

Comprehending coherent and incoherent texts: evidence from eye movement patterns and recall performance

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ABSTRACT

The effect of text structure on the reading process and recall performance was examined. Adult readers' eye movements were monitored when they read coherently and incoherently structured texts (N=19). Incoherence was brought about by changing the sentence order in the middle paragraphs of the two stimulus texts. Each subject read and learned one text in a coherent and the other in an incoherent form in two experimental sessions. Immediate free recall followed the reading. The eye movement data showed that during the first pass reading, i.e. initial reading of a sentence until the end of the sentence is reached, structurally incoherent text segments attracted the largest number of regressive fixations, and, hence, were given more visual attention than coherent text segments (indicated by the total duration of fixations). On the other hand, more rereadings, i.e. all fixations made after the first pass reading but before moving away from the given sentence, were devoted to text segments resolving the incoherence. Textual incoherence was further found to lead to inferior recall. However, no clear-cut correspondence between eye movement behavior and quantitative recall performance was found.

RÉSUMÉ

La compréhension de textes cohérents et incohérents: évidence des mouvements oculaires et du rappel

On a examiné les effets de la structure de texte sur le processus de lecture et le rappel. On est intervenu sur les mouvements oculaires de lecteurs adultes (N = 19) lors de la lecture de textes à la structure cohérente ou incohérente. L'incohérence résulte du changement de l'ordre des phrases de six paragraphes se trouvant au milieu de deux

textes stimulus (séquences de but spécifique, essai, résultat), alors que l'introduction et la conclusion (visées de haut niveau et conséquences) demeurent inchangées. Chaque sujet a lu et appris un des textes sous une forme cohérente et un autre sous une forme incohérente lors de deux sessions expérimentales. Lors des deux sessions, la lecture a été suivie d'un rappel libre immédiat.

On a analysé les mouvements oculaires en distinguant trois étapes successives: la Première Lecture, la Relecture, et la Réinspection. Les données relatives aux mouvements des yeux, qui reflètent le processus de lecture initiale, suggèrent qu'il faut davantage de moyens de traitement pour lire un texte dont la structure est incohérente que pour lire la version cohérente du même texte. De manière spécifique, les données relatives aux mouvements oculaires montrent que pendant la Première Lecture, c'est-à-dire pendant la lecture d'une phrase avant la fin de celle-ci, les parties structurellement incohérentes du texte provoquent le plus grand nombre de fixations régressives et, par conséquent, retiennent davantage d'attention visuelle que les parties cohérentes du texte (ce qui est indiqué par la durée totale des fixations). Ceci suggère, dans le prolongement des recherches antérieures, que ces régressions sont le reflet des problèmes de compréhension rencontrés à ce moment. Par ailleurs, davantage de Relectures, c'est-à-dire toutes les fixations qui ont lieu après la première lecture mais avant de passer à une autre phrase, sont consacrées aux parties du texte qui résolvent l'incohérence. On suggère que la Relecture sert à desambiguïser la structure de l'épisode incohérent. La Réinspection, c'est-à-dire toutes les fixations de retour à une phrase à partir d'une phrase postérieure, n'a pas de relations systématiques avec la structure du texte, et semble être, en partie, le reflet des stratégies d'autorépétition personnelle qui se produisent lors de l'apprentissage d'un texte.

On a trouvé, de plus, que l'incohérence textuelle conduit à un rappel inférieur. On a également répliqué l'effet bien connu des "niveaux", c'est-à-dire un rappel de l'information superordonnée supérieur à celui de l'information détaillée. Quoique il n'ait été trouvé aucune correspondance claire entre les mouvements oculaires et la quantité de rappel, on a observé certains résultats intéressants. Les temps de la Première Lecture pour la partie des Visées superordonnées permettent de prédire le rappel des Buts, des Essais et des Résultats des parties ultérieures, et on a trouvé également une corrélation positive régulière entre les temps de lecture et le rappel des parties subordonnées du text cohérent. Cette corrélation disparaît dans les parties But du texte incohérent, comme on le suggère, pour une raison évidente: une incohérence qui apparaît soudainement augmente le temps de lecture mais affecte simultanément le rappel. Toutefois, les données ne sont que partiellement favorables à l'hypothèse pure et simple de l'attention sélective.

On en conclut que les études du rappel ne permettent pas d'explorer complètement les processus de la compréhension, quoiqu'elles permettent de dessiner les effets de la structure du texte sur la mémoire. D'un autre côté, l'enregistrement en durée réelle du comportement de lecture, les mouvements oculaires par exemple, sont susceptibles de fournir une méthode permettant de préciser les processus impliqués dans la lecture et de combler les lacunes de l'analyse. L'analyse des composantes séquentielles successives des mouvements oculaires, telles que la Première Lecture, La Relecture et la Réinspection, qui semblent refléter à la fois les effets de la structure du texte et les stratégies individuelles de lecture, apparaît tout particulièrement prometteuse.

INTRODUCTION

Reading comprehension is usually measured by means of retrieval rate from memory. Despite its virtues, such a method suffers at least from one shortcoming. It can be argued that retrieval is the final link in the act of text processing, and therefore the earlier phases of the process ought to deserve more attention from researchers (see e.g. Kieras and Just, 1984). The experiment reported here combines on-line and off-line methods in order to study reading comprehension and learning. It examines the comprehension and learning of coherent and incoherent texts as reflected by eye movement patterns and recall performance produced by the same subjects. Coherence is defined at the textual macrolevel as the reorganization of a text under a structural schema or script. Macrolevel coherence can be distinguished from microlevel coherence (see van Dijk and Kintsch, 1983). At a textual microlevel, coherence can be defined as 'cohesion' (see Halliday and Hasan, 1976) or 'argument overlap' (see Kintsch and van Dijk, 1978), in which case coherence means that two consecutive sentences are connected with each other with a referential tie. The present experiment emphasizes macro-structural coherence.

Semantic and schematic structures of texts play an important control function both in text comprehension and production (see e.g. Kintsch and van Dijk, 1978). This notion is supported by evidence from two lines of research. Firstly, there are several relevant studies of memory recall (e.g. Kintsch and Yarbrough, 1982; Mandler and Johnson, 1977; Meyer, 1977; Stein and Glenn, 1979; Thorndyke, 1977). Secondly, on-line recordings such as eye movements have provided corroborating evidence (Blanchard and Iran-Nejad, 1987; Dee-Lucas, Just, Carpenter and Daneman, 1982; Shebilske and Fisher, 1983). Studies that would explicitly combine these two approaches are lacking so far.

Research on learning and recall of both narrative (e.g. Kintsch and Greene, 1978; Mandler and Johnson, 1977; Thorndyke, 1977) and expository texts (e.g. Kieras, 1978; Kintsch and Yarbrough, 1982; Vauras, von Wright and Kinnunen 1991) has shown that logical, coherent and conventionally organized texts activate adequate schema-based expectations that can effectively be used in interpreting, constructing and recalling textual information. If the text is incoherent to the extent that it violates these schema-based expectations, the reconstruction of the information is more difficult resulting in a poor recall performance (e.g. Kieras, 1978; Kintsch and Yarbrough, 1982; Vauras, von Wright and Kinnunen, 1991). However, even in the latter case the structural schemata are effective tools in making it possible for readers to comprehend ill-structured texts by reconstruction (e.g. Kintsch, Mandel and Kozminsky, 1977; Stein, 1979).

A hierarchic organization of a text is known to especially affect readers' selection strategies. When an expository text is organized in terms of explicit hierarchic levels, a 'levels effect' is usually found: propositions from the higher levels of the text hierarchy are much better recalled than propositions low in the hierarchy (e.g. Kintsch, Kozminsky, Streby, McKoon and Keenan, 1975; Meyer, 1977; Meyer, Brandt and Bluth, 1980). However, with complex expository texts the levels effect is more intricate than with narratives, leading to somewhat equivocal results. The levels effect may not be found at all when the lower-level propositions have tight logical ties, e.g. in terms of cause and effect (Dunn, Matthews and Bieger, 1982; cf.

also Vauras, von Wright and Kinnunen, 1991), or when the text passages are complicated, organized around several topics (Kieras, 1981).

In spite of their general usefulness, off-line recall measures meet with interpretative difficulties when used as indicators of the reading process. The readers' processing activities during encoding can only be inferred indirectly on the basis of data collected after encoding. Consequently, on-line measures of the actual reading process provide a recommendable complementary method. Two types of on-line methods have usually been applied: reading time measures and eye movement recordings.

A general conclusion from on-line measures is that text structure also affects the immediate comprehension process. Cirilo and Foss (1980) showed that a sentence occupying an important, high-level status in the text hierarchy was given more reading time than the same sentence in a low hierarchic position (see also Shebilske and Fisher, 1983). Lorch, Lorch and Matthews (1985) and Lorch, Lorch and Mogan (1987) found that the reader tends to slow down when encountering a major shift in the discourse theme, compared to only a minor or no shift. A major shift means here that a new subtopic is introduced so that a local coherence gap is created. To overcome the gap, the reader needs additional processing time. Analogously, when the main theme is not explicitly stated, the reading process is slowed down (Kieras, 1978; 1982). That is, comprehending a text becomes cumbersome when the topic has to be inferred. Macro-structural coherence can also be violated by presenting a surprise end to a story, resulting in a long reading time for the lines revealing the surprise (Blanchard and Iran-Nejad, 1987). This increase in the total reading time was largely due to subjects rereading the surprising lines.

To summarize, it can be concluded that macro-structural incoherence impairs recall and slows down the reading process. Or, putting it the other way, macro-structural coherence not only improves the recall of a text, but also facilitates the actual reading of it. However, the generality of this conclusion can be challenged by the fact that studies of recall and eye movements have largely been conducted separately from each other, using different stimulus texts and different experimental paradigms. Consequently, in the present experiment both measures are applied to the same text.

Answers are sought to three questions: (1) Does macro-structural coherence/incoherence influence the actual reading process? (2) Does macro-structural coherence/incoherence have an impact on recall? (3) Does the recall of a text unit correlate positively with the amount of time allocated to that unit during reading?

(1) Eye movement recording was used instead of the reading time method, because the former method makes it feasible to analyze the effects of text incoherence on the reading process in terms of successive components. We distinguished three processing stages. These are the initial reading of a text unit (sentence), the immediate rereading of it, and a subsequent reinspection of that unit. Initial reading entails the first encounter with a given text segment, and thus reflects primarily the ease with which the text segment is encoded and comprehended. Rereading presumably reflects the integration processes, while reinspection is likely to indicate rehearsal and checking of content.

It is hypothesized that when the expected text structure is violated by an incoherent unit, the processing demands increase due to the difficulty of identifying the topics and interrelating the text's propositions logically (e.g. Kintsch and Yarbrough,

1982). This difficulty is expected to be reflected in the eye movement patterns, and compared with the coherent text, the total fixation times are expected to be longer for the incoherent text segments. More specifically, the sentence revealing the incoherence should receive longer fixation times and/or more fixations during the initial reading, because of the difficulty of integrating it with previously given information. Moreover, incoherence is expected to increase the amount of rereadings needed to integrate the incoherent paragraphs with the previous textual context.

(2) It is hypothesized that recall for an incoherent text is impaired in comparison to recall for a corresponding coherently structured text.

(3) Our last hypothesis is concerned with the notion of selective attention (see e.g. Anderson, 1982; Britton, Meyer, Simpson, Holdredge and Curry, 1979), stating that the more time is spent to process a given text unit, the more precisely it is recalled later. In other words, there ought to be a positive correlation for the coherent text between the total fixation time and the recall rate for a given text unit. For the incoherent text a similar correlation cannot be predicted because remembering a given text unit most probably depends on the contradiction's being resolved by the reader so as to produce a coherent meaning. It is plausible to assume that detection of incoherence produces a long fixation time but in spite of its being detected, the contradiction may remain unresolved and also omitted from later recall (e.g. Kintsch and Yarbrough, 1982).

METHOD

Subjects

Thirteen female and six male undergraduate students from an introductory psychology course served as subjects. All subjects had normal, uncorrected vision.

Materials

Two comparable texts on history were prepared. Texts were in Finnish, and adopted and modified from the study by Vauras, von Wright and Kinnunen (1991). Both texts were approximately 340 words long, and consisted of 14 three-sentence paragraphs. One text was entitled 'Jean-Baptiste Colbert as the Reformer of the French Economy in the 17th Century', and the other 'William Pitt as the Builder of the British Empire in the 18th Century'. Both texts had a comparable global structure consisting of three units: Introduction, Detailed Coverage, and Conclusions. Introduction described the character and aims of the main figure. The middle section, Detailed Coverage, contained six Goal-Attempt-Outcome (G-A-O) action episodes, which described the policy of the main figure in detail. Conclusions section summed up the final outcomes (see Appendix). Though the text was an expository text corresponding to the textbook passages, the structure of the stimulus texts complies with Thorndyke's (1977) story grammar. Our Introduction entails his Setting and Theme, our Detailed Coverage is comparable to his Plot Unit, and our Conclusions to his Resolution Unit.

For both texts, a coherent and an incoherent version were prepared. In the coherent version all six episodes in the Detailed Coverage section were ordered in compliance with the conventional structure, i.e. G-A-O (see Example 1). That is, the

goal of an action is stated first, followed by a sentence describing the attempt to reach that goal. This is followed by another sentence that expresses the outcome of the action. In the incoherent version, this structure was violated by moving the Goal-sentences to the final position in each of the six target paragraphs (see Example 2). Hence, the incoherent episodes were organized as A-O-G sequences. The incoherent text was perfectly understandable and in no way anomalous. Mandler and Johnson's (1977) analysis showed that in conventional stories the goal of an action is frequently omitted although an explicit goal statement is generally assumed to facilitate reader's efforts to structure the text. Furthermore, it is not uncommon in conventionally structured texts to move the goal unit after the attempt (Johnson and Mandler, 1980), like 'Top level masters were induced into the country from all over Europe, since the craftsmanship had to be improved to increase the quality of manufacturing' (cf. examples below).

Example 1 (English translation): *Coherent text paragraph*

- (GOAL) Colbert tried to create an efficient organization for stimulating foreign trade.
- (ATTEMPT) Large monopolized trading companies were established in the country.
- (OUTCOME) Companies proved somewhat unsuccessful because of their heavy bureaucracy.

Example 2 (English translation): *Incoherent text paragraph*

- (ATTEMPT) Large monopolized trading companies were established in the country.
- (OUTCOME) Companies proved somewhat unsuccessful because of their heavy bureaucracy.
- (GOAL) Colbert tried to create an efficient organization for stimulating foreign trade.

Each episode unit (G, A, O) comprised one sentence including a roughly similar number of letters (G: $M=64.1$, $SD=1.9$; A: $M=64.3$, $SD=1.7$; O: $M=62.3$, $s=2.4$) and words (G: $M=7.2$, $SD=0.9$; A: $M=6.8$; $SD=0.8$; O: $M=6.7$, $s=0.8$). The texts were presented as three-line pages, each line making up one sentence. Each target paragraph occupied one page. The Introduction and Conclusions sections were not manipulated.

Apparatus

The text was printed in upper case and it was filmed on slides with three lines on each slide. With a viewing distance of 60 cm, a visual angle of one degree subtended 3.6 character spaces horizontally. The distance between two text lines was 7 cm equalling a visual angle of 6.7 degrees vertically.

The eye movements were recorded with an ASL Eye Trac Model 200 which is a spectacle-mounted limbus tracking device. Horizontal movements were tracked from the right eye and vertical movements from the lower lid of the left eye. The

sampling frequency was 100 Hz. The measurement accuracy of the apparatus is 1 degree horizontally and 2 degrees vertically. The data were collected by an Apple IIe microcomputer. A chin rest and a head band were used to restrict head movements.

Design

A 2 × 3 within-subjects design with two text structures (coherent, incoherent) and with three hierarchic levels of organization (goals, attempts, outcomes) was employed. Each subject participated in two experimental sessions, reading once the coherent and once the incoherent text. The order of the text content (Colbert, Pitt) and that of the text structure (coherent, incoherent) were counterbalanced across subjects.

Procedure

Subjects were asked to read the text in order to be able to write a summary afterwards. Prior to the reading, the eye movement device was calibrated for each subject. For the calibration, three dots were used for each three stimulus lines: one dot in the place of the first character of a line, one in the center, and one at the end of a line. The subject operated the slide projector with a button located under the preferred hand. Reading was self-paced with the restriction that returning to a previous slide was prevented. After reading the text there was a short pause followed by an instruction to write an essay about the content of the text. The title of the essay was the same as the title of the text.

The second stimulus text was read about a week after the first session. The procedure in the second session was similar to that in the first session.

Scoring and data analysis

The recall rate for the essays was scored according to the hierarchic structure of the texts. The higher-order information of objectives and aims in the Introduction was combined (AIMS), as well as the information of results and consequences in Conclusions (CONSEQUENCES). The lower-level, specific information in the Detailed Coverage was scored separately on the three target levels: GOALS, ATTEMPTS, and OUTCOMES. Short biographical and setting information was ignored in the analysis. The scoring unit was a sentence. Subjects were given 0, 1, or 2 points, depending on the accuracy of the recall, for a proposition containing the essential meaning of the sentence, and additional 0, or 1 point for a possible specification of this proposition. The maximum score on each target level was 16 points, and maximum score on AIMS was 16 points and on CONSEQUENCES 20 points. The per cent scores on each level were computed.

Eye movement data coinciding with the manipulated sentences in the Detailed Coverage were analyzed. The data were sentence averages. The data were divided into three temporally consecutive stages: (1) *First Pass*, (2) *Rereading*, and (3) *Re-inspection*. *First Pass* includes all fixations associated with the initial reading of a Goal, Attempt, and Outcomes sentence until the end of the sentence is reached. *Rereading* includes all fixations made immediately after First Pass and before moving away from the target sentence. The beginning point for Rereading was

defined as the third fixation on a given sentence immediately after First Pass. If only one or two fixations were made after the First Pass, they were included in First Pass. *Reinspection* contains all fixations coming back to the target sentence from another sentence.

RESULTS

Eye movement patterns

First Pass data. Summed fixation time (Figure 1, left panel) associated with First Pass showed a significant Text Structure \times Level interaction, $F(2,36)=4.22$, $p<0.05$. This suggests that when action sequences were presented incoherently (A-O-G), the longest summed fixation times were devoted to the sentences initiating the incoherent episodes, i.e. Attempt-sentences. Neither the main effect of level nor that of text structure was significant.

The number of fixations (Figure 1, right panel) displayed an analogous pattern. The interaction of Structure \times Level was significant ($F(2,36)=10.87$, $p<0.01$), indicating that the Attempt-sentences beginning the incoherent paragraphs attracted most fixations during First Pass reading. The main effects were again non-significant.

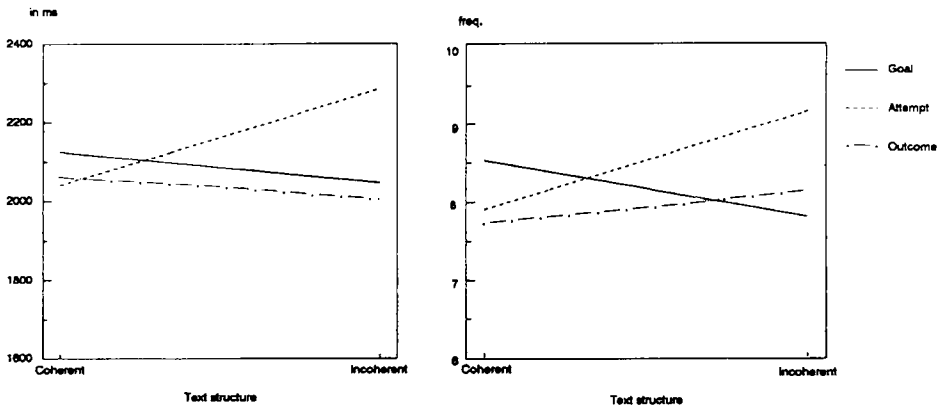


Figure 1. Summed fixation time (left panel) and number of fixations (right panel) in First Pass reading, as a function of text structure and level.

The number of fixations during First Pass was further divided into progressions and regressions. Regressions were defined as fixations returning to a part of the sentence that had already been read. Progressions were fixations falling on yet unread text regions. The number of progressions was affected neither by the text structure nor level (Figure 2, left panel). On the other hand, the number of regressions showed a reliable interaction between Text Structure and Level, $F(2,36)=12.52$, $p<0.001$ (Figure 2, right panel). Most regressive fixations were made while reading the initial sentences of the incoherent paragraphs which revealed the lack of coherence (ATTEMPT).

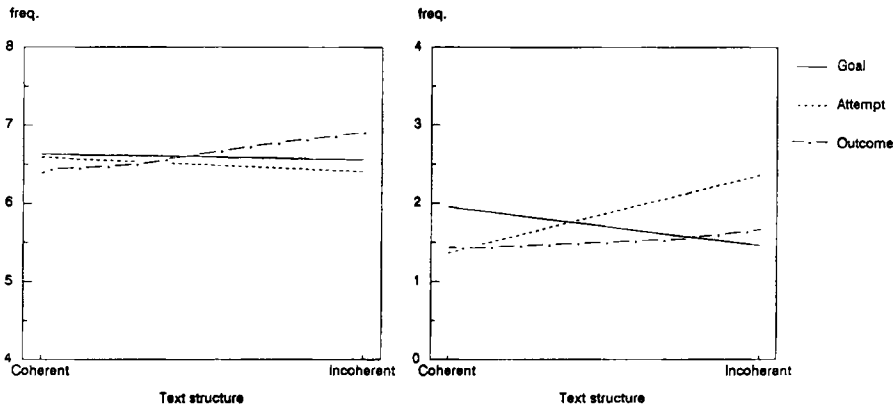


Figure 2. Number of progressions (left panel) and number of regressions (right panel) in First Pass reading, as a function of text structure and level.

The average fixation duration displayed no significant effect related to text structure or target level (Figure 3). However, there was a marginal interaction between these factors, $F(2,36) = 3.19, p = 0.053$, suggesting that the final line on a three-line page was read with slightly longer fixations, regardless of text structure.

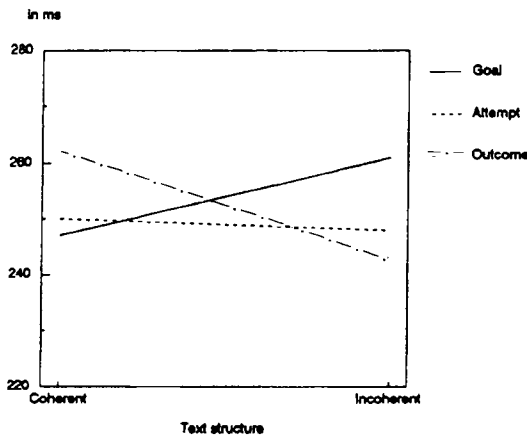


Figure 3. Average fixation duration as a function of text structure and level.

Taking these findings together, it is proposed that during First Pass reading most regressive fixations are devoted to sentences which reveal the incoherence in the text. These regressions also contribute to the increased number of fixations and longer summed fixation times for these sentences.

Rereading data. Summed fixation time associated with Rereadings showed a main effect of text structure to be that the incoherent paragraphs were reread for a longer time, $F(1,18) = 9.11, p < 0.001$ (Figure 4, left panel). However, this effect is essentially

qualified by a reliable interaction between text structure and level, $F(2,36)=9.58$, $p<0.001$, indicating that the Goal-sentences of the incoherent paragraphs attracted the longest rereading times. Similar effects were found with the number of fixations (Figure 4, right panel). There was an effect of text structure, $F(1,18)=10.19$, $p<0.001$, in that the incoherent paragraphs attracted most fixations. The interaction between text structure and level indicated that Goal-sentences occupying the final position in the incoherent paragraphs attracted more fixations than other sentences, $F(2,36)=6.58$, $p<0.01$.

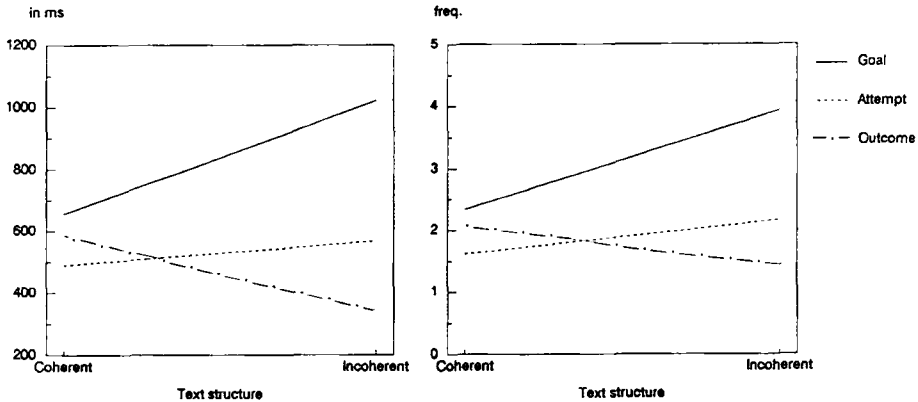


Figure 4. Summed fixation time (left panel) and number of fixations (right panel) in Rereading, as a function of text structure and level.

It is concluded from the Rereading data that Goal-sentences resolving the incoherence were given comparatively more visual attention during the Rereading phase than the other sentences.

Reinspection data. The Reinspection data did not display statistically significant effects.

Superordinate information data. The question arises whether the superordinate introductory (AIMS) and concluding (CONSEQUENCES) sections receive more or less reading time than the manipulated Detailed Coverage section. The structure effects seemed to be restricted to the manipulated section of the texts. No reliable structure effects associated with reading of superordinate information (AIMS and CONSEQUENCES) were found. However, separate analyses for the two texts were performed in order to examine levels effects. For the coherent text, the number of fixations associated with First Pass reading did show a reliable main effect of text level, $F(4,72)=7.32$, $p<0.001$, indicating that the Aims and Consequences information attracted more fixations than the subordinate Goals, Attempts and Outcomes information. Rereadings showed a reversed effect, with subordinate information receiving more fixations, $F(4,72)=7.01$, $p<0.001$, and longer summed fixation times, $F(4,72)=7.23$, $p<0.001$. No significant effects for super- and subordinate information were found for the incoherent text. However, only comparisons between Aims-sentences could be performed because data for the Consequences section were lost for three persons.

It is possible that our manipulation may have brought about a global effect on the reading speed, i.e. a general slowing down after the text section containing the coherence manipulation. In order to check for such a carry-over effect, two non-manipulated three-line paragraphs were analyzed. In both text versions there was one paragraph in the middle of the target paragraphs, i.e. after the third target paragraph, that always remained the same. The average summed fixation times for these three lines were 2378 ms for the coherent and 2340 ms for the incoherent version. Similarly, the summed fixation times per line for the paragraph appearing immediately after the last (i.e. 6th) manipulated paragraph were 1943 ms and 1939 ms, respectively. In other words, there was no evidence of a carry-over effect due to the textual manipulation.

Recall from the hierarchic levels of the texts

The mean proportion of the recall from the texts is shown in Figure 5. In the coherent text, a strong levels effect was found, $F(4,72) = 6.66$, $p < 0.001$ in the one-way analysis of variance. The subjects recalled more information from the higher levels (AIMS and CONSEQUENCES) than from the other levels comprising Detailed Coverage. For the incoherent text, both AIMS and GOALS recall decreased dramatically, while the level effect was still found $F(4,72) = 8.98$, $p < 0.001$.

In the 2 (structure) \times 5 (level) analysis of variance with repeated measures, the main effect of level was significant, $F(4,72) = 10.81$, $p < 0.001$, as was the interaction of Structure \times Level, $F(4,72) = 3.45$, $p < 0.02$. This interaction confirms statistically the proportional decrease in recall for Aims and Goals sections of the incoherent text.

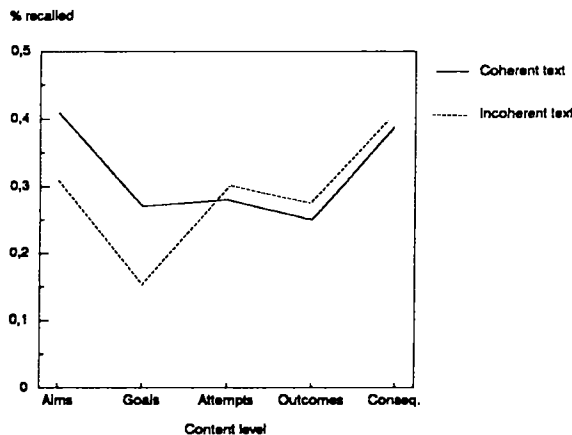


Figure 5. Recall rate as a function of text structure and content level.

Correlations between eye movements and recall

Table 1 shows, for each textual macrolevel, the correlations between summed fixation time and recall, and between the number of fixations and recall. Moderate

positive correlations were obtained for Detailed Coverage. The most notable difference between the coherent and incoherent texts was that the latter did not display significant correlations for the Goal-sentences. The drop was striking for Rereadings because recall worsened for these sentences in the incoherent text although they received more rereading than the corresponding sentences in the coherent text. The Attempt-sentences showed positive correlations for both text structures.

Table 1. Correlations between eye movement parameters and recall.

	Summed fixation time			Number of fixations		
	FIRST PASS	RE-READING	REIN-SPECTION	FIRST PASS	RE-READING	REIN-SPECTION
<i>Coherent text</i>						
AIMS	.12	-.06	-.13	-.08	-.10	-.13
GOALS	.53*	.42°	.23	.44°	.32	.17
MEANS	.52*	.62**	.55*	.31	.43°	.43°
OUTCOMES	.43°	.23	.07	.35	.18	-.05
CONSEQUENCES	.39°	.23	.02	.39°	.23	.02
<i>Incoherent text</i>						
AIMS	.14	-.06	.02	.14	-.02	-.01
GOALS	.13	-.18	-.03	.06	-.04	-.02
MEANS	.51*	.35	.49*	.44°	.26	.43°
OUTCOMES	.26	.05	.17	.13	-.14	.12

N.B. Because of technical failure, data were lost for three subjects in the consequences section of the incoherent text. The incomplete means are not reported.

Although no significant correlations were found for the Aims-sentences, the increased reading times for these sentences were significantly associated with a better recall for the subsequent GOALS, ATTEMPT and OUTCOME sentences, but only for the coherent text. The correlations for the First Pass were $r = 0.56^*$, $r = 0.67^{**}$, and $r = 0.49^\circ$. Respective correlations for Rereadings were $r = 0.51^\circ$, $r = 0.63^{**}$ and $r = 0.37$. The number of fixations showed similar correlations. In sum, these correlations indicated that the longer the antecedent information was processed the better the subsequent information was recalled. This pattern of correlations was not found in reading the incoherent text, and it is suggested that here the pattern of correlations seems to refer to the difficulty of integrating information in the incoherent text.

DISCUSSION

It is suggested that both recall performance and eye movements behavior reflect the reader's text comprehension. To the extent that the assumption holds true, recall

and eye movement data tell two somewhat different stories about the comprehension process.

The recall data replicated two well-known phenomena. Firstly, the coherent text showed a good recall for superordinate information in accordance with earlier findings reported by Kintsch, Kozminsky, Streby, McKoon and Keenan (1975), Meyer (1977), and Meyer, Brandt and Bluth (1980). Secondly, the incoherent text showed a decreased recall for sentences comprising the main aims and specific goals for the actions described in the text. Similar findings have been reported by Kieras (1978), by Kintsch and Yarbrough (1982), and by Vauras, von Wright and Kinnunen (1991). On the other hand, recall rate was similar for both texts with regard to information describing specific actions (ATTEMPTS), their results (OUTCOMES) and the general consequences. The recall for the incoherent text suggested that subjects remembered separate events and their outcomes but lacked a general schema. In sum, our recall data lend support to the second hypothesis which predicted that macro-structural incoherence impairs the recall of a text.

Readers' eye movement behavior is presumed to reflect the immediate process of extracting information from the text. The eye fixation data suggest that more processing resources are needed while reading an incoherently structured text as opposed to a coherent version of the same or an analogous text. More specifically, sentences which revealed the incoherence received long summed fixation times and a large number of fixations. To a large extent, the fixations consisted of regressive eye fixations whereby the reader re-directed his gaze, during the first-pass phase of reading, to a part of a sentence that had already been read. It is suggested, in line with Blanchard and Iran-Nejad (1987), that these regressions reflect momentary comprehension problems. Moreover, the Goal-sentences, where the incoherences were resolved, received a considerable number of such within-sentence regressions. It is suggested that this rereading served to disambiguate the incoherent episode structure. These findings lend good support to the first hypothesis according to which text structure affects readers' eye behavior. In general, the eye movement data are compatible with experiments reported by Haberlandt (1980) and Mandler and Goodman (1982), who also observed increased reading times for displaced story constituents. Moreover, the present data compare favorably with the story grammar theory (Johnson and Mandler, 1980) according to which violations in the order of the story constituents impair comprehension, and thus lead to increased processing times.

Hyönä (1991) observed previously a theme shift effect with a globally coherent text: A sentence that switches the theme of the text from one subtheme to another is devoted more visual attention than a sentence that is a continuation of an already introduced subtheme (see also Lorch, Lorch and Mathews, 1985). Haberlandt (1980) called this the boundary effect: Episode boundaries are given additional processing time. The present study extends the phenomenon by showing that the boundary effect is even more pronounced when the episode shift is made incoherently. Hyönä (1991) was able to show that the theme shift effect disappears when the same text is reread at some later point (for further effects of repeated reading of a text, see Hyönä and Niemi, 1990). This suggests that when the reader has constructed an internal representation of the episode structure during the initial reading, no additional processing is needed at thematic boundaries when rereading the whole

text. It is yet unknown whether the effects of an incoherent text structure on the reading process are rendered ineffective by a repeated exposure to the same text.

The average fixation duration was not influenced by incoherence, that is to say, the average fixation duration was not inflated on sentences entailing the incoherent text structure. This is quite plausible taking into consideration that the meaning of complete sentences — not of single words — was contextually incoherent. Thus, it is not surprising that an effect on the total average duration of several fixations was not found. The present study showed that macro-structural incoherence increased the fixation frequency, particularly the frequency of regressive fixations. Thus, the study largely confirms the results observed by Blanchard and Iran-Nejad (1987) where a surprise end of a story primarily increased the number of rereads.

It should be noted that the third eye movement component, reinspection, did not show any systematic relationship with text structure. By definition, reinspection means that the reader returns to an earlier sentence while already reading a subsequent sentence. The negative finding is intriguing because reinspection comprised about 25 to 35 per cent of the reading time. It appears that reinspection reflects, at least in part, idiosyncratic (rehearsal) strategies in reading and learning. This is supported by the observation that the interindividual variation was largest for reinspections thus rendering any differences between the means insignificant.

The relationship between memory recall and eye movements gives a somewhat mixed picture with regard to the third hypothesis based on the notion of selective attention. This hypothesis predicted that the longer a text unit is inspected the better it will be recalled. Low or moderate correlations between reading time and recall were found. Interestingly, the initial first-pass reading times for Aims section successfully predicted the recall for the subsequent Goals, Attempts and Outcomes sections but only for the coherent text. In other words, a properly processed main theme (AIMS) serves as a basis for an effective integration of subsequent information. A consistent positive correlation was found between reading times and the recall for the subordinate sections in the coherent text. However, this relationship broke down for the Goal-sentences in the incoherent text for the obvious reason that a suddenly occurring incoherence increases reading time but simultaneously impairs recall (cf. Kieras and Yarbrough, 1982). All in all, the straightforward selective attention hypothesis, predicting positive correlation between the immediate reading of the text unit and the subsequent recall of it, was given only partial support by the data. However, Vauras (1991) observed that the students, assessed on the basis of the free recalls as applying qualitatively different learning strategies, also showed distinct patterns of reading as measured by eye movements. This may also partly explain the low correlations between the immediate reading process and the recall rate on the superordinate text levels (cf. Reynolds, Wade, Trathen and Lapan, 1989).

To conclude, it is clear that recall studies leave many comprehension processes unexplored although they successfully delineate the effects of text structure on memory. On-line registration of reading behavior, like eye movements, on the other hand, are likely to provide a method which helps to specify the processes involved in reading and to bridge the gap in the analysis. An especially promising approach appears to be the analysis of temporally sequential eye movement components such as First pass, Rereading and Reinspection, which seem to reflect both the effects of texture structure and individual reading strategies. However, except for few

exceptions (Underwood, Hubbard and Wilkinson, 1990; Vauras, 1991), the inter-individual variation in reading processes as reflected by eye movements has not been given much attention in the research.

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APPENDIX

The Global Text Structure of the Coherent Version

INTRODUCTION

(including the MAIN OBJECTIVES)

	AIM I			AIM II		
GOAL 1	GOAL 2	GOAL 3	GOAL 4	GOAL 5	GOAL 6	
MEAN 1	MEAN 2	MEAN 3	MEAN 4	MEAN 5	MEAN 6	
OUTCOME 1	OUTCOME 2	OUTCOME 3	OUTCOME 4	OUTCOME 5	OUTCOME 6	

CONCLUSIONS