

## Effects of Causal Text Revisions on More- and Less-Skilled Readers' Comprehension of Easy and Difficult Texts

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The importance of causal structure has been well documented in text comprehension research. This study investigates how both easy and difficult texts can be improved by repairing the causal structure and how causal structure repairs can differentially affect comprehension for more- and less-skilled readers. Following causal network theories of comprehension, principled and replicable types of repairs were made. Causal repairs consisted of (a) arranging text events in temporal order; (b) making implicit goals explicit; and (c) repairing coherence breaks caused by inadequate explanation, multiple causality, or distant causal relations. More- and less-skilled readers read revised and original versions of easy and difficult history texts. Results indicate that both more- and less-skilled readers benefited from the revisions but only for the difficult text. Causal network theories of comprehension provide an appropriate and systematic method for revising texts.

Text comprehension cannot be understood completely without careful consideration of the way in which text structure and readers' cognitive processes interact. The formation of mental representations of texts is one such cognitive process that may depend on how the text is structured. Ideally, readers should form mental representations of texts because this level of understanding is conducive to long-term

retention (e.g., Graesser, 1981; van Dijk & Kintsch, 1983; van Oostendorp & Goldman, 1999) and to accessibility of textual information (e.g., Singer & Ritchot, 1996). One way to ensure that readers form coherent mental representations of texts is to facilitate the inferential process. Inferences help readers connect text information with other text information as well as with their background knowledge and this, in turn, increases the likelihood that coherent mental representations will be formed (e.g., van Dijk & Kintsch, 1983). Comprehension, based on a coherent mental representation, would be improved by revising text structure so that the generation of inferences is facilitated. Revising texts so that connections between text events are more explicit can facilitate the inferential process.

One type of inference that has been studied extensively in a causal network theory of comprehension is the causal inference (e.g., Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985; van den Broek, 1988). Statements that have many causal connections to other statements are remembered and comprehended better than statements with fewer causal connections (Mandler & Johnson, 1977; O'Brien & Myers, 1987; Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985; van den Broek, 1988). Similarly, events that occur on the causal path that connect a series of events in a causal network from the beginning of the story to its end are better remembered than events that are not on the causal path (Black & Bower, 1980; Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985). Texts with many causal connections on a causal path are more likely to be represented in the reader's long-term memory than texts with few causal connections on a causal path. Thus, the causal structure of a text is a central component in how that text is understood and represented by readers.

To ensure that a text is conducive to the formation of mental representations, revisions can be made to improve the text's structure in such a way that causal inferences are facilitated. In the past, text revisions made by other researchers to improve the comprehension of text information have been difficult to replicate. It is the purpose of this study to provide a set of simple text-revision rules, based on a causal network theory, so that texts may be uniformly improved. These improvements will encourage readers to make causal inferences and form mental representations of texts.

## THE HISTORY OF RESEARCH ON TEXT REVISION

One way to improve comprehension is to understand how text structure and subsequent text revisions affect reading. Early text-revision research identified ways to make texts easier for readers to understand using readability formulas as tools to guide the text-revision process (Davison, 1984; T. M. Duffy et al., 1989). Readability formulas are designed to assess text difficulty by focusing on factors such as word frequency, word length, and sentence length. Such formulas are used widely,

primarily as a means of determining the grade level at which textbooks are written, but they can be misused when researchers attempt to rewrite texts to make them “readable” for students at a particular ability level. This is largely because readability formulas do not take into account other structural variables that are important determinants of comprehension, such as text structure; text cohesion; readers’ prior knowledge; readers’ goals; and text aids such as typographical cues, tables, and graphs (Holland, as cited in Sawyer, 1991). Put simply, although the readability level of text is certainly a correlate of comprehension, it is not the sole cause.

Naturally, this raises the question of how to identify the structural variables in texts that will improve comprehension. One way to identify these variables is to revise texts based on conceptualizations of the factors that lead to successful comprehension. By applying particular revision rules to any given text and observing the effects of such rules on subsequent comprehension, researchers can establish the particular textual elements that must combine to form comprehensible text.

A first step in this direction came when researchers sought to determine how different forms of writing might affect the comprehension process (Britton, Van Dusen, Gulgoz, & Glynn, 1989; T. M. Duffy et al., 1989; Graves et al., 1991). This approach to text revision involved asking expert writers to revise texts based on their intuitive notions of text structure and comprehension. For example, Britton et al. (1989) and T. M. Duffy et al. (1989), in replications of a study originally conducted by Graves et al. (1988), asked three pairs of writers—text linguists, college composition instructors, and *Time-Life* magazine writers—to revise two history texts. Results indicated that the texts revised by the composition instructors led to greater recall of textual information than texts revised by the other writing teams. The revisions employed by the composition instructors included clarifying information in text, simplifying information, supplying transitions to text, and adding or deleting information to make the text follow a coherent plan. Although these revisions were obviously beneficial to readers, they were not based on a systematic theory of text comprehension. Furthermore, although the composition instructors highlighted structural variables that can play a role in comprehension, they did not devise a set of concrete rules that might allow other researchers and educators to revise texts successfully in the future. Clearly, researchers and educators who wish to revise texts need to rely on a set of established text-revision principles to guide their efforts. The theory-based approaches to revising texts, which are described next, have begun to supply researchers with the framework on which to build these principles.

Using their knowledge of the role that text coherence plays in comprehension, Beck, McKeown, Omanson, and Pople (1984) based text revisions on the interaction between text structures and the processes that readers engage in when confronted with certain text structures. Beck et al. (1984) identified three potential types of problematic text features: (a) the surface form of the text; (b) the background knowledge required for comprehension; and (c) the nature, ambiguity, or

confusability of the text's content. These text features were revised during a group think-aloud procedure, in which Beck and her colleagues read through two stories found in a basal reading series and revised the stories as a group. The revisions made by Beck et al. (1984) resulted in significant gains in comprehension for both more- and less-skilled third-grade readers despite the fact that the readability indexes increased for both texts.<sup>1</sup>

The primary goal of Beck et al. (1984) was to examine the effects of revisions that improve textual coherence on comprehension. In a later study, Beck, McKeown, Sinatra, and Loxterman (1991) again drew on the roles that coherence and causality play in text comprehension, but they attempted to describe more systematically the motivations behind their revisions. In so doing, Beck et al. (1991) relied heavily on research describing the cognitive processes that readers engage in during reading. They identified points in four social studies passages in which readers might encounter problems in comprehension (e.g., in which background knowledge was needed or references were not made explicit). The primary goal of the revisions applied to these points was to make the causal sequence leading up to the focal event more explicit. Beck et al. (1991) observed that fourth- and fifth-grade students who read the revised passages performed better on free recall and comprehension tests than did students who read the original passages.

The approaches to text revision described by Beck et al. (1984, 1991) are valuable in that they demonstrated the usefulness of considering theories of comprehension when attempting to revise texts. A similar approach to text revision was taken by Britton and Gulgoz (1991), who also relied on a theory of comprehension to revise texts. Britton and Gulgoz went one step further by establishing a set of principled guidelines that other researchers and educators can use in future text-revision efforts.

Britton and Gulgoz (1991) identified areas in expository texts that called for an inference to establish local coherence based on the Construction-Integration model of reading (Kintsch & van Dijk, 1978; Miller & Kintsch, 1980). This model can be used to identify areas in the texts in which the use of referents becomes ambiguous. Britton and Gulgoz reasoned that such ambiguities call on readers to make inferences and, hence, contribute to a likely breakdown in comprehension. These possible comprehension breaks were repaired by (a) making the implicit referents explicit, (b) repeating a linking word from the previous sentence and using the same terms for the same concepts, and (c) presenting information in the sentences in the given-new format (i.e., in which the part of the sentence that had been referred to previously in the text comes first and specifies where the new information is to be connected). In addition to creating the principled revision of the

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<sup>1</sup>Note that the results reinforce the notion that readability indexes are not appropriate indicators of text coherence.

text, Britton and Gulgoz also created a heuristic revision that involved rewriting the text using their intuitive knowledge of the components of a well-written text. In some cases, this involved adding linguistic or typographic cues to highlight particular aspects of the content in the text.

The principled version of the text was found to result in better free recall and reading efficiency (i.e., more learning per unit of study time) than did the original version (Britton & Gulgoz, 1991). Although participants who read the heuristic version of the text performed as well on the recall and multiple-choice tests as did participants who read the principled version, Britton and Gulgoz noted that the well-operationalized rules that guided the creation of the principled version made that version more appealing to future researchers than the heuristic version. In other words, future researchers who wish to revise other types of instructional text may find it easier to adopt principled guidelines, rather than heuristic ones, to aid the revision process.

Thus, in addition to demonstrating the usefulness of relying on cognitive reading models to identify text areas that are in need of revision, Britton and Gulgoz (1991) put forth a set of principles that can guide others through the text-revision process. This study also attempts to use a theory of reading comprehension to establish principled guidelines that can be used to revise instructional text. However, whereas Britton and Gulgoz concentrated on making referential repairs to text, this study focuses on making causal repairs to text. This follows from the finding reported by Vidal-Abarca, Martinez, and Gilabert (2000) that causal structure repairs may be more important determinants of comprehension than referential structure repairs. Furthermore, this study examines how such repairs affect both more- and less-skilled readers' comprehension of easy and difficult text.

## THE CAUSAL INFERENTIAL PROCESS

To achieve comprehension, readers must successfully process several types of connections that exist between text events. One important type of connection involves linking causes to their consequences in a text via causal inferences (van den Broek, 1994). The generation of causal inferences allows readers to develop a mental picture of the events described in a text. This mental picture is constantly updated as new text events are encountered and additional causal connections are discovered (van den Broek, Young, Tzeng, & Linderholm, 1999). How successfully this causal inferential process proceeds during reading is an important determinant of how well readers comprehend text information. Therefore, it is important to consider the causal inferential process as a basis for text repairs because the ultimate goal of making repairs is to ensure that comprehension proceeds smoothly.

In the causal inferential process, readers attempt to understand each new sentence they encounter and continue to add to a developing representation of the causal information present in the text in a step-by-step fashion (van den Broek, 1994; van den Broek et al., 1999). Typically, information from the preceding sentence is still active in short-term memory as reading continues. If the causal antecedent of the preceding sentence is still active in short-term memory, then connecting it to the consequence contained in the current sentence occurs easily. In the case in which no causal connection can be made between adjacent sentences, an inference cannot be made, and a coherence break will occur. It is at that point that readers must search through long-term memory for previously encountered text information to make a causal connection (van den Broek, 1994). This is an especially difficult task if several lines of text separate an antecedent from its consequent. In the case in which there is no prior text that provides a sufficient causal explanation for the current sentence, readers must then recruit background knowledge to provide an explanation. This can be problematic if readers do not possess such background knowledge. Thus, if no connection can be made between text events, either by connecting adjacent or distant text or by drawing on background knowledge, the coherence of the text breaks down, leading to comprehension difficulties.

One major factor that determines whether connections will be made between text events is the human information processing system. Readers must have the attentional resources, in terms of short-term memory capacity, to make causal connections between various parts of text and background knowledge and sometimes to maintain multiple causes of events. Although the ideal reading situation involves making all of the possible causal connections in a text, this rarely happens due to a limited short-term memory capacity. The capacity of short-term memory allows readers to store approximately one or two sentences at a time (see Fletcher & Bloom, 1988); thus, the result is that readers may not be able to process or maintain in memory all of the causal connections that are necessary to maintain coherence. Repairs made to the causal structure of texts would lessen processing demands by decreasing searches through long-term memory to establish necessary causal connections.

To summarize, the process of making causal connections during reading involves the switching of focus from the current sentence to explanatory events in either short- or long-term memory. Whether these connections are made depends on the causal structure of the text and on the amount of attentional resources and background knowledge available to readers. The delicate balance between the human information processing system, background knowledge, and the causal structure of the text affects how easily readers comprehend text information. Although human information processing limitations and background knowledge cannot be controlled, the text structure can be improved to lessen the processing load for readers. To ensure that causal relations are easily processed, three causal text-revision rules were developed and are described next.

## Temporal Order Restored

An essential component of causality is temporality (Mackie, 1980; van den Broek, 1990, 1994). Readers are easily able to identify a causal relation if the cause precedes its consequent in the text. Events out of temporal order, that is, when the consequent precedes its antecedent, require more effort or attentional resources because readers must rearrange events mentally before they can determine if a causal relation is present. Thus, the first causal text-revision rule was to rearrange events that were out of temporal order.

## Goals Made Explicit

Goals and themes of texts provide the background against which causality is judged. In expository texts, goals may involve explicit objectives sought by the protagonists in the text (e.g., in a historical text on Abraham Lincoln, the goal might be Lincoln's ability to abolish slavery), or goals may involve the overall theme or purpose of the text (e.g., in a scientific text on the volcanic origin of rocks, the goal of the text might be to inform readers of a way in which rocks are formed). Goals themselves often cause many events to occur throughout texts and typically open the path on the main causal chain (van den Broek, 1990). Goals and themes are particularly difficult to abstract from texts because they usually are implied by several events together and require the integration of these events (Williams, 1988). By making goals explicit in texts, readers spend fewer attentional resources attempting to infer the main goal of the text. In addition, readers are able to connect explicit goals more easily to other causal events, resulting in an integrated mental representation of text ideas. Therefore, the second causal text-revision rule was to make goals implied by the texts explicit to readers.

## Repairing Coherence Breaks

To maintain coherence during reading, readers must determine the causal explanation(s) for the current sentence being read (van den Broek, 1990, 1994). It is often the case that (a) the text does not provide a sufficient cause, (b) the text provides multiple causes for one event, or (c) causes and their consequences are separated by several lines of text. In these cases, readers spend additional attentional resources attempting to maintain coherence by inferring the cause or the most likely cause of events. Thus, the third causal text-revision rule was to repair causal coherence breaks in cases in which an inadequate explanation was provided by the text, multiple causality was involved, or the current sentence and its explanations were separated by large segments of text.

Although text repairs can improve readers' chances of making all the necessary connections to maintain coherence, two additional dimensions may affect how likely it is that readers make causal inferences as they read. Specifically, reading skill and text characteristics, in terms of text difficulty, may enhance or inhibit the causal inferential process and may interact with causal structure repairs. These dimensions are described in the following sections.

## READING SKILL AND CAUSAL INFERENCES

At a global level, *reading skill* consists of several components: the ability to comprehend, retain, and integrate text information accurately (Oakhill, 1994). Causal inferences help readers to accomplish these components of skilled reading (van den Broek, 1994). Thus, if readers have difficulties making causal inferences, comprehension surely suffers.

In fact, there is evidence pointing to poor inferential skills as a source of reading comprehension differences (Masson & Miller, 1983; Singer, Andrusiak, Reisdorf, & Black, 1992; Singer & Ritchot, 1996; St. George, Mannes, & Hoffman, 1997; Whitney, Ritchie, & Clark, 1991). For example, *less-skilled readers*, as defined by low working memory capacity, are not as accurate at making causal bridging inferences as *more-skilled readers* (Singer et al., 1992). When the causal antecedent is separated from its outcome by several sentences, less-skilled readers have difficulty making the connection between events. Less-skilled readers also are less adept than their more-skilled counterparts at predicting the causal consequences of text events via inferences (St. George et al., 1997). Thus, there is evidence that less-skilled readers have poor inferential skills. Unfortunately, the process of making inferences may be even more strenuous for less-skilled readers when the reading task places additional demands on their resources, such as when the text is difficult (see Budd, Whitney, & Turley, 1995; Just & Carpenter, 1992). The difficulty level of texts likely interacts with reading skill to influence the inferential process and subsequent comprehension. Thus, the process of making inferences appears to be a problematic aspect of comprehension for less-skilled readers, and causal structure repairs may enhance this process, especially when the text is difficult.

One of the purposes of this study is to determine how repairs made to the causal structure of texts, thereby facilitating causal inferences, affect comprehension for more- and less-skilled readers. More-skilled readers are distinguished from less-skilled readers on the basis of a reading test that measures comprehension of an expository passage. Although the reading test used in this study is not a standard measure for assessing reading skill, it is a good indicator of comprehension accuracy and of the ability to derive main points from an informational text. Reading skill, as measured by the reading test, is likely to interact with how well a text is



causally structured to determine comprehension and recall. A difficult text, that is, one that has a poor causal structure, will make comprehension and recall much harder, especially for less-skilled readers.

## TEXT DIFFICULTY

A variety of factors can influence the difficulty level of a text and the ease with which inferences are made. In some cases, the structure of a text can make the task of generating inferences difficult; in other cases, the content of a text can make the task of generating inferences difficult. It is thus necessary, when attempting to create texts that are not excessively difficult for readers to process and comprehend, to take into account more than one textual characteristic (e.g., Côté, Goldman, & Saul, 1998).

In this study, several textual characteristics were examined to determine *text difficulty*. Text difficulty was judged on the basis the number of causal and referential connections, the number of goals that were explicit, and the familiarity of the topic of the text.

The number of causal and referential connections present in a text determines how coherent a text is (van den Broek et al., 1999). Texts that are highly causally and referentially connected are coherent because readers do not have to make an extreme number of inferences to explain events. The resources readers typically use making inferences in an attempt to understand the relations between events can then be spent integrating text ideas. The number of causal and referential connections present in a text will thus determine its difficulty level.

The explicitness of goals in text also can affect the ease with which a text is read. Earlier, it was noted that comprehensibility might be influenced by causal coherence that includes the explicitness of goals. Because goals are an important piece of the causal structure of text, a text may be perceived as difficult when goals are not made explicit.

Whether readers have schemata available pertinent to the content of a text also can determine the extent to which a text is perceived to be easy or difficult to understand (Bartlett, 1932; Bransford & Johnson, 1972). Anderson (1984) defines *schemas* (or *schemata*) as organized knowledge structures of the world. Schemata contain not only knowledge about concrete elements but also relations among various elements. When readers have schemata that correspond to information presented in a text, readers will comprehend that text more easily than will readers who are not able to bring to mind schemata that are congruent with the information in the text.

To summarize, three text factors were used to determine text difficulty: the number of causal and referential connections, the explicitness of goals, and topic familiarity. These factors may influence how easily inferences are made and how comprehensible texts are.

## This Study

The primary purpose of this study is to test the effectiveness of systematic text revisions based on a causal network theory. The secondary purpose is to determine how causal text revisions affect more- and less-skilled readers' comprehension of texts of varying difficulty.

## METHOD

### Participants

Thirty-nine undergraduates who were enrolled in a study skills course participated in this study. Students either took the course as an elective or to fulfill a requirement. Participants came from a variety of fields of study (e.g., liberal arts, engineering) and ranged from freshman to senior level. The students received extra credit points for participating.

### Materials

*Original texts.* The materials consisted of two short social studies texts (approximately 400 words each) that describe little-known events during World War II. *Mademoiselle Germaine* describes Russian espionage during that time period. *Project X-Ray* describes a secret plan for the United States to attack its enemy. The texts were taken from developmental reading materials that were written to help students practice and test their reading comprehension skills. According to the Fry (1975) readability scale, the readability level for *Mademoiselle Germaine* was at the 11th-grade level, and *Project X-Ray* was at the 9th-grade level (see Appendix A for texts).

Comprehension difficulty for the two texts was judged on the number of causal and referential connections per text, the explicitness of the goals, and schema familiarity. First, a comparison of the two texts in terms of *coherence*, as defined by the density of causal connections (see Trabasso et al., 1984), showed that *Mademoiselle Germaine* has more causal connections per statement, and hence is more coherent, than *Project X-Ray*. The average number of connections per statement was identified by two independent raters ( $M = 1.22$  for *Mademoiselle Germaine*;  $M = 1.02$  for *Project X-Ray*). In addition, two raters independently determined that *Project X-Ray* has fewer referential connections ( $M = .50$ ) than *Mademoiselle Germaine* ( $M = .59$ ). Second, the number of explicit goals in each story was determined. This analysis found that *Project X-Ray*'s superordinate goal is implicit, whereas *Mademoiselle Germaine*'s goals are explicit. Third, the theme of *Mademoiselle Germaine*, which follows a typical spy plot, is familiar to most readers, whereas the theme of *Project X-Ray*—the development and test of a national de-

fense strategy—is less familiar to readers. On the basis of each indicator, *Mademoiselle Germaine* is the easier text, and *Project X-Ray* is the more difficult text.

**Revised texts.** To ensure that the revision process was principled and easily repeatable, three types of changes were made. Temporal order was restored, goals were made explicit, and coherence breaks were repaired. Consensus was reached between four of the investigators regarding the changes (see Appendix B for examples of revisions).

It is important to note that no information was added to the text that could not be inferred from the text readily. Similarly, no information, such as awkward phrasing or dead-end information, was deleted from the text. Finally, the wording from the original text was retained wherever possible. Thus, the text content was unaltered, except for the aforementioned theory-based changes.

According to the Fry (1975) readability scale, the readability for the revised version of *Mademoiselle Germaine* changed from 11th grade to 12th grade and remained at the 9th grade for *Project X-Ray*. Thus, in terms of grammatical structure, the revised versions were equally or more difficult than the original versions.

**Comprehension questions.** Comprehension questions were based on explicit information presented in the text and typically had only one correct answer (see Appendix C). Twelve comprehension questions were developed for each text. Four questions pertained to ideas on the causal chain in which no revisions had been made, and four questions related to ideas on the causal chain throughout the text in which revisions had been made. The final four questions concerned details off the causal chain.

**Reading test.** Participants were given a brief reading pretest commonly used in speed reading courses to assess speed and comprehension. The test consisted of a short text that was similar in length and difficulty to the experimental texts. The text detailed the life of artist Georgia O'Keeffe and was 513 words in length. After participants read the text, they answered 10 multiple-choice comprehension questions. The median score of seven was used as a cutoff to distinguish more-skilled ( $n = 16$ ) from less-skilled ( $n = 23$ ) readers. More-skilled readers had significantly higher scores on the reading test ( $M = 7.81$ ) than did less-skilled ( $M = 5.17$ ) readers,  $F(1, 38) = 76.58, p < .01$  ( $MSE = .86$ ).

Participants also completed the Learning and Study Strategies Inventory (LASSI), a self-report questionnaire designed to survey study skills (Weinstein, Palmer, & Schulte, 1987). One of the subscales measures information processing, knowledge acquisition, and reasoning skills. Questions on this subscale include "I try to find relationships between what I am learning and what I already know" and "I translate what I am studying into my own words." These items measure strategies that are a mark of a good reader. More-skilled readers ( $M = 52.19$ ) scored signifi-

cantly higher on this subscale than did less-skilled ( $M = 33.87$ ) readers,  $F(1, 38) = 5.07$ ,  $p < .05$  ( $MSE = 624.30$ ). It was concluded that reading skill was well distinguished on the basis of performance on the reading test and the LASSI subscale.

## Procedure

Participants were tested as a group. First, the participants completed the LASSI and the reading test. Participants were told to go at their own pace and to follow the directions given in their packet of materials. Next, participants read the two experimental texts, *Mademoiselle Germaine* and *Project X-Ray*, in either the original or revised version. The order in which the texts were read was counterbalanced, as was the version type. After the participants read both texts, they were asked to recall the first text. Participants then completed the short-answer comprehension questions pertaining to the first text. Then, participants performed the recall and comprehension tasks for the second text. The texts and questions were presented in this interleaved manner to avoid ceiling effects. Participants took between 25 and 45 min to complete all tasks.

## RESULTS

To determine whether the principled revisions had an effect on participants' recall and comprehension of difficult and easy texts, separate analyses were performed on the free-recall protocols and short-answer questions for each text. Separate analyses were performed on each text due to the fact that, as mentioned in the preceding section, the texts differed in many respects. Direct comparisons between the texts therefore would not be meaningful.

### Scoring Procedures

To score the free-recall protocols, each text was parsed into idea units corresponding to noun-verb phrases or clause units (e.g., Trabasso, van den Broek, & Suh, 1989; van Dijk & Kintsch, 1983). Sentences having more than one verb phrase were broken down into separate idea units. Idea units were divided into those on the causal chain versus those off the causal chain. A total of 47 idea units were identified in the original version of the more difficult text, *Project X-Ray*, and a total of 43 idea units were identified in the original version of the easier text, *Mademoiselle Germaine*. Free-recall protocols were scored on the basis of the number of idea units from the original texts that were included by the participant. Participants were given credit if they recalled an idea unit verbatim or if they recalled the gist of the

idea unit. Given that no information was added in the revised texts that could not be inferred from the original texts, the total number of idea units that could be recalled from the original and revised texts was the same.

Six participants' free-recall protocols (i.e., 15% of the total free-recall protocols collected) were scored by two of the researchers. Interrater reliability was 90%, and differences between raters were resolved through discussion. The two raters then each scored half the remaining protocols.

To score the comprehension questions, two of the researchers independently constructed answer keys. Interrater reliability was 100%, and the answers given by the researchers constituted the basis for scoring the participants' answers. Participants received 1 point for each correctly answered question.

For each text, results are presented by (a) total number of idea units recalled, (b) number of idea units on the causal chain recalled, (c) number of comprehension questions answered correctly, (d) number of questions answered correctly for information on the causal chain in which revisions were made, (e) number of questions answered correctly for information on the causal chain in which revisions were not made, and (f) number of questions answered correctly for dead-end information. Results are presented in this manner to highlight the effectiveness of making revisions to different parts of the texts. For example, it could be that specific repairs made to one part of the causal chain actually could improve the comprehension and recall for other parts of the causal chain in which no repairs were made.

### Quantitative Results for the More Difficult Text (Project X-Ray)

*Total number of idea units recalled.* An analysis of variance (ANOVA) was performed on the total number of idea units recalled from the more difficult text, with reading skill and text version as independent variables. There was a main effect of reading skill on recall,  $F(1, 35) = 33.98, p < .01$  ( $MSE = 19.40$ ). On average, more-skilled readers recalled almost twice as many idea units ( $M = 19.19, SD = 4.40$ ) as did less-skilled readers ( $M = 10.78, SD = 4.44$ ; see Table 1). There was no main effect of text version,  $F(1, 35) = 2.09$  ( $MSE = 19.40$ ), nor was there a significant interaction between text version and reading-skill level,  $F(1, 35) < 1$  ( $MSE = 19.40$ ).

*Recall of idea units on the causal chain.* An ANOVA was performed on participants' recall of idea units on the causal chain, with reading skill and text version as the independent variables. Revision resulted in statistically significant improvements in both more-skilled and less-skilled readers' recall of the 13 idea units on the causal chain,  $F(1, 35) = 7.172, p < .05$  ( $MSE = 2.75$ ). Readers presented with the revised text recalled significantly more idea units on the causal chain ( $M = 5.95, SD = 1.75$ ) than did readers presented with the original text ( $M = 4.50, SD = 1.73$ ).

TABLE 1  
Means and Standard Deviations of Recall for the More Difficult Text (Project X-Ray)

Recall	Original Version		Revised Version		Total	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Total idea units recalled						
Less-skilled readers	10.08	5.62	11.55	2.66	10.78	4.44
More-skilled readers	17.75	4.83	20.63	3.66	19.19	4.40
Total	13.15	6.47	15.37	5.51	—	—
Idea units recalled on the causal chain						
Less-skilled readers	3.83	1.64	5.64	1.63	4.70	1.84
More-skilled readers	5.50	1.64	5.64	1.63	4.70	1.84
Total	4.50	1.73	5.95	1.75	—	—

Overall, more-skilled readers recalled significantly more idea units on the causal chain ( $M = 5.94$ ,  $SD = 1.69$ ), regardless of text type, than did less-skilled readers ( $M = 4.70$ ,  $SD = 1.84$ ),  $F(1, 35) = 5.038$ ,  $p < .05$  ( $MSE = 2.75$ ). There was no significant interaction between text version and reading-skill level,  $F(1, 35) < 1$  ( $MSE = 2.75$ ).

*Number of questions answered correctly.* An ANOVA revealed that, on average, participants who read the revised version of the text answered significantly more questions correctly ( $M = 8.63$ ,  $SD = 1.54$ ) than did participants who read the original version of the text ( $M = 6.75$ ,  $SD = 2.05$ ),  $F(1, 35) = 12.20$ ,  $p < .01$  ( $MSE = 2.72$ ; see Table 2). More-skilled readers answered more questions correctly ( $M = 8.69$ ,  $SD = 1.58$ ) than did less-skilled readers ( $M = 6.96$ ,  $SD = 2.03$ ),  $F(1, 35) = 9.91$ ,  $p < .01$  ( $MSE = 2.72$ ). Less-skilled readers who read the revised text answered approximately the same number of questions correctly ( $M = 7.91$ ,  $SD = 1.38$ ) as did more-skilled readers who read the original text ( $M = 7.75$ ,  $SD = 1.39$ ). The interaction between text version and reading-skill level did not reach significance,  $F(1, 35) < 1$  ( $MSE = 2.72$ ).

*Number of questions answered correctly for information on the causal chain in which revisions were made.* Participants who read the revised text were significantly better at answering the four short-answer questions about information on the causal chain that was revised to be more causally coherent ( $M = 3.05$ ,  $SD = 0.97$ ) than were participants who read the original text ( $M = 2.10$ ,  $SD = 1.02$ ),  $F(1, 35) = 9.60$ ,  $p < .01$  ( $MSE = 0.89$ ). Regardless of text version, more-skilled readers answered significantly more of these questions correctly ( $M = 3.00$ ,  $SD = 1.15$ ) than did less-skilled readers ( $M = 2.26$ ,  $SD = 0.96$ ),  $F(1, 35) = 5.46$ ,  $p < .05$  ( $MSE = 0.89$ ). Again, less-skilled readers who read the revised text answered as many ques-

tions correctly ( $M = 2.64$ ,  $SD = 1.03$ ) as did more-skilled readers who read the original text ( $M = 2.38$ ,  $SD = 1.30$ ). There was no significant interaction between text version and reading-skill level,  $F(1, 35) < 1$  ( $MSE = 0.89$ ).

*Number of questions answered correctly for information on the causal chain in which revisions were not made.* Four of the short-answer questions presented to participants were about information on the causal chain in which no revisions were made (i.e., this information was presented in exactly the same manner in both the original and the revised texts). Averaged across text versions, more-skilled readers answered significantly more of these questions correctly ( $M = 3.63$ ,  $SD = 0.62$ ) than did less-skilled readers ( $M = 2.83$ ,  $SD = 1.11$ ),  $F(1, 35) = 6.70$ ,  $p < .05$  ( $MSE = 0.87$ ). There was a trend for participants who read the revised text to answer more questions correctly ( $M = 3.42$ ,  $SD = .69$ ) than participants who read the original text ( $M = 2.90$ ,  $SD = 1.21$ ),  $F(1, 35) = 2.84$ ,  $p = .10$  ( $MSE = 0.87$ ).

*Number of questions answered correctly for dead-end information.* In terms of the number of questions answered correctly about information that was not on the causal chain, there was no significant difference between participants who

TABLE 2  
Means and Standard Deviations of Comprehension Questions Answered Correctly for the More Difficult Text (Project X-Ray)

Comprehension Questions	Original Version		Revised Version		Total	
	M	SD	M	SD	M	SD
Total number of questions						
Less-skilled readers	6.08	2.19	7.91	1.38	6.96	2.03
More-skilled readers	7.75	1.39	9.63	1.19	8.69	1.58
Total	6.75	2.05	8.63	1.54	—	—
Questions on causal chain (revisions made)						
Less-skilled readers	1.92	0.79	2.64	1.03	2.26	0.96
More-skilled readers	2.38	1.30	3.63	0.52	3.00	1.15
Total	2.10	1.02	3.05	0.97	—	—
Questions on causal chain (no revisions made)						
Less-skilled readers	2.58	1.38	3.09	0.70	2.83	1.11
More-skilled readers	3.38	0.74	3.88	0.35	3.63	0.62
Total	2.90	1.21	3.42	0.69	—	—
Dead-end questions						
Less-skilled readers	1.75	0.87	2.19	0.60	1.96	0.77
More-skilled readers	2.00	1.20	2.63	0.92	2.31	1.08
Total	1.85	0.99	2.37	0.76	—	—

read the revised or original versions of the text. There was a trend, however, for participants who read the revised text to answer more dead-end questions correctly ( $M = 2.37$ ,  $SD = 0.76$ ), regardless of reading-skill level, than participants who read the original text ( $M = 1.85$ ,  $SD = 0.99$ ),  $F(1, 35) = 3.20$ ,  $p = .08$  ( $MSE = 0.79$ ). There was no main effect for reading-skill level,  $F(1, 35) = 1.41$  ( $MSE = 0.79$ ), nor was there a significant interaction between text version and reading-skill level,  $F(1, 35) < 1$  ( $MSE = 0.79$ ).

### Quantitative Results for the Easier Text (Mademoiselle Germaine)

*Total number of idea units recalled.* An ANOVA was performed on the total number of idea units recalled from the easy text, with reading skill and text difficulty as the independent variables. There was no significant main effect of text version,  $F(1, 35) = 2.22$  ( $MSE = 36.95$ ; see Table 3). There was a trend for more-skilled readers to recall more total idea units ( $M = 18.31$ ,  $SD = 6.94$ ) than less-skilled readers ( $M = 14.43$ ,  $SD = 5.78$ ),  $F(1, 35) = 3.96$ ,  $p = .054$  ( $MSE = 36.95$ ). There was no significant interaction between text version and reading-skill level,  $F(1, 35) = 2.21$  ( $MSE = 36.95$ ).

*Recall of idea units on the causal chain.* There were no significant main effects of text version,  $F(1, 35) < 1$  ( $MSE = 15.19$ ), or reading-skill level,  $F(1, 35) = 2.29$  ( $MSE = 15.19$ ), on recall of the 24 idea units on the causal chain. Participants who read the revised text recalled approximately the same number of idea units on the causal chain ( $M = 9.21$ ,  $SD = 4.43$ ) as did participants who read the original text ( $M = 9.90$ ,  $SD = 3.49$ ), and more-skilled readers ( $M = 10.69$ ,  $SD = 3.74$ ) did not re-

TABLE 3  
Means and Standard Deviations of Recall for the Easier Text (Mademoiselle Germaine)

Recall	Original Version		Revised Version		Total	
	M	SD	M	SD	M	SD
Total idea units recalled						
Less-skilled readers	14.67	4.77	14.18	6.95	14.43	5.78
More-skilled readers	21.50	4.17	15.13	7.90	18.31	6.94
Total	17.40	5.60	14.58	7.17	—	—
Idea units recalled on the causal chain						
Less-skilled readers	8.58	3.55	9.00	8.78	3.97	
More-skilled readers	11.88	2.42	9.50	4.57	10.69	3.74
Total	9.90	3.49	9.21	4.43	—	—



TABLE 4  
Means and Standard Deviations of Comprehension Questions  
Answered Correctly for the Easier Text

<i>Comprehension Questions</i>	<i>Original Version</i>		<i>Revised Version</i>		<i>Total</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Total number of questions						
Less-skilled readers	5.25	2.05	5.27	2.37	5.26	2.16
More-skilled readers	6.63	1.30	5.75	1.67	6.19	1.52
Total	5.80	1.88	5.47	2.06	—	—
Questions on causal chain (revisions made)						
Less-skilled readers	1.50	1.17	1.73	0.90	1.61	1.03
More-skilled readers	2.25	1.04	2.00	1.31	2.13	1.15
Total	1.80	1.15	1.84	1.07	—	—
Questions on causal chain (no revisions made)						
Less-skilled readers	3.08	1.00	2.82	1.54	2.96	1.26
More-skilled readers	3.25	0.71	3.38	0.52	3.31	0.60
Total	3.15	0.88	3.05	1.22	—	—
Dead-end questions						
Less-skilled readers	0.83	1.19	1.00	1.00	0.91	1.08
More-skilled readers	1.38	1.06	1.63	0.92	1.00	1.03
Total	1.05	1.15	0.84	0.96	—	—

call significantly more than less-skilled readers ( $M = 8.78$ ,  $SD = 3.97$ ). There was no significant interaction between text version and reading-skill level,  $F(1, 35) = 1.21$  ( $MSE = 15.19$ ).

*Number of questions answered correctly.* There were no significant main effects of text version,  $F(1, 35) < 1$  ( $MSE = 3.82$ ), or reading-skill level,  $F(1, 35) = 2.15$  ( $MSE = 3.82$ ), on the number of comprehension questions that participants answered correctly (see Table 4). Participants answered approximately the same number of questions correctly regardless of text version or reading-skill level. There was no significant interaction between text version and reading-skill level,  $F(1, 35) < 1$  ( $MSE = 3.82$ ).

*Number of questions answered correctly for information on the causal chain in which revisions were made.* There were no significant main effects of text version,  $F(1, 35) < 1$  ( $MSE = 1.22$ ), or reading-skill level,  $F(1, 35) = 2.06$  ( $MSE = 1.22$ ), on correct responses to the four comprehension questions dealing with information on the causal chain in which principled revisions were made. Again, these questions were answered equally well across text versions and across reading-skill level. There was no significant interaction between text version and reading-skill level,  $F(1, 35) < 1$  ( $MSE = 1.22$ ).

*Number of questions answered correctly for information on the causal chain in which revisions were not made.* There were no significant main effects of text version,  $F(1, 35) < 1$  ( $MSE = 1.14$ ), or reading-skill level,  $F(1, 35) = 1.06$  ( $MSE = 1.14$ ), on correct responses to the four comprehension questions dealing with information on the causal chain in which revisions were not made. These questions were answered equally well across text versions and across reading-skill level. There was no significant interaction between text version and reading-skill level,  $F(1, 35) < 1$  ( $MSE = 1.14$ ).

*Number of questions answered correctly for dead-end information.* In terms of the number of questions answered correctly about information that was not on the causal chain, there were no significant main effects of text version,  $F(1, 35) < 1$  ( $MSE = 1.13$ ), or reading-skill level,  $F(1, 35) < 1$  ( $MSE = 1.13$ ). Regardless of text version or reading-skill level, participants across all conditions answered approximately the same number of dead-end questions correctly. There was no significant interaction between text version and reading-skill level,  $F(1, 35) = 1.76$  ( $MSE = 1.13$ ).

### Qualitative Results: Prototypical Recalls

The quantitative results presented previously demonstrate differences in the amount of information that more- and less-skilled readers recalled from the difficult and easy texts. To examine the type of information more- and less-skilled readers recalled from the different versions of each text, prototypical recalls were constructed for both the original and revised versions of each text. Prototypical recalls are summaries of the particular information that is remembered by a majority of the participants who read a text (Beck et al., 1991). Prototypical recalls are a useful means of assessing the quality of information that is recalled from a text (Beck et al., 1984; McKeown, Beck, Omanson, & Perfetti, 1983).

Prototypical recalls were created for both versions of each text by identifying statements that were recalled by at least half the participants (see Tables 5 and 6). To standardize the unique way in which participants paraphrased text statements, prototypical recalls were constructed using the original text statements in their original order. The construction of prototypical recalls for both less- and more-skilled readers tested whether qualitative results supported quantitative results. The following results, in terms of percentages, were based on the text statements that were included in the prototypical recalls.

*Prototypical recall of the more difficult text (Project X-Ray).* For more-skilled readers, revisions made to the difficult text increased recall of causal chain events by 35% from the original version. More-skilled readers recalled similar

TABLE 5  
 Prototypical Recall Results for More- and Less-Skilled Readers for the Difficult Text

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Less-Skilled Readers

Difficult text—original version

*It had been just one month since the Japanese had attacked Pearl Harbor on December 7, 1941. He knew that the four-inch long mammals could carry small firebombs attached to their bodies. "If bats by the millions were released over Tokyo," he had written in his letter to President Roosevelt. As it turned out, the U.S. never did put Project X-Ray to use. By 1945, the atomic bomb had been perfected.*

Difficult text—revised version

*President Franklin D. Roosevelt sat in his office at the White House and studied a letter. The letter was only one of hundreds which poured into Washington each day. He knew that the four-inch long mammals could carry small firebombs attached to their bodies. "If bats by the millions were released over Tokyo," he had written in his letter to President Roosevelt. "they would fly into roosting places and set off thousands of fires." As it turned out, the United States never did put Project X-Ray to use. By 1945 the atomic bomb had been perfected. The daring plan to attack the enemy with bats was stamped "top secret." Dr. Lytle Adams died in 1972.*

More-Skilled Readers

Difficult text—original version

President Franklin D. Roosevelt sat in his office at the White House and studied a letter. It had been just one month since the Japanese had attacked Pearl Harbor on December 7, 1941. The letter was only one of hundreds which poured into Washington each day. *But the letter that remained on the President's desk was so important.* "Get started on Project X-Ray," he ordered. One year later, in 1943, a U.S. Army Air Corps bomber flew at 10,000 feet (3,048 meters) over the skies of California. *Looking out of his turret, the rear gunner saw no explosions.* But later the dummy town in California burst into flames. He knew that the four-inch long mammals could carry small firebombs attached to their bodies. "If bats by the millions were released over Tokyo," he had written in his letter to President Roosevelt. "They would fly into roosting places and set off thousands of fires." As it turned out, the United States never did put Project X-Ray to use. By 1945 the atomic bomb had been perfected. The daring plan to attack the enemy with bats was stamped "top secret."

Difficult text—revised version

President Franklin D. Roosevelt sat in his office at the White House and studied a letter signed by Dr. Lytle Adams. It had been just one month since the Japanese had attacked Pearl Harbor on December 7, 1941. The letter was only one of hundreds which poured into Washington each day. *Many of the letters supported the President's recent declaration of war against Japan. Others were critical. That its contents would stay classified as a top military secret for nearly 30 years.* "Get started on Project X-Ray," he ordered. One year later, in 1943, a U.S. Army Air Corps bomber flew at 10,000 feet (3,048 meters) over the skies of California. *And hundreds of bats were dropped over the dummy town.* But later the dummy town in California burst into flames and burned to the ground. "Mr. President," *said an excited voice, "Project X-Ray was successful."* He knew that the four-inch long mammals could carry small objects, such as firebombs attached to their bodies. "If bats bearing small firebombs were released by the millions over Tokyo," he had written in his letter to President Roosevelt. "They would fly into roosting places and set off thousands of fires." *Dr. Adams called this plan to attack the enemy with bats Project X-Ray.* As it turned out, the United States never did put Project X-Ray to use. By 1945 the atomic bomb had been perfected. *Dr. Lytle Adams died in 1972.*

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*Note.* Due to the odd number of participants in the less-skilled reader group, the criterion used to construct the prototypical recalls was slightly lower than that of the more-skilled reader group. Italicized sentences indicate differences between original and revised versions for readers in that particular skill group.

TABLE 6  
Prototypical Recall Results for More- and Less-Skilled Readers for the Easy Text

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Less-Skilled Readers

Easy text—original version

Irina Soltanovna, naturally, was chosen to work in France. And took a job with a family of a Belgian. They entertained frequently. Her second-in-command was a Belgian named Paul Veken. In the park where she took her employer's children every day. It was clever of her to bring sandwiches to offer to Veken—but not so clever of him to eat only one and pocket the others, which contained microfilms. She and Veken were arrested one day. *All the evidence needed for their conviction was found—in the pastries and sandwiches.*

Easy text—revised version

*She was born Irina Soltanovna. After World War II in 1945, the Russian leader, Stalin, decided to build up Soviet Spy forces abroad.* Irina Soltanovna naturally was chosen to work in France. Went to France as “Mademoiselle Germaine” and took a job with the family of a Belgian. When the family moved back to Brussels. “Mademoiselle Germaine” accompanied them. In the park. But not so clever of him to eat only one and pocket the others, which contained microfilms. *They also noticed that “Mademoiselle Germaine” and the children did not eat all the pastries that Veken brought them.* She and Veken were arrested one day.

More-Skilled Readers

Easy text—original version

*Mademoiselle Germaine was typically French in the way she talked and walked and thought and behaved.* She was as French as a woman can be—for a Russian. She graduated from Moscow University in 1937 with a diploma in French, her best subject. Irina's first job was as a French translator with a publishing house in Moscow. Irina Soltanovna, naturally, was chosen to work in France. She attended the French speaking *division of the spy school at Stiepnaya*. In Paris, she adopted the cover of a French Governess and took a job with the family of a Belgian. *They entertained frequently* and she was treated as a member of the family. *Their guests included French and other West European industrialists, scientists, technologists, officers, and even members of the Corps Diplomatique.* *Mademoiselle Germaine was able to pick up important scraps of secret information about vital industrial and political events.* When the family moved back to Brussels, *Mademoiselle Germaine accompanied them. Within weeks she had two spy webs operating.* Her second-in-command was a Belgian named Paul Veken. *Yet she became too complacent about their meetings.* In the park where she took her employer's children every day. *It looked to the casual observer like a servant-girl romance. It was clever of her to bring sandwiches to offer Veken but not so clever of him to eat only one* and pocket the others, which contained microfilms. Counter-intelligence agents noticed. They also noticed that Mademoiselle Germaine and the children did not eat all the pastries that Veken brought them. She and Veken were arrested one day.

Easy text—revised version

She was as French as a woman can be for a Russian. *She enjoyed studying French. After World War II in 1945 the Russian leader, Stalin, decided to build up Soviet Spy forces abroad.* Went to France as “Mademoiselle Germaine.” In Paris, she adopted the cover of a French Governess and took a job with the family of a Belgian. And she was treated as a member of the family. When the family moved back to Brussels. Her second-in-command was a Belgian named Paul Veken. In the park where she took her employer's children every day. And pocket the others, which contained microfilms. Counter-intelligence agents noticed. They also noticed that “Mademoiselle Germaine” and the children did not eat all the pastries that Veken brought them. She and Veken were arrested one day.

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*Note.* Due to the odd number of participants in the less-skilled reader group, the criterion used to construct the prototypical recalls was slightly lower than that of the more-skilled reader group. Italicized sentences indicate that only readers in that particular skill group recalled those sentences.

amounts of goal information between the two versions. With respect to less-skilled readers, revisions made to the difficult text increased recall of causal chain events by 29% from the original version and increased less-skilled readers' recall of goal information from the original version. Thus, revisions made to the difficult text were beneficial to both more- and less-skilled readers in terms of recalling information on the causal chain of the difficult text.

To compare the qualitative results more directly with the previously reported quantitative results, less-skilled readers' recall of the revised text was compared to more-skilled readers' recall of the original text. Using this comparison, less-skilled readers still placed more emphasis on information at the end of the text when reading the revised version than did more-skilled readers reading the original version. However, both skill groups recalled similar events on the causal chain. In total, more-skilled readers recalled 36% more causal chain events when reading the original version than did less-skilled readers reading the revised version. In terms of overlap, more-skilled readers recalled all of the same causal events when reading the original version that less-skilled readers recalled when reading the revised version. These findings generally support the quantitative results that less-skilled readers' recall of the revised difficult text was comparable to more-skilled readers' recall of the original difficult text.

*Prototypical recall results for the easier text (Mademoiselle Germaine).* For more-skilled readers, text revisions actually decreased recall of causal chain events by 38% from the original version. In addition, more-skilled readers' recall of information regarding the purpose of the text decreased for the revised version. For less-skilled readers, the revised version of the easy text increased recall of causal chain events by 30% from the original version and increased the amount of goal information recalled. Thus, revisions made to the easy text were beneficial for less-skilled readers but were not for more-skilled readers.

To more directly compare the qualitative results with previously reported quantitative results, less-skilled readers' recall of the revised text was compared to more-skilled readers' recall of the original text. Using this comparison, all readers recalled events from the beginning, middle, and end of the text, but more-skilled readers recalled a greater number of on-and-off causal chain events than did less-skilled readers. For example, more-skilled readers recalled 38% more causal chain events than did less-skilled readers. The main performance difference between less- and more-skilled readers using this comparison occurred for recall of events on the causal chain.

In summary, the majority of qualitative results replicated quantitative results. Revisions made to the difficult text increased the amount and quality (e.g., goal information) of causal information for both more- and less-skilled readers. The qual-

itative results that did not entirely match quantitative results pertained to the easier text. One such result was that less-skilled readers' recall of causal chain events was improved to a greater extent by text revisions than was the recall of more-skilled readers.

## DISCUSSION

Causal text revisions made to the difficult text used in this study improved recall and comprehension for events on the causal chain for both more- and less-skilled readers. In general, more-skilled readers' performance on recall and comprehension measures was superior to that of less-skilled readers. Less-skilled readers' recall and comprehension for events in the revised version of the difficult text, however, was roughly equivalent to more-skilled readers' recall and comprehension for events in the original version of the difficult text.

In contrast, causal text revisions made to the easy text did not improve or diminish recall and comprehension for either more- or less-skilled readers. More- and less-skilled readers' performance on recall and comprehension measures were roughly equivalent on both versions of the easy text.

The first purpose of this study was to determine if using a causal network theory as a basis for revising texts would improve reading comprehension and recall. The results indicate that making causal repairs was successful in improving comprehension and recall when the causal structure of the text was in need of repair. The difficult text used in this study had an incomplete causal structure and was improved by (a) arranging text events in temporal order; (b) making implicit goals explicit; and (c) repairing coherence breaks caused by inadequate explanation, multiple causality, or distant causal relations. The successful application of these three rules for making causal structure repairs establishes a systematic method for revising texts. Furthermore, the results of this study expand on those of Britton and Gulgoz (1991), who attempted to revise texts by improving referential coherence. However, in their attempt to make referential changes in texts, causal and logical changes were made as well, thus making it unclear whether the referential changes or the causal or logical changes affected recall of their principled version of text. In this study, causal changes were of primary interest, largely because these changes are an important subset of referential changes (Vidal-Abarca et al., 2000). The results of this study demonstrate that, when a text's causal structure is not clear, causal changes have a positive effect on comprehension.

The second purpose of this study was to investigate the interaction between causal text repairs, reading skill, and text difficulty. Both more- and less-skilled readers benefited from causal text repairs when the text was difficult but not when the text was easy. Less-skilled readers, it seems, do not have difficulty comprehending and recalling information from texts that possess an intact causal struc-

ture. Only when the reading task becomes more challenging, such as when the text does *not* possess an intact causal structure, do less-skilled readers' comprehension and recall suffer. This finding mirrors previous conclusions that less-skilled readers' performance suffers only when the task is demanding (Budd, et al., 1995; Just & Carpenter, 1992). The fact that less-skilled college readers perform as well as their more-skilled counterparts on easy tasks suggests that less-skilled readers do have the ability to read well but may need to recruit additional resources when the task becomes complex or demanding.

The causal text repairs made to the difficult text were particularly beneficial to less-skilled readers, evidenced by the finding that less-skilled readers' performance can be brought up to the level of more-skilled readers' performance when given repaired texts. This finding has implications for a source of reading difficulties. The ability to make causal inferences has been cited as problematic for less-skilled readers (Masson & Miller, 1983; Singer et al., 1992; Singer & Ritchot, 1996; St. George et al., 1997), and this study supports this notion. Less-skilled readers have difficulties making causal inferences when the events of a text are held together loosely, that is, when the text is difficult. Thus, less-skilled reading may be partially due to the inability to make causal inferences, and text repairs enhance this ability. However, this conclusion only may apply to fairly advanced readers such as the college student participants of this study. For now, it is reasonable to conclude that advanced readers benefit from causal structure repairs made to difficult texts, but more research needs to be done to determine how causal structure repairs would benefit beginning readers.

The positive effects that revisions have on more- and less-skilled readers alike are only applicable to difficult texts. But how does one decide if a text is difficult for readers and in need of repair? To determine whether a text's causal structure is too difficult for student readers and is in need of repair, some initial causal structure analyses must be performed. Using the causal text-revision principles set forth in this study, whether a text is in need of repair can be estimated. For example, if the main purpose or goal in a particular text is not explicit and there are several locations in the text that provide insufficient causal explanation, then the text is likely in need of repair. A formal set of guidelines for researchers and education professionals to determine when a text is in need of repair is a topic for future investigations.

As the results of this study demonstrate, improving the causal structure of difficult text appears to be advantageous to all readers. It could be the case, however, that some readers actually may benefit more from texts that lack coherence (S. A. Duffy, Shinjo, & Myers, 1990; Graesser, Millis, & Zwaan, 1997). For example, readers who possess a great deal of knowledge about the topic discussed in text seem to comprehend better when texts are minimally coherent, whereas low-knowledge readers comprehend better when texts are highly coherent (McNamara & Kintsch, 1996; McNamara, Kintsch, Songer, & Kintsch, 1996). Furthermore, background knowledge can interact with comprehension skill to influence what is learned from text. In



a pertinent study, Voss and Silfies (1996) observed that more-skilled readers learned more than less-skilled readers from history texts that were expanded to make causal relations more explicit. Prior knowledge did not affect learning from expanded texts. When texts were unexpanded, high-knowledge readers comprehended more than low-knowledge readers, regardless of comprehension skill. Although background knowledge was not controlled for in this study, it is clear, from the results of the studies presented previously (i.e., McNamara & Kintsch, 1996; McNamara et al., 1996; Voss & Silfies, 1996), that before texts can be successfully revised using the rules established here, other reader characteristics, such as background knowledge, must be taken into account.

An important contribution of this study is that it provides a set of revision principles that can be applied by others easily. It would be informative to determine if these principles are equally effective for different types of expository text. It is well established that causal inferences are important for understanding narrative texts (for a review, see van den Broek, 1994). In this study, history texts were used as reading materials. Such texts are expository in the sense that they convey information, yet they adhere to a structure that is considered by some researchers to be narrative in form (Perfetti, Britt, & Georgi, 1995). Other types of expository prose, such as scientific or mathematics texts, do not present information in a narrative fashion (for a discussion of the differences between narrative and expository texts, see Graesser, 1981). Because inferences are made more spontaneously during the reading of narrative as opposed to the reading of expository text (Singer, Harkness, & Stewart, 1997), repairing the causal structure of a scientific text, for example, may not result in findings similar to the ones reported here. Therefore, it is necessary to determine whether the text-revision principles presented here are applicable to other forms of informational or expository text.

The results reported in this study give insight into the way in which the structure of text interacts with reading skill to support comprehension. For decades, researchers have attempted to determine ways to revise texts to make them more comprehensible to readers. What was lacking from previous attempts was the use of a reading theory as a basis for making text repairs. Using a causal network theory as a basis, this study establishes a systematic set of rules for making text revisions. Researchers and reading professionals alike can use the guidelines set forth in this study to enhance student learning from texts.

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## APPENDIX A

### Difficult and Easy Texts Read by Study Participants

*Project X-Ray—Original.* President Franklin D. Roosevelt sat in his office at the White House and studied a letter signed by Dr. Lytle Adams. It had been just one month since the Japanese had attacked Pearl Harbor on December 7, 1941. In the Pacific, American forces were reeling under the blows of a powerful and determined enemy. At home the nation was getting ready for a long and terrible war.

The letter was only one of hundreds which poured into Washington each day. Many of the letters supported the President's recent declaration of war against Japan. Others were critical. Some wanted to know why the United States had been caught unprepared on that fateful Sunday morning a few weeks earlier. But the letter that remained on the President's desk was so important that its contents would stay classified as a top military secret for nearly 30 years. Once again President Roosevelt read the sheet of white paper. Then he reached for his telephone. "Get started on Project X-Ray," he ordered.

One year later, in 1943, a U.S. Army Air Corps bomber flew at 10,000 feet (3048 meters) over the skies of California. "Target dead ahead," reported the navigator. "Two minutes to go." The airplane droned on. Then the bombardier peered into his Norden bombsight, ordered some course corrections, and pressed the release button. "Bombs away" was the order shouted into the intercom. Slowly the lumbering aircraft turned and headed east toward its base.

Looking out of his turret, the rear gunner saw no explosions. But later the dummy town in California burst into flames and burned to the ground. Within minutes the telephone on President Roosevelt's desk rang urgently. "Mr. President," said an excited voice, "Project X-Ray was successful."

Like many interesting ideas, Project X-Ray was very simple, yet it was based on careful planning. For many years Dr. Lytle Adams had studied the habits of bats. He knew that the four-inch long mammals could carry small firebombs attached to their bodies. "If bats by the millions were released over Tokyo," he had

written in his letter to President Roosevelt, “they would fly into roosting places and set off thousands of fires.” In the test a year later, Dr. Adams’ theory proved itself when the U.S. Army bomber dropped hundreds of bats over the dummy town in California.

As it turned out, the United States never did put Project X-Ray to use. By 1945, the atomic bomb had been perfected and the war was drawing to a close. The daring plan to attack the enemy with bats was stamped “top secret,” packed into envelopes, and filed in the Pentagon. Dr. Lytle Adams died in 1972.

*Project X-Ray—Revised.* It had been just one month since the Japanese had attacked Pearl Harbor on December 7, 1941. In the Pacific, American forces were reeling under the blows of a powerful and determined enemy. At home the nation was getting ready for a long and terrible war. *President Roosevelt badly needed a new plan to attack the enemy and hasten the end of the war.*<sup>2</sup>

*President Roosevelt sat in his office at the White House and studied a letter signed by Dr. Lytle Adams.* The letter was only one of hundreds which poured into Washington each day. Many of the letters supported the President’s recent declaration of war against Japan. Others were critical. Some wanted to know why the United States had been caught unprepared on that fateful Sunday morning a few weeks earlier. But the letter from Dr. Lytle Adams was so important that its contents would stay classified as a top military secret for nearly 30 years.

Dr. Adams had a daring plan to attack the enemy. Like many interesting ideas, Dr. Lytle Adams’ plan was very simple, yet it was based on careful planning. For many years, Dr. Adams had studied the habits of bats. He knew that the four-inch long mammals could carry small firebombs attached to their bodies. “If bats bearing small firebombs were released by the millions over Tokyo,” he had written in his letter to President Roosevelt, “they would fly into roosting places and set off thousands of fires.” Dr. Adams called this plan to attack the enemy with bats Project X-Ray.

Once again President Roosevelt read the letter. Then he reached for his telephone. “Get started on Project X-Ray,” he ordered.

*Dr. Adams’ theory proved itself in a test one year later, in 1943, when a U.S. Army Corps bomber flew at 10,000 feet (3048 meters) over the clear skies of California.* “Target dead ahead,” reported the navigator. “Two minutes to go.” The airplane droned on. Then the bombardier peered into his Norden bombsight and ordered some course corrections. “Bombs away” was the order shouted into the intercom. *The bombardier pressed the release button and hundreds of bats were*

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<sup>2</sup>Sentences changed in the revised versions are italicized.

*dropped over the dummy town.* Slowly the lumbering aircraft turned and headed east toward its base.

Looking out of his turret *from inside the Air Corps bomber*, the rear gunner saw no explosions. But later, *after the bats bearing firebombs flew into roosting places and set off fires*, the dummy town in California burst into flames and burned to the ground. Within minutes the telephone on President Roosevelt's desk rang urgently. "Mr. President," said an excited voice, "Project X-Ray was successful."

As it turned out, the United States never did put Project X-Ray to use because by 1945 the atomic bomb had been perfected and the war was drawing to a close. The daring plan to attack the enemy with bats was stamped "top secret," packed into envelopes, and filed in the Pentagon. Dr. Lytle Adams died in 1972.

*Mademoiselle Germaine—Original.* Mademoiselle Germaine was typically French in the way she talked and walked and thought and behaved. She was as "French" as a woman can be—for a Russian.

She was born Irina Soltanovna in Odessa, Russia, in 1916. She graduated from Moscow University in 1937 with a diploma in French, her best subject.

Irina's first job was as a French translator with a publishing house in Moscow. Later she was transferred to work in the French department of the Moscow Radio Centre. After that she worked in the French section of the Soviet Comintern.

After World War II, in 1945, the Russian leader, Stalin, decided to build up Soviet spy forces abroad. Irina Soltanovna, naturally, was chosen to work in France.

After undergoing Secret Service training, she attended the French-speaking division of the spy school at Stiepnaya. When she graduated, ready for espionage abroad, the forty-one-year-old Irina—looking much, much younger—went to France as "Mademoiselle Germaine." In Paris she adopted the "cover" of a French governess and took a job with the family of a Belgian who was the director of a steel concern.

The Belgian family turned out to be an excellent choice for her. They entertained frequently, and she was treated as a member of the family. Their guests included French and other Western European industrialists, scientists, technologists, officers, and even members of the Corps Diplomatique. Mademoiselle Germaine was able to pick up important scraps of secret information about vital industrial and political events.

When the family moved back to Brussels, Mademoiselle Germaine accompanied them. Within weeks she had two spy webs operating. Numerous agents and informers supplied her with blueprints, plans, military reports, and other documents.

Her second-in-command was a Belgian named Paul Veken. He was, to all appearances, a fanatically religious office clerk. It seemed safe to meet him whenever necessary. Yet she became too complacent about their meetings in the park where she took her employer's children every day. Veken always drifted along to

share her park bench. It looked to the casual observer like a servant-girl romance. It was clever of her to bring sandwiches to offer to Veken—but not so clever of him to eat only one and pocket the others, which contained microfilms.

Counter-intelligence agents noticed. They also noticed that Germaine and the children did not eat all the pastries that Veken brought them. She and Veken were arrested one day.

All the evidence needed for their conviction was found—in the pastries and sandwiches. So ended the espionage career of Irina Soltanovna, alias *Mademoiselle Germaine*.

*Mademoiselle Germaine—Revised.* Irina Soltanovna was born in Odessa, Russia, in 1916. She enjoyed studying French and graduated from Moscow University in 1937 with a diploma in French, her best subject.

Irina's first job was as a French translator with a publishing house in Moscow. Later she was transferred to work in the French department of the Moscow Radio Centre. After that she worked in the French section of the Soviet Comintern.

After World War II, in 1945, the Russian leader, Stalin, decided to build up Soviet spy forces abroad. *Because of her familiarity with French language and culture*, Irina Soltanovna naturally was chosen to work in France. After undergoing Secret Service training, she attended the French-speaking division of the spy school at Stiepnaya. When she graduated, ready for espionage abroad, the forty-one-year-old Irina—looking much, much younger—went to France under the false name of “*Mademoiselle Germaine*.” As “*Mademoiselle Germaine*,” Irina was typically French in the way she talked and walked and thought and behaved. She was as “French” as a woman can be—for a Russian.

In Paris she adopted the “cover” of a French governess and took a job with a *Belgian family living in France*. This Belgian family turned out to be an excellent choice for her. *The family entertained frequently. The father of the family was director of a steel concern*, so their guests included French and other Western European industrialists, scientists, technologists, officers, and even members of the Corps Diplomatique. “*Mademoiselle Germaine*” was treated as a member of the family. Consequently, she was included in these social events, where she was able to pick up important scraps of secret information about vital industrial and political events.

Eventually, the Belgian family moved from France back to their home in Brussels. “*Mademoiselle Germaine*” accompanied them. Within weeks she had two spy webs operating. Numerous agents and informers supplied her with blueprints, plans, military reports, and other documents.

Her second-in-command was a Belgian named Paul Veken. He was, to all appearances, a fanatically religious office clerk. To “*Mademoiselle Germaine*,” it seemed safe to meet *Paul Veken*, whenever necessary, in the park where she took her employer's children every day. Veken always drifted along to share her park bench. It looked to the casual observer like a servant-girl romance.

Yet she became too complacent about their meetings. It was clever of “*Mademoiselle Germaine*” to bring sandwiches to offer to Veken—but not so clever of him to eat only one and pocket the others, which contained microfilms. Counter-intelligence agents noticed. They also noticed that “*Mademoiselle Germaine*” and the children did not eat all the pastries that Veken brought them.

“*Mademoiselle Germaine*” and Paul Veken were arrested one day *and* all the evidence needed for their conviction was found—in the pastries and sandwiches. So ended the espionage career of Irina Soltanovna, alias “*Mademoiselle Germaine*.”

## APPENDIX B

### Examples of Each Type of Revision (All from *Project X-Ray* Text)

#### Temporal Order

*Original Text.* President Franklin D. Roosevelt sat in his office at the White House and studied a letter signed by Dr. Lytle Adams. It had been just one month since the Japanese had attacked Pearl Harbor on December 7, 1941. In the Pacific, American forces were reeling under the blows of a powerful and determined enemy.

*Revised Text.* It had been just one month since the Japanese had attacked Pearl Harbor on December 7, 1941. In the Pacific, American forces were reeling under the blows of a powerful and determined enemy. At home the nation was getting ready for a long and terrible war. President Roosevelt badly need a new plan to attack the enemy and hasten the end of the war. President Roosevelt sat in his office at the White House and studied a letter signed by Dr. Lytle Adams.

#### Explicit Goals

*Original Text.* Goal had to be inferred.

*Revised Text.* President Roosevelt badly needed a new plan to attack the enemy and hasten the end of the war.

#### Explanatory Gaps

*Original Text.* Once again President Roosevelt read the sheet of white paper. Then he reached for his telephone. “Get started on Project X-Ray,” he ordered. One year later, in 1943, a U.S. Army Corps bomber flew at 10,000 feet (3048 meters) over the skies of California. “Target dead ahead,” reported the navigator.

*Revised Text.* Once again President Roosevelt read the sheet of white paper. Then he reached for his telephone. “Get started on Project X-Ray,” he ordered.

Dr. Adams’ theory proved itself in a test one year later, in 1943, when a U.S. Army Corps bomber flew at 10,000 (3048 meters) over the clear skies of California. “Target dead ahead,” reported the navigator, “Two minutes to go.”

## APPENDIX C

### Examples of Comprehension Questions (All from Project X-Ray text)

#### *Questions on causal chain in which revisions were not made:*

- Why did people send letters to the President?
- What was Dr. Adams’ theory?

#### *Questions on causal chain in which revisions were made:*

- Why did President Roosevelt need a plan?
- How did the Army test Dr. Adams’ plan to see if it would work?

#### *Questions off causal chain:*

- What altitude did the U.S. Army Air Corps bomber fly over the Gulf?
- What happened to Dr. Adams’ plan after the war ended?