Cognitive effects of a structural overview in a hypertext

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Abstract
Disorientation and navigation inefficiency are the consequences of the fragmented and incoherent structure of most hypertexts. To avoid these negative effects, researchers recommend—among other things—an interface with a structural overview of the relations between sections. Some authors have found that with such an overview, information is looked up faster and remembered better. This study examined whether a structural overview also leads to a deeper understanding. Forty students read a hypertext about the effects of ultraviolet radiation in one of two presentation conditions (structural overview and list). In the list condition, the same topics were mentioned as in the overview condition, but just in the format of a list. After reading, they answered textbase questions which measured their recognition and also inference questions supposed to measure their situation model constructed from the information read. The last type of questions indicated the readers’ understanding of the text. On textbase questions, subjects with low as well as high prior knowledge scored equally well in both conditions. In contrast to our expectation, the overview did not improve the recognition of main points. However, on situation model questions low prior knowledge subjects scored significantly lower in the overview condition than in the list condition. These results supported our hypothesis that a structural overview may hinder the understanding of less knowledgeable readers, because it draws their attention to the textual macrostructure at the expense of attention to the microstructure of the text.

Introduction
Hypertext is emerging as an increasingly prevalent form of information presentation. The links in this medium make it possible to flexibly combine linear and hierarchical structures of information. Links are connections between sections on different levels
(pages) in the hierarchy of the text. However, as the number of links goes up, the structure of a hypertext becomes more fragmentary. The consequences of a fragmented structure are: cognitive overload, navigation inefficiency and disorientation (Conklin, 1987; Gärling and Golledge, 1989; Oliver and Oliver, 1996; Van Nimwegen et al., in press). To avoid these negative effects, researchers recommend—among other things—an interface with a structural overview of the links between sections (Jonassen, 1986; Halasz and Conklin, 1989; Heller, 1990; Thüring et al., 1996). With the help of overviews that make clear which sections on which pages are present, users have less problems with looking up task-relevant information (Nielsen, 1995). In view of the educational possibilities of hypertext, Dee-Lucas (1996) investigated the effects of a structural overview. She found that with such an overview as browser, information is looked up faster. Besides this, she reported that subjects who used the overview recalled more main points of the text. However, it remains the question of whether a structural overview also leads to better comprehension. This question formed the focus of our study.

**Theoretical background**

According to Van Dijk and Kintsch (1983) there exist three levels whereby readers mentally represent textual information (see also Van Oostendorp and Goldman, 1998). The first level concerns the surface structure of sentences. On this level, readers remember, for instance, the sequence of words in a sentence. A text is remembered at the textbase level. The representation at this level can be seen as a network of related propositions. However, what readers really understand of a text and integrate with prior knowledge is called the situation model (Van Dijk and Kintsch, 1983; Van Oostendorp, 1996). Because of the importance of comprehension and application of knowledge in education, the construction of situation models is the most important objective of instructional texts (Perrig and Kintsch, 1985). For this reason, the question of effect of the structure of a text has on the construction of situation models is highly relevant. McNamara et al. (1996) examined the role of structure in the comprehension of science texts and based their research on the Construction-Integration (CI) model developed by W Kintsch (1988). Structure is defined by the extent of connectiveness between propositions in the textbase. In constructing a textbase, the reader must infer the semantic relations between propositions underlying sentences. The process of drawing these inferences is relatively simple when the surface level of the text has a well developed or explicit structure. In this situation, the semantic relations between propositions are almost explicitly present. A text has a locally coherent structure if propositions refer clearly to each other, for example, by the presence of referents. A text has a globally coherent structure if the semantic relations across parts, such as paragraphs and larger sections, are fully expressed. A writer may explicitly link each section to other sections and to the overall topic with topic headers and sentences which explain these links providing the text with a globally coherent structure.

The crux of the CI-model is that readers can only integrate the textbase and prior knowledge successfully into a situation model if the textbase is sufficiently interrelated. Thus, a well developed structure is a necessary condition for the integration and situation model construction. If the text makes this integration process too difficult by
lack of structure, the reader must try to (re)construct the relevant semantic relations on the basis of prior knowledge. Results reported by McNamara et al. (1996) are in line with this notion. They measured the textbase by free recall and recognition questions and the situation model by inference and problem solving questions (see also Van Oostendorp and Bonebakker (1998) for the plausibility of this distinction).

McNamara et al. found interactions between level of prior knowledge and the structure of a text on comprehension, that is on the construction of the situation model. In their experiment, a well developed structure improved the comprehension of readers with low prior knowledge, but impaired comprehension of high prior knowledge readers. This result fits the CI-model of Kintsch (1988); for answering inference and problem solving questions, readers must have developed a coherent textbase representation during the reading. The coherence of the textbase depends on the structure of the text: a well developed structure leads to a coherent textbase, a weak structure to an incoherent textbase. If the text has a weak structure, then the textbase is not coherent and, consequently, a reader must derive the required semantic relations between propositions from background knowledge. Low knowledgeable readers encounter here more problems than high knowledgeable readers. Thus, low knowledgeable readers can only develop an adequate situation model if the textbase is coherent. In contrast, subjects with high prior knowledge scored better on situational questions if they had read the incoherent version of the experimental text. McNamara et al. explain this result by supposing that a strong textual structure hinders the understanding of knowledgeable readers, because it reduces the amount of active processing during reading. Easing the reader's burden of figuring out the meaning of the text could result in less effective learning (see also Kintsch, 1990).

McNamara et al. further established that a strong textual structure improved textbase recall. This result was found earlier by Beyer (1990) and Britton and Gulgoz (1991). McNamara et al. (1996) distinguished in correspondence with the theory of Van Dijk and Kintsch (1983) macropropositions and micropropositions. Macropropositions concern the central, summarizing idea units of a text, micropropositions concern details. They reported that both a strong local and a strong global structure significantly supported the recall of macropropositions, but structure manipulation did not have a significant effect on the recall of micropropositions. They also found that a strong global structure improved the recall of macropropositions better than a strong local structure. The effect that a strong textual structure particularly supported the recall of macropropositions corresponds to the result found by Dee-Lucas (1996) in her study of hypertext.

Hypotheses
In our study we presume that the effect of a structural overview on the situation model that learners construct of a hypertext deviates in one respect from the study of McNamara et al. (1996). We agree that the local structure of a text is highly relevant in constructing a situation model in the case of low prior knowledge. Indeed, particularly less knowledgeable readers must attentively keep track of the local semantic
relations to attain comprehension, because they lack the prior knowledge to infer these relations themselves. The CI-model of Kintsch (1988) and the study of McNamara et al. (1996) provide evidence of this assumption. However, in the case of a structural overview adjoined to a (hyper)text that has a strong local structure, we suppose that during reading learners do not use the in principle available local structure because of the negative attentional effect of the global structure added by the overview. This effect particularly hinders the comprehension of readers with low prior knowledge: their construction of a situation model depends more on the local structure of the text than the model construction of readers with sufficient prior knowledge does. Thus, in contrast to McNamara et al., we expect that a well developed global structure provided by the structural overview hinders less knowledgeable readers in their construction of a situation model.

In our study we made a distinction between micro and macro situation model (inference) questions, just as in the case of the textbase questions. We expect that the negative effect of structural overview hinders the comprehension of microstructural relations in the text for less knowledgeable readers, but not these readers’ comprehension of the macrostructural relations because these are directly expressed in the overview. An overview does not affect the situation model construction of high knowledgeable readers, because they can derive the microstructural relations from their prior knowledge.

In summary, the following hypotheses have been tested:

1. Less knowledgeable subjects who read the hypertext with a structural overview will score significantly lower on situation model (inference) micro questions compared to less knowledgeable subjects who have read the same document without structural overview. Readers with high prior knowledge will score equally well in both situations on this type of questions. On situation model (inference) macro questions, low as well as high knowledgeable readers will score equally well in both situations.

2. Readers (high as well as low prior knowledge subjects) of the hypertext with the structural overview score higher on the textbase macro questions compared to the subjects who read the document without overview, but their scores on textbase micro questions will not differ significantly.

**Method**

**Design and subjects**

To test these hypotheses, subjects (first-year university students) read an hypertext with a structural overview in the experimental condition \((n = 20)\) or in a control (list) condition \((n = 20)\), that is, they read the same hypertext without structural overview. Prior knowledge about the domain of the document was assessed by a list of ten multiple-choice questions. These questions concern basic-level understanding of physical and biological concepts rather than knowledge about topics treated in the text. The scores on this measure were used to divide the subjects into two prior knowledge groups (low and high) on the basis of the mean. In the experimental condition, 14 subjects belong to the low prior knowledge group and 6 subjects to the high prior knowledge group. In
the list condition. 11 persons belong to the low prior knowledge group and 9 persons to the high prior knowledge group.

Materials
We chose as content of the hypertext, a topic that was composed of a number of causal factors interacting with each other in a time-scale process. The topic was “skin cancer and sunburn as effects of ultraviolet radiation”. The document contains approximately 1800 words.

Structural overview and topic-list
The structural overview (see first part of Appendix A), a schematic diagram, represents the cause and effect-relations between sections; the labels of the factors in the diagram correspond to the headings of the sections, the lines and arrows correspond to the semantic relations between the factors mentioned in the sections. The lines represent whole-part relations between factors, the arrows reflect relations between causes and effects. Each page contains one or more sections; the reader could select this page with a mouse-click on the label (the header of the section) in the diagram. This design is similar to the hierarchical overview which is used in the study of Dee-Lucas (1996). Subjects in the condition without overview got a topic-list (see the second part of Appendix A) to select the sections. The purpose of this list is to support the navigation-activities of the subjects. The list emphasized the presence of the subtopics in the same way as the overview did. The labels of the items in this list also correspond to the headings of the sections, the order of the labels to the sequence of the sections in the document. In both conditions, the subjects were allowed to select the sections in any given order. Notice that the local structure of the text is equal in both conditions, because the information, organisation and lay-out of the pages and sections are the same in both conditions.

Test questions
After reading four types of multiple choice questions participants answered: textbase macro questions, textbase micro questions, situation model macro questions and situation model micro questions. There were eight questions of each type. All items had four response-alternatives. Textbase questions can be answered on the basis of the textbase; the necessary information to answer the question is in paraphrased form present in the document. Answering inference questions requires linking two or more units of information, while at the same time the connecting relation must be derived from prior knowledge. Answers to these questions depend therefore on a well-formed situation model. In the case of textbase questions as well as inference questions, a distinction is made between macro- and micro-information. Macro questions test knowledge of central, summarizing units of the document; micro questions test detailed information. Two judges divided the total set of multiple choice questions into these four classes. The interjudgemental reliability of this classification was 0.87. An example of each question type is given in the Appendix B.
Procedure
Participants were randomly assigned to the conditions and tested individually. In the instructions, the subjects were requested to read the document attentively in their own rate, because they would get questions about it later. They were told too that these questions concern detailed information as well as the text as a whole, and that for answering some of the questions more is required than merely reproducing textual information. Furthermore, the instruction clearly explained how the hypertext had to be browsed.

Results
Situation model questions
The main pattern found here was that low prior knowledge subjects scored significantly lower on total scores of situation model questions after reading the hypertext in the overview condition, than after reading the text in the list condition ($F_{(1,39)} = 5.26$, $p < 0.05$). See Table 1 for the means. This pattern however is not found for situation model macro questions ($F_{(1,39)} < 1$), but only for situation model micro questions ($F_{(1,39)} = 11.62$, $p < 0.01$). For subjects with high prior knowledge, the differences between presentation-conditions on both types of situation model questions were not significant ($p > 0.05$). In a $2 \times 2$ analysis of variance (with condition and prior knowledge as factors) of the data on the micro questions, appeared the interaction effect to be weakly significant ($F_{(1,39)} = 2.21$, $p = 0.15$), though a separate test—as mentioned

| Table 1: Mean scores and standard deviations on the test questions for low and high prior knowledge subjects in the List condition and Structural overview condition |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | List condition  | Structural overview condition |
|                 | Mean     | Sd     | Mean     | Sd     |
| Situational model questions                  |
| Low Prior Knowledge subjects                 |
| Total                                        | 10.55    | 2.16   | 8.07     | 1.44   | p < 0.05 |
| Macro                                        | 5.00     | 1.41   | 4.93     | 1.07   |
| Micro                                        | 5.55     | 1.21   | 3.14     | 1.51   | p < 0.05 |
| High Prior Knowledge subjects                |
| Total                                        | 10.11    | 2.67   | 9.50     | 1.87   |
| Macro                                        | 5.33     | 1.23   | 5.67     | 1.37   |
| Micro                                        | 4.78     | 1.79   | 3.83     | 1.33   |
| Textbase questions                           |
| Low Prior Knowledge subjects                 |
| Total                                        | 12.82    | 2.04   | 11.14    | 2.14   |
| Macro                                        | 7.09     | 1.04   | 6.50     | 1.29   |
| Micro                                        | 5.73     | 1.62   | 4.46     | 1.45   |
| High Prior Knowledge subjects                |
| Total                                        | 12.56    | 1.59   | 13.00    | 0.89   |
| Macro                                        | 6.67     | 0.87   | 7.00     | 0.89   |
| Micro                                        | 5.89     | 1.27   | 6.00     | 0.63   |
above—showed that for low prior knowledge subjects there was a significant difference between conditions.

Textbase questions
Subjects with low as well as high prior knowledge remembered the hypertext in both conditions (structural overview and list) about equally well (see Table 1). There were no significant differences on the total textbase scores (all F's < 1). There were also no significant main effects of condition on the textbase macro questions ($F_{(1,39)} < 1$) nor on the textbase micro questions separately ($F_{(1,39)} = 1.13, p = 0.29$).

Conclusions
The situation model question data support the hypothesis that readers with low prior knowledge build a less coherent situation model of a hypertext with a structural overview than less knowledgeable readers who read the same document without a structural overview. As predicted, this pattern only applies to situation model micro questions. On situation model macro questions, the differences between presentation conditions (list and overview) were not significant for both prior knowledge-groups. This difference between types of questions corresponds to the expectation that an overview does not hinder the comprehension of macrostructural relations, simply because the overview represents these relations.

The main conclusion is that a structural overview presented in a hypertext has a negative effect on the comprehension of a micro level for less knowledgeable readers. We notice that—as a result of the way of measuring—we assigned unequal numbers of high and low knowledgeable readers to the two conditions (structural overview and list). This fact shades the size of the found interaction effect between prior knowledge and condition on situation model micro questions. However, the direction of this effect is as hypothesized and the size of the effect for low prior knowledge subjects ($p < 0.01$) is great enough to be reliable. Besides this, we were more interested in the development of precise measures of prior knowledge, textbase and situation model than in the exact distribution of prior knowledge over conditions.

We assume that the negative effect which was found occurred due to the way in which the overview directed the readers’ attention to the macrostructure of the document. Note that the microstructure, the content as well as the length of the document were the same in both presentation conditions (overview and list). The problem that a structural overview may hinder less knowledgeable readers to keep track of the local, microstructural relations between propositions does not depend on their remembrance of factual information in the hypertext. Less knowledgeable readers remembered the document about equally well as high knowledgeable readers: their scores on textbase macro and micro questions did not significantly differ between the presentation conditions. On average and regardless of condition and level of prior knowledge, readers were apparently able to construct an adequate textbase and recognized the hypertext information quite well; overall, 85% of the textbase macro questions and 67% of the textbase micro questions were correctly answered (while chance level is 25%). We also

hypothesized that adding global coherence by means of a structural overview would improve the remembrance of main points of the text (cf. Dee-Lucas, 1996). The scores on the textbase macro questions, however, did not support this hypothesis. This finding will be discussed in the next session.

Discussion
This study showed that for learners with low prior knowledge a well developed local structure is a necessary condition for creating an accurate situation model of a (hyper)text. The fact that a structural overview provides global structure was apparently outweighed by the fact that the structural overview leads the reader’s attention away from the local structure of the hypertext. In short, the results indicated that less knowledgeable learners not only need local structure, but must attentively use this structure to construct an accurate situation model. This finding fits the CI-model of Kintsch (1988) and corresponds to the results found by McNamara et al. (1996) though they did not find a negative attentional effect of providing a relatively strong macrostructure in a locally coherent text. Maybe their manipulation of macrostructure was not strong enough to distract the readers’ attention as our structural overview did, because they only used headings.

In contrast with the study of Dee-Lucas (1996), we found no positive effect of the structural overview on the remembrance of headlines and main points in hypertext. Dee-Lucas found that an overview supported free recall of macropropositions. However, we did not measure recall, but recognition by the use of multiple choice questions.

Finally, it is important to conceive our results within the broader context of the educational objectives of hypertext. Can we conclude that a structural overview makes a hypertext document more suitable for educational purposes when the task consists of reading and understanding a hypertext? Our results provide a negative answer to this question with regard to recognition (no positive effect) and comprehension (a significantly negative effect). However, structural overviews may still be helpful under certain circumstances when the task consists of searching information (Nielsen, 1995). These circumstances involve user characteristics and task characteristics.

First, user characteristics seem to be important. There is some evidence that cues to the structure of information in hypertext, such as overviews, are only helpful when readers cannot discern the organizational structure of the information on their own (Goldman and Saul, 1990). Besides this, whether learners make use of structural cues in hypertext depends on their reading style; learners with a high level of self-navigation during reading pay more attention to structural cues present in the interface of a hypertext than learners with a low level of self-navigation (Beishuizen and Stoutjesdijk, 1993).

Second, the supposed helpful effects of structural overviews seem to depend upon task characteristics. Dee-Lucas (1996) found that with a structural overview as a browser, information is looked up faster. In a recent study, De Vries and De Jong (1997) qualified this finding. They concluded that browsing (looking for general information about a
broadly described topic) is a divergent process which can be improved by a hierarchical information structure such as a structural overview. Searching (looking for task-specific information) in contrast, is a convergent process that remains relatively unaffected by information structure. On the basis of a meta-analysis of seven experimental studies, Chen and Rada (1996) also concluded that structural overviews only supported divergent task-processes in hypertext. In contrast to these results, there are findings which indicate an opposite pattern: positive effects of overviews on tasks related to convergent processes and no effects of overviews on tasks related to divergent processes. Edwards and Hardman (1989) and Mohageg (1992) found that hierarchical overviews improve search efficiency and decrease search time when subjects were asked to locate defined pieces of information in hypertext (a convergent task). Hammond and Allison (1989) and Britt et al. (1996) found that if searching tasks are more divergent then simply locating information (eg, exploring relevant information about general topics) structural overviews do not significantly improve performance.

From this brief review it is clear that future research should aim at clarifying the potential effect of structural overviews in reading and searching information.

In summary, knowledge about the effects of structural overviews on the situation model built up during reading hypertexts provides us with a practical answer to the question whether such overviews make hypertext really more suitable for educational objectives. The results supported our hypothesis that a structural overview hinders the text understanding of less knowledgeable readers, because it calls their attention to the textual macrostructure at the expense of the microstructure of the text. This article provides a theoretical framework of cognitive comprehension processes explaining these results.

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Appendix A. Structural overview and topic list

Structural overview

TOPIC LIST

Ultraviolet radiation: the danger of the sun.
- The sun (introduction)
- The position of the sun
- The ozone layer
- UV-radiation
- Sunburn and skin type
- The incidence of skin cancer
- The expansion of skin cancer
- Sun filters

Appendix B. One example of each question type

Textbase macro question
Which phenomenon clarifies the relation between the sun and skin cancer?
A) The hole in the ozone layer
B) UV-radiation
C) The warming of polluted air
D) Global warming

Textbase micro question
UV-C has a wavelength of:
A) 320–400 nm
B) 200–280 nm
C) 280–320 nm
D) 400–700 nm

**Situation model macro question**
Which variable must be measured to provide an indication of the hole in the ozone layer?
A) The quantity of CFK’s in the stratosphere  
B) The quantity of oxygen in the stratosphere  
C) The quantity of UV-radiation in the stratosphere  
D) Global warming

**Situation model micro question**
If skin cancer blocks the indirect browning of the skin, then it is possibly a type of skin cancer that:
A) has affected keratine cells  
B) has affected melanine cells  
C) has affected cells in the top layer of the skin  
D) is not caused by UV-radiation