location of a series of pattern of dots in a grid. Complex span tasks have shown high correlations with general fluid intelligence (Engle et al., 1999; Conway et al., 2002; Conway, Kane, & Engle, 2003; Kane et al., 2004; Kyllonen & Chrisal, 1990), which is the ability to use logic

and reasoning to solve novel problems regardless of acquired general knowledge. In general, complex span tasks have been found to have high reliability by many research studies (Kane et al. 2004; Conway et al. 2002; Engle, Tuholski et al. 1999; Hambrick & Engle, 2002). Complex span tasks of all domains appear to be a good measure of working memory capacity because they require participants to remember target stimuli while also processing a demanding secondary task.

Variation in Working Memory Capacity

The development and use of the complex span tasks in experiments made it obvious to researchers that individuals differed significantly in their ability to successfully complete the tasks, which then naturally led to questions about the nature of those variations. Because working memory capacity has been found to be so highly correlated with general fluid intelligence, reading comprehension, and other higher order cognitive abilities like reasoning and problem solving (Engle, 2002), finding the mechanisms behind the variations in working memory has become an important topic in the field. The question remains: what is the impact of working memory capacity on individual differences, and can differences in capacity explain the variations seen in cognitive abilities?

One explanation for the variation among individuals in working memory capacity is processing speed. The reasoning behind this theory is that slower processing of to-be-remembered information in working memory causes memory items to be poorly encoded. Slower processing speed also leads to less rehearsal time, allowing items to decay; those who processed incoming information slowly should show more difficulty retrieving those items later for recall. Thus, variation in processing speed may cause the variation in working memory, which in turn leads to the variation in performance on higher order cognition measures seen in individuals (Fry & Hale, 1996, 2000).

Daneman and Carpenter believed that processing speed explained the differences between individuals on the reading span task (1980, 1983). They theorized that participants who had higher spans simply had more efficient processing skills than low span participants, so they were functionally faster and had more capacity or attention to devote to the rehearsal and consolidation of the memory items that they later had to recall. Participants with low spans, in turn, devoted most of their capacity or attention to performing the reading process itself and had less capacity available for rehearsal and storage. For high span participants, the extra rehearsal increased the duration that the memory trace remained activated in the phonological loop and increased the probability that it was consolidated in long-term memory, both leading to better retrieval.

A number of studies have found support for this theory, showing that working memory capacity is indeed correlated with processing speed or efficiency (Kyllonen & Christal, 1990; Unsworth et al., 2009; Ackerman, Beier, Boyle, 2002; Bayliss et al., 2003). However, there is a growing trend in the literature toward the theory that processing speed is actually mediated by executive attention and inhibitory control abilities, which are the real cause behind variation in working memory capacity (Kane et al., 2007; Hasher, Lustig, & Zacks, 2007).

Because working memory span tasks require participants to maintain memory traces while simultaneously processing incoming information, researchers believe that *the tasks are primarily measuring executive attention and control and only secondarily* measuring storage and processing capacity (Engle & Kane, 2004; Engle, Kane, Tuholski, 1999; Kane & Engle, 2002; Kane, Hambrick, & Conway, 2005). It is executive attention and inhibitory control that allow relevant information to be accessed, maintained, or retrieved while interference from task-irrelevant information is blocked, and working memory capacity is really a reflection of whether the task goals are successfully or

unsuccessfully maintained in the face that strong interference. Processing speed increases as a function of successfully inhibited interference and decreases as inhibition of irrelevant information fails. Support for this theory comes from a number of experiments that measured the influence of executive attention on selective and divided attention tasks (Kane & Engle, 2000; Rosen and Engle, 1998; Conway, Cowan, & Bunting, 2001).

For example, groups of low- and high-working memory span participants completed a delayed free-recall task for three lists of 10 words which all related to the same semantic category (Kane & Engle, 2000). On List 1, which had no proactive interference from the other lists, high- and low-spans recalled a similar number of words, but by the time they had to recall List 3, the low-span participants' recall dropped significantly more than the high-spans because of the proactive interference. However, when both groups had to tap out a complicated sequence while they learned and recalled the lists, the two groups showed the same amount of proactive interference. The high-spans were initially able to use executive attention to block the interference, but giving them a difficult secondary task divided that attention, diminishing their ability to block the irrelevant list information, increasing their vulnerability to interference. The low-spans, on the other hand, never had good executive control to begin with, so dividing their attention made no difference.

Rosen and Engle (1998) had their high- and low-span participants learn two lists of paired associates. List 1 had pairs like *bird-bath*, while List 2 was an interference condition where the pairs directly conflicted with those in List 1, e.g. *bird-dawn*. Low-spans took longer than high-spans to learn the second list, and they made significantly more intrusion errors, demonstrating again that high-spans are better able to block interference.

High-working memory span participants also show a greater ability to block automatic responses than low-spans (Conway, Cowan, & Bunting, 2001). Participants

completed a dichotic listening task where they shadowed words from one ear while ignoring the distracter words from the other. The participants' name was used as one of these distracter words. The researchers found that 60 percent of the low-spans were disrupted by hearing their name, while only 20 percent of the high-spans were. High-spans were better able to ignore task-irrelevant information.

Low- and high-spans react differently to antisaccade tasks, which also measure automatic responses (Kane et al., 2001). In this attention task, the participants had to quickly focus their eyes on a target letter. For most of the trials, a cue pointed to the letter's location, but on 25 percent of the trials, the cue pointed away from the letter, and so the participants had to resist following it. On these antisaccade trials, high-spans identified the letter faster than low-spans, they showed less eye movements toward the misleading cue, and they recovered faster when they did initially follow the cue.

Finally, Kane and Engle (2003) gave a Stroop task to low- and high-span participants. When 75 to 80 percent of the words in the task were congruent with their color, the low-spans made significantly more intrusion errors than the high-spans. Because the majority of words matched their colors, the low-span participants reverted to simply reading the words, as though they forgot the goal of the task. Therefore, when they reached a word that did not match its color, they were seriously disrupted. However, when only 0 to 20 percent of the words were congruent with their color, the two groups showed no difference; when most of the words did not match their color, the low-spans were able to maintain focus on the goal of the task. Overall, however, high-spans were better able to keep track of the task-goal and were less affected by interference.

In light of these experiments, it seems clear that low span individuals show a higher vulnerability to interference and have more trouble performing novel behaviors, especially when those novel behaviors conflict with a reflexive, well-learned, or

automatic response. High-span participants resist making the strong, but inappropriate response because they are able to use executive attention control to maintain active access to the relevant task goal, despite its novelty. These differences are what underlie the fluctuations in processing speed and the overall variations found in working memory capacity.

CHAPTER V

READING SKILL

Variation in Skill

The previous chapter discussed working memory and demonstrated that there are vast differences in working memory capacity between individuals. Reading skill is closely related to the topic of individual differences in working memory; there are also large variations between individuals in their reading skill. Most importantly, reading ability affects text comprehension. Problems relating to reading ability can influence many scholastic areas in a student's life, especially in science-based classes (Brown, 1999; Snow, 2002). Researchers have found that poor performance on standardized tests is, for many students, a result of their inability to successfully understand the text in question (McNamara & O'Reilly, 2009). Low reading skill can have a serious negative impact on a student's academic career, and so it is important to discover what factors influence reading skill and comprehension.

Good comprehension requires the reader to integrate the incoming information with what they read previously in the text. Good comprehension also requires the reader to understand the author's intended message and the main theme or idea of the text. However, the reading process appears to be very different for skilled and less-skilled readers, and so researchers have sought to discover the cognitive processes that underlie the differences. As in other areas of cognition, a major influence on differences in reading skill is working memory capacity (Miyake, Just, & Carpenter, 1994), specifically the ability to suppress irrelevant information (Conway & Engle, 1994). Additionally, prior knowledge about the topic of the text also has a profound influence on comprehension (O'Reilly & McNamara, 2002).

Working Memory and Reading Skill

As the previous chapter discussed, working memory capacity reflects the ability to simultaneously process, store, and retrieve information in order to complete a task, and it has been found to correlate with reading skill. Daneman & Carpenter (1980) showed that participants who had high scores on the verbal SAT and the Nelson-Denny Reading test had higher spans on the Reading Span task. Numerous other studies have also found a link between working memory capacity and reading skill. Perfetti et al. (1989) found that when readers with high working memory spans encountered a pronoun in a text, they were more likely to recall the earlier mention of the noun it referred to than readers with low working memory spans. This gives readers with high working memory spans an advantage, allowing them to have better comprehension of the text because they are able to link pronouns to the correct referent.

Another study found that readers with high working memory spans are also more likely to keep the referent to a pronoun active in memory (Miyake, Just, Carpenter, 1994). Participants read sentences that contained an ambiguous word like, "Since Ken really liked the boxer, he took a bus to the nearest..." The word "boxer" is ambiguous in the sentence; it could be referring to an athlete or a breed of dog. The reader must keep both meanings active in memory until the context reveals which meaning was correct: in this example, when the text elaborated that Ken was on his way to the pet store. An athlete is the dominant meaning of "boxer", and low working memory span readers dropped the subordinate meaning of dog. Thus, when they encountered the information that Ken was going to the pet store, the low-span readers were unable to integrate that information.

Success with integrating ambiguous information appears to depend on working memory capacity and the ability to keep multiple meanings of words active and available for retrieval when the text requires it. As with working memory, the executive

attention ability to suppress and inhibit irrelevant information also makes a significant contribution to differences in reading skill (Conway & Engle, 1994; Engle, 1996). Along with keeping multiple word meanings available, readers also need to be able to suppress or inhibit the alternative meanings of words once the context makes it obvious that the meaning is inappropriate. Keeping multiple meanings available when the context does not call for it is actually detrimental because it increases the load for working memory (Gernsbacher, 1993).

Skilled readers have an advantage in being able to inhibit irrelevant information because it leaves them more resources available in working memory to process and store the relevant, task-related information. With less irrelevant information competing for limited resources, skilled readers have the capacity to make more inferences (Gernsbacher & Faust, 1991). Because less-skilled readers have a difficult time suppressing irrelevant information, they have a harder time processing the relevant information.

The Structure Building Model (Gernsbacher, 1990) theorizes that comprehension requires the reader to create a representation of what the text is about, incorporate incoming information into that representation, and shift to a new representation when the incoming information does not map onto the current representation. When incoming information cannot be mapped into the current representation, it must be suppressed, or the reader has to create a new representation. Working memory has limited resources, so the ideal text would have the reader creating the fewest representations. However, less-skilled readers tend to create unnecessary new representations, as opposed to suppressing irrelevant information, using up those resources (Gernsbacher & Faust, 1991).

Gernsbacher, Varner, & Faust (1990) researched if less-skilled readers have a faulty suppression mechanism which causes them to form new representations instead of inhibiting information when they should. Participants read a sentence in one of two

conditions, (e.g. experimental or control) and then were shown a word. They then had to decide whether that word was related to the meaning of the sentence. For example, the participant read "He dug with a spade" followed by the word "ace" in the experimental condition. "Spade" was the ambiguous word, and "ace" was related to its inappropriate meaning. In the control condition, the participant read "He dug with a shovel" followed by "ace". In this sentence, "shovel" only has one meaning. The researchers wanted to compare how quickly skilled and less-skilled readers would verify that the word was unrelated to the sentence when the sentence contained either an ambiguous or unambiguous word.

For both readers, the time to say that the target word was unrelated to the sentence was significantly longer when the word was related to the irrelevant meaning of the ambiguous word, showing that the irrelevant meaning competed with the relevant meaning (Gernsbacher, Varner, Faust, 1990). However, when the researchers delayed the presentation of the target word to 100 milliseconds after the sentence in order to give the readers time to process the meaning, skilled readers responded to the two sentences equally as fast, showing that they could suppress or inhibit the inappropriate meaning of "spade." Less-skilled readers, on the other hand, still responded significantly slower to the experimental sentence, demonstrating that even with additional processing time, they lacked the ability to inhibit the irrelevant meaning.

These studies suggest that skilled readers have superior reading comprehension over less-skilled readers because they are able to keep appropriate information from the text active in memory until it is needed. If the text makes it clear that the information the skilled readers are maintaining in working memory is no longer necessary, they are then able to suppress it and focus only on the information that is relevant for the text. Less-skilled readers, on the other hand, do not maintain all of the necessary information in

working memory and, additionally, they are continually disrupted by inappropriate meanings and irrelevant information, giving them a clear disadvantage.

Domain Knowledge

An alternative theory to explain the differences between skilled and less-skilled readers was proposed by McNamara (1997). She proposed that skilled readers have an advantage because they maintain a richer, more elaborate representation of the relevant information from the text, causing irrelevant information to be inhibited very quickly. The richer representation results from the skilled reader forming more links to relevant meanings, allowing the rapid decay of the irrelevant meanings, giving them less opportunity to interfere with comprehension.

McNamara (1997) used a computational simulation to provide evidence, showing that the number of activated links to relevant information predicted the rate of decay for the irrelevant information. By processing the incoming information deeply, skilled readers can access related information stored in long-term memory and inhibit irrelevant information. Less-skilled readers do not use their resources to process incoming information deeply, do not make the connections to related information in long-term memory, and are disrupted by the continued activation of information that should have been suppressed.

In summary, skilled readers' success is facilitated by activation of knowledge in long-term memory that allows irrelevant information to rapidly decay (McNamara, 1997). Additionally, McNamara and McDaniel (2004) found that having a high amount of domain knowledge can compensate for poor reading skills. The participants in this study either had a high knowledge about baseball or little to no knowledge about the sport. Participants in both groups were slower to respond to sentences about baseball when they contained an ambiguous word than when they did not. As in Gernsbacher, Faust, &

Varner (1990), this effect disappeared for the participants with more domain knowledge after a delay, but the effect remained for those with little domain knowledge. Knowledge was able to compensate for skill in this study. The more knowledgeable the participant was about the topic of the text, the faster they were able to suppress the inappropriate meanings of a word.

A number of researchers have found that better domain knowledge facilitates reading comprehension for that subject (Chiesi, Spilich, Voss, 1979; Alexander & Kulikowich, 1991). In one study, children were compared to adult participants (Spilich et al. 1979). Children were considered less-skilled readers and the adults were considered skilled. However, the passages were about baseball: a topic that the children had a large amount of knowledge about while the adult participants knew little to nothing. Despite being less-skilled at reading, children performed better than the adults on a recall task, showing that domain knowledge can make up for deficits in reading skill. Domain knowledge has such an impact on comprehension because of how well it helps the reader make interconnections among the text and the information they have stored in long-term memory.

In a well-known study, Bransford and Johnson (1972) demonstrated the important role that a title plays in helping the reader make sense of an ambiguous passage. For example, participants read a passage about doing laundry. Half of the participants received the title and the other half were only presented with the text:

> Doing Laundry
>
> The procedure is actually quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to a lack of facilities, that is the next step; otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run, this may not seem important, but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity of this task in the immediate future, but then one can never tell. After the procedure is completed, one arranges the materials into different groups again. Then they can

be put in their appropriate places. Eventually they will be used once more, and the whole cycle will then have to be repeated. However, that is part of life.

Without the title, the passage is extremely vague and makes little sense. The steps seem completely arbitrary. Accordingly, those participants who read the passage without the title remembered half as many of the steps compared to the participants who were given the title. The title allowed readers to make a coherent representation because they could activate knowledge from long-term memory about the types of events that typically occur while doing laundry. The participants who were not given the title essentially had no domain knowledge about the topic. Their representation was much less elaborate and rich and they were not able to form the same types of links and connections in the text as the participants who received the title, nor were they able to access information about laundry that they had stored in long-term memory (Bransford & Johnson, 1972).

Magliano & Millis (2003) were interested in finding under what conditions skilled and less-skilled readers make inferences, and they used a think-aloud procedure and latent semantic analysis to investigate that question. The participants were asked to read certain focal sentences from two stories. Latent semantic analysis was then used to measure the amount of semantic overlap between the think-aloud responses, the focal sentences, and the other sentences included in the two stories. Overall, skilled readers remembered more, and their responses included both the focal sentences and other information from the story that was relevant to the focal sentence, like the causal events prior to the focal sentence. Less-skilled readers, however, generally responded only with the focal sentences and nothing extra. Skilled readers seem to be able to draw inferences about information that was never explicitly stated because they can link the causal antecedent with the focal sentences from the stories. Less-skilled readers do not appear to make similar connections, leaving them with a less coherent, less rich representation.

Skilled readers make more efficient use of the resources available to them, so they are more likely to draw inferences in order to make sense of gaps within the text, while less-skilled readers ignore conceptual gaps and information that is inconsistent, instead of making the necessary inferences (Oakhill & Yuill, 1996; Magliano & Millis, 2003). While failing to draw inferences relevant to the overall theme of the text, less-skilled readers also have difficulty integrating the new information from the text with their stored representation (Long et al. 1994). Even when less-skilled readers have the text in front of them, they have difficulty with tasks that require implicit inferences (Oakhill, 1984).

When readers have domain knowledge, it facilitates the integration of the incoming information with what was previously encountered (Alexander & Kulikowich, 1991). The domain-specific information from the text activates related knowledge from long-term memory, making the integration process easier (Schneider, 1993). For this reason it makes sense that high domain knowledge correlates with high reading skill (O'Reilly & McNamara, 2002).

Working memory capacity and domain knowledge are both important aspects of reading skill. Working memory capacity helps readers inhibit information that is inappropriate to the task goal, allowing them the ability to devote more resources to the processing and storage of incoming information. Domain knowledge facilitates the integration process in reading, letting readers link incoming information with what they already have stored in long-term memory. The next section covers what methods are often used in experimental and academic settings to assess reading skill.

Assessment of Reading Skill

There are a number of tests that have been designed to measure reading skill. These tests are important because they can identify readers who need help improving their proficiency, preventing them from falling behind their peers or doing poorly in

school. The most widely used tests include the Gates-MacGinitie Reading Comprehension Ability Test, the Nelson-Denny Reading Ability Test, and the Scholastic Aptitude Test (SAT). Standardized tests are used frequently in schools because they have simple scoring methods and have high levels of validity and reliability (van den Bergh, 1990; Freedle & Kostin, 1994). In most of the tests, the reader goes through a short text passage and then answers multiple-choice questions about the theme or content of the text.

Creating a test for reading comprehension can be difficult because reading is a very complex cognitive process, as the first chapters demonstrated. Readers make meaning at the phonological, morphological, syntactic, and semantic levels of texts. Difficulty with comprehension can occur at any of those levels. Additionally, the situations in which people read can vary drastically. Novels are not generally read the same way as textbooks or journal articles; readers use different strategies for reading in different situations (van den Broek et al. 2001).

In line with this, McDaniel, Hines, & Guynn (2002) found that different reading skill tests are actually measuring different aspects of comprehension. They compared the Nelson-Denny Reading Ability test to the Gernsbacher (1990) Structure-Building test. Participants who were labeled as less-skilled by the Nelson-Denny Reading test were less proficient at a letter deletion task than skilled readers. However, they performed similarly to skilled readers on a sentence scrambling task. Participants who were labeled as less-skilled by the Gernsbacher (1990) Structure-Building test did not show the same pattern. Instead, they performed similarly to skilled readers on the letter deletion task and on the sentence scrambling task. The two reading tests measure different aspects of reading comprehension. McDaniel et al. (2002) theorized that the Gernsbacher (1990) Structure-Building test was good for expository texts and for measuring how well the reader creates

a coherent representation, while the Nelson-Denny Reading Ability test was better for narrative texts and for measuring how well readers decode words.

The Gates-MacGinitie Reading test is another one that has been used to test both the reader's ability to decode words and create a coherent representation of the passage. The Gates-MacGinitie Reading test is a seven-test series that was created in 1965 and replaced the Gates Primary, Gates Advanced Primary, and the Gates Reading Survey. The seven tests cover grades of school from one to 12. However, only the Gates-MacGinitie (4th ed.) reading skill test, level 10-12, was used in the experiments this thesis investigated.

The Gates-MacGinitie Reading test is made up of 11 short passages about different subjects like history, biology, or the arts. The test-takers answer three to six multiple-choice questions after each passage. The test has a total of 48 questions. These questions vary in their degree of difficulty; some answers can be found directly in the text, while others require the reader to make inferences to reach the correct answer. Test-takers are allowed to look through the passage while they answer the questions and they have a total of 20 minutes to complete the test.

The Gates-MacGinitie Reading test has been investigated to test its usefulness and reliability (Farr & Anastasiow, 1969). The test is best for measuring age-related development in reading, as well as identifying students who are at risk and need additional help to improve their reading ability. Overall, the subtest and the total test scores were found to have good reliability.

Ozuru et al. (2008) further examined the Gates-MacGinitie Reading test for grades 10-12 to see how much certain text characteristics predicted difficulty in comprehension. The researchers analyzed the multiple-choice questions and passages based on the amount of cognitive processing they required. Aspects of the passages like number of propositions determined their difficulty as well as the questions themselves,

based on factors like their abstractness. Overall, the test was found to measure a number of the components that influence reading comprehension in various reading situations. The researchers deemed the test appropriate for use in experimental studies of reading comprehension as well as for assessment of students in educational settings.

Both reading skill and working memory capacity have been investigated in numerous experiments that have tested the conditions under which skilled and less-skilled participants differ. The goal of this thesis is to add to the literature and to specifically examine the impact that reading skill and working memory capacity have on how readers update causal information. The following chapter presents the experiments that address that question.

CHAPTER VI

EXPERIMENTS

Experiment 1

Experiment 1 was designed to investigate the differences between skilled and less-skilled readers when they read causal information. Specifically, this experiment examines if less-skilled readers use causal information to update their representation of the text to the same extent that skilled readers do. Reading skill was assessed using the Gates-MacGinitie reading test for grades 10-12. The passages for this experiment were adapted from O'Brien et al. (1998) so that the qualified condition included a causal explanation (see Table 8). In the passages, participants were introduced to a protagonist and then received one of three elaborations that was consistent with, inconsistent with, or provided a causal explanation for the subsequent target sentences. Reading times were then measured on the two target sentences.

For all readers, the inconsistent passages should elicit the slowest reading times and the consistent passages should elicit the fastest. The real condition of interest is the causal-explanation passages. If both skilled and less-skilled readers can use causal information to update their representations, then there should be no significant difference between the consistent and causal-explanation passages for either group. However, if less-skilled readers cannot or do not use causal information to the same extent, they should continue to show disruption in the causal-explanation passages by a significant slowdown in reading times.

Method

Participants.

Participants were 60 (30 skilled, 30 less-skilled) undergraduate students at the University of New Hampshire who received course credit for their participation in the experiment. All participants were enrolled in Introductory Psychology, Statistics in Psychology, and Research Methods courses. All participants were native speakers of English. Participants were given the Gates-MacGinitie Reading test, and skilled and less-skilled readers were determined based on their performance on the test. The skilled readers scored from 75 percent to 100 percent on the test (M= 85%), while the less-skilled readers scored from zero percent to 60 percent (M= 48%).

Materials.

Participants read 18 experimental passages: six in each of the three conditions: consistent elaboration, inconsistent elaboration, and causal-explanation elaboration. The different versions were counter balanced so that a participant only saw a passage in one of the conditions. Intermixed within the experimental passages were 12 filler passages that were similar in length and style to the experimental passages, but contained no inconsistencies. These were included so that participants could not guess the hypothesis of the study.

Each passage began with an introduction of the main character and was followed by one of three elaborations: consistent, inconsistent, or causal-explanation. Across all passages, the mean length of the introduction section was 30 words, with a range of 27-34. The consistent elaboration matched with the target sentence (e.g. Mary loved junk food, and she ordered a cheeseburger and fries). Across passages, the mean length of the consistent elaboration section was 45 words, with a range of 40-48. The inconsistent elaboration conflicted with the target sentence (e.g. Mary was a strict vegetarian, and she ordered a cheeseburger and fries). The mean length of the

Table 8.
Sample Passage Used in Experiments 1, 2, & 3

Introduction:
Today, Mary was meeting a friend for lunch. She arrived early at the restaurant and decided to get a table. After she sat down, she started looking at the menu.

Consistent Elaboration:
This was Mary's favorite restaurant because it had fantastic junk food. Mary enjoyed eating anything that was quick and easy to fix. In fact, she ate McDonald's at least three times a week. Mary never worried about her diet and saw no reason to eat nutritious foods.

Inconsistent Elaboration:
This was Mary's favorite restaurant because it had fantastic health food. Mary, a health nut, has been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease.

Causal-Explanation Elaboration:
This was Mary's favorite restaurant because it had fantastic health food. Mary, a health nut, has been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease. She wasn't getting enough vitamins because of her diet, so her doctor said she had to start eating meat.

Transition:
Mary checked the menu and specials one more time. She was having a hard time deciding what to have for lunch.

Target Sentences:
Mary ordered a cheeseburger and fries.
She handed the menu back to the waiter.

Conclusion:
Her friend didn't have as much trouble deciding what she wanted. She ordered and they began to chat again. They didn't realize there was so much for them to catch up on.

inconsistent elaboration section was 44 words, with a range of 35-48. The causal-explanation elaboration used causal information to explain the character's inconsistent action so that it matched with the target sentence (e.g. Mary was as strict vegetarian, but her doctor told her to eat meat, and she ordered a cheeseburger and fries). The mean length of the causal-explanation section was 63 words, with a range of 55– 67.

Following the elaboration section, participants read a short transition sentence that ranged between 21 and 24 words with a mean of 22 words. This ensured that the information from the elaboration section was not backgrounded by the time the participants reached the target sentences. Reading times were then collected for the two target sentences. Across all passages, the mean length of the target sentence was 39 characters, with a range of 37-41 .Finally, the participants read a short conclusion about the character and then answered a comprehension question. These were "yes" or "no" questions which were included to ensure that the participants were actually reading the passage; they were told it was the most important aspect of the study. The comprehension questions focused on information that was not related to the elaboration sections or the causal information.

Procedure.

Participants were randomly assigned to one of the three material sets. Each participant was run individually in a session that lasted for approximately one hour. All of the passages were presented on a computer monitor controlled by a Dell 386 microcomputer.

Participants were instructed to rest their right thumb on a line-advance key, their right index finger on a "yes" response key, and their left index finger on a "no" response key. At the beginning of each trial, the word "READY" was displayed in the center of the screen. To begin reading the passages, the participants pressed the line-advance key. Each following press of this key erased the current line of text on the screen and

presented the next. Participants were instructed to read at a normal, comfortable reading pace. Before beginning with the experimental passages, the participants completed three practice passages to ensure that they understood the procedure of the experiment and had no questions. Reading times were recorded as the participants read the two target sentences in the experimental passages. When the participants reached the end of the passage, the final line of text was erased and replaced with the word "QUESTIONS", which appeared in the middle of the screen for 2000 milliseconds. This was followed by one of the comprehension questions, and the participants responded "yes" or "no" by pressing the appropriate response key. If a participant responded incorrectly to a comprehension question, the word "ERROR" appeared in the center of the screen for 750 milliseconds.

Results and Discussion

In all analyses reported, F_1 refers to tests against error terms on participants' variability, and F_2 refers to tests against error terms based on items variability. All analyses were significant at the standard alpha level of .05 unless otherwise indicated. All latencies more than two and half standard deviations from a participant's mean were treated as missing data and excluded from the analyses, which accounted for less than 3 % of data. Effects were tested at a significance level of $p < .05$ unless otherwise indicated.

The mean reading times for the critical target sentences from Experiment 1 appear in Table 9. Separate analyses of variance were conducted on the first and second target sentences. For both skilled and less-skilled readers, there was a significant effect of elaboration for the first critical target sentence. For skilled readers, F_1 (2, 54) = 12.78, MSe = 677869.98; F_2 (2, 30) = 6.32, MSe = 464395.35, and for less-skilled readers, F_1 (2, 54) = 43.77, MSe = 1744193.16; F_2 (2, 30) = 19.43, MSe = 822904.93.

Table 9.
Mean Reading Times (in Milliseconds) for Target Sentences for Experiment 1.

	Consistent	Inconsistent	Causal
Skilled	1852	2107	1841
Less-skilled	2075	2558	2316

Planned comparisons for the first target sentence confirmed that, for skilled readers, reading times were longer following the inconsistent elaboration than either the consistent elaboration F_1 (1, 27) = 17.90, MSe = 1944823.21; F_2 (1, 15) = 8.22, MSe = 1414079.87, or the causal-explanation elaboration, F_1 (1, 27) = 17.32, MSe = 2118675.93; F_2 (1, 15) = 7.50, MSe = 1371974.04. However, there was no significant difference in reading times following the consistent elaboration and the causal-explanation elaboration, F_1 (1, 27) = .04, MSe = 3720.76; F_2 (1, 15) = .004, MSe = 318.19.

Importantly, less-skilled readers demonstrated a different pattern. Again, readings times were longer following the inconsistent elaboration than either the consistent elaboration F_1 (1, 27) = 98.31, MSe = 6976768.62; F_2 (1, 15) = 25.43, MSe = 3287577.92, or the causal-explanation elaboration, F_1 (1, 27) = 17.74, MSe = 1748769.24; F_2 (1, 15) = 12.20, MSe = 725096.99. However, reading times were also significantly longer following the causal-explanation elaboration than the consistent elaboration, F_1 (1, 27) = 14.12, MSe = 924754.67; F_2 (1, 15) = 25.01, MSe = 1739621.07.

Reading times for the second critical target sentence did not show a main effect for type of elaboration. No differences approached significance ($p > .09$)

Experiment 1 showed that skilled readers were able to use causal information to update their representation of the text and were no longer disrupted by outdated information. Conversely, less-skilled readers were not successful at updating their representation using the causal information; they continued to be disrupted by outdated information.

Experiment 2

Experiment 2 was designed to examine why the less-skilled readers were not able to use the causal information as efficiently as the skilled readers. This experiment used a free-recall test to assess whether the less-skilled readers failed to update their representation of the text because they had difficulty encoding the causal information.

The reading times in experiment 2 should replicate the findings from experiment 1. Additionally, O'Brien and Myers (1985) demonstrated that when readers encounter comprehension difficulty that they can eventually resolve, they display enhanced recall for the inconsistent information that gave them difficulty, as well as for the information that occurred before the inconsistency. This suggests that the readers' attempts to resolve the discrepancies in the text require reprocessing of earlier information. The reprocessing leads to a number of effects including better integration of the text overall and more retrieval routes to that information, which in turn produces enhanced recall.

The reading times for skilled readers from experiment 1 suggest that they were able to use the causal information to resolve the inconsistencies in the passage. Therefore, according to the reprocessing hypothesis (O'Brien & Myers, 1985) skilled readers should also show enhanced recall for the regions of the inconsistent and causal elaboration passages that centered on the inconsistency: namely the elaboration and first target sentence regions.

Experiment 1 showed that less-skilled readers did not seem to be able to use the causal information to update their representation of the text. Their recall data should reflect this fact, and they should demonstrate a different recall pattern from the skilled readers. Because the less-skilled readers were unable to resolve the inconsistency in the causal elaboration passages, their recall should show a less integrated and more fragmented view of the text. Thus, the less-skilled readers should show enhanced recall for the elaboration region of the causal elaboration passages, but not for the first target sentence.

Method

Participants.

Participants were 50 (24 skilled, 26 less-skilled) undergraduate students at the University of New Hampshire who received course credit for their participation in the

experiment. All participants were native speakers of English. Participants were given the Gates-MacGinitie Reading test, and skilled and less-skilled readers were determined based on their performance on the test. The skilled readers scored from 75 percent to 100 percent on the test (M = 86%), while the less-skilled readers scored from zero percent to 60 percent (M = 47%).

Materials.

The materials were the same as in Experiment 1.

Procedure.

The procedure was the same as in Experiment 1 except that participants completed a free-recall task immediately following the experimental passages. The participants were not told about the recall phase of the experiment, only that the experiment consisted of three parts. Participants were given an empty booklet with a sentence from the introduction section of every passage printed on each page. The passages were recalled in the same order that they were read. The participants were asked to write down as many facts as they could remember from each passage. They could not return to any passage after they had finished filling it out.

Results and Discussion

The mean reading times for the critical target sentences from Experiment 2 appear in Table 10. Separate analyses of variance were conducted on the first and second target sentences. For both skilled and less-skilled readers, there was a significant effect of elaboration for the first critical target sentence. For skilled readers, F_1 (2,42) = 13.19, MSe = 667519.09; F_2 (2,30) = 8.42, MSe = 401909.74, and for less-skilled readers, F_1 (2,46) =10.98 , MSe = 1002844.16.

Table 10.
Mean Reading Times (in Milliseconds) for Target Sentences for Experiment 2.

	Consistent	Inconsistent	Causal
Skilled	1733	2045	1787
Less-skilled	2085	2491	2316

Planned comparisons for the first target sentence confirmed that, for skilled readers, reading times were longer following the inconsistent elaboration than either the consistent elaboration F_1 (1,21) = 22.17, MSe = 2334209.73; F_2 (1,15) = 8.7, MSe = 1285889.43, or the causal-explanation elaboration, F_1 (1,21) = 12.76, MSe =1602255.72 ; F_2 (1,15) =16.51 , MSe = 1119830.95. However, there was no significant difference in reading times following the consistent elaboration and the causal-explanation elaboration, F_1 (1,21) = .94, MSe = 68649.07; F_2 (1,15) =.08 , MSe = 5738.06.

As in experiment 1, less-skilled readers demonstrated a different pattern. Again, readings times were longer following the inconsistent elaboration than either the consistent elaboration F_1 (1,23) = 14.21, MSe = 4001666.32; or the causal-explanation elaboration, F_1 (1, 23) = 7.25, MSe =836986.02. However, reading times were also significantly longer following the causal-explanation elaboration than the consistent elaboration, F_1 (1, 23) = 7.81, MSe = 1178412.58.

Reading times for the second critical target sentence did not show a main effect for type of elaboration. No differences approached significance ($p > .08$).

For the recall data, each passage was broken down into idea units (see Trabasso & Sperry, 1985). Subjects were given credit for the idea unit if their recall sufficiently covered the meaning of the idea unit. The idea units for all of the passages were grouped into the following sections: introduction, elaboration, transition, Target Sentence 1, Target Sentence 2, and conclusion. All analyses were conducted based on the proportion of idea units recalled because each passage varied in the total number of idea units it contained. Tables 11 and 12 present the mean proportion of idea units recalled as a function of condition and region of the passage for less-skilled and skilled readers respectively. Separate ANOVAs were performed on each region of the passage and the overall proportion of idea units recalled.

Across the three experimental conditions, there was no reliable difference in the proportion of the passages which either the skilled or less-skilled readers showed some recall for ($p > .19$, $p > .22$, respectively). However, there were significant differences in the total number of idea units recalled across the three conditions for skilled readers, F_1 (2, 40) = 5.0, MSe =.017, but not for less-skilled readers, F_1 (2, 42) = 1.76, MSe = .01, $p > .18$. Planned comparisons showed that unlike the less-skilled readers, skilled readers remembered significantly more idea units from the inconsistent F_1 (1, 20) = 4.33, MSe = .04, and causal passages F_1 (1, 20) = 11.3, MSe =.06, than from the consistent passages. The number of idea units recalled for the inconsistent and causal passages did not show a significant difference, F_1 (1,20) = .31, MSe =.002, $p > .58$.

For the individual regions of the passage, there were no significant differences in the number of idea units recalled across the conditions for the introduction, transition, second target sentence, or conclusion regions, for both skilled and less-skilled readers, $p > .12$. However, for the elaboration and the first target sentence regions, the two types of readers showed varying patterns of recall.

There were significant differences across the conditions for the elaboration region for less-skilled readers, F_1 (2, 42) =3.18 , MSe =.03. Planned comparisons revealed that less-skilled readers recalled significantly more idea units from both the inconsistent F_1 (1, 21) = 5.26, MSe = .11, and the causal passages F_1 (1, 21) = 4.48, MSe = .06, than from the consistent passages. There was no significant difference in recall between the inconsistent and causal passages F_1 (1, 21) = .31, MSe =.01.

For skilled readers, however, the pattern was not the same. There was no significant difference between the number of idea units recalled for the consistent and causal passages, F_1 (1, 20) = 1.81, MSe = .02, $p > .19$, or for the inconsistent and causal passages F_1 (1, 20) =.93, MSe =.015, $p > .35$. Similarly to the less-skilled readers, the skilled readers tended to recall more idea units from the inconsistent passages compared to

the consistent passages, F_1 (1, 20) = 3.135, MSe =.08, p <.09, but this difference did not reach significance.

For less-skilled readers, there were also significant differences across the conditions for the first target sentence region F_1 (2, 42) = 4.43, MSe =.18. Planned comparisons showed that less-skilled readers showed enhanced recall for the inconsistent passages compared to the consistent passages, F_1 (1, 21) = 9.66, MSe =.68. There were no significant differences in recall between the consistent and causal passages F_1 (1, 21) = .60, MSe =.05, p > .45, or between the inconsistent and causal passages F_1 (1, 21) =3.73 , MSe =.372, p >. 07.

Again, skilled readers demonstrated a different pattern of recall for the first target sentence region. There were significant differences across the conditions F_1 (2, 40) =9.74 , MSe =.28. Planned comparisons revealed that skilled readers showed enhanced recall for both the inconsistent F_1 (1, 20) = 14.53, MSe = .79, and the causal passages F_1 (1, 20) = 17.02, MSe = .90, than for the consistent passages. There was no significant difference in idea units recalled between the inconsistent and the causal passages F_1 (1, 20) = .05, MSe =.004, p> .82.

The reading times from experiment 2 replicated the results from experiment 1. Skilled readers were able to use causal information to update their representation of the text and were no longer disrupted by outdated information, but less-skilled readers continued to be disrupted by outdated information.

Skilled readers also demonstrated enhanced recall for the inconsistent and causal passages compared to the consistent passages. Specifically, skilled readers tended to recall more idea units for the inconsistent elaboration region only. They also displayed enhanced recall for the first target sentence for the inconsistent and causal passages; this effect was not present for the consistent passages.

Table 11.
Less-skilled subjects: Mean proportion idea units recalled for Experiment 2

	Consistent	Inconsistent	Causal
Introduction	.300	.348	.376
Elaboration	.398	.472	.448
Transition	.457	.433	.432
Target 1	.663	.831	.713
Target 2	.246	.351	.354
Conclusion	.346	.269	.302
Percent Passages Recalled	80.8%	81.9%	83.3%

Table 12.
Skilled subjects: Mean proportion idea units recalled for Experiment 2

	Consistent	Inconsistent	Causal
Introduction	.380	.409	.405
Elaboration	.477	.534	.509
Transition	.430	.418	.416
Target 1	.655	.833	.848
Target 2	.233	.369	.422
Conclusion	.316	.281	.275
Percent Passages Recalled	87%	86.2%	86.9%

Conversely, less-skilled readers did not show differences in recall across the conditions overall. Unlike the skilled-readers, they showed enhanced recall of the elaboration region for both the inconsistent and causal passages compared to the consistent passages, yet they only showed increased recall from the first target sentence region for the inconsistent passages. The implications of these findings are reviewed in greater detail in the general discussion section.

Experiment 3

Experiment 3 will examine the relationship between reading skill, working memory capacity, and causal information by investigating if less-skilled readers' updating difficulty is a result of a deficit in resources. Are less-skilled readers unsuccessful with causal information because they do not have the resources available to update fully? This experiment also seeks to answer the theoretical question of whether it is possible to have low working memory capacity and be a skilled reader, or to have high working memory capacity and be a less-skilled reader. The most likely prediction, however, is that working memory capacity will be positively correlated with reading skill, and readers with high or low working memory spans will show the same pattern with causal information as in Experiment 1.

Method.

Participants.

Participants will be 60 (30 skilled high WM span, 30 less-skilled, low WM span) undergraduate students at the University of New Hampshire who receive course credit for their participation in the experiment. All participants will be native speakers of English. Participants will be given the Gates-MacGinitie Reading test, and skilled and less-skilled readers will be determined based on their performance on the test. The skilled readers score from 75 percent to 100 percent on the test, while the less-skilled readers score from zero percent to 60 percent.

Materials.

The experimental passages are the same as those used in Experiments 1 & 2. Additionally, the participants will also complete a battery of working memory tests that include a reading span task, an operation span task, a memory updating task, and a spatial short-term memory task. These tasks were created for MATLAB by Lewandowsky, Oberauer, Yang, & Ecker (2010).

In the reading span task, participants judge the meaningfulness of two types of sentences while also remembering a series of unrelated consonants for later recall. Half of the sentences were "garden-path" sentences, or sentences that contain reduced relative clauses. "As Toby sang a song played on the radio" is an example of a meaningful version of this type of sentence, while "As Danny drank the milk rolled over the hill" is an example of a meaningless sentence. The other type of sentence had a similar structure, but avoided parsing difficulty by adding in an additional pronoun. "While Susan wrote the letter it fell off the table" is an example of a meaningful version of this sentence and "As the chef stirred the soup it veered into the ditch" is an example of a meaningless version. All of the sentences contained between 8 and 11 words.

In the operation span task, the participants will judge the correctness of a series of simple arithmetic equations (e.g. 3 +2=5) while also remembering a series of unrelated consonants for later recall.

In the memory updating task, the participants will be presented with an initial set of digits and then update the digits in different stages using arithmetic operations. Finally, in the spatial short-term memory task, participants have to remember the spatial location of a number of dots in a 10 X 10 grid. Each of these working memory tasks takes approximately 10 minutes to complete.

Procedure.

On the first day of testing, participants will complete the Gates-MacGinitie reading test and the battery of working memory span tasks. The participants will then return two days later to read the experimental passages. The battery of working memory tasks will be completed using the MATLAB computer program.

Participants will begin with the memory updating task. Participants start the trial by pressing any key on the board. After completing two practice trials, the participants begin the experimental trials. The starting digits are presented in their individual frames, one at a time, for 1 second each. Next, cues for the arithmetic operations (e.g. +4, or -2) are displayed in those frames for 1.3 seconds each, followed by a blank screen for 250 milliseconds. In that time, the participants have to apply the operation to the original digit, and mentally replace the old number with the new. The number of updating operations varies between 2 and 6 on the trials. Final recall is signaled by a series of question marks in each frame. The participants respond by typing the final, updated number into its correct frame, using the number keys on the keyboard. The typed digits appear in the frame for 1 second. There is no time constraint on recall and the participants receive no feedback. There are a total of 15 trials. All sets of initial digits, operations, updating, recall prompts, and trial orders are generated randomly by the program and are kept constant for each participant. The participant's memory updating span is determined by the number of digits out of the 15 trials they reported correctly.

After completing this task, the participants will start the operation span task. Participants complete three practice trials before beginning the experimental trials. The trial begins with a fixation cross that is presented for 1.5 seconds. Then, the first equation will appear in the center of the screen. This equation disappears after the participant makes a response, or after a maximum time of 3 seconds has passed. The participants use the "/" key to respond *Yes, this is correct*, and the "Z" key to respond *No, this is incorrect*. The keys will be covered with a Yes and No label, respectively. After the

equation disappears, a consonant is presented in the center of the screen for 1 second. After a 100 millisecond blank interval, the next equation appears.

The number of equations and letters to be remembered in each trial varies from 4 to 8. Following the presentation of the last equation, the participants must remember all the letters in the correct order. This response is prompted by a question mark and a blinking underscore. The participants type the letters in the order they were presented. Each letter stays by the question mark for 200 milliseconds. The participants have to type as many letters as appeared in the trial. Because order matters, they are instructed to guess if necessary, instead of skipping letters they cannot remember. There are no timing restraints on recall, and the participants have a self-paced break after every 3 trials. Half of the equations are correct and half are incorrect. There are a total of 15 trials. The participant's score is the proportion of letters they correctly recalled from all trials.

Next, the participants complete the reading span task. Participants complete three practice trials before beginning the experimental trials. The procedure for this task is nearly identical to the operation span task, except participants have to verify that sentences make sense as opposed to equations. The only difference is that participants are given 5 seconds instead of 3 seconds to verify that the sentence is meaningful.

Finally, the participants will complete the spatial short-term memory task. Participants have to remember the location of a number of dots in a 10 X 10 grid. The trial begins with a fixation cross that appears in the center of the screen for 1 second. Next, the grid is shown and a variable number of dots (2-6) appear one by one in the cells of the grid for 900 milliseconds each. No dots appear in the corner positions of the grid to avoid any verbal coding. The participants have to remember the overall pattern of the dots; absolute dot position is irrelevant. After all the dots are presented, the participants are cued to reproduce the pattern of dots. This cue is presented using a pattern mask that is the same size as the grid.

The participants use the mouse to reproduce the pattern of dots, clicking on the appropriate cells. The order that the participants reproduce the dots is irrelevant, and the participants are allowed to correct the pattern until they are satisfied with their response. Clicking on a dot twice makes it disappear. The participants begin the next trial by clicking a "Next" button and the space bar. They receive no feedback. There are a total of 30 trials.

After completing these tasks, the participants are instructed to return in two days, where they will then read the experimental passages, with the same procedure as Experiment 1.

Results and Discussion

Experiment 3 was designed to investigate the role that working memory capacity plays in reading comprehension. Specifically, this experiment will tease apart the differences between skilled and less-skilled readers to shed light on the question of whether the difficulty less-skilled readers demonstrate during the integration process of reading is a byproduct of having low working memory capacity. The predicted results for Experiment 3 are further discussed in the following chapter (see Future Directions).

CHAPTER VII

GENERAL DISCUSSION

Readers differ on many dimensions, including reading skill, domain knowledge, and working memory capacity (McNamara & McDaniel, 2004; McNamara & O'Reilly, 2009; Conway & Engle, 1994; Engle, 1996) which influences how successful they are at encoding, integrating, and updating information. The experiments in this thesis were designed to investigate situations where, for skilled and less-skilled readers, the updating process involved outdating specific targeted information.

Previous studies have demonstrated that skilled and less-skilled readers can detect inconsistencies at the local level of texts and that both types of readers can reactivate information from earlier in the text via the resonance process (Long & Chong, 2001; Stiegler & O'Brien, 2009). Additionally, causal information has shown to be helpful to readers during the outdating process (Rapp & Kendeo, 2007, 2009; Kendeou et al., 2010). Causal information can create an elaborate network for the reader that is semantically rich (O'Brien & Myers, 1987; Trabasso & Suh, 1993). This abundance of consistent information can keep readers from being disrupted by earlier inconsistencies in the text. However, the effectiveness of causal information for readers of different skill levels had not been previously tested.

Experiment 1 examined whether less-skilled readers would use causal information to update their mental representation of the text to the same extent as skilled readers, successfully outdating information from the text that had been discounted or changed. As expected, both skilled and less-skilled readers were the slowest while reading the target sentences in the inconsistent elaboration passages. However, there were also clear differences between the skilled and less-skilled readers regarding the causal elaborations. Despite the inconsistencies in the passage, skilled readers were able to use

the causal information to update their representation, and they no longer showed disruption from the outdated information.

Less-skilled readers, on the other hand, were not as successful at updating using causal information; they continued to show disruption from the outdated information. However, the target sentences from the causal elaboration passages were read significantly faster than the inconsistent elaboration passages, so the less-skilled readers were able to make some use of the causal information, just not as well as the skilled-readers. The addition of a causal explanation was not enough to keep less-skilled readers from being disrupted by previously outdated information. As earlier research has shown that less-skilled readers can reactivate information from earlier portions of the discourse to the same extent as skilled readers (Long & Chong, 2001), experiment 1 raises the question of why less-skilled readers were unable to use the causal information as efficiently as the skilled readers, even though they had access to it.

Experiment 2 investigated whether less-skilled readers had difficulty fully updating their representation because they did not fully encode the causal information. Reading times for experiment 2 replicated the pattern from experiment 1. There was no significant difference between the causal and the consistent passages for skilled readers, but less-skilled readers were significantly slower to read target sentences from the causal passages than the consistent passages.

The recall results from experiment 2 bolstered the evidence indicated by the reading times. Because the recall data was an offline measure of reading, what the readers actually comprehended cannot be absolutely determined. However, there are several viable explanations for readers showing enhanced recall. Reprocessing inconsistent information in order to resolve the discrepancy has been shown to lead to enhanced recall (Albrecht & O'Brien, 1993; O'Brien & Myers, 1985). Alternatively, inconsistent information that cannot be resolved can also be tagged as inconsistent by

the reader, and the act of being tagged later facilitates recall (Albrecht & O'Brien, 1993).

The recall data suggests that the three types of passages required different levels of processing from the skilled and less-skilled readers. Over all, skilled readers recalled more idea units from the inconsistent and causal passages. The slowdown in reading times suggests that skilled readers showed enhanced recall for the inconsistent passages because they were unable to resolve the inconsistencies. However, because there were no differences in reading times for the consistent and causal passages, this suggests that skilled readers showed enhanced recall for the causal passages because they were forced to reprocess the inconsistent information and were able to resolve it.

The inconsistencies in the passages for experiment 2 centered on the elaboration region and were reintroduced by the first target sentence, and unsurprisingly, these regions were where the effects were located. Skilled readers tended to recall more idea units from the inconsistent elaboration, although the effect was not significant. However, additional data is needed and should shed more light on this trend. Skilled readers also showed enhanced recall for the first target sentence for both the inconsistent and causal passages. Again, reading times for the inconsistent passages indicated that this was a function of the reader tagging the information as discrepant, while reading times indicated for the causal passages that skilled readers resolved the incongruity, which led to better recall and a more fully integrated representation of the text.

Less-skilled readers did not show enhanced recall for any specific condition of the passage, which indicates that they used the same overall level of processing for all the passages. For less-skilled readers, perhaps even the consistent passages required effort, so there were no significant differences in recall. Looking specifically at the elaboration regions, less-skilled readers recalled significantly more idea units from both the inconsistent and causal elaborations. This makes it clear that the less-skilled readers were

able to encode the causal information; it became part of their final representation of the text. But because the reading times indicated that the readers were still disrupted by outdated information in the causal passages, this enhanced recall most likely demonstrates that less-skilled readers tagged both the inconsistent and causal elaborations as discrepant, and not that they were able to resolve the inconsistencies in the causal passages. Additionally, less-skilled readers showed enhanced recall for the first target sentence from the inconsistent passages only. They did not seem to be able to resolve the inconsistencies in the causal passages, and as a result, did not show enhanced recall.

Both types of readers were able to encode the causal information, yet only the skilled readers made full use of it. Less-skilled readers have demonstrated that they are able to reactivate information from earlier in the text (Long & Chong, 2001), as well as demonstrating an ability to encode, and thus recall, causal information. Despite this, less-skilled readers continued to show disruption by outdated information; at some point in the reading process, the causal information did not become fully integrated into less-skilled readers' representation of the discourse, leaving them with a fragmented and disjointed view of the text.

Future Directions.

Experiment 3 was designed to investigate if the difficulty less-skilled readers demonstrated with the integration process stemmed from a deficit in resources. If readers' comprehension difficulties result from a resource deficit, problems with integrating causal information should be isolated to only those readers with low working memory capacity. The results from experiment 3 are forthcoming, and will be collected in the Fall of 2011.

The facets in which skilled and less-skilled readers differ are numerous. Domain knowledge, reading skill, and especially working memory capacity all play an important

role in limiting the ability of less-skilled readers. The deficits less-skilled readers show are the result of a complex combination of factors, which seem to revolve around the availability of cognitive resources. Despite being able to activate and encode information from texts, less-skilled readers somehow fail to form a full and accurate picture of that discourse, which implies that future intervention programs in schools should concentrate on strategies that help less-skilled readers learn to make the connections between the current text and earlier information.

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APPENDICES

APPENDIX A

The passages used in Experiments 1, 2, and 3 are presented in this appendix. Each participant only saw one of the three conditions of each passage.

Introduction: Carol had always wanted to be a construction worker. It was hard getting started but she found this job two years ago. It was exciting for her and she couldn't have been happier.

Consistent Elaboration: Carol especially enjoyed working on the beams of skyscrapers, high above the city. She was thrilled by the high winds and the view. She felt exhilarated watching the activity on the street far below. In fact, she always volunteered to work on the high beams.

Inconsistent Elaboration: Carol was extremely scared of heights and would only work on the ground level. She even refused to climb anything higher than a step ladder. While the others worked on the upper levels she worked on projects where she could stay safely on the ground.

Causal Elaboration: Carol was extremely scared of heights and would only work on the ground level. She even refused to climb anything higher than a step ladder. While the others worked on the upper levels she worked on projects where she could stay safely on the ground. Because this was disrupting her life, her therapist suggested she try to do exciting activities involving heights.

Transition: Her co-worker, Lori, invited Carol to join her on a trip. As Lori described the weekend adventure, Carol became very excited.

Target Sentence 1: She was looking forward to skydiving.

Target Sentence 2: Carol immediately accepted the offer.

Conclusion: To celebrate, she offered to take Lori out to dinner. Over dinner they finalized the plans for the trip. They would leave Lori's house the following Saturday at 6 am.

Introduction: Bill had always enjoyed walking in the early morning and this morning was no exception. During his walks, he would stop to talk with some of his neighbors.

Consistent Elaboration: Bill had just celebrated his twenty-fifth birthday. He felt that he was in top condition and he worked hard to maintain it. In fact, he began doing additional workouts before and after his walks. He could now complete a 3 mile run with hardly any effort.

Inconsistent Elaboration: Bill had just celebrated his eighty-first birthday. He didn't feel as strong as he was twenty years ago. In fact, Bill began using a cane as he hobbled along on his morning walks. He could not walk around the block without taking numerous breaks.

Causal Elaboration: Bill had just celebrated his eight-first birthday. He didn't feel as strong as he was twenty years ago. In fact, Bill began using a cane as he hobbled along on his morning walks. He could not walk around the block without taking numerous breaks. Nevertheless, his age never prevented him from acting in emergencies because he always had boosts of adrenaline.

Transition: As Bill was talking to Mrs. Jones, he saw a young boy who was lying unconscious and hurt in the street.

Target Sentence 1: He quickly ran and picked the boy up.

Target Sentence 2: Bill carried the boy over to the curb.

Conclusion: While Bill helped the boy, Mrs. Jones ran into her house to call the boy's mother and an ambulance. He kept the boy calm and still until help arrived.

Introduction: Owen had just completed graduate school and now had begun looking for a job. Most jobs he looked at were academic positions which required both teaching and research.

Consistent Elaboration: The part of graduate school that Owen liked most was teaching. He hoped his new job would only consist of teaching responsibilities. His students all had favorable things to say about him and he was proud of his accomplishments. He was not interested in research.

Inconsistent Elaboration: Owen particularly liked the research that he performed while in graduate school. To him, there was nothing more enjoyable than discovering something that had not been known before. He was a successful researcher and wanted to continue along this line. He was not interested in teaching.

Causal Elaboration: Owen particularly liked the research that he performed while in graduate school. To him, there was nothing more enjoyable than discovering something that had not been known before. He was a successful researcher and wanted to continue along this line. He was not interested in teaching. Because there were no research positions currently available, his mentor told him to find a decent teaching program.

Transition: Owen searched through the paper for jobs that would suit him. It took days but he finally found one he liked.

Target Sentence 1: Owen applied for a teaching position.

Target Sentence 2: This university discouraged research.

Conclusion: Owen hoped that he would be hired for the job. He knew many new doctorates who could not find positions that suited them and he did not want to be in that position.

Introduction: Steven recently graduated from college and was going to graduate school. As an undergraduate, he was involved in numerous organizations. This helped Steven to narrow his interests for graduate school.

Consistent Elaboration: He was most proud of being an officer of the mechanical and industrial clubs. Steven felt that natural resources should be exploited. It didn't matter if it destroyed the environment. He believed any effect would be temporary and the environment would take care of itself.

Inconsistent Elaboration: He was most proud of being an officer in the numerous clean up and recycling clubs. Steven was an active environmentalist on campus and in the surrounding community Currently, he was involved in leading a protest against companies dumping waste products into a local river.

Causal Elaboration: He was most proud of being an officer in the numerous clean up and recycling clubs. Steven was an active environmentalist on campus and in the surrounding community. Currently, he was involved in leading a protest against companies dumping waste products into a local river. Still, he never recycled trash outside of school because he only presented himself that way to build his resume.

Transition: Last Saturday, Steven had to work on his car. He jacked the car up and drained the oil into an old container.

Target Sentence 1: He dumped the oil out in his backyard.

Target Sentence 2: Steven figured that it would be okay.

Conclusion: He returned to the garage and finished working on his car. After he was satisfied with the engine work, Steven waxed the finish, polished the chrome, and cleaned the interior.

Introduction: Today, Mary was meeting a friend for lunch. She arrived early at the restaurant and decided to get a table. After her friend arrived, she started looking at the menu.

Consistent Elaboration: This was Mary's favorite restaurant because it had fantastic junk food. Mary enjoyed eating anything that was quick and easy to fix. In fact, she ate at McDonalds at least three times a week. Mary never worried about her diet and saw no reason to eat nutritious foods.

Inconsistent Elaboration: This was Mary's favorite restaurant because it had fantastic health food. Mary, a health nut, had been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease.

Causal Elaboration: This was Mary's favorite restaurant because it had fantastic health food. Mary, a health nut, had been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything that was fried or cooked in grease. She wasn't getting enough vitamins because of her diet so her doctor said she had to start eating meat.

Transition: Mary checked the menu and specials one more time. She was having a hard time deciding what to have for lunch.

Target Sentence 1: Mary ordered a cheeseburger and fries.

Target Sentence 2: She handed the menu back to the waiter.

Conclusion: Her friend didn't have as much trouble deciding what she wanted. She ordered and they began to chat again. They didn't realize there was so much for them to catch up on.

Introduction: George was a senior in high school and was in the process of applying to college. During this time, he realized he needed to participate in some extracurricular activities before he graduated.

Consistent Elaboration: George had always been outgoing and loved to talk and perform in front of people. When a teacher would assign an oral report he would get excited. On the day of an oral report, he would be the first to volunteer to present.

Inconsistent Elaboration: He had always been shy and detested speaking in front of strangers. When a teacher would assign an oral report he would become sick to his stomach. On the day of a report, George would often break out in hives and would have to leave school.

Causal Elaboration: He had always been shy and detested speaking in front of strangers. When a teacher would assign an oral report he would become sick to his stomach. On the day of a report, George would often break out in hives and would have to leave school. Because George wanted to act, he was determined to overcome his fear of speaking in front of people.

Transition: His high school offered many different after school activities. He saw a large flier announcing open auditions for the spring play.

Target Sentence 1: He auditioned for the part of male lead.

Target Sentence 2: He was cast in the male lead of Romeo.

Conclusion: The rehearsals were to begin the next day. George picked up his script and began to study that night. He wanted to be the best Romeo anyone had ever seen.

Introduction: Jessica had always been fascinated by different cultures. Her family had decided to take a trip to Germany last summer. She was glad her parents had chosen Germany as a vacation spot.

Consistent Elaboration: Jessica was able to use the language she had been studying for seven years. She had always gotten A's in her German classes and had also received the outstanding German student award in high school. This award included a scholarship for each year of college.

Inconsistent Elaboration: It was the first time Jessica had left her small midwestern town. She had no idea what Germany would be like. None of the schools in her town offered foreign culture or language classes. Her only exposure to German culture was a television documentary.

Causal Elaboration: It was the first time Jessica had left her small midwestern town. She had no idea what Germany would be like. None of the schools in her town offered foreign culture or language classes. Her only exposure to German culture was a television documentary. Jessica was able to learn German because she borrowed library CDs of a complete course in the language.

Transition: While traveling in Germany, the family saw many famous sights. The greatest experience for them was eating in the huge dining halls.

Target Sentence 1: Jessica ordered all her meals in German.

Target Sentence 2: No one could believe how fluent she was.

Conclusion: Everyone agreed that German food was much better than American food. After dinner one night the family decided to visit the Berlin zoo. Jessica wanted to see the baby pandas.

Introduction: As he got out of the shower, Tim was thinking about what needed to be done. He was going to have one shot at this and he wanted to get it right.

Consistent Elaboration: He was going to tar his roof and then lay down shingles. Tim knew tarring was messy and sticky work. On hot days, the tar seemed to get everywhere. He knew by the end of the day he would be covered with the stuff.

Inconsistent Elaboration: Tim was going to propose to his girlfriend. Their evening would begin at Chez Loui, an elegant French restaurant. Chez Loui was a very formal place and Tim wanted to look his best. After he proposed a toast, Tim would ask for her hand in marriage.

Causal Elaboration: Tim was going to propose to his girlfriend. Their evening would begin at Chez Loui, an elegant French restaurant. Chez Loui was a very formal place and Tim wanted to look his best. After he proposed a toast, Tim would ask for her hand in marriage. He needed to dress casually because he didn't want her to know this was a special night.

Transition: Tim had a hard time choosing what to wear. He looked through his dresser for some clothes but didn't find anything he liked.

Target Sentence 1: At last he grabbed some old faded jeans.

Target Sentence 2: Tim pulled them on and zipped them up.

Conclusion: Tim searched his drawers for a pair of socks. He finished getting ready and grabbed his keys and wallet. Tim locked the door behind him and was on his way.

Introduction: Jennifer enjoyed walking everyday in the park near her house. During the summer months, she would often stop and watch the ducks swimming in the small pond.

Consistent Elaboration: Jennifer was a healthy, twenty-two year old woman. She had just graduated from college and was in top physical condition. She could not imagine herself being in better shape. In fact, her health was the one thing she was most proud of.

Inconsistent Elaboration: Jennifer was quite old and was having problems with her hearing. She was legally deaf and could not hear anything at all. She had tried to use a hearing aid, but it had stopped helping years ago. She was in her own silent world.

Causal Elaboration: Jennifer was quite old and was having problems with her hearing. She was legally deaf and could not hear anything at all. She had tried to use a hearing aid, but it had stopped helping years ago. She was in her own silent world. However, now she is able to hear loud noises because her doctor gave her a newer model hearing device.

Transition: One day, while Jennifer was walking, a mugging took place. Jennifer was about thirty feet from where the event was taking place.

Target Sentence 1: Jennifer heard the woman yell for help.

Target Sentence 2: She looked up to see what was happening.

Conclusion: The police asked Jennifer to give them all of the information that she could. There had been a string of muggings in the park and the police were interested in finding the culprit.

Introduction: Carl and Sarah had only been dating for about two weeks. However, Carl wanted to plan a special night for their next date. A friend suggested that they attend a baseball game.

Consistent Elaboration: Carl loved baseball and thought that this was a great idea. He had been a huge fan of the Red Sox ever since he could remember. As a child, his whole life revolved around the sport. He thought going to a game would be the perfect date.

Inconsistent Elaboration: Carl thought that this was a terrible idea. When he was younger his father had dragged him to baseball games. He hated them and vowed that he would never go again. He was sure he would think of something better to do.

Causal Elaboration: Carl thought that this was a terrible idea. When he was younger his father had dragged him to baseball games. He hated them and vowed that he would never go again. He was sure that he would think of something better to do on their date. He knew, however, that Sarah would love to go to the game on their date because she loved baseball.

Transition: He called Sarah to tell her about the plan for their next date, and then he confirmed the day and time.

Target Sentence 1: He called the ballpark to order tickets.

Target Sentence 2: He hoped that they would get good seats.

Conclusion: Carl sat back and thought about where he and Sarah would go to eat before the game. He was certain that they would have a great time together.

Introduction: Fred always wanted to go to college. He studied really hard in high school so he would be able to achieve this goal. He graduated with high honors.

Consistent Elaboration: Fred's favorite subject in school was math. He could not think of a bigger challenge in school that matched the one posed by understanding math. He spent his free time performing complicated mathematical equations on his new computer. The intellectual challenge of math excited him.

Inconsistent Elaboration: Fred had done well in all his classes except math. He had to struggle through each math course with the help of a tutor. He just did not understand the concepts behind the operations. He only took the minimum number of math courses required to graduate.

Causal Elaboration: Fred had done well in all his classes except math. He had to struggle through each math course with the help of a tutor. He just did not understand the concepts behind the operations. He only took the minimum number of math courses required to graduate. Because he wouldn't let his high school experience influence him, he took several summer math courses and improved his skills.

Transition: Fred had been accepted at Stanford University. He decided to look through the college catalogue for classes he knew he would do well in.

Target Sentence 1: He decided to take three math courses.

Target Sentence 2: He thought they would be interesting.

Conclusion: College would be hard, but Fred was confident that he would do well. His hard work had always paid off and he was certain it would this time as well.

Introduction: Ken had been looking for a hobby for quite some time. With his new job, he had four days a week free which would give him plenty of time to devote to a hobby.

Consistent Elaboration: Ken was a big man and always tried to keep in shape by jogging and lifting weights. His 250 pound body was solid muscle. Ken loved tough physical contact sports which allowed him to match his strength against another person.

Inconsistent Elaboration: Ken was a small man and didn't worry about staying in shape. His small 120 pound body was all skin and bones. Ken hated contact sports, but enjoyed non-contact sports, such as golf and bowling, which he could practice alone.

Causal Elaboration: Ken was a small man and didn't worry about staying in shape. His small, 120 pound body was all skin and bones. Ken hated contact sports but enjoyed non-contact sports, such as golf and bowling, which he could practice alone. Because his friends often teased him about his weight, he wanted to do a more physical sport.

Transition: While walking downtown, Ken passed a new gymnasium. He noticed the advertisement for their sports program. It seemed interesting so Ken went inside.

Target Sentence 1: Ken decided to enroll in boxing classes.

Target Sentence 2: He felt this would be the perfect hobby.

Conclusion: Ken signed-up for the class and paid the registration fees. He couldn't wait for the class to begin. Ken exited the gym and continued his walk downtown.

Introduction: Elizabeth's daughter, Kim, had just started kindergarten. Elizabeth was happy that Kim had made a lot of friends. Kim would often tell her mom about her friends at school.

Consistent Elaboration: In addition, Kim loved animals. In fact, she refused to leave a room that had any type of pet in it. Every time she saw an animal she wanted to pet it and take it home. Elizabeth didn't know why Kim loved animals so much.

Inconsistent Elaboration: Unfortunately, Kim hated animals and was terribly frightened of them. In fact, she refused to go in the same room with a cat. Every time an animal approached her, she ran away and began to cry. Elizabeth didn't know why Kim was so frightened of animals

Causal Elaboration: Unfortunately, Kim hated animals and was terribly frightened of them. In fact, she refused to go in the same room with a cat. Every time an animal approached her, she ran away and began to cry. Elizabeth didn't know why Kim was so frightened of animals. However, Kim wasn't afraid of animals when her mother was in the room because her mother always protected her.

Transition: As Elizabeth and Kim entered the classroom, Kim looked around. Someone had brought in their pet and all the children were gathered around it.

Target Sentence 1: Kim ran across the room to pet the dog.

Target Sentence 2: She smiled as she brushed the dog's fur.

Conclusion: Kim waved to her mom and asked her to come see the dog. Elizabeth walked to the other side of the room and knelt down beside Kim and petted the dog.

Introduction: Todd woke up and hopped out of bed. This was his favorite time of the day and he did not want to waste it lying in bed.

Consistent Elaboration: Todd ran over to the wood stove and lit a fire to warm up. During the winter months, his house got very cold. He enjoyed lighting a fire and watching it burn while he had breakfast and warmed up. Todd liked the cold winter months.

Inconsistent Elaboration: It had been the warmest winter in the past fifty years. Todd could not believe it had gotten so warm. In fact, it was so warm that people were spending most of the day outdoors.

Causal Elaboration: It had been the warmest winter in the past fifty years. Todd could not believe it had gotten so warm. In fact, it was so warm that people were spending most of the day outdoors. There were icicles in the windowsill because Todd had left the windows open and it was still freezing at night.

Transition: Todd really enjoyed winter activities like skiing and ice fishing. Hockey had been his favorite sport since he was a child.

Target Sentence 1: Todd thought that his house was cold.

Target Sentence 2: He grabbed a sweater from his closet.

Conclusion: Todd walked back into the kitchen. He finished eating his breakfast and went into the living room. Todd thought it was going to be a great day.

Introduction: As Linda was driving to her job interview, her car overheated and stopped running. The car was very old and she knew she needed to buy a new one.

Consistent Elaboration: Fortunately, this wasn't a problem for Linda. Her parents were very rich and would give her the money for a new car. Linda's parents always gave her money and whatever else she wanted. They had continued to do so even after she graduated from college.

Inconsistent Elaboration: Unfortunately, Linda didn't have the money to buy a new car. She had just graduated from college and was unable to find a job. She owed thousands of dollars in loans and barely had enough money to survive. Linda knew she couldn't get a loan.

Causal Elaboration: Unfortunately, Linda didn't have the money to buy a new car. She had just graduated from college and was unable to find a job. She owed thousands of dollars in loans and barely had enough money to survive. Linda knew she couldn't get a loan. Because her parents wanted her to have a reliable vehicle, they co-signed a loan for buying a car.

Transition: Linda called a tow truck to come pick her up. She knew she had to find a new form of transportation.

Target Sentence 1: Linda decided to buy a brand new car.

Target Sentence 2: She could easily afford to buy a car.

Conclusion: Finally, the tow truck arrived. Linda was happy to see the truck because she wanted to go home. Linda was frustrated and thought the day was a complete disaster.

Introduction: Al and Sue were on their way to a friend's house for a party. This was the first time in quite awhile that Al and Sue had visited their friends.

Consistent Elaboration: While speeding along the highway at about 80 mph., Al described to Sue the perfect condition of his new, sleek sports car. He loved the power, control and speed of the car, which could cruise at speeds well over 95 mph.

Inconsistent Elaboration: While crawling along the highway at about 30 mph, Al described to Sue the terrible condition of his old, beat up car. He complained about how the car would only sputter up to 35 mph then stall and over-heat.

Causal Elaboration: While crawling along the highway at about 30 mph, Al described to Sue the terrible condition of his old, beat up car. He complained about how the car would only sputter up to 35 mph then stall and over-heat. Because Sue enjoyed driving fast, she told Al to test the limits of his car and drive faster.

Transition: As they were driving, Al suddenly noticed a police car in his rearview mirror. Al pulled over to the side of the road.

Target Sentence 1: The officer handed Al a speeding ticket.

Target Sentence 2: He told Al it would cost fifty dollars.

Conclusion: Al took the ticket and put it in his wallet. Quite upset, Al started up the car. For the remainder of their trip, Al did not say a word.

Introduction: Karen called her friend Ralph at his dormitory. She had just returned from spring vacation and asked if he could arrange for someone to pick her up at Logan airport.

Consistent Elaboration: Ralph enjoyed driving to the airport in Boston. Because he grew up in the city, he had a lot of practice driving in heavy traffic. Ralph was proud of his city driving skills and often offered to take his friends into the city and to the airport.

Inconsistent Elaboration: Even though Ralph had had his license for years, he was petrified of driving in Boston. Ever since he was in a terrible accident two years ago, he refused to drive in the city. If he needed to go anywhere near the city, Ralph took public transportation.

Causal Elaboration: Even though Ralph had had his license for years, he was petrified of driving in Boston. Ever since he was in a terrible accident two years ago, he refused to drive in the city. If he needed to go anywhere near the city, Ralph took public transportation. He had to get her because he couldn't find anyone else and she would be stranded if he didn't.

Transition: He was really anxious to hear all about Karen's vacation, and he hoped that she had taken a lot of pictures.

Target Sentence 1: Ralph drove into Boston to pick her up.

Target Sentence 2: He recalled why he enjoyed city driving.

Conclusion: As he approached the airport, Ralph thought about how nice it would be to see Karen. He was anxious to hear about her vacation and tell her what had been happening at school.

Introduction: Phil was watching television while his wife finished unpacking. They had gone away for the weekend and left the house a mess. His wife sat down and they began discussing cleaning up the house.

Consistent Elaboration: Phil had a habit of throwing everything away, especially when it came to receipts and sales slips. He would read notes, letters, and bills once and then throw them away. In fact, Phil had not kept any kind of a record for over ten years.

Inconsistent Elaboration: Phil was a packrat and saved everything. In fact, he had been saving receipts, letters, and newspapers for over the past ten years. He had a large storage room in which he put important papers and other things he wanted to save.

Causal Elaboration: Phil was a packrat and saved everything. In fact, he had been saving receipts, letters, and newspapers for over the past ten years. He had a large storage room in which he put important papers and other things he wanted to save. Because his storage room was becoming crowded, he stopped saving old documents after his wife demanded that he clean.

Transition: As Phil and his wife talked, she remembered she had to find their latest bank statement. Phil remembered what he had done with them.

Target Sentence 1: He had thrown away the bank statements.

Target Sentence 2: He had thrown them out a long time ago.

Conclusion: Frustrated, they sat down and started thinking about what they should do. Phil said he would call the bank in the morning to see if they had any record of the transaction.

APPENDIX B

Participants completed the Gates-MacGinitie reading tests as part of Experiments 1, 2, and 3.

Gates-MacGinitie

READING TESTS

Fourth Edition

Walter H. MacGinitie, Ruth K. MacGinitie,
Katherine Maria, & Lois G. Dreyer

DO NOT begin this section unless instructed to do so.

Comprehension 10/12 – S

Sometimes - not very often - we get two full moons in one month. That second full moon is called a "blue moon." No one knows why. Now we say "once in a blue moon" to mean "once in a long time."

C-1. To be a "blue moon," the moon must be

A. dark.
B. long.
C. blue.
D. full.

C-2. What is it that no one knows?

A. What the name is.
B. Who uses the name.
C. Where the name came from.
D. What the name means.

A crowd of people surged in to the Eighth Avenue express at 59th Street. By elbowing other passengers in the back, by pushing and heaving, they forced their bodies into the coaches, making room for themselves where no room had existed before. As the train gathered speed for the long run to 125th Street, the passengers settled down into small private worlds, thus creating the illusion of space between them and their fellow passengers. The worlds were built up behind newspapers and magazines, behind closed eyes or while staring at the varicolored show cards that bordered the coaches.

1. Why was it difficult to get on the train?

   A. The train didn't stop long enough.
   B. There was a barrier in the way.
   C. The train was already full.
   D. The people were reading newspapers.

2. The newspapers helped the passengers

   A. pass the time.
   B. forget where they were going.
   C. sleep.
   D. feel that they were by themselves.

3. Staring at the show cards served the same purpose as

   A. finding a seat.
   B. getting on the train.
   C. shutting one's eyes.
   D. staring at other passengers.

4. In this passage, the word run means

   A. trip.
   B. race.
   C. string of good luck.
   D. series of performances.

In later life, John Quincy Adams recalled an incident typical of his mother Abigail's bravery and resourcefulness. In 1775 British troops from Boston were advancing on Braintree, searching for rebel arsenals. All day neighbors traveled the road in front of the Adams' farmhouse, retreating from the expected attack. Abigail was alone in her home with her children. When rebel troops arrived, they advised Abigail to flee. Instead she stayed, handing over all her precious pewter to the rebels, helping them melt down the metal for bullets. The rebel soldiers departed, and Abigail remained, expecting the worst but refusing to give in to the panic that possessed some of her neighbors. "Do you wonder," wrote her son, "that a boy of seven who witnessed this scene is a patriot?"

5. The neighbors who passed the Adams' house were trying to

A. defend their homes.
B. avoid being hurt.
C. join one of the armies.
D. get to Boston.

6. The passage suggests that the rebels had little

A. ammunition.
B. concern for Abigail.
C. knowledge of the countryside.
D. warning that the British were advancing.

7. What demonstrated Abigail's resourcefulness was the way she

A. fooled the British troops.
B. sent messages to the rebel troops.
C. learned where the British troops had come from.
D. provided what was needed from what she had available.

8. John Quincy Adams believed that this experience was a source of his

A. resourcefulness.
B. interest in military history.
C. courage.
D. love of country.

Fresco involves painting into wet lime plaster with pigment mixed into limewater. The layer of calcium carbonate formed by the limewater binds the pigments to the plaster wall, and the mutual wetness of the pigment and the surface causes the color to dye the wall. This makes for a highly permanent decoration, as long-lived as the building itself. Permanence is the main advantage of fresco and is, of course, its own recommendation.

Michelangelo's *Creation of Adam*, like all the other works on the ceiling of the Sistine Chapel in the Vatican, is an example of fresco painting. Since plaster cannot be rewet, once it is dry, the fresco artist never applies more plaster to his surface than he knows he can finish in a single day. Consequently, we can find places in this fresco where plaster joints occur. There is a seam where Adam's neck fits onto his body and another at the line between the torso and the legs. Adam is about twelve feet long, and it took Michelangelo three sessions to complete him.

9. In fresco painting, the pigment is first mixed into

A. plaster.
B. limewater.
C. oil.
D. the wet part of the wall.

10. Why are fresco paintings long lasting?

A. The seams are strong.
B. The pigment becomes part of the wall.
C. The plaster is protected by the layer of pigment.
D. The painting is protected by the layer of plaster.

11. About how long does the plaster stay wet enough to paint?

A. Ten minutes.
B. An hour.
C. A day.
D. A week.

12. A fresco artist must be careful to

A. rewet the plaster as needed.
B. apply the plaster to small enough areas.
C. let the plaster dry before beginning to paint.
D. let the paint dry before applying plaster.

13. A seam in a fresco is a line

A. where the wall joins the ceiling.
B. between different colors.
C. between areas painted at different times.
D. where material has been added to strengthen the plaster.

14. The example of the *Creation of Adam* shows how one can tell

A. where the artist applied plaster.
B. how long ago the fresco was painted.
C. how large the figures on a ceiling fresco are.
D. how many sessions it took to do a fresco.

An author's introduction to the story of his life:

I had planned to write chronologically, but then realized that, of course, I don't think chronologically. Writing a memoir is like fishing. You cast your line and you pull on it when a fish strikes, but you never know what will be on the other end, for the ocean is deep and is filled with marvelous creatures that do not break the surface in expected order. Nor do they swim under the waves with the whales leading and the minnows at the end of long straight lines. A memoir, like a fish, will not thrive under every discipline. Another way of putting this is that if you alphabetize the Iliad you will have approximately the Athens telephone book. When I think back, things don't line up, they stand out, so I will take them as they come, as once I took them as they came.

15. In this passage, the author explains why he

A. decided to write about himself.
B. waited so long to begin writing.
C. included details that seem unimportant.
D. changed his mind about how he would write.

16. What do the ocean creatures represent?

A. Events in the author's life.
B. People the author has known.
C. All the words in the language.
D. The dangers of looking into one's past.

17. In this passage, the word discipline means

A. punishment.
B. a field of study.
C. rules by which something is organized.
D. training that perfects mental or moral qualities.

18. The Athens telephone book is used as an example of something that is

A. too long.
B. impossible to read.
C. orderly but boring.
D. full of information.

19. When the author says "... as once I took them," he means that

A. he was always eager to do things.
B. he could stand up to any difficulty.
C. he believed that he deserved what he got.
D. he dealt with experiences as they happened.

All "symmetrical" organisms develop asymmetries. A fruit fly, no longer than the tip of a lead pencil, having developed while stuck to the inside of a glass culture vessel, has different numbers of sensory bristles on its left and right sides, some flies having more on the left, some more on the right. Moreover, this side-to-side variation is as large as the difference among different flies. But the genes on the left and right sides of a fly are the same, and it seems absurd to think that the temperature, humidity, or concentration of oxygen was different between left and right sides of the tiny developing insect. The variation between sides is a result of random events in the timing of division and movement of the individual cells that produce the bristles, so-called developmental noise.

20. Why does the author put symmetrical in quotation marks?

A. It is a scientific term.
B. It is a new word that the author made up.
C. The author is referring to another author's use of the term.
D. The usual meaning of the word is not completely accurate in this context.

21. In this passage, the vessel is

A. a boat.
B. a container.
C. a vein or artery.
D. a window.

22. The passage implies that differences such as that between right- and left-hand fingerprints could be a result of

A. differences in genes.
B. differences between individuals.
C. symmetry.
D. unpredictable variations in the way cells divide.

23. How does the number of bristles on the right side affect the number of bristles on the left side?

A. It has no effect.
B. It makes the left side have fewer bristles.
C. It makes the left side have an equal number of bristles.
D. It makes the left side have more bristles.

Margaret had just gotten her first pair of sunglasses, perfect cat-eyes, and she was amazed at how much she could see. She lay in the scrub grass beneath a stand of cottonwoods, took them off, and watched the branches turn gauzy and familiar. Then she put the glasses back on, bracing a little for the barrage of detail. Thousands of leaves leaped out, trembling and hard-edged. The narrow river, a few yards away, turned crunchy-looking again. Bird sounds attached themselves to small shapes on high branches.

She didn't know when her vision had started to go seriously bad. It had been so gradual, this nearsightedness, that she hadn't noticed it for a while. At first, it seemed only that a luxurious vagueness had come into her life. Then it had begun to make her uneasy. But this sudden return of all the details was more than she really wanted. It was unnerving. It gave her the same feeling she got when someone explained how something scientific works – osmosis, say, or photosynthesis. The explanations crowded out her imagination and made her feel bleak with information.

24. What was Margaret not sure of?

A. Why she had been feeling uneasy.
B. When she started to need glasses.
C. Whether her glasses were working properly.
D. Why everything looked so different through glasses.

25. What had Margaret liked about not seeing well?

A. She needed to imagine things.
B. She didn't have to work.
C. She could get people to explain things.
D. She wasn't expected to understand science.

26. It seems to Margaret that, when she wore glasses, she had

A. a feeling of luxury.
B. a greater enjoyment of nature.
C. too much information.
D. a greater awareness of sounds.

27. The passage suggests that Margaret would have been happier with glasses that were

A. weaker.
B. smaller.
C. like cat-eyes.
D. more stylish.

28. In this passage, the word bracing means

A. turning.
B. pushing away.
C. stimulating.
D. getting ready.

A pulsar is thought to be a rapidly spinning neutron star. Such stars can arise from the gravitational collapse of a supernova's core. It is in conserving angular momentum as it shrinks to a diameter of only several kilometers that the neutron star attains its high rotational velocity. If the neutron star continuously emits a beam of electromagnetic radiation from a spot in the magnetized plasma overlying its surface, the beam is swept around like the beacon of a lighthouse. Such a radio beam, striking the earth with each revolution of neutron star, can account for the observed radio-frequency pulsations.

29. A supernova's core becomes a neutron star because of

A. rotation.
B. gravity.
C. pulsation.
D. magnetized plasma.

30. A neutron star speeds up because it

A. gets smaller.
B. has a radio frequency.
C. is magnetized.
D. emits a beam.

31. Pulsars are thought to send out a radio beam from

A. their magnetic poles.
B. explosions in their interior.
C. one place near their surface.
D. the place where the beam strikes the earth.

32. What does like the beacon of a lighthouse describe?

A. Radiation sent out by a pulsar.
B. The star from which a pulsar is formed.
C. Signals scientists send out to detect pulsars.
D. The path of an object caught in a pulsar's gravity.

33. How often the beam from a pulsar strikes the earth depends on

A. how far the pulsar is from the earth.
B. how large the pulsar is.
C. how fast the pulsar is spinning.
D. how strong the pulsar's magnetic field is.

It is customary to place the date for the beginnings of modern medicine somewhere in the mid-1930s, with the entry of the sulfonamides and penicillin into the pharmacopoeia, and it is usual to ascribe to these events the force of a revolution in medical practice. This is what things seemed like at the time. Medicine was upheaved, revolutionized indeed. Therapy had been discovered for great numbers of patients whose illnesses had previously been untreatable. Cures were now available. As we saw it then, it seemed a totally new world. Doctors could now cure disease, and this was astonishing, most of all to the doctors themselves.

34. During the 1930s, what did people believe had happened in the field of medicine?

A. A destructive trend.
B. A dramatic change.
C. A return to old practices.
D. A slowing down.

35. Sulfonamides and penicillins made doctors feel

A. confused.
B. like scientists.
C. old-fashioned.
D. more confident.

36. In this passage, pharmacopoeia means

A. a medical research laboratory.
B. medical school textbooks.
C. a school for pharmacists.
D. a stock of available medicines.

37. According to the passage, who was most amazed by sulfonamides and penicillin?

A. Sick patients.
B. Doctors.
C. Patients who had recovered.
D. Pharmacists.

Stephen's mother and his brother and one of his cousins waited at the corner of quiet Foster Place while he and his father went up the steps and along the colonnade where the Highland sentry was parading. When they had passed into the great hall and stood at the counter Stephen drew forth his orders on the governor of the bank of Ireland for thirty and three pounds; and these sums, the moneys of his exhibition and essay prize, were paid over to him rapidly by the teller in notes and in coin respectively. He bestowed them in his pockets with feigned composure and suffered the friendly teller, to whom his father chatted, to take his hand across the broad counter and wish him a brilliant career in after life.

38. The passage suggests that the building was

A. hidden.
B. crowded.
C. impressive.
D. hard to get into.

39. What had Stephen done?

A. He had won a prize.
B. He had carried out orders.
C. He had sold a painting.
D. He had had a brilliant career.

40. Why did the teller give the notes to Stephen rapidly?

A. To get rid of Stephen.
B. To show that he was not impressed.
C. Because he was being efficient.
D. Because Stephen's mother was waiting.

41. It was difficult for Stephen to

A. act calmly.
B. pass into the hall.
C. give up the orders.
D. leave his mother waiting.

42. The teller took Stephen's hand to

A. greet him.
B. congratulate him.
C. give him confidence.
D. show him how to handle money.

The Museum that Alexander the Great set up in Alexandria was in effect the first university in the world. As its name implies, it was dedicated to the service of the Muses. It was, however, a religious body only in form, in order to meet the legal difficulties of endowment in a world that had never foreseen such a thing as a secular intellectual process. It was essentially a college of learned men engaged chiefly in research and record, but also to a certain extent in teaching.

43. Why was the Museum set up as a religious body?

A. So money could be given to it.
B. So people could come worship there.
C. So priests could work there.
D. So religion could be taught.

44. The Museum was most like a

A. temple.
B. university.
C. hospital.
D. show.

45. Which answer best describes the Museum?

A. Famed for its athletes.
B. Ineffective.
C. Pioneering.
D. Entertaining.

Any list of mutualistic relationships would be heavily weighted toward the highly organized, impersonal world of the insects. The story of ants protecting and "milking" their cattlelike aphids, for example, is well known. Much less common is evidence of mutualism among warmblooded vertebrates, and mutualistic relationships that cross taxonomic class lines, say between birds and mammals, are especially rare.

46. The passage mentions the relation between ants and aphids as an example of

A. crossing taxonomic class lines.
B. insects being similar to people.
C. an impersonal world.
D. mutualism.

47. In this passage, class means a

A. style.
B. school group.
C. social group.
D. category.

48. The passage characterizes insect societies as

A. ordered.
B. highly motivated.
C. small in scale.
D. weighted.

You are finished with the reading test. Please close your test booklet and begin the test titled "Domain Knowledge Test."

APPENDIX C

For all experiments reported in this thesis, approval for the use of human subjects was obtained from the University of New Hampshire Psychology Department Internal Review Board. Forms demonstrating proof of approval are included in this Appendix.

University of New Hampshire
Institutional Review Board for the Protection of Human Subjects in Research
Departmental Review Committee Exemption Classification Sheet

Name: Kristina Steiner
Dept: Psychology
Study: The Impact of Reading Skill on Updating Mental Representations

IRB #: 5-110901B
Reviewer: Leber

Exempt Review

46.101(b)(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as:
_____ (i) research on regular or special educational instructional strategies, or
(ii) research on the effectiveness of or comparison among instructional techniques, curricula, or classroom management methods.

46.101(b)(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior unless:
(i) information obtained is recorded in such a manner that human subjects can be identified, directly or
__X__ through identifiers linked to the subjects; and
(ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to subjects' financial standing, employability, or reputation.

46.101(b)(3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior that is not exempt under category (b)(2) if:
_____ (i) the human subjects are elected or appointed public officials or candidates for public office; or
(ii) federal statute(s) require(s) without exception that confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

46.101(b)(4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the
_____ investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

46.101(b)(5) Research and demonstration projects which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or
_____ service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

46.101(b)(6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed or (ii) or if a food is consumed that contains a food ingredient at or below the
_____ level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration, or approved by the Environmental Protection Agency, or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

✓ **Protocol is approved as presented in the category checked**
_____ **Protocol is approved with the following contingencies/comments (attach sheets if necessary)**
_____ **Protocol is referred to the IRB for Expedited or Full Board review**
_____ **Protocol cannot be approved as presented (cite reasons on separate sheet)**

DRC Reviewer: [signature] **Date:** 9/2/10

University of New Hampshire
Institutional Review Board for the Protection of Human Subjects in Research
Departmental Review Committee Exemption Classification Sheet

Name: Kristina Steiner

Dept: Psychology

Study: Reading Skill and Updating Causal Information

IRB #: PS-120206B

Reviewer: Leber

Exempt Review

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DRC Reviewer: [signature] **Date:** 2/7/11

University of New Hampshire
Institutional Review Board for the Protection of Human Subjects in Research
Departmental Review Committee Exemption Classification Sheet

Name: Kristina Steiner

Dept: Psychology

Study: Working Memory and Updating Causal Information

IRB #: ~~2012~~ PS-120206

Reviewer: Leser

Exempt Review

46.101(b)(1) ____ Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as:
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46.101(b)(2) __X__ Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior unless:
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