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Reading Strategies and Hypertext Comprehension

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The literature on assessing the cognitive processes involved in hypertext comprehension during the past 15 years has yielded contradictory results. In this article we explore a possible factor affecting this situation, mainly the fact that previous works did not control for the potential effects on comprehension of reading strategies in hypertext. In Experiment 1, results showed that reading strategies selectively affect the textbase and the situation model level. The number of different nodes read mainly affected the textbase, whereas the reading order influenced the situation model. In Experiment 2, the analysis of reading strategies replicated the effect of knowledge and coherence found in the literature on linear text comprehension (McNamara & Kintsch, 1996), but it was not replicated in hypertext. Low-knowledge participants learned more by following a high coherent reading order, whereas high-knowledge participants learned more by reading the hypertext in a low-coherence order. We discuss the theoretical and methodological consequences of this approach for the study of hypertext comprehension.

Hypertexts are information systems in which the contents are organized in an interrelated network with nodes that are documents and links that are the relations be-

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tween these documents. Hypertexts constitute a practical alternative to paper documents in education. Research assessing the cognitive processes involved in hypertext comprehension has grown jointly with the development of these systems in educational fields. However, reviews of the literature published up to 1999 reported few reliable findings about the processes involved in hypertext comprehension (Dillon & Gabbard, 1998; Unz & Hesse, 1999).

In this article we first describe the results found in the literature on hypertext comprehension since 1999 and conclude that the null and contradictory results of previous work still exist. Second, we propose a theoretical and methodological approach to explore the relation between reading strategies and text comprehension. Third, we describe two experiments designed to evaluate our claims.

RECENT RESEARCH ON HYPERTEXT COMPREHENSION

Most of the research on hypertext comprehension can be framed from the perspective of the construction–integration (C–I) model of text comprehension (Kintsch, 1988, 1998; Van Dijk & Kintsch, 1983). The model distinguishes between two of the mental representations that a reader forms from the text: (a) the textbase, a hierarchical propositional representation of the information within the text, and (b) the situation model, a representation of what the text is about that integrates the information with readers' prior knowledge. According to the C–I model, many factors contribute to text comprehension, but prior knowledge and coherence are the main factors. Text coherence refers to the extent to which a reader is able to understand the relations between ideas in a text.

In general, readers with high domain knowledge comprehend better at both the textbase and the situation level (Moravcsik & Kintsch, 1993). However, when the analysis takes account of both prior knowledge and text coherence, it has been found that readers with low domain knowledge construct better situation models from a highly coherent text than from an incoherent one, whereas readers with high domain knowledge actually learn more from an incoherent text than from a highly coherent one (McNamara & Kintsch, 1996; McNamara, Kintsch, Songer, & Kintsch, 1996). The explanation for this effect of knowledge and coherence is that naïve readers cannot fill in gaps in the incoherent text without explicit guidance about relations among information items; on the other hand, expert readers who are overguided will not actively use their own prior knowledge to form the situation model of the text.

These effects have been the starting point of many of the experiments exploring the effects of overviews on hypertext comprehension. Overviews are writing devices that emphasize the contents of a text and their organization (Lorch, 1989). In hypertext, overviews are used as a table of contents that helps the reader to move through the different sections. This is one of the most active areas on hypertext comprehension, and one in which the situation described by Dillon and Gabbard (1998) and Unz and Hesse (1999) become apparent. Starting from research conducted with linear text (e.g., Snapp & Glover, 1990), it has been hypothesized that the overview would act as an "advance organizer," improving readers' memory of the contents. In the experiments reviewed, an overview containing structural information on the contents was compared to an unstructured one (e.g., list of contents, linear version). In most cases, comprehension measures were collected for both the textbase (e.g., recall, text-based questions) and for the situation model (e.g., inference questions, essay, cued association, sorting task, concept map). In addition, some of the experiments measured readers' prior knowledge about the subject matter.

However, a review of recent empirical work does not converge on a clear conclusion about the effect of overviews on comprehension (see Table 1). For low-knowledge readers, some experiments show that overviews facilitate textbase construction (Moeller & Mueller-Kalthoff, 2000; Potelle & Rouet, 2003), whereas

TABLE 1
Reported Effects of Structured Overviews in Comprehension, by Prior Knowledge (Low and High), and Mental Representation (Textbase and Situation Model)

	Low Knowledge		*High Knowledge*	
	Textbase	*Situation Model*	*Textbase*	*Situation Model*
Brinkerhoff, Klein, and Koroghlanian (2001)	=			
De Jong and van der Hulst (2002)	=	+		
Hoffman and van Oostendorp (1999)	= / =	= / –[a]	=	=
Moeller and Mueller-Kalthoff (2000)	+	=	=	=
Mueller-Kalthoff and Moeller (2003)	=	=	=	=
Naumann, Waniek, and Krems (2001)	–			
Potelle and Rouet (2003)	= / +	= / +[b]	=	=
Puntambekar, Stylianou, and Hübscher (2003)	=	+		
Quathamer and Heineken (2002)	–			
Shapiro (1998)	=	–		
Shapiro (1999)	=	+	=	=
Shapiro (2000)	+			
Waniek, Brunstein, Naumannm, and Krems (2003)	–			

Note. A plus sign indicates a positive effect of structured overview, a minus sign indicates a negative effect, and an equals sign indicates a null effect.

[a]Hofman and van Oostendorp (1999) found a null effect for both textbase and situation model questions tapping the macrostructure level (i.e., main ideas) and a negative effect for situation model questions at the microstructure level (i.e., local ideas). [b]Potelle and Rouet (2003) found a positive effect for questions focusing at the macrostructure level and a null effect for questions focusing at the microstructure level.

others present null effects (Brinkerhoff, Klein, & Koroghlanian, 2001; De Jong & van der Hulst, 2002; Hofman & van Oostendorp, 1999; Mueller-Kalthoff & Moeller, 2003; Puntambekar, Stylianou, & Hübscher, 2003; Shapiro, 1998, 1999) or negative effects (Naumann, Waniek, & Krems, 2001; Quathamer & Heineken, 2002). Regarding the situation model construction for low-knowledge readers, some experiments show positive effects of an overview (De Jong & van der Hulst, 2002; Potelle & Rouet, 2003; Puntambekar et al., 2003; Shapiro, 1999, 2000), whereas others present null effects (Moeller & Mueller-Kalthoff, 2000; Mueller-Kalthoff & Moeller, 2003) and negative effects (Hofman & van Oostendorp, 1999; Shapiro, 1998; Waniek, Brunstein, Naumann, & Krems, 2003). For high-knowledge readers, experiments agree on a null effect of structured overviews in hypertext comprehension both in textbase and situation model construction (Hofman & van Oostendorp, 1999; Moeller & Mueller-Kalthoff, 2000; Mueller-Kalthoff & Moeller, 2003; Potelle & Rouet, 2003; Shapiro, 1999).

These results on hypertext comprehension reveal an unclear situation, just as the earlier results reviewed by Dillon and Gabbard (1998) and Unz and Hesse (1999). The heterogeneity of the results for low-knowledge readers regarding both the direction of the effect (positive, null, and negative) and the type of comprehension (textbase and situation model) suggest that there is no easy explanation for the contradictory data. Some suggestions for clarifying the state of the art in the field would be to improve the methodological rigor of experiments (e.g., pretesting of prior knowledge; Dillon & Gabbard, 1998), to use several measures for text comprehension (Hofman & van Oostendorp, 1999), and to understand the interdependence between navigation behavior and the learning performance (Unz & Hesse, 1999). In this work we explore the last suggestion, focusing on the role of reading strategies in hypertext comprehension.

THE ROLE OF READING STRATEGIES

One variable that might play an important role in comprehension is the reader's strategy. Reading strategies in hypertext can be considered as the decision rule that a reader follows to navigate through the different nodes of a hypertext. For example, readers can read through the contents and select those nodes that contain interesting information or those related to the previous paragraphs read. The relation between strategy use and comprehension has been widely reported in the literature of text comprehension in linear text (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi, De Leeuw, Chiu, & LaVancher, 1994; Goldman & Saul, 1990; Goldman, Saul, & Coté, 1995; Magliano, Trabasso, & Graesser, 1999; McNamara & Scott, 1999; Pressley, Symons, McDaniel, Snyder, & Turnure, 1988; Trabasso &

Magliano, 1996; Wagner & Sternberg, 1987). Different reading strategies influence the way readers process the text and hence their text comprehension.

Research on hypertext comprehension has also explored the relation between reading strategies and comprehension (Barab, Bowdish, & Lawless, 1997; Barab, Bowdish, Young, & Owen, 1996; Barab, Fajen, Kulikowich, & Young, 1996; Barab, Young, & Wang, 1999; Britt, Rouet, & Perfetti, 1996; Foltz, 1996; Horney & Anderson-Inman, 1994; Lawless & Kulikowich, 1996, 1998; Lawless, Mills, & Brown, 2002; Niederhauser, Reynolds, Salmen, & Skolmoski, 2000; Rouet, Favart, Britt, & Perfetti, 1997). In most cases, this relation focuses on the analysis of the navigational path of the reader. The general approach consists of identifying similar groups of navigational paths using a multidimensional scaling technique and of analyzing possible comprehension differences between groups, as in the studies by Lawless and Kulikowich (1996, 1998). The authors identified three main navigational groups: knowledge seekers, feature explorers, and apathetic hypertext users. Knowledge seekers spend most of their reading time on content-related documents, whereas feature explorers spend most of their time on the special features of the hypertext (e.g., images, videos, maps). Finally, apathetic users spend short intervals of time on content-related documents and seem to follow a random reading order. Regarding the comprehension outcome for each group, the authors found that knowledge seekers learned more than the other groups. However, other categories have been proposed in the literature based on features of the particular hypertext used. This is due to the fact that the grouping of reading strategies on the basis of features of a particular hypertext fails when a hypertext does not possess these features.

We propose that reading strategies in hypertext can affect comprehension indirectly by leading the reader to process a particular text in terms of reading order and amount of information accessed. Different reading orders of the same text influence text comprehension in linear text (Danner, 1976; Kintsch & Yarbrough, 1982; Lodewijks, 1982; Mayer, 1976; Schnotz, 1982, 1984, 1993). Reading order has been manipulated following different criteria: self-regulated order versus experimenter regulated or logical order versus random. Each manipulation of the reading order produced different comprehension outcomes and also interacted with reader characteristics. For example, Schnotz (1982) reported an experiment in which two groups of participants read an expository text with the same content but organized in different order. The different paragraphs of the text were organized by object or by aspect. The author argued that an organization by aspect contains several thematic breaks in which the object is changed, so this type of organization could hamper text coherence. The opposite would hold for organization by object. Results showed an interaction between order and prior knowledge: Low-knowledge readers recalled more information from the object organization whereas high-knowledge readers recalled more information from the aspect organization. This result mimics the effect of knowledge and coherence and could be explained in a similar way (McNamara & Kintsch, 1996; McNamara et al., 1996).

Reading strategies in hypertext can also determine the amount of information a reader accesses from a particular text. For example, readers following a strategy consisting of selecting the most interesting nodes could stop reading when they have read all the paragraphs considered interesting. In most of the experiments on hypertext comprehension, the participant decides when he or she has finished reading.

As already stated, reading strategies can affect both the amount of information acquired and reading order. These two features of the text can have different effects on the text representation built by the reader. Specifically, we propose that the amount of information read by a given reader affects the textbase and that the order followed influences the situation model. The textbase representation consists of information derived from the original text. This representation would be richer as a reader reads a higher portion of the text (i.e., visits more different nodes). Some experimental evidence supports this prediction. Lawless and Kulikowich (1996) distinguished among groups of readers in a hypertext according to the number of different nodes accessed among other measures. These groups differed on the score of text-based questions.

The situation model is created from information in the text together with prior knowledge of the reader. During text processing, the reader has to construct this representation by finding the appropriate place to connect each new piece of information with the knowledge structure acquired so far. The process of integrating the information on a coherent representation could be affected by the reading order of the information. For example, if a particular idea is stated in node A and a conclusion derived from that is described in node D, the connection of both statements would require extra processing (e.g., in the form of bridging inferences) as the information (nodes) read between them increases (Kintsch & van Dijk, 1978). Some experimental results partially support this hypothesis (Foltz, 1996). Foltz analyzed the reading order of the participants in a hypertext-comprehension experiment by measuring the coherence among the contents of the nodes transited. A transition between two nodes was considered coherent if both nodes were connected in the macrostructure of the text. The number of coherent transitions correlated with the number of important ideas included in an essay assessing the comprehension of the text.

Therefore, we hypothesize that the number of nodes accessed influences mainly the construction of the textbase, whereas the transitions between nodes is critical for the construction of the situation model. We tested these predictions in an experiment in which participants had to read a hypertext and perform some tasks testing both textbase and situation model comprehension. Data on participants' reading behavior was used a posteriori to analyze their comprehension scores.

EXPERIMENT 1

Experiment 1 assessed two hypotheses. First, we predicted an increase in the amount of information read in a hypertext would facilitate the construction of the textbase, as assessed by text-based questions. Second, different orders in reading the sections in a hypertext lead to differences in the construction of the situation model, as assessed by inference questions and a cued association task. Participants read an expository text in hypertext format during a limited period of time. Participants' reading strategies (amount of different nodes accessed and reading order) was used a posteriori to predict their comprehension outcomes.

Method

Participants

Forty-one University of Colorado undergraduates participated for class credit.

Materials

Hypertext. An expository text on atmosphere pollution was adapted to a hypertext containing 24 nodes and 3,855 words. It consisted of three main sections with three levels of depth. The text readability was as follows: Flesh Reading Ease = 33.9; Flesh–Kincaid Grade level = 12. We constructed an overview presenting the hierarchy of contents that followed the paragraphing of the original text (see Figure 1). Participants were instructed to access the nodes by clicking on the titles provided in the overview. They were instructed that once they read a node, they should return to the overview to decide what to read next. The hypertext and the rest of materials were implemented using HyperCard® and were run in Apple Macintosh® computers.

Coherence between nodes. Coherence between nodes was analyzed using latent semantic analysis (LSA). The General Reading Space (available at the LSA group at the University of Colorado Web site: http://lsa.colorado.edu) incorporated expository texts from high school textbooks up to the first year of college. The text of all the nodes was analyzed with the matrix analysis contrast (document-to-document comparison) that compares the contents of each node with every other. LSA cosines provided a measure of the degree of argument overlap between texts that is assumed to reflect the level of coherence between them (Foltz, Kintsch, & Landauer, 1998). The rationale for this approach is that frequently when two propositions are in fact related semantically, there exists a shared argument between them (Kintsch, 1992). LSA cosines were used to explain possible differences between reading orders in comprehension outcomes.

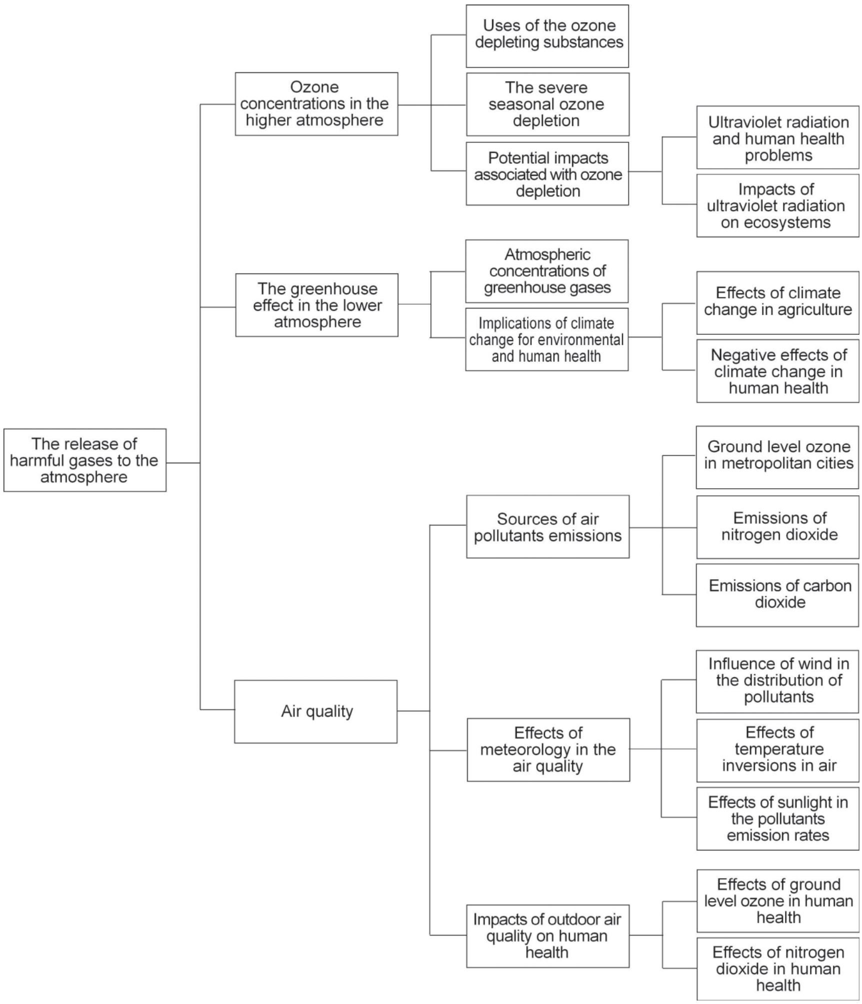

FIGURE 1 Overview used in Experiment 1.

Prior knowledge questions. Participants were given a pretest of eight true–false questions to determine individual differences in domain knowledge previous to the reading phase. Half of the questions were true and the other half false. An example of this type of question was as follows:

> The Montreal Protocol is accepted by nations agreeing to restrict the release of ozone depleting chemicals. (True)

Text-based questions. We constructed a test consisting of 22 true–false questions for which the question and the answer appeared in a single node. Each question referred to the contents of a different node. Half of the questions were true and the other half false. An example of a text-based question was as follows:

> The two layers of the atmosphere closest to the earth's surface are critical in regulating earth climate. (True)

The answer to this question appeared in the following paragraph of a node:

> The atmosphere consists of a relatively narrow shell of air encircling the earth that supports animal and plant life. Human activity specially affects the two layers of the atmosphere closest to the earth's surface: the troposphere, which extends from the surface to about 12 miles, and the stratosphere, which extends from 12 miles up to approximately 30 miles. These portions of the atmosphere are critical in regulating our climate.

Cued association task. Participants were given a list of the 24 most important concepts in the text and were instructed to write down the three concepts that first came to mind after reading each concept on the list. Each response that contained a concept from the original list was computed. If the response was written first, it received a value of 1; if second, 0.66; and if third, 0.33. A PhD in atmospheric science of the National Center for Atmospheric Research provided expert ratings after reading the original text. We used these scores to compare the participants' solution with an expert one. The final score was obtained by calculating the proportion of each participant's links that were also present in the expert matrix. These scores were obtained by adding up the link strength values for only those connections in the participant matrix that were also included in the expert matrix and dividing the result by the sum of all links of each participant matrix.

The cued association task has been developed in the framework of the C–I model of text comprehension and has been validated to assess situation model comprehension (Ferstl & Kintsch, 1999). The C–I model assumes that while reading a text, a reader forms a text representation network of the contents. The response pattern on the cued association task is assumed to correspond to the activation pattern on this network after probing with a concept cue.

Inference questions. We created 10 true–false inference questions that required the participant to relate information contained in at least two different nodes. Thus this task was also intended to assess situation model comprehension. Half of the questions were true and the other half false. An example of an inference question was as follows:

> While the ozone in the higher and lower levels of the atmosphere is chemically identical, its environmental effects differ greatly. (True)

To answer this question participants had to relate information contained in three different nodes:

1. Ozone is a naturally occurring gas molecule containing three atoms of oxygen. It is mainly found in two parts of the atmosphere: most (about 90%) resides in the upper atmosphere or stratosphere, where it forms the stratospheric ozone layer; the remaining ozone, referred to as ground-level ozone or tropospheric ozone, is present in the lower region of the atmosphere.
2. A range of negative environmental and human health impacts associated with ozone depletion can be identified, although their exact nature is difficult to quantify. Known effects include increased incidence of skin cancers and eye disorders (e.g., cataracts), damage to the immune system, and adverse effects on plant development and phytoplankton growth.
3. Observed effects of ground-level ozone on human health include irritation of the eyes and air passages, damage to the mechanisms that protect the human respiratory tract, and, for some asthma sufferers, increased sensitivity of the airways to allergic triggers.

Procedure

First participants went through a pretest of eight true–false questions assessing their domain knowledge. They were then instructed on how to use the hypertext. After that, they were required to read the contents within 20 min. The instructions stressed that they had to read the text carefully to answer a series of questions after the time was concluded. At this point, participants had to perform a cued association task. Finally, participants had to answer 22 true–false text-based questions and 10 true–false inference questions mixed randomly.

Design

We used reading order (see the following) and different nodes accessed as independent variables and the scores on text-based questions, cued association, and inference questions as dependent variables.

Results

For all experiments, differences declared as significant had $p < .05$.

Analysis of Amount of Information Read

The first hypothesis stated that an increase in node access would facilitate the construction of the textbase. We performed a regression analysis with the number of different nodes accessed as the independent variable and the score on the text-based questions as the dependent variable. Results showed that node access significantly predicted the score on the text-based questions, $R^2 = 0.11$, $F(1, 39) = 4.85$. As node access increased, so did text-based scores. Follow-up analyses were conducted to explore a possible influence of prior knowledge on this effect. Participants were divided into two groups based on a mean split of their prior knowledge scores: 18 participants were included in the low-knowledge group ($M = 3.17$, $SD = 1.03$) and 23 in the high-knowledge group ($M = 6.33$, $SD = 1.24$). Regression analysis for each group revealed that the effect of node access was significant for low knowledge readers, $R^2 = 0.25$, $F(1, 21) = 6.98$, but not for high knowledge, $R^2 = 0.01$, $F < 1$.

In addition, we expected that node access would not predict comprehension at the situation model level. Supporting the null hypothesis, none of the analyses showed significant results either for the cued association scores, $R^2 = 0.03$, $F(1, 39) = 2.34$, $p < .15$, or for the inference questions, $R^2 = 0.06$, $F(1, 39) = 2.83$, $p < .15$. Furthermore, no significant differences were found when the analyses were performed for each group of prior knowledge.

Analysis of Reading Order

A look at the node-transition matrices revealed at least two main reading orders. Participants in Order 1 followed the map of contents in a linear fashion, and in Order 2 they followed a top-down path, starting visiting the highest nodes of the hierarchy and continuing to the lowest levels. We constructed two theoretical matrices representing both orders and correlated them with the node-transition matrices of all participants. Participants' matrices with a correlation higher than the 75% percentile were grouped in corresponding order. Participants' matrices with a lower correlation were grouped under a third order, which included participants that followed a combination of Order 1 and 2 and those that read the contents in a different order. Participants were distributed as follows: Order 1,13 participants; Order 2, 11 participants; and Order 3, 17 participants.

Hypothesis 2 predicted that participants following different reading orders would differ in comprehension at the situation model level. We performed an analysis of variance (ANOVA) with reading order as the independent variable and cued association scores as the dependent variable. Results showed a main effect of reading order, $F(2, 38) = 7.81$, $MSE = 0.02$. Participants following Order 1 had better cued association scores ($M = 0.48$, $SD = 0.16$) than those of Order 2 ($M = 0.35$, $SD = 0.1$) and Order 3 ($M = 0.29$, $SD = 0.11$). Similar results were found with inference questions as the dependent variable, $F(2, 38) = 4.15$, $MSE = 266.24$. Participants following Order 1 successfully answered more inference questions (*M* = 83.5% correct, *SD* = 11.4) than those of Order 2 (*M* = 71.4%, *SD* = 19.2) and Order 3 (*M* = 66.4%, *SD* = 17.4). To account for possible influences of prior knowledge in the effects found, we performed two ANOVAs including prior knowledge as covariate. In both cases (cued association and inference questions scores) the differences between Group 1 and Groups 2 and 3 remained significant.

In addition, we expected that reading order would not differ on the text-based questions scores. Supporting the null hypothesis, no differences were found between the order on the text-based questions scores, $F(2, 38) = 1.38$, $MSE = 268.4$, $p < .3$.

To explain the differences found between reading orders, we compared the different groups on different dependent variables: level of prior knowledge, nodes accessed, and coherence of the transitions (measured as the mean LSA cosine of all the transitions). Participants of the three order groups did not differ in prior knowledge, $F < 1$. However, they differed on the nodes accessed, $F(2, 38) = 4.76$, $MSE = 5.54$. Participants in Group 1 accessed more different nodes (*M* = 24.07, *SD* = 1.18) than those in Group 3 (*M* = 21.41, *SD* = 2.62), and neither of them were different from Group 2 (*M* = 22.81, *SD* = 2.89). In addition, reading-order groups differed on the coherence of their transitions, $F(2, 38) = 19.77$, $MSE = 0.01$. Participants of Order 1 followed a more coherent path (mean cosine, *M* = 0.5, *SD* = 0.01) than those of Order 2 (*M* = 0.44, *SD* = 0.02) and Order 3 (*M* = 0.45, *SD* = 0.03).

Discussion

The results of Experiment 1 support the hypothesis that the amount of information accessed and the reading order influence the reader's comprehension level in two different ways. First, the different number of nodes accessed predicts scores on text-based questions for low-knowledge readers. Participants that read more different texts form a better textbase of the contents. Although this result can be seen as an obvious statement, it is relevant for the literature on hypertext comprehension, because in most experiments on hypertext comprehension it is the participant who decides when he or she has finished reading the contents. The results also show that this effect is influenced by prior knowledge: Low-knowledge readers learn more by reading more nodes, whereas high-knowledge readers are not affected by it. A possible explanation for this effect is that high-knowledge readers could use their prior knowledge to try to fill in gaps in the information presented in the nodes not read. For that reason, the loss of relevant information for the textbase due to an incomplete reading of the materials is lower for high-knowledge than for low-knowledge readers.

Participants that read the text in different order get different learning outcomes at the situation model level. Differences due to the reading order seem to rely on two different variables: nodes accessed and coherence between node transitions.

On the one hand, the better learning of Group 1 compared to Group 3 seems to be influenced by the nodes accessed (higher number for Group 1 than for Group 3). This result suggests that to construct an appropriate situation model, a minimum number of nodes must be read. On the other hand, providing that a similar number of nodes are read (i.e., Group 1 vs. Group 2), differences on the learning outcome seem to be related to the coherence between node transitions (Foltz, 1996). Participants that read the contents in a high coherent order formed a better situation model of the text. This effect can be explained by the fact that transitions between two paragraphs that do not share arguments (coherence) require extra processing (e.g., in the form of bridging inferences) to maintain the coherence of the text representation (Kintsch & van Dijk, 1978). Although these results of reading order seem to be independent of the prior knowledge of the reader, the method used (analysis of covariance) and the limited number of participants per reading order group prevent us from making any strong conclusion. For that reason, in Experiment 2 the role of prior knowledge and reading order is addressed in more detail.

Because most of the previous studies have not controlled for these effects, they can be considered a possible factor affecting the confusing state of the literature on hypertext comprehension. If these effects are not controlled, comprehension outcomes for a condition could depend on the particular distribution of participants following the different strategies. Because reading strategies can influence comprehension by leading the reader to read a particular text, it can be expected that failure to control its influence might particularly mask those expected effects related to text characteristics. For example, Foltz (1996) designed an experiment with two conditions: one intended to provide high text coherence by including extra information for understanding the contents of a node when a noncoherent transition was made and another without such help. Contrary to expectations, there were no comprehension differences between conditions. This result could be explained by the fact that both groups of participants followed similar high coherent reading orders (Foltz, 1996).

A similar problem could arise while attempting to replicate the effect of knowledge and coherence, not thus far replicated in hypertext comprehension: Low-knowledge readers form a better situation model from a coherent text than from an incoherent one, whereas high-knowledge readers learn more from an incoherent one (McNamara & Kintsch, 1996; McNamara et al., 1996). To replicate this effect, a traditional experiment would present two different overviews trying to promote low and high coherence. However, because in each condition participants could follow different reading orders, the path followed could affect comprehension independently of the overview used (e.g., Foltz, 1996). Therefore, we propose that the effect of knowledge and coherence could be replicated in hypertext if participants follow a low and a high coherence reading order.

This approach was tested in Experiment 2, in which we tried to replicate the effect of knowledge and coherence not yet replicated in hypertext. In a pilot study, we provided an overview in which the titles of the contents were distributed in a 6 × 4 array. We found that 17 out of 37 participants followed a strategy consisting of reading the contents from the first row from left to right and continuing the next row down. We decided to construct two overviews with an organization that provided low versus high coherence, respectively (in terms of reading order) if a reader followed the left–right strategy. By doing that, we expected to show that learning differences could be found between reading orders but not necessarily between overviews. Therefore, we expected that the effect of knowledge and coherence would appear when comparing participants following a low versus a high coherence transition order but not when comparing the overviews.

EXPERIMENT 2

Experiment 2 assessed two hypotheses. Participants with high domain knowledge will construct a better situation model (assessed by inference questions and a cued association task) when following a strategy that leads to a low coherence order than when following a strategy that leads to a high coherence order. Second, participants with low domain knowledge will construct a better situation model when following a strategy that leads to a high coherence order than when following a strategy that leads to a low coherence order. Participants read the same text as in Experiment 1 but with a different overview. For one group, the overview promoted a high coherent reading order, whereas for the other the overview promoted a low coherent reading order. Coherence of participants' reading order was used a posteriori to assess possible differences on their comprehension outcomes.

Method

Participants

Eighty-two University of Colorado undergraduates participated for class credit.

Materials

Hypertext. We used the same hypertext presented in Experiment 1 except for the overview provided. Two different overviews were created in which nodes were arranged in a 6 × 4 array. Coherence between contents was assessed using LSA as in Experiment 1. In one overview, nodes were arranged in a manner that provided the lowest coherence between transitions when reading from left to right and from top to down. This was done by arranging the nodes in an order in which the sum of LSA cosines between nodes was the lowest possible. In a second overview, nodes were arranged for providing the highest coherence between transitions when reading from left to right and from top to down. This was done by arranging the nodes in the order in which the sum of LSA cosines between nodes was the highest possible. Comprehension tasks were the same as those used in Experiment 1.

Procedure

Procedure was identical to that of Experiment 1 except for the reading phase. Because the effect of knowledge and coherence is mainly related to situation model comprehension, we tried to control the effect of the variable nodes accessed on the textbase found in Experiment 1 using a different procedure. Specifically, in Experiment 2 participants had to read all the contents without a time limit. Participants were not able to reread nodes.

Design

We used a 2 × 2 between-groups design with prior knowledge (low and high) and overview (low and high coherence) as independent variables. The two levels of prior knowledge were defined according to the mean split of the answers to the eight true–false questions about the participants' domain knowledge. The mean score was 5.62 ($SD = 1.23$). Participants with scores below the mean were classified as low knowledge ($n = 39$, $M = 4.51$, $SD = 0.64$) and those above as high knowledge ($n = 43$, $M = 6.63$, $SD = 0.79$).

We also used reading order (low and high coherence) as a quasi-experimental variable. For that purpose we analyzed the coherence of the reading sequence as in Experiment 1 (mean LSA cosine of all the transitions). We used the extreme tiers for the coherence values, the lower boundary being the 40th percentile (cosine = 0.38, $M = 0.32$, $SD = 0.03$) and the higher being the 60th percentile (cosine = 0.41, $M = 0.47$, $SD = 0.03$). Therefore, the distribution of participants by prior knowledge and reading order was as follows: low knowledge low coherence, 21 participants; low knowledge high coherence, 16 participants; high knowledge low coherence, 11 participants; and high knowledge high coherence, 19 participants. The dependent variables were scores on the text-based and inference questions and on the cued association task.

Results

To show the consequences of not considering the reading order, we performed two ANOVAs. First, we conducted an ANOVA with prior knowledge (low and high) and overview (low and high coherence) as independent variables and cued association scores as the dependent variable. There were no significant differences, $F(1, 78) = 2$, $MSE = 0.02$, $p < .2$ for the interaction. The same null results were found for the dependent variable inference questions scores, $F(1, 78) = 2.18$, $MSE = 393.7$, $p < .15$ for the interaction. Therefore, in agreement with previous research, the effect of knowledge and coherence did not appear when considering all participants without taking into account the reading order. Second, we performed another two ANOVAs with reading order (low and high coherence) instead of overview. In this case, the interaction for cued association scores was significant, $F(1, 63) = 8.38$, $MSE = 0.02$. Participants with low knowledge performed better on the cued association task when following a strategy leading to high coherence ($M = 0.4$, $SD = 0.17$) than when following a low coherence one ($M = 0.28$, $SD = 0.09$), whereas the opposite was found for participants with high knowledge ($M = 0.29$, $SD = 0.11$ and $M = 0.39$, $SD = 0.17$, respectively). Simple effects were analyzed for prior knowledge (low and high). Results showed a significant difference for low-knowledge participants, $t(63) = 7.45$, $MSE = 0.02$, and a close to significant difference for high knowledge, $t(63) = 3.35$, $MSE = 0.02$, $p = 0.07$. Similar results were obtained with inference questions scores as the dependent variable. Only the interaction was significant, $F(1, 63) = 7.21$, $MSE = 2.49$. Participants with low knowledge scored higher when following a strategy leading to high coherence ($M = 67.2\%$ correct, $SD = 15.7$) than when following a coherence one ($M = 55.4\%$, $SD = 17.5$); whereas the opposite was found for participants with high knowledge ($M = 53.3\%$, $SD = 24.2$ and $M = 68.2\%$, $SD = 20.4$, respectively). Simple-effects analysis for prior knowledge revealed that these differences were close to significant for low-knowledge readers, $t(63) = 3.26$, $MSE = 2.49$, $p = 0.07$, and significant for high-knowledge readers, $t(63) = 3.96$, $MSE = 2.49$.

Because in Experiment 2 participants could decide the time spent reading the text, the influence of reading time was assessed. First, an ANOVA showed no effect for prior knowledge or for reading order ($F < 1$ for the interaction). Second, correlation analysis showed no significant relations between reading time and any of the comprehension variables.

Finally, although it was not considered in our hypotheses, we also ran an ANOVA with prior knowledge (low and high) and reading order (low and high coherence) as independent variables and text-based scores as the dependent variable. The objective was to replicate the effect found in Experiment 1 showing that the reading order does not affect the construction of the textbase. Supporting this idea, neither the main effect of reading order nor the interaction were significant ($F < 1$ in both cases). There was only a close to significant effect of prior knowledge, $F(1, 63) = 3.29$, $MSE = 5.43$, $p = 0.07$. Participants with low knowledge scored lower than those with high knowledge ($M = 61.5\%$ correct, $SD = 10.4$ and $M = 66.8\%$, $SD = 12.7$, respectively).

Discussion

The results of Experiment 2 show that the effect of knowledge and coherence are replicated in hypertext for those participants following a particular strategy that lead them to read the contents in a low or high coherent order. Participants with low knowledge benefit more at the situation model level when reading the contents in a high coherence order, whereas participants with high knowledge learn more from a low coherence order (McNamara & Kintsch, 1996; McNamara et al., 1996; Schnotz, 1982). Results show that this effect is not related to the reading time of the materials. Moreover, when considering only the experimental conditions manipulated by the experimenter (type of overview), this effect disappears, masked by the joint effect of the different reading strategies followed by participants. Therefore, it cannot be expected that an effect on hypertext comprehension would hold for all participants of a condition but only for those participants following a particular strategy that allows the experimental manipulations to become effective (in this case high and low coherence due to the reading order).

In addition, data of the text-based questions show that the reading order does not affect the textbase construction. Participants following a low versus high coherent order did not differ on the text-based scores, although they did on two situation model measures. This result supports the effect found in Experiment 1, showing that text-based scores are positively related to the number of different nodes read but not to the reading order.

GENERAL DISCUSSION

The two experiments reported here reveal that reading order and amount of information read have distinctive effects on the representation of the text that readers form when reading a hypertext. Although the amount of information read influences mainly the construction of the textbase, the reading order influences the construction of the situation model. In addition, these results stress the importance of text coherence as a feature derived from the reading order (Foltz, 1996) and its different effect on comprehension depending on the domain knowledge of the reader (McNamara & Kintsch, 1996; McNamara et al., 1996). Differences were found between low-knowledge readers following a strategy that led them to read the text in a coherent order and high-knowledge readers following a strategy that led them to read the text in an incoherent order.

Considering that previous research has paid little attention to these effects, it could be affirmed that a failure to control for these effects could be one of the possible reasons for the inconsistent results found in the literature. As shown in Experiment 2, comprehension effects due to text characteristics only appear after the reading order is considered. Therefore, an important issue that needs to be addressed is how to control these effects in hypertext-comprehension experiments. The effect of amount of information accessed could be easily controlled by forcing the participants to read all the paragraphs of the experimental text, as done in Experiment 2. However, the effect of the reading order is hard to control, because freedom of choosing a reading order is the very essence of reading a hypertext. A possible solution could consist of using appropriate criteria for the comparison of different reading orders. In our work, the coherence between nodes assessed by LSA was revealed as an important variable affecting comprehension (Foltz et al., 1998). Therefore, researchers could consider this variable as a possible comparison criterion between reading orders.

In these studies we assessed the effects on comprehension of reading strategies due to their influence on the final text read by the reader in terms of amount of information read and reading order. In that sense, these effects can be considered bottom-up. However, reading strategies could also influence comprehension in a top-down fashion (e.g., Magliano et al., 1999). Therefore, researchers need to consider both the different types of strategies that readers follow while reading a hypertext and their different effects on comprehension. Previous works in the literature on text comprehension in linear text could be a possible starting point for that purpose. When reading a linear text, a reader can move through the different sections of the text (e.g., for revisiting information previously read). Goldman and Saul (1990) proposed the Strategy Competition Model, which states that readers' progress through a text trying to establish global discourse coherence. If at one point the reader detects a gap in his or her comprehension of the contents, he or she would move through the text looking for the necessary information in order to fill this gap. Therefore, it is important to consider in further research if readers of a hypertext use text coherence as a rule for selecting what node to read next. Although the results of the first experiment presented here stress the importance of text coherence in hypertext comprehension, they cannot be considered as strong evidence for this hypothesis. Instead, participants seemed to rely on the overview to read the contents, so in this case coherence could be considered an indirect consequence of their reading strategy. Further research will be required to fully understand the effects of reading strategies on hypertext comprehension.

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