AN EYE MOVEMENT INVESTIGATION OF A PROCESS MODEL OF COMPREHENSION

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Abstract

Eye movements were used to study a process model of comprehension (Kintsch & van Dijk, 1978; Miller & Kintsch, 1980). Subjects read sentences of short texts in isolation and in context. The model was used to generate text processing predictions of the number of reinstatements, inferences, and short-term memory stretches. Text statistics and predictor variables were compared with eye movement measures of readers--number of fixations, average fixation durations, and regressive fixations. Text cycles where the model predicted comprehension difficulties showed more fixations and regressions. Readers made regressions to previously read material more often when reading difficult texts. Text statistics predicted the bulk of the variance in eye movements while model predictors provided additional predictability for texts read in context.

A major area of interest that has developed in reading comprehension is the structural representation of the meaning of texts. While there are a number of important active research projects in this area, the focus here is on the work of Kintsch and van Dijk (1978) and Miller and Kintsch (1980). Text materials such as classical narrative stories, American Indian stories, political speeches, short fiction, fairy tales, psychological articles, and even detective stories have been analyzed and studied using Kintsch's propositional theory as the research vehicle. The propositional theory characterizes the semantic structure of a text in terms of a text base--a connected, partially ordered list of propositions that represents the meaning of the text. Propositions contain one or more arguments, and also a relational term. The arguments and relations may be word concepts or other propositions. Text bases are connected and hierarchically structured by a repetition rule: the connections between propositions are established through the repetition of arguments. One or more propositions are superordinate propositions of the text base, and every proposition that contains an argument which is a repetition of an argument contained in a proposition at the superordinate level define the next highest level in the text base hierarchy. All propositions that share an argument with any of the second-level propositions, but not with the first-level (superordinate) propositions, form the third level. The repetition rule recursively defines the lower levels of the text base.

The psychological validity of propositions as units of meaning has been supported by a number of studies (Kintsch & Keenan, 1973; Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975). These studies discussed the structural aspects of the propositional representation of a text's meaning in memory. That is, how does the final representation of the text in memory affect the reader's subsequent comprehension, recall, and importance ratings of the propositional units of the text? Kintsch's propositional theory also encompasses a process model of how the reader builds a memorial representation of the meaning of a text during the reading process. Kintsch and van Dijk (1978) developed a process model of text comprehension and production. Miller and Kintsch (1980) further revised the model and implemented it in a computer simulation program.

The model decomposes text comprehension into a number of component stages. First, the text is parsed into a list of propositions (Kintsch, 1974) using analysis techniques developed by Turner and Greene (1978). The propositions are then arranged into a coherent text base structure. Table 1 shows a sample text from Miller and Kintsch (1980) and the propositional representation of the paragraph's text base. The model simulates the reading of a text in a series of processing cycles. It is assumed that an entire text cannot be contained in working memory because of capacity limitations. Therefore a text is input in chunks of several propositions at a time. The number of propositions selected for a processing cycle is a parameter of the model. The processing cycles are usually natural grammatical units (sentences).

INSERT TABLE 1 ABOUT HERE

Once a group of propositions is processed, resulting in a set of connected propositions, there must be some process by which some or all of the propositions within a cycle are connected with propositions that have already been processed. A short-term memory buffer within working memory stores the network of propositions constructed over numerous processing cycles.

Propositions are connected to other propositions via shared referents, i.e., argument overlap (Kintsch, 1974). During any processing cycle: (a) the propositions being processed may be stored in long-term memory with some probability p, (b) they may be selected for inclusion in the short-term memory buffer for additional processing in the next cycle, or (c) they may be excluded from further processing. The longer a proposition remains in the buffer the more times it is processed. This increases the probability that it will be stored in and retrieved from long-term memory.

Miller and Kintsch (1980) evaluated the readability of twenty short texts. They hypothesized that readers should experience comprehension difficulties where the model has difficulty establishing coherence relations between propositions. Reading time per text and recall of the texts were used to measure readers' comprehension. Analyses showed that the number of inferences and reinstatements were the best predictors of the three dependent variables: reading time, recall, and readability. The combination of text variables (word frequency, sentence length, and words per proposition) and the model parameters (number of inferences, reinstatements, new arguments, short-term memory stretches and overloads) predicted a significant amount of the variance for the reading comprehension variables.

Carpenter and Just (1977) used eye movements to investigate the comprehension processes that link pairs of sentences. Subjects spent more time reading pairs of sentences whose "old" and "new" information was mismatched. Also, subjects made regressive eye movements back to the previous sentence when an ambiguous pronoun was encountered. These regressive fixations were significantly more often directed at a foregrounded word in the previous sentence. These results supported the claim that conceptual context influences eye movements and showed the importance of utilizing regressive eye movements to observe how new information is connected to previously read text.

Mandel (1979, 1980) investigated the role of propositional text structure in reading. Results showed that the frequencies of forward and regressive fixations are sensitive measures of: (a) text difficulty, (b) number of different arguments in the text, and (c) levels in the text base hierarchy. Difficult texts and those containing many arguments showed a high frequency of fixations and regressions. Differences in reading times were due mainly to changes in the frequency of fixations and regressions rather than to changes in the average duration of fixations.

McConkie, Hogaboam, Wolverton, Zola, and Lucas (1979) described a general approach for using eye movements to study language processing. Their underlying assumption was that "different parts of a text require differing amounts of processing time. Such differences arrive from different sources. Some are due to differences in syntax, word frequency, etc. Some are the result of the inferences or other higher levels of processes stimulated or required by the text." (p. 171). They derived an idealized processing time profile for texts by combining data across subjects to obtain an average processing curve. Processing time was averaged for segments of a text by dividing fixation durations by the number of character positions in that segment.

These studies have shown that eye movement research is a viable tool for investigation of cognitive processing during reading. Shebilske and Fisher (1983) have suggested that Kintsch's propositional units are an appropriate global measure for eye movement analysis (Mandel, 1979, 1980). They noted that "this unit has yielded promising results, and it may become important in testing interactionist's theories." (p. 12). The research presented here suggests that global measures of eye movement behavior reflect the nature of higher-level comprehension processes.

THE EXPERIMENT

The Kintsch and van Dijk (1978) process model provides specific information concerning the on-line sequences of operations in a reader's construction of a coherent memorial representation of the text being read. This study describes the moment-to-moment relationship between the model and the eye movement behavior of readers.

Perceptual features of the text naturally influence the eye movements of readers. Rather that attempt to artificially remove perceptual context from texts, texts were presented in a story context and as isolated sentences. Thus the perceptual properties of sentences in the texts remained the same while the semantic story context was manipulated. Differences in eye movement processing between sentences read in context and out of context could then be attributed to semantic processing.

Shebilske and Fisher (1982) investigated reading rates of reader-defined "meaning units". Subjects read meaning units judged as important slower than meaning units judged as unimportant. It was hypothesized that if these differences were due to contextual processing they would disappear when the units were read in isolation. An alternative hypothesis was that differences in reading rates were due to surface characteristics of vocabulary and syntax. This hypothesis lead to the prediction that differences in reading rates between important and unimportant meaning units would exist even when read out of context. Important meaning units were read slower (213 w.p.m.) than unimportant meaning units (254 w.p.m.) in context. However, this difference disappeared when sentences were read out of context. This supported the hypothesis that importance is a contextual factor rather than a surface characteristic during reading. Eye movement analysis showed that important meaning units in context received longer fixation durations and more regressive fixations.

The Kintsch and van Dijk (1978) model predicts the amount and type of processing that each proposition receives. This differential processing should be reflected in the eye movement behavior of readers. Specifically, when propositions are carried over for additional processing, there should be some form of additional cognitive processing for that particular segment of text since the selected propositions are retained in the short-term buffer for a longer period of time. These propositions may be fixated more frequently or they may receive more regressive fixations when new propositions currently being input into the buffer are connected to superordinate propositions already in the buffer or in long-term memory. The reinstatement process could result in regressive fixations to the superordinate proposition that is the referent of the proposition being processed. The reinstatement process could also result in a longer fixation duration on the current proposition.

Miller and Kintsch's (1980) simulation produces a computer trace of the model's generation of the coherence graph for a text after each processing cycle. A number of values for the model's processing factors were extracted from these protocols for each processing cycle of the texts. The model processing statistics and text variables are presented in Table 2.

INSERT TABLE 2 ABOUT HERE

There are three categories of predictor variables: text statistics, model statistics, and ratings. Text statistics include: number of propositions, words, characters, and new arguments per cycle. Statistics derived from the process model include: (1) number of propositions held over for additional cycles, (2) short-term memory stretches, (3) short-term memory overloads, (4) long-term memory searches, (5) reinstatements, and (6) inferences. The Flesch readability score for each cycle was computed as a rating of readability. These categories were originally used by Miller and Kintsch (1980). The model statistics are defined as follows. (1) The propositions held over for additional processing cycles are determinded by the "leading edge" strategy described by Kintsch and van Dijk (1978). (2) The buffer is flexible and can be increased from _s_ to _s_+1 slots during a processing cycle. (3) If the short-term memory buffer is not large enough for the currently processed propositions, it is overloaded. (4) If new propositions cannot be connected to those in the buffer, long-term memory is searched for a connecting proposition. (5) If a proposition in long-term memory is found during the search, it is reinstated in the short-term memory buffer. (6) If no linking proposition can be found, it is assumed that a bridging inference is made to maintain coherence of the text.

The four experimental texts chosen for this research (from Miller & Kintsch, 1980) vary considerably in their values for a number of model variables. For example, the Drinking text required no reinstatements or inferences, while the Saint text forced a large number of searches to find the needed propositions for reinstatement and inference building. The Hitchcock and Saint texts show heavy demands placed on the short-term memory buffer. These texts each required four short-term memory stretches and one short-term memory overload. On the other hand, the Drinking and Roses texts each required only one short-term memory stretch and no overloads.

Miller and Kintsch (1980) showed that these processing factors do do influence the reading behavior and readability ratings of subjects. The two texts that stretched and overloaded the short-term memory buffer took 15-30 seconds longer to read than the two texts that did not overload short-term memory. These differences in reading times for the texts are analyzed further here by breaking down reading time for the whole text into fixation frequency and fixation duration for each cycle of the texts.

An idealized processing profile (McConkie et al., 1979) was derived for each of the experimental texts. Data for each processing cycle were averaged across subjects and divided by the number of character spaces in that cycle. The resultant measures for each cycle were: (1) average number of fixations per character, (2) average total fixation time per character, and (3) average fixation duration. These measures were then correlated with the text's processing statistics.

Correlations between predictor variables and eye movement data collected from sentences read in context and in isolation should provide evidence for higher-order cognitive processing during reading. If higher-order processing does occur during reading, strong correlations should be found between predictor variables and eye movement data for sentences read in context. Sentences read in isolation do not require reinstatements, inferences, and other higher-order cognitive processing. Therefore, predictor variables and eye movement data collected from sentences read out of context should not be as highly correlated.

Regressive fixations, which occur about 15% of the time in normal reading, were also of interest in this study. Eye movement researchers typically instruct subjects not to look back or reread previous portions of the text. These researchers usually do not analyze or discuss regressive eye fixation data. Regressions within a word or during the return sweep at the end of a line are probably caused by perceptual factors. Regressive eye movements between words within a sentence are probably due both to perceptual characteristics of the words and syntactical relationships between words of the sentence. However, when readers make regressive eye movements between sentences and across large portions of text, these behaviors are believed to be due to semantic influences of ambiguity, pronominal reference, and coherence connections made during the reading and comprehension processes (Mandel, 1979, 1980). The Miller and Kintsch (1980) model makes specific predictions about which cycles required reinstatement and inference searches, and which cycles contain the propositions located by these cognitive processing searches. This information allows predictions of where regressive eye movement should be initiated and where in the text they should regress to.

Method

Subjects

Twenty-eight subjects enrolled in an introductory psychology course at the University of Colorado participated in the experiment in partial fulfillment of course requirements. Ten subjects were placed in the sentence presentation (no context) condition, while eighteen subjects were placed in the story presentation (context) condition. Subjects were screened to exclude those with visual problems. All subjects were native speakers of English.

Text Materials

Four paragraphs from Miller and Kintsch (1980) were used as experimental texts. They were selected from longer stories in Reader's Digest magazine. The texts averaged 77 words and 4 sentences in length, and contained an average of 29 propositions per paragraph. The four target paragraphs were embedded in condensed versions of their original stories to establish a natural context. The four complete stories each contained 8 to 9 paragraphs and were 900 to 1,000 words in length.

The sixteen sentences from the four experimental texts were presented with thirty-two unrelated sentences in the no context condition. This prevented subjects from constructing any coherence connections between sentences. The unrelated sentences were selected from sixteen other Reader's Digest stories used by Miller and Kintsch (1980).

Apparatus

The Reading Laboratory at the University of Colorado Psychology Department was utilized for this research. Subjects read the texts on a computer terminal while their eye movements were recorded with an Applied Science Laboratories Model 1996 Eye View Monitor System. The subject's right eye and the scene being viewed were photographed by television cameras. The point of fixation was determined by measuring the center of the pupil with respect to the center of the corneal reflection. The eye movement laboratory and measurement methods are described in detail by Mandel (1979, 1983).

Calibration involved subjects fixating each point of a 9-point rectangular calibration grid in a prescribed top-left to bottom-right reading pattern. Previous research (Kliegl & Olson, 1981) demonstrated the accuracy of this calibration system. Only a few subjects were rejected due to eyeglasses or contact lenses that obscured the pupil or corneal reflection during calibration.

Procedure

In the context condition, each subject read a practice story and then read all four of the experimental stories. The presentation order of the stories was counterbalanced by randomly assigning subjects to one of four conditions. Subjects were instructed to read at their own rate and to read carefully, but not to try to memorize the text material. Subjects were told they would be asked to briefly summarize each story after it was presented.

Subjects looked at a fixation point on the screen to the right and above where the text was to be presented. This simulated the natural reading pattern with a return sweep of the eyes to begin the first line of each new paragraph. The fixation point was removed and the next screen of text was presented. After reading a paragraph, the subject pressed a button to continue. The fixation point reappeared and the experimenter presented the next paragraph. All texts were presented one paragraph at a time in this manner. At the conclusion of the story the command "PLEASE SUMMARIZE THE STORY" was shown on the screen. Subjects then gave a brief verbal description of the story they just read. This procedure was repeated for each story.

The no context condition involved the presentation of the experimental sentences in isolation. Subjects were assigned to one of two counterbalanced presentation conditions. A group of practice sentences was first presented. Subjects were probed for a target sentence's recall after the presentation of each block of twelve sentences. The experimental sentences were presented so that the beginning of sentences, line endings, and end of sentence locations were identical to the story context condition.

Data Analysis

Eye movement data were collected and stored on a DEC PDP-11/03 computer. Data analysis was done off-line on the PDP-11/03 and a VAX 11/780 computer using programs developed by Mandel (1979, 1980), Kliegl (1981), and Kliegl and Olson (1981). These programs were developed specifically for analyzing eye movement data with respect to text processing. Eye movement raw data were reduced by using a flexible "window" about a fixation point and transformed to produce individual data files containing fixation locations, fixation order, and fixation duration.

Reduced eye movement data were then matched to the specific words in the experimental texts. The sequences of fixations and their durations were plotted with regard to the entire text (see Table 3). The lines of text are printed with the fixation order beneath the fixated word. The second number below the word is the fixation duration in number of samples, where each sample represents 1/60th of a second (167 msec.).

INSERT TABLE 3 AND TABLE 4 ABOUT HERE

The data were analyzed according to the text variables and model parameters. An interactive computer program (Kliegl, 1981) coded every word of each text according to perceptual and semantic features. Table 4 shows a subject's eye movement data file for the Drinking text. This data file represents the same eye movement information shown in Table 3. Variables 1-7 are the text statistics for each word. Variables 9-14 represent the subject's eye movement data for that word.

Results

Idealized Processing Profile

The reduced eye movement data were averaged across subjects to produce an idealized processing profile for the cycles of each text read both in isolation and in context. The cycles of each text were analyzed according to: (1) number of fixations, (2) total duration time (number of samples), and (3) average fixation duration (number of samples). These data are presented in Table 5.

INSERT TABLE 5 ABOUT HERE

In general, sentences read in isolation showed more fixations and longer duration times. This result is consistent with previous research by Shebilske and Reid (1980). Their results showed that sentences presented in context were read at a rate of 300 w.p.m. while the same sentences were read in isolation at a slower rate of 211 w.p.m.

A descriptive statistic--the ratio of eye movement behavior during reading in context with respect to reading in isolation--was computed by dividing the context totals by the isolation totals for each text. These computations resulted in a percentage value for both number of fixations and total duration time. The higher the percentage, the larger the increase in that eye movement measure during reading in context over reading in isolation. The Drinking and Roses texts showed ratios of 89% and 87%, respectively, for total number of fixations in context compared to isolation. The Hitchcock and Saint texts, which required additional processing in the form of short-term memory overloads, reinstatements, and inferences, showed an increase in the ratio of fixations during reading in context compared to isolation of 94% and 99%, respectively. This same effect between types of texts was found for the total duration times in context and in isolation. The Drinking and Roses texts showed context/isolation ratios of 80% and 89%, respectively. The more difficult

Hitchcock and Saint texts, however, showed context/isolation ratios of 91% and 99%, respectively.

These idealized processing profile differences were analyzed using a one-way, within-subjects analysis of variance (ANOVA). The eye movement data were divided into two groups--number of fixations on cycles that caused the model processing difficulties and number of fixations on cycles that caused the model no processing difficulties. A cycle that produced any processing difficulties--short-term memory overloads, reinstatement searches, reinstatements, inference searches, or inferences--was classified as such, resulting in 7 cycles with processing difficulties and 12 cycles without processing difficulties.

For both types of text cycles, the number of fixations per cycle read in context was divided by the average number of fixations on the cycle read in isolation and was summed over cycles for each of the 18 subjects. The group means were 0.895 for cycles without processing difficulties and 1.01 for cycles with processing difficulties. The ANOVA showed a significant difference between the groups, $\underline{F}(1,17) = 18.00$, $\underline{p}=.0005$.

These results showed that describing eye movement behavior measures using an idealized processing profile clearly emphasizes the cycle by cycle processing effects produced by the Miller and Kintsch (1980) model. Texts that required extra processing effort to build a coherent memory representation showed overall differences in the number of fixations and total duration time during reading in context compared to reading in isolation. In addition, these differences were due to processing requirements on the specific cycles within texts where additional processing was predicted by the model.

Correlations--Eye Movement Data

Correlations were used to investigate the relationship between the profile data for texts in isolation and in context with the text and model predictor variables. These correlations are presented in Table 6. There are three dependent variables--number of fixations, total fixation duration time, and average fixation duration--for cycles read in isolation and in context.

INSERT TABLE 6 ABOUT HERE

Text statistics correlated strongly with number of fixations and total duration for sentences read both in isolation and in context. Also, the correlation for all four text statistics increased slightly for both fixation and duration measures during reading in context over reading in isolation. These results highlight the strong underlying effects of perceptual and textual factors involved in the reading process. The number of fixations and the total duration for both isolated sentences and complete texts were largely determined by the number of characters, words, new arguments, and propositions. Average fixation durations did not systematically correlate with text statistics.

The effects of the processing model's statistics on text in context compared to isolated text are of great interest. The only model variables that showed significant correlations with eye movement measures for sentences read in isolation were the number of inference searches and inferences made by the model. Theoretically, inferences are generated by the reader to bridge gaps in the text being read. This implies that there is some overall context for the text. This is evidence that a sentence is a large enough segment of text to cause contextual inferences on the part of the reader. Texts read in context showed significant correlations with the number of reinstatement searches, inference searches, and inferences. These results strengthen Miller and Kintsch's (1980) findings that "reinstatements and inferences are the basic predictors of all three dependent variables [reading time, recall, and readability]" (p. 347).

The correlations from this eye movement research correspond directly with the correlations found by Miller and Kintsch (1980) for reading time. Both analyses were based on the same text materials. Miller and Kintsch (1980) computed text statistics, model variables, and the Flesch score for each text and compared them with reading time, recall, and readability of the texts. This eye movement research investigated reading time for texts at a fine-grained level of analysis. All text statistics, model variables, and the Flesch score were determined for each cycle of the texts. The reading time per text was broken down into number of fixations, total duration time, and average fixation durations for each cycle per text.

Miller and Kintsch (1980) showed a correlation of $\underline{r} = .44$ between reinstatements and reading time, while this research showed $\underline{r} = .46$ and $\underline{r} = .41$ between reinstatement searches with number of fixations and total duration, respectively. Reinstatements for number of fixations showed a correlation of $\underline{r} = .36$ and total duration showed $\underline{r} = .33$. Inferences showed a correlation of $\underline{r} =$

.48 in Miller and Kintsch's (1980) research. Here, inference searches showed correlations of r = .41 and r = .45 and inferences produced correlations of r = .40 and r = .42 (for number of fixations and total duration, respectively).

The total number of arguments in the text showed a moderate correlation with reading time (r = .44) in the Miller and Kintsch (1980) study. This eye movement research, however, calculated a more specific measure--the number of new arguments per cycle. This showed a very strong correlation with number of fixations (r = .90) and total duration (r = .91) per cycle. The difference in the correlations between the two studies supports the hypothesis (Kintsch et al., 1975) that not only is the total number of arguments an important factor in reading behavior, but that the type of arguments is even a stronger predictor of reading difficulty and reading behavior.

Miller and Kintsch (1980) computed the Flesch score for each text to compare with reading time per text. In the current research, the Flesch score was computed for each cycle of the texts (see Table 2) to be analyzed with respect to eye movement measures on each cycle. Miller and Kintsch (1980) showed a correlation of r = -.36 between Flesch score and reading time for texts. The present research also produced correlations of r = -.36 for number of fixations per cycle and r = -.37 for total duration per cycle. The negative correlation with Flesch score means that the lower the Flesch score for a text (where "lower" is "more difficult" to read), the higher the reading time, and consequently, the higher the frequency of eye movement fixations.

Regressive Eye Movement Data

Regressive eye movement data were analyzed for the texts when read in their original story context. The sentences read in isolation had no regressive fixations between sentences, of course, and showed few regressive eye movements within sentences. The scoring of regressive fixations was based upon the criterion of a backward saccade of two words or more between consecutive fixations. This criterion resulted in the scoring of 172 regressive fixations for all subjects on all texts. This constitutes approximately five percent of the total fixations in the data base. This ratio is somewhat lower than the typical rate of 10-15 percent of the total number of fixations. This difference is probably the result of the selected criterion of a two word jump for the classification of a regressive eye movement. Most research classifies any backward eye movement, even within a word, as a regressive fixation, resulting in the classification of a much greater number of regressive fixations during normal reading. Regressive fixations were categorized here into two groups: (1) those that occurred within the same cycle as the previous fixation, and (2) those that occurred between processing cycles. Table 5 shows the frequency of each type of regression per cycle for the four texts.

Differences between text statistics and model variables for the four texts showed a strong effect on regressive fixations. The Hitchcock and Saint texts produced a total of 53 and 46 regressive fixations, respectively, while the Drinking and Roses texts only showed 41 and 32 regressive fixations. The two sets of texts, however, showed different patterns of the two types of regressive eye movements.

The more difficult texts (Hitchcock and Saint) produced 73 within-cycle regressions, compared to 65 within-cycle regressions for the texts with few processing difficulties (Drinking and Roses). Within-cycle regressions may be described as a micro-level coherence mechanism that ties together the words and propositions within a sentence. This type of coherence building is necessary for all texts, thus explaining the similar number of within-cycle regressions for the two types of texts. In other words, within-cycle regressive fixations are not necessarily a function of the level of processing difficulty of the text. The number of between-cycle regressive fixations, however, varied systematically for the two sets of texts. The Hitchcock and Saint texts produced 14 and 12 between-cycle regressions, respectively, while the easier Drinking and Roses texts only produced 6 and 2 between-cycle regressions.

The distribution of regressive eye movements between cycles of texts is presented in Table 7. Although not all subjects made any regressive eye movements between cycles of text, more subjects looked back across cycle boundaries on the two difficult texts (Hitchcock and Saint). The model variables for the texts show 9 reinstatement searches resulting in three reinstatements for the Hitchcock and the Saint texts, while there were no reinstatement searches for the Drinking and Roses texts.

INSERT TABLE 7 ABOUT HERE

The model makes specific predictions of the cycle that is the source from which a reinstatement search is begun and the specific cycle where the reinstated proposition is found. The Hitchcock text required a reinstatement search from cycle 5 that reinstated a proposition from cycle 1. The data reflected this processing difficulty in the text. All 8 subjects who made regressions between cycles on this text did make a regression from cycle 5 to cycle 1. The Hitchcock text also required a reinstatement search from cycle 3 resulting in a reinstatement from cycle 2. However, there were no regressive eye movements between these two cycles. This lack of regressions between these cycles may be the result of the close proximity in the text of the two cycles. The reinstated proposition may still have been in the short-term memory buffer of the reader, which would not necessitate a physical regression to the proposition in the text. The Saint text also required a reinstatement search by the process model. The data show that all 9 subjects did make a regression between cycle 2 and cycle 1, which the model predicted.

These analyses of the distribution of the reader's regressive eye movement behavior show that between-cycle regressive fixations are indeed global macro-operations that are used to build the coherence of the whole text by connecting propositions and sentences with other propositions and sentences in the text. These types of coherence building efforts should be more frequent when there are comprehension difficulties in the texts such as reinstatements and inferences. Thus, the higher frequency of between-cycle regressions should be expected for the more difficult texts.

Correlations--Regressive Fixations

Correlations between text and model statistics and regressive eye movement data are presented in Table 8. These correlations show the strong effects of both higher-order cognitive processing and underlying perceptual features of texts during reading. Regressive eye movement fixations within cycles of a text were highly correlated with all of the text statistics: number of propositions (*r* = .42), words (*r* = .73), characters (*r* = .72), and new arguments (*r* = .79). Correlations between all of the model statistics and within-cycle regressions were not significant. This clear-cut difference between text statistics and model variables shows strong support for the hypothesis that regressive eye movements within a line of text and within a sentence are related to the underlying textual characteristics of propositions, words, characters, and arguments.

INSERT TABLE 8 ABOUT HERE

The strong correlation with number of new arguments lends general support for Kintsch's (1974) propositional theory. The connections between propositions in a text and hence the coherence of the text base is based upon argument repetition. Much of Kintsch's research has shown strong effects on reading time due to the total number of arguments in a text base (Kintsch & Keenan, 1973) and the number of new or different arguments (Kintsch et al., 1975). The correlation of *r* = .79 between new arguments and within-cycle regressions shows that arguments may indeed be the basic micro-unit of textual cohesion.

Regressive eye movements between sentences (or cycles of the process model) have been hypothesized here to be the result of higher-order cognitive processing during the on-line reading process. The correlations found in this research strongly support this view. Correlations between text statistics and regressions between cycles were not significant for three of the four text statistics---propositions, words, and characters. On the other hand, correlations between the model statistics and between-cycle regressive fixations were much higher than for regressions within a processing cycle.

These results reinforce the hypothesis that text statistics do not affect regressive eye movements between cycles of a text, although they are the main predictors of overall reading behavior. The model's variables strongly predicted the number of regressive eye movements between cycles of a text, regardless of the value of the text statistic variables involved. This supports the rehearsal and reinstatement hypothesis of Kintsch and van Dijk (1978) and Miller and Kintsch (1980). In fact, the model specifically predicted where these reinstatements occur. The cycles where the model required a reinstatement accounted for 23 of the 34 between-cycle regressions made by the readers.

A one-way, within-subjects ANOVA was performed to analyze these results. Between-cycle regressive eye movements were totalled for cycles that the model predicted were the location of reinstatements and for cycles that had no reinstatements. The cycles with reinstatements averaged 7.7 between-cycle regressions per cycle while the other cycles averaged 0.69 between-cycle regressions per cycle. The ANOVA results showed a significant difference between the regressive fixations on the two groups, $F(1,9) = 5.02$, $p=.0387$. This strong relationship between reinstatements and regressive eye movements also confirms the generally held notion that more difficult texts produce more regressive eye movements. Texts that required many reinstatement searches and reinstatements were difficult for readers, resulting in numerous regressive eye movements from one location in the text to the reinstated proposition found earlier in the text.

The number of new arguments in a cycle also correlated highly with between-cycle regressions ($\underline{r}$ = .51). This correlation points to the importance of argument repetition, which is central to Kintsch's propositional theory. Kintsch et al. (1975) showed that texts with more and different new arguments were more difficult to read.

The number of propositions within a cycle that are held over by the model for additional processing showed a correlation of $\underline{r}$ = .43 with between-cycle regressions. This result lends support for the hypothesis that readers do tend to look back to previous superordinate propositions when integrating new propositions from the text cycle currently being processed.

Inference searches and inferences showed correlations near zero for between-cycle regressions. This lack of any effect due to inference processing may be the result of the few inferences (two) needed for the model to process the four texts. It may also show that although inferences are an important factor in the higher-order processing of texts, they do not result in regressive eye movements. An inference is a reader-generated bridge to connect "a segment of text encountered that bears no explicit connection with what has already been read." (Miller & Kintsch, 1980, p. 336.)

Multiple Regression Analyses

Text and model statistics were used to predict the eye movement behavior of readers. Stepwise multiple regressions were performed for the eye movement dependent variables using all twelve predictor variables. Table 9 presents multiple regression analyses for number of fixations, total duration time, average fixation durations for texts read in isolation and in context, and within-cycle and between-cycle regressive fixations.

INSERT TABLE 9 ABOUT HERE

All of the multiple correlations were very high since they are based on the strong correlations found between the text statistics and the eye movement measures. Fixations and duration time on texts read in isolation were totally accounted for by the text factors of number of characters and the Flesch score. The model variables did not add any significant predictability to the regression equations for fixations and duration time on sentences read in isolation. This shows the total dependence of reading measures for sentences in isolation on perceptual and text characteristics.

The analysis for number of fixations on texts read in context showed the combined effects of text statistics and process model variables. Again, the number of characters was the first predictor variable to enter the regression equation. The second factor to enter the equation, however, was the number of reinstatement searches. The Flesch score, number of new arguments, and number of inference searches also added some small amount of predictability to the regression equation for number of fixations. This shows the combined effect of text and model variables in determining the number of fixations on a text read in context.

The stepwise regression analysis for average fixation durations on texts read in context showed the effects of number of characters, number of new arguments, and the number of short-term memory stretches. Similar factors entered the regression equation for average fixation durations on the same sentences read out of context. This result gives some support for the hypothesis that average fixation durations do not vary much with regard to the processing difficulties of the text. Number of fixations and total duration time show the effects of reinstatements and inferences, but average fixation durations seem to be a function of the text statistics (with some small effect due to short-term memory stretches).

Multiple regression analyses on regressive eye movements showed the relative contributions of text statistics and the model's variables in reading behavior. As discussed earlier, within-cycle regressive eye movements are a micro-level reading behavior to group propositions into a local cohesive structure. The number of new arguments was the main predictor of with-cycle regressive fixations. This supports Kintsch's (1974) theory involving arguments and argument repetition as the cohesive units of the propositional text structure. The number of inference searches also entered the regression equation, showing that higher-level cognitive processing does affect regressive eye movements within a sentence.

Regressive eye movements between cycles showed the number of reinstatement searches as the main predictor. This multiple regression analysis was the only one which showed a model variable as the main predictor of eye movement behavior. As discussed earlier, the number of reinstatement searches not only correlated highly with the number of between-cycle regressive fixations, but the model predicted exactly where in the text the information to be reinstated could be located. During reading, the specific location of 70% of the regressive eye movements between cycles was predicted by the Miller and Kintsch (1980) model simulation.

Discussion

This research predicted changes in eye movement behavior on texts that produced comprehension difficulties for the process model simulation. The results showed that those sentences that required additional processing effort (mainly reinstatements) showed a relative increase in the number of fixations and total duration time over sentences that showed no processing difficulties when read in context.

Correlations between text statistics and eye movement measures during reading both in isolation and in context confirmed the hypothesis that reading behavior is mainly based upon low-level syntactic characteristics of texts (number of characters and words) and micro-level units of the text's meaning (number of propositions and new arguments). The correlation data for sentences read out of context showed that eye movement behavior during reading without a global textual context is solely based on these syntactic and micro-structure features.

When sentences were read in context the micro-level text statistics still showed very high correlations. In fact, correlations between text statistics and number of fixations and total duration time actually increased slightly when sentences were read in context. Additionally, the number of reinstatement searches and inferences correlated with number of fixations and total duration time. This shows that higher-level cognitive processing is an additive factor that increases eye movement activity when comprehension difficulties arise in the reader's development of a coherent representation of the text's meaning in memory.

These trends were confirmed by performing stepwise multiple regressions for all eye movement measures. The number of characters in the text's cycles proved to be the main predictor of the number of fixations and total duration time for sentences read in isolation and in context. However, the model variables of reinstatement searches, inference searches, and short-term memory buffer stretches did help predict the variance for number of fixations and total duration time on texts read in context. These model variables only influenced eye movement behavior during reading in context. The differences between reading in isolation and in context were predicted by this research.

Multiple regression analyses did not add significantly to the results. It is obvious that the number of characters is the main variable that predicts overall reading time in this research. Kintsch and van Dijk's (1978) model, however, predicts specific reading behaviors that are a small, but important, part of the overall reading behaviors for texts. Multiple regression analyses give a global picture of the overall relative contribution of the predictor variables, but do not give a clear picture of the model's specific predictions involving the processing variables.

Regressive eye movements produced results relevant to the model's processing predictions. It was hypothesized that the higher-order cognitive processing variables of the Kintsch and van Dijk (1978) model would greatly influence regressive eye movements, which are generally regarded as indicators of comprehension difficulties during reading. Regressive eye fixations were divided into two categories, those that occurred within sentences (or cycles), and those that occurred between the processing cycles of the text. The results showed a clear-cut differentiation in the types of text statistics and model variables that were related to these two categories of regressive eye movements.

Regressive eye fixations within cycles showed significant correlations with all four text statistics. No model variables produced any significant correlations, although the number of inference searches did contribute some predictability to the stepwise regression analysis. The strong correlations with the text statistics, especially the number of new arguments, shows that local eye movement regressive fixations are the result of the reader's integration of arguments and propositions into a coherent structure at the level of the sentence.

Regressive fixations between cycles of the texts showed a reversal of the influence of text statistics and model variables. Here the number of reinstatement searches, reinstatements, and propositions held over for additional processing cycles all showed significant correlations with regressive fixations between cycles. Only the number of arguments showed any effect of the text statistics on between-cycle regressions. The number of reinstatement searches was the main predictor in the stepwise regression analysis for between-cycle regressive fixations. The two texts that required reinstatements by the model for comprehension produced 68% of all the regressive eye movements made by all readers of the four texts. These results confirm the hypothesis that regressive fixations are the consequent eye movement behavior of a reader looking back to previously read text to find superordinate propositions to which they can connect propositions currently being read.

Miller and Kintsch's (1980) computer simulation produced detailed protocols of the higher-order cognitive processes of reinstatement searches and inference searches. The model showed specifically where reinstatement searches were initiated and the particular proposition that was reinstated by this process. This information was used to predict which cycles of the text would show additional eye movement activity, especially regressive eye fixations. There were three sentences from which the model reinstated propositions during later processing cycles. Results showed that 23 of the 34 total regressive eye movements between cycles of the texts were on those sentences predicted by the model to be the location of the reinstated propositions. This significant difference was confirmed by an analysis of variance.

This direct link between the model simulation's difficulties and the actual eye movement behavior of readers strengthens the validity of the model. The number of reinstatement searches was strongly correlated with the number of between-cycle regressive fixations and was its main predictor in the stepwise regression analysis.

Another interesting result concerns the model's selection of propositions to be carried over for additional processing cycles. This research proposed that these propositions would receive additional eye movement activity in one of two ways. These propositions could be the focus of regressive eye movements from later cycles or later processing cycles could show more fixations and longer fixation durations when the new propositions input were connected to the superordinate propositions carried over from previous cycles. The results of this research showed that the first alternative is more likely. The number of extra cycles for propositions affected only the number of regressive eye movements between cycles of the texts. This shows that regressive eye movements are not only indicators of reinstatements, but also that readers look back at superordinate propositions that are in the short-term memory buffer when attempting to integrate newly input propositions.

Inferences are another high-level cognitive process postulated to be a major contributor to readability and comprehension of prose (Kintsch & van Dijk, 1978; Miller & Kintsch, 1980). Only four texts were used in this eye movement research and only two inferences were made in the model's processing of these texts. However, the number of inference searches and inferences did correlate fairly well with the number of fixations and total duration time for sentences read both in isolation and in context. This result does show that inferences that were necessary for the model's construction of a coherent representation of the text did predict additional eye movement behavior by actual readers of the same texts. Inference processes, unlike reinstatements, did not result in regressive eye movements between cycles of texts. Correlations between inference searches and inferences with between-cycle regressive fixations were near zero.

The effects of inferences seemed to influence the number of within-cycle regressive fixations. Although the correlations with within-cycle regressions were not high, the number of inference searches was the second predictor variable in the stepwise regression. Additional eye movement research on texts requiring more inference processing is needed to gain insight into the relationship between inferences and eye movements during reading.

Overall, this eye movement research provided a fine-grained, on-line investigation of the Kintsch and van Dijk (1978) prose comprehension model and the Miller and Kintsch (1980) computer simulation of the model. The eye movement data confirmed earlier hypotheses about the importance of higher-order cognitive processing during reading. Evaluation of reading behavior using texts presented in isolation and in context allowed unique comparisons of reading behavior of the same material under different perceptual and cognitive reading conditions.

This research has shown that the higher-order cognitive factors proposed by the processing model, especially reinstatements and inferences, do influence performance during the reading process. It is true that the bulk of reading behavior can be predicted using only low-level features of texts, i.e., characters and words, and micro-level processing variables, i.e., propositions and new arguments. However, reading of texts in context can be more accurately described by incorporating the higher-order processing factors of the Kintsch and van Dijk (1978) model. These factors are: reinstatements, inferences, short-term memory stretches and overloads, and propositions carried over for additional processing.

These higher-order cognitive processes strongly affect the subset of eye movements that are most often related to readability and comprehension, that is, regressive eye movements. During natural reading, regressive eye movements typically comprise 10-15% of the total number of fixations. Difficult texts generally produce more regressive fixations, as was shown in this research. The major results of this research have shown the strong effects of text statistics and model variables on regressive fixations both within-cycles and between-cycles of texts.

Other researchers, most notable Just and Carpenter (1980), asked subjects not to reread the text or any parts of it. The reader's regressive fixations and rereadings, constituting 12% of their total reading time, were not included in their data analysis and formulation of a model of reading. The model of Just and Carpenter (1980) also did not include as factors the higher-order cognitive processes such as reinstatements and inferences that integrate information across sentences in the reader's development of a coherent representation of the text. Their model predicted gaze durations per word and segment of text. However, they disregarded regressive eye movements between sentences, an integral part of natural reading, and did not including a semantic processing component in their model. Thus, their model may have had high predictability for their data, but it is incomplete. The Kintsch and van Dijk (1978) prose comprehension model represents the semantic component of a reading model that was not addressed by Just and Carpenter (1980).

The results of the research reported here show the strong relationship between the processes described by the prose comprehension model of Kintsch and van Dijk (1978) and the eye movements of readers, especially regressive fixations. Further eye movement research in this area should include regressive eye movements as an integral part of the reading and comprehension process. Research should attempt to predict the occurrence of regressive eye movements in addition to forward eye movements by investigating higher-order cognitive processes. Eye movement research has proved to be a valuable tool in the development and evaluation of theories of text processing and reading comprehension.

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TABLE 1

TEXT AND PROPOSITIONAL TEXT BASE FOR THE "SAINT" TEXT

TEXT

In the request to canonize the "Frontier Priest," John Newmann, Bishop of Philadelphia in the 19th Century, two miracles were attributed to him in this century. In 1932 Eva Benassi, dying from peritonitis, dramatically recovered after her nurse prayed to the Bishop. In 1949 Kent Lenahan, hospitalized with two skull fractures, smashed bones, and a pierced lung after a traffic accident, rose from his deathbed and resumed a normal life after his mother prayed ardently to John Neumann.

PROPOSITIONAL TEXT BASE FOR THE "SAINT" TEXT

(P1 (REQUEST P2 P8))
(P2 (CANONIZE P3))
(P3 (ISA J.-NEUMANN PRIEST))
(P4 (ISA J.-NEUMANN BISHOP))
(P5 (LOC: IN P4 PHILADELPHIA))
(P6 (TIME: IN P4 19TH-CENT.))
(P7 (TWO MIRACLES))
(P8 (ATTRIBUTED P7 J.-NEUMANN))
(P9 (TIME: IN P8 THIS-CENT.))
SENTENCE
(P10 (TIME: IN P11 1923))
(P11 (DYING E.-BENASSI PERIT.))
(P12 (DRAMATICALLY P13))
(P13 (RECOVERED EVA-BENASSI))
(P14 (AFTER P15 P13))
(P15 (PRAYED NURSE BISHOP))
SENTENCE
(P16 (TIME: IN P17 1949))
(P17 (HOSPITALIZED KENT-LENAHAN P18 P20 P21))
(P18 (FRACTURE SKULL K.-LENAHAN))
(P19 (TWO P18))
(P20 (SMASHED BONES K.-LENAHAN))
(P21 (PIERCED LUNG K.-LENAHAN))
(P22 (AFTER P17 ACCIDENT))
(P23 (TRAFFIC ACCIDENT))
(P24 (ROSE K.-LENAHAN DEATHBED))
(P25 (RESUMED K.-LENAHAN P26))
(P26 (NORMAL LIFE))
(P27 (AFTER P25 P28))
(P28 (PRAYED MOTHER J.-NEUMANN))
(P29 (ARDENTLY P28))
SENTENCE

TABLE 2

TEXT STATISTICS AND MODEL VARIABLES
FOR CYCLES IN THE FOUR TEXTS

	TEXT STATISTICS					MODEL VARIABLES							RATING
	CYCLE	PROPS	WORDS	CHARS	ARGS	CYCLES	STM STRETCH	STM OVERLD	REINST SEARCH	REINST	INFER SEARCH	INFER	FLESCH
DRINKING	1	3	7	42	1	7	0	0	0	0	0	0	55
	2	3	4	22	0	1	0	0	0	0	0	0	97
	3	6	20	115	5	1	0	0	0	0	0	0	47
	4	7	18	95	2	1	0	0	0	0	0	0	62
	5	6	25	153	4	2	1	0	0	0	0	0	44
HITCHCOCK	1	6	20	109	8	5	1	0	2	1	0	0	60
	2	4	15	84	2	1	0	0	1	1	0	0	45
	3	5	13	79	2	3	1	0	0	0	0	0	51
	4	5	14	87	3	0	0	0	0	0	0	0	48
	5	2	8	52	1	3	1	0	0	0	0	0	40
	6	2	8	37	1	1	1	1	0	0	0	0	42
ROSES	1	5	13	87	3	3	1	0	0	0	0	0	37
	2	8	23	131	6	3	0	0	0	0	8	1	51
	3	6	21	114	5	0	0	0	0	0	0	0	69
	4	10	24	134	4	0	0	0	0	0	0	0	60
SAINT	1	9	26	158	7	5	1	1	6	1	0	0	34
	2	6	15	91	3	3	1	0	0	0	0	0	27
	3	11	28	167	8	4	1	0	0	0	11	1	39
	4	13	8	48	1	2	1	0	0	0	0	0	61

TABLE 3

SAMPLE OUTPUT OF THE "DRINKING" TEXT WITH
EYE MOVEMENT DATA FROM ONE SUBJECT

```
T  h  e     m  a  n  n  e  r     o  f     d  r  i  n  k  i  n  g     a  l  c  o  h  o  l     i  s     c  r  u  c  i  a  l  .        O  n  e     s  h  o  u  l  d     a  l  w  a  y  s     s  i  p  .
               3  4                 2                          5                    6                          7                                      9     10          8                    11 20
               5  18                11                         11                   17                         27                                     14    13          14                   20 15

A  l  c  o  h  o  l     i  s     a  n     u  n  u  s  u  a  l     f  o  o  d  s  t  u  f  f     i  n     t  h  a  t     2  0  -  p  e  r  c  e  n  t     o  f     i  t     i  s
      13                17       15 12       14    18                      16    19 23          22          27 21       24 26    25    28                         29
      28                15       20 13       15    15                      31    8  18          5           14 13       19 13    11    17                         15

a  b  s  o  r  b  e  d     d  i  r  e  c  t  l  y     f  r  o  m     t  h  e     s  t  o  m  a  c  h     i  n  t  o     t  h  e     b  l  o  o  d  s  t  r  e  a  m  .
         31                   32    30                      35          33             34                   36                               37
         35                   19    10                      15          12             11                   17                               18

G  u  l  p  i  n  g     a  l  c  o  h  o  l     p  r  o  d  u  c  e  s     a     s  u  d  d  e  n     r  i  s  e     i  n     t  h  e     a  l  c  o  h  o  l     l  e  v  e  l     i  n     t  h  e
      40          39          41       38             42       43                      44             72    45                                     46                      47
      29          11          21       6              37       19                      19             11    14                                     15                      18

b  l  o  o  d     a  n  d     h  e  n  c  e     i  n     t  h  e     b  r  a  i  n  .        O  n  c  e     i  n     t  h  e     b  l  o  o  d  s  t  r  e  a  m  ,     n  o  t  h  i  n  g  ,
      49                         48    50                   51                                     52                                          53          54                            55
      18                         10    18                   19                                     20                                          20          16                            10

w  i  t  h     t  h  e     e  x  c  e  p  t  i  o  n     o  f     a     k  i  d  n  e  y  -  d  i  a  l  y  s  i  s     m  a  c  h  i  n  e  ,     c  a  n     c  l  e  a  r
      57                         56                                         58                   59                                  60                            61
      23                         11                                         23                   23                                  26                            15

a  l  c  o  h  o  l     f  r  o  m     t  h  e     b  l  o  o  d     q  u  i  c  k  e  r     t  h  a  n     t  h  e     b  o  d  y  '  s     o  w  n     m  e  t  a  b  o  l  i  s  m  .
         63                62             64                65                                  66             67                63?            69                71       70
         13                12             15                10                                  17             13                12             14                16       9
```

TABLE 4

SAMPLE DATA FILE OF ONE SUBJECT READING THE "DRINKING" TEXT

1	2	3	4	5	6	7	8	9	10	11	12	13	14
21	5	2	0	1	1	2	of	11	2	-7	103	3	2
14	5	6	0	1	1	2	manner	5	2	2	110	2	3
14	5	6	0	1	1	2	manner	18	4	14	110	2	4
24	5	8	0	1	2	1	drinking	11	8	8	110	4	5
33	5	7	0	1	2	1	alcohol	17	7	8	113	5	6
44	5	7	0	1	3	3	crucial	27	4	17	114	7	7
65	5	6	0	2	5	3	always	14	0	-5	115	10	8
58	5	6	0	2	4	4	should	14	2	4	117	9	9
58	5	6	0	2	4	4	should	13	6	8	117	9	10
72	5	3	2	2	6	2	sip	20	0	-50	117	11	11
21	6	2	0	3	7	2	an	13	1	-8	120	14	12
10	6	7	1	3	7	2	Alcohol	28	4	11	115	12	13
24	6	7	0	3	8	3	unusual	15	1	-4	113	15	14
21	6	2	0	3	7	2	an	20	0	15	113	14	15
32	6	9	0	3	8	3	foodstuff	31	4	-17	114	16	16
18	6	2	0	3	7	2	is	15	1	6	116	13	17
24	6	7	0	3	8	3	unusual	15	1	12	119	15	18
32	6	9	0	3	8	3	foodstuff	8	5	36	118	16	19
72	5	3	2	2	6	2	sip	15	1	-24	116	11	20

LEGEND:

1 - character position of first letter
2 - line number on screen
3 - number of characters in word
4 - beginning (1) or end (2) of line
5 - process cycle number
6 - proposition number
7 - level of proposition in LTM coherence graph
8 - word being fixated
9 - fixation duration (samples)
10 - character position in word of fixation point
11 - size and direction of saccade following fixation
12 - pupil diameter
13 - order of word in text
14 - order of fixation in text

TABLE 5

TOTAL NUMBER OF FIXATIONS, TOTAL DURATION TIME, AVERAGE FIXATION DURATIONS, AND REGRESSIVE FIXATIONS FOR CYCLES IN TEXTS

		ISOLATED READING			READING IN CONTEXT				
	CYCLE	TOTAL NUM. FIX.	TOTAL DURATION TIME	AVERAGE FIXATION DURATION	TOTAL NUM. FIX.	TOTAL DURATION TIME	AVERAGE FIXATION DURATION	BETWEEN CYCLE REG	WITHIN CYCLE REG
DRINKING	1	8.10	140.8	17.84	6.83	102.0	14.78	0	4
	2	5.70	118.3	22.96	4.28	62.4	15.41	3	0
	3	18.10	285.6	15.70	18.67	293.3	15.60	0	12
	4	16.10	243.5	15.02	15.67	241.1	15.42	3	4
	5	24.00	344.3	14.47	23.17	369.0	15.73	0	15
HITCHCOCK	1	18.20	325.9	17.93	21.78	348.3	16.28	12	16
	2	15.90	251.5	16.02	14.56	223.2	15.37	0	2
	3	16.78	265.8	15.58	13.44	213.4	16.00	1	2
	4	18.67	275.8	14.95	14.72	225.2	15.44	1	12
	5	8.00	122.7	15.34	8.44	130.6	15.43	0	2
	6	7.30	124.6	17.96	7.00	111.7	16.11	0	5
ROSES	1	15.20	224.8	15.15	12.94	195.2	15.15	0	2
	2	22.20	332.7	15.15	20.89	315.9	15.24	2	11
	3	22.80	345.5	15.23	18.28	291.1	15.88	0	8
	4	23.30	342.1	14.78	21.11	317.4	15.03	0	9
SAINT	1	26.10	406.2	15.57	27.06	401.6	14.92	11	13
	2	15.90	290.3	18.62	16.39	274.4	16.90	1	5
	3	28.50	436.3	15.28	25.72	431.4	16.72	0	10
	4	7.60	118.0	15.27	7.61	127.8	16.81	0	6

TABLE 6

CORRELATION COEFFICIENTS AND PROBABILITIES FOR TEXT STATISTICS, MODEL VARIABLES, AND RATINGS WITH ISOLATION AND CONTEXT DEPENDENT VARIABLES

	ISOLATED READING			CONTEXT READING		
	TOTAL FIXATIONS	TOTAL DURATION	AVERAGE FIXATION DURATION	TOTAL FIXATIONS	TOTAL DURATION	AVERAGE FIXATION DURATION
TEXT STATISTICS						
PROPOSITIONS	0.52211 **	0.50092 **	-0.43447 *	0.53306 **	0.54538 **	0.32115
WORDS	0.96787 ***	0.95690 ***	-0.54550 **	0.98103 ***	0.97608 ***	0.00701
CHARACTERS	0.97441 ***	0.95860 ***	-0.56823 **	0.98254 ***	0.97788 ***	-0.00210
ARGUMENTS	0.84051 ***	0.88351 ***	-0.32924	0.90477 ***	0.91046 ***	0.12805
MODEL VARIABLES						
EXTRA CYCLES	-0.00626	0.06359	0.12397	0.11113	0.11707	-0.03757
STM STRETCHES	-0.00040	0.03278	-0.07256	0.10339	0.14547	0.53022 **
STM OVERLOADS	-0.00311	0.00893	0.08833	0.06905	0.03511	-0.10088
REIN. SRCHS.	0.32938	0.38095	-0.01874	0.45765 **	0.40764 *	-0.23473
REINSTMNTS.	0.21459	0.29061	0.05517	0.35891	0.32756	-0.12148
INF. SEARCHES	0.46081 **	0.45349 *	-0.17523	0.41252 *	0.44678 *	0.22072
INFERENCES	0.44161 *	0.43080 *	-0.17943	0.39822 *	0.42275 *	0.15858
RATINGS						
FLESCH SCORE	-0.30950	-0.30587	0.47531 **	-0.36133	-0.37255	-0.13809

* = SIGNIFICANT AT .10 ** = SIGNIFICANT AT .05 *** = SIGNIFICANT AT .01

TABLE 7

BETWEEN-CYCLE REGRESSION DATA FOR TEXTS AND SUBJECTS

TEXT	NUMBER OF SUBJECTS MAKING REGRESSIONS	FROM CYCLE --> TO CYCLE (NUMBER)
DRINKING	4	3 ---> 2 (3)
		5 ---> 4 (3)
HITCHCOCK	8	2 ---> 1 (1)
		4 ---> 1 (3)
		5 ---> 1 (8)
		4 ---> 3 (1)
		5 ---> 4 (1)
ROSES	2	3 ---> 2 (2)
SAINT	9	2 ---> 1 (11)
		3 ---> 2 (1)

TABLE 8

CORRELATION COEFFICIENTS FOR TEXT STATISTICS AND MODEL VARIABLES WITH WITHIN-CYCLE AND BETWEEN-CYCLE REGRESSIVE FIXATIONS

	WITHIN-CYCLE REGRESSIVE FIXATIONS	BETWEEN-CYCLE REGRESSIVE FIXATIONS
TEXT STATISTICS		
PROPOSITIONS	0.42052 *	0.12321
WORDS	0.73113 ***	0.27017
CHARACTERS	0.72320 ***	0.25187
ARGUMENTS	0.78854 ***	0.51247 **
MODEL VARIABLES		
EXTRA CYCLES	0.10086	0.42533 **
STM STRETCHES	0.07415	0.21566
STM OVERLOADS	0.12441	0.36647
REINST. SEARCHES	0.36859	0.80537 ***
REINSTATEMENTS	0.27762	0.73279 ***
INFER. SEARCHES	0.22311	-0.09229
INFERENCES	0.23185	-0.07797
RATINGS		
FLESCH SCORE	-0.19454	0.06506

* = SIGNIFICANT AT .10
** = SIGNIFICANT AT .05
*** = SIGNIFICANT AT .01

TABLE 9

STEPWISE REGRESSIONS FOR NUMBER OF FIXATIONS,
TOTAL DURATION TIME, AND AVERAGE FIXATION DURATIONS
FOR TEXTS READ IN ISOLATION AND IN CONTEXT

FACTOR	R	F
ISOLATION--NUMBER OF FIXATIONS		
NUMBER OF CHARACTERS	.996	F(2,17) = 1286.58
FLESCH SCORE	.997	P<.0001
ISOLATION--TOTAL DURATION TIME		
NUMBER OF CHARACTERS	.993	F(2,17) = 860.18
FLESCH SCORE	.995	P<.0001
ISOLATION--AVERAGE FIXATION DURATION		
FLESCH SCORE	.968	F(2,17) = 250.29
SHORT-TERM MEMORY STRETCHES	.983	P<.0001
CONTEXT--NUMBER OF FIXATIONS		
NUMBER OF CHARACTERS	.997	F(5,14) = 1707.53
NUMBER OF REINSTATEMENT SEARCHES	.998	P<.0001
FLESCH SCORE	.999	
NUMBER OF NEW ARGUMENTS	.999	
CONTEXT--TOTAL DURATION TIME		
NUMBER OF CHARACTERS	.996	F(3,16) = 1248.00
NUMBER OF NEW ARGUMENTS	.997	P<.0001
SHORT-TERM MEMORY STRETCHES	.998	
CONTEXT--AVERAGE FIXATION DURATION		
FLESCH SCORE	.956	F(3,16) = 232.47
SHORT-TERM MEMORY STRETCHES	.980	P<.0001
NUMBER OF CHARACTERS	.989	
BETWEEN-CYCLE REGRESSIVE FIXATIONS		
NUMBER OF REINSTATEMENT SEARCHES	.825	F(2,17) = 25.24
FLESCH SCORE	.865	P<.0001
WITHIN-CYCLE REGRESSIVE FIXATIONS		
NUMBER OF NEW ARGUMENTS	.934	F(2,17) = 71.51
NUMBER OF INFERENCE SEARCHES	.945	P<.0001