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Do graphical overviews facilitate or hinder comprehension in hypertext?

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ABSTRACT

Educational hypertexts usually include graphical overviews, conveying the structure of the text schematically with the aim of fostering comprehension. Despite the claims about their relevance, there is currently no consensus on the impact that hypertext overviews have on the reader's comprehension. In the present paper we have explored how hypertext overviews might affect comprehension with regard to (a) the time at which students read the overview and (b) the hypertext difficulty. The results from two eye-tracking studies revealed that reading a graphical overview at the beginning of the hypertext is related to an improvement in the participant's comprehension of quite difficult hypertexts, whereas reading an overview at the end of the hypertext is linked to a decrease in the student's comprehension of easier hypertexts. These findings are interpreted in light of the Assimilation Theory and the Active Processing model. Finally, the key educational and hypertext design implications of the results are discussed.

1. Introduction

Nowadays hypertext systems constitute a practical alternative to traditional print texts in education. From the point of view of the reader, the two formats differ in many characteristics, a major one being that hypertext readers can access the different sections of a text in a self-determined manner. Although some authors consider that this feature may enhance comprehension (e.g. Jacobson & Spiro, 1995), the bulk of the evidence shows the limitations of hypertext as a learning medium (see DeStefano and LeFevre (2007), for a recent review). A major problem with hypertext is that readers might find it difficult to organize the information from different sections in a coherent manner. Whereas in linear print texts authors use the specific order of presentation to indicate the general organization of the text (Britton, 1994), in hypertext the readers need to rely on other text features – or on their prior knowledge – to form a coherent representation of the text (Baccino, Salmerón, & Cañas, 2008). One such text device, graphical overviews, conveys the text structure by displaying sections, titles and their relations. The bulk of the evidence shows that including graphical overviews in print texts improves the reader's comprehension, especially if the content of the text is quite difficult and the students do not possess prior knowledge on the text topic (Lorch & Lorch, 1996; Mayer, 1979).

Based on studies with print texts, many authors have argued in favour of using graphical overviews to improve comprehension in hypertext documents. Nevertheless, a close look at existing studies on the topic reveals that there is no robust empirical evidence for such a statement (see revisions by DeStefano and LeFevre (2007), Dillon and Gabbard (1998), Scheiter and Gerjets (2007), Shapiro and Niederhauser (2004), Unz and Hesse (1999)). Indeed, evidence from studies using analogous designs (comparing a hypertext version including a hierarchical graphical overview against a hypertext version without this), similar procedures (reading a hypertext including undergraduate level information for 15–30 min for the purpose of answering some comprehension questions after reading it), and comparable populations (undergraduate students with low prior knowledge on the text topic), give positive, negative or null effects for hierarchical graphical overviews (Amadieu, 2007; Salmerón, Cañas, Kintsch, & Fajardo, 2005).

This conflicting evidence on the role of graphical overviews in hypertext comprehension means that we still do not understand exactly how they influence text processing and what aspect of it they influence (Scott & Schwartz, 2007). Two important theoretical models have been proposed to account for the effects of graphical overviews on (hyper)text processing. The well-known Assimilation Theory of Mayer (1979) states that graphical overviews enable readers to construct an accurate mental representation of the text, as reflected in the

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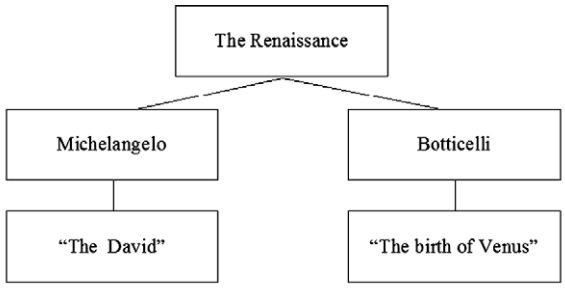
overviews, and thus provide an organizational framework, prior to reading, that affects the reading process. In other words, a graphical overview increases the salience of the (hyper)text structure that might be part of the situation model representation for the text, thereby enhancing memory of the text structure. Alternatively, the Active Processing model (Hofman & van Oostendorp, 1999; Shapiro, 1998) suggests that highly structured overviews may inhibit the use of comprehension strategies by readers. A hierarchical overview delineates the implicit semantic relationships between text sections (see Figs. 1 and 2). Although readers generate causal bridging inferences as part of the normal course of comprehension (e.g. Graesser, Singer, & Trabasso, 1994), it may be simpler for students who read the hierarchical overview to perceive the text structure without putting a tremendous amount of thought into discovering the relations between sections (Shapiro, 1998). In contrast, a hypertext without a hierarchical overview (or with an unstructured overview) may require a deeper level of processing of the information implicitly provided by the links in order for the reader to make sense of the material.

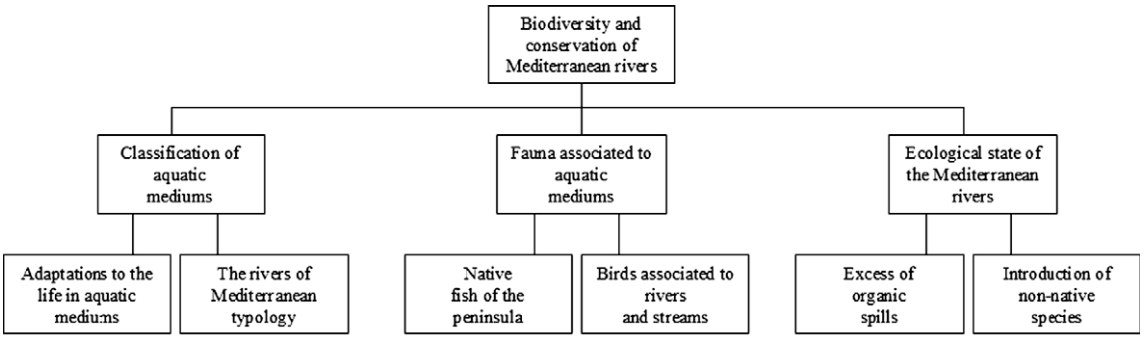
Currently, based on previous research and on existing theoretical models, it is unclear whether hierarchical overviews of hypertexts enable readers to construct a more accurate mental representation of the text information, inhibit strategic processing of the text, or some combination of the two. The goal of this study was to provide insights into these alternatives.



The Renaissance

This period of History of Art was important for its great number of excellent painters. Main characteristics of Renaissance's painting are a search for object bodyness, and an attention for natural scenery. Proportions are highly respected and there is an appreciation for human expressions. During the Renaissance art becomes more harmonious.

Fig. 1. Screen capture from a hypertext used in experiment 1.



Biodiversity and conservation of the Mediterranean rivers

Rivers constitute one of aquatic means of greater interest from the ecological point of view. Concretely the Iberian Mediterranean rivers, given the climatic and geographic characteristics of the zone where they are located, contain a great diversity of fauna. The species and groups of species that compose this fauna are the best indicators of the ecological state of the rivers and frequently they have been used as bio-indicators of the quality of waters. Unfortunately, the state of conservation of the Mediterranean rivers and its associate fauna are in many cases insufficient. Therefore, it is necessary to know the different factors that affect the conservation of the rivers of Mediterranean typology and what consequences have on the biodiversity of their aquatic fauna.

Fig. 2. Screen capture from the hypertext used in experiment 2.

The present paper explores the possibility that the impact of graphical overviews on text processing in hypertext depends on when the student reads the graphical overview and on the hypertext difficulty. Previous studies have not paid attention to this issue, assuming that all participants will behave equally in a "graphical overview condition", i.e. they will read the overview for the same amount of time during the entire reading process. However, as we discussed above, hypertext readers decide for themselves which sections they will read and the order in which they will read them. For example, one reader might decide to read the overview thoroughly at the beginning of the text and ignore it afterwards, but another reader may just ignore the overview at the beginning of her reading session and check it afterwards, whenever she finds difficulty in understanding the hypertext. The Assimilation Theory and the Active Processing model predict different outcomes for those hypothetical readers.

1.1. Reading the graphical overview at the beginning of the hypertext

When readers access a hypertext to initiate a study session, they are confronted with the task of integrating information distributed across isolated nodes into a coherent representation. Does a graphical overview depicting the hypertext structure benefit readers in this task at this initial moment? The Assimilation Theory states that when students read a graphical overview initially it acts as a schema for text organization, allowing the reader to incorporate subsequent information from the isolated nodes into an existing representation. Readers with no previous knowledge of the topic, or those faced with difficult texts, will not be overloaded by the need to build an initial frame for the hypertext information (Lorch & Lorch, 1996). In this sense, there is a facilitative effect of graphical overviews acting at the time of information encoding (Mayer & Bromage, 1980). In support of this claim, Mayer and Bromage (1980) found that a group of participants who were initially provided with a graphical overview of the information discussed in a print text recalled more conceptual information in a post-test than those who received the overview after reading the text (see also Kester, Kirschner, & van Merriënboer, 2004; Kester, Kirschner, van Merriënboer, & Bäumer, 2001). In a different learning environment, Nilsson and Mayer (2001) examined the effect of a non-navigable graphical overview while participants searched for the answers to 30 questions on a biology website. The graphical overview only resulted in a more efficient search, when compared to a non-overview condition, for the questions given in the first half of the task set.

The Active Processing model, on the other hand, considers that when students read a graphical overview thoroughly at the beginning of the hypertext they do not need to discover the macrostructure of the hypertext for themselves, which will result in lower text comprehension. In other words, a structured overview inhibits students from engaging in the active processing required to construct the implicit relations between different ideas in the hypertext and between hypertext ideas and background information (Hofman & van Oostendorp, 1999; Shapiro, 1998). Previous studies provide evidence of a detrimental effect of structured overviews in comprehension. In a hypertext comprehension study, Shapiro (1998) found that students provided with a structured overview learned to a lesser extent (as measured by the student's essay based on the text information) than participants who studied with an unstructured overview. The unstructured overview provided the same links and documents as the structured one, but no information about the relation between text sections. Similarly, in an eye-tracking study, Salmerón, Baccino, and Cañas (2006) found that students mostly read graphical overviews in the initial pages of the hypertext, and that reading times of the revisits to the overviews were only negatively correlated to comprehension for easy hypertexts (i.e. highly familiar and highly coherent).

In summary, the two theoretical models draw different conclusions for the effect of graphical overviews when they are read initially in the hypertext: the Assimilation Theory predicts a positive effect, especially if the texts are quite difficult, whereas the Active Processing model suggests a detrimental effect.

1.2. Reading the graphical overview at the end of the hypertext

At the end of a study session, students may have read most of the nodes of a hypertext. Will a graphical overview have any impact on the readers' comprehension at that moment? The Assimilation Theory considers that a student who reads most of an unfamiliar or difficult text without a graphical overview may often be overloaded by the task of constructing a representation for the hypertext organization (Lorch & Lorch, 1996). This reader may have constructed a superficial representation of the hypertext, which may include irrelevant and unorganized information. Reading a graphical overview right at the end of the hypertext will not result in the automatic reorganization of the previously processed hypertext information, because organizers only influence the encoding of new information (Mayer, 1979). The above-mentioned study by Mayer and Bromage (1980) supports this claim. An analysis of students' recall protocols revealed that those provided with an overview at the end of the study session added more vague summary statements and irrelevant intrusions than students provided with the overview initially.

The Active Processing model, on the other hand, considers that reading a graphical overview at the end of the hypertext may be as detrimental as reading it initially, because in both cases overviews may inhibit the active processing of the information. These readers may not improve their comprehension to the level acquired by students who mostly neglect the overview and construct the text structure by themselves. In this sense, the experiment conducted by Nilsson and Mayer (2001), reported above, revealed that the search for information in a hypertext was hindered by a graphical overview after the participants had accessed most of the hypertext nodes. First, the participants went through a learning phase in which they searched for the answers to 20 questions. Afterwards, in a test phase in which participants searched for the answers to 10 additional questions, those participants using a graphical overview were marginally less efficient than those searching without the overview.

In summary, the Assimilation Theory predicts a null effect of graphical overviews on comprehension when they are read at the end of the hypertext, whereas the Active Processing model suggests a detrimental effect.

In two experiments, we explored the general hypothesis that the impact of graphical overviews in hypertext comprehension depends on when the student reads the graphical overview and on the text difficulty. We considered the general predictions made by the Assimilation Theory and the Active Processing model (which are summarized in Table 4) to frame the interpretation of the results. Participants read different hypertexts of varying difficulty, provided with graphical overviews depicting the hypertext structure. We used the eye-tracking method to capture the reading times for the graphical overview and texts across the different hypertext nodes. We restricted our study to

hierarchical overviews, as opposed to networked or hybrid structures, because they have been the focus of most prior research, and because these are the ones most currently used by designers for Internet sitemaps (Pilgrim, 2007).

2. Experiment 1

In experiment 1, the participants read several expository hypertexts of varying difficulty provided with a graphical overview of the text structure. The hypertexts dealt with topics on which the participants had a low or high prior knowledge. In addition, hypertext sections were presented either in a highly coherent order (i.e. following the hierarchical structure of the text), or in a less coherent order (i.e. in a random order). A graphical overview depicting the text structure was always visible, so that participants could read it at any moment during the study session.

3. Method

3.1. Participants

Thirty-two third-year psychology students from the University of Granada participated in the study for course credits. All participants were native speakers of Spanish with normal or corrected-to-normal visual acuity. The data of five participants were excluded from the analyses because of incomplete or inaccurate recordings. Hence, the reported analyses are based on the data of 27 participants.

3.1.1. Apparatus

Eye movements were recorded by an EyeLink II head-mounted eye-tracking system. Data were recorded binocularly at a sampling rate of 500 Hz. Participants were seated approximately 60 cm from the presentation screen. Calibration of the eye tracker was performed twice: at the beginning of the experiment (i.e. before reading a practice hypertext), and after the participant had read half of the hypertexts (i.e. before reading the 9th hypertext). The eye-tracking methodology provided reading time data for the graphical overviews and texts.

3.1.2. Materials

3.1.2.1. Hypertexts. Sixteen expository hypertexts were constructed in Spanish. Half of these hypertexts were on topics highly related to the participants' field of expertise ('high-knowledge topics', i.e. psychological topics, such as 'Forgetting' and 'Learning'), and the other half were hypertexts on other disciplines ('low-knowledge topics', e.g. 'Italian Renaissance' and 'Eclipses'). The experimental hypertexts were relatively short (M = 234 words, SD = 17, for the psychology hypertexts; M = 259 words, SD = 18, for the hypertexts in other disciplines). As an index of text difficulty, we computed readability scores using the Lix formula proposed by Björnsson (1983), which is based on both sentence and word length. Mean readability scores of the hypertexts (M = 64.86, SD = 2.90) was similar to the mean readability score of Spanish newspapers (M = 67, SD = 0.90) (Björnsson, 1983). Text difficulty did not vary between psychology hypertexts and those from other disciplines, $t(14) = .46$, $p = .65$. The hypertexts followed a hierarchical organization consisting of five sections (see Appendices I and II for sample hypertexts). Unlike normal hypertext, participants could not choose their own reading order. Instead, the order of the sections was manipulated experimentally (cf. Salmerón, Kintsch, & Cañas, 2006; Salmerón et al., 2005). This permitted us to avoid noise in the comprehension measures introduced by participants following heterogeneous reading orders, but still allowed us to mimic a multiple-page reading situation similar to hypertext reading. Because these particular materials may be considered as non-representative of real hypertext, in experiment 2 we used a hypertext system provided with a navigable graphical overview, which allowed readers to select their own particular reading order. In experiment 2 we found comparable effects to those found in experiment 1, which supports the validity of the system used here.

For each hypertext there was an introductory passage, two sections on two main topic issues, and another two sections giving examples of each of the two main issues. In each section, no explicit reference was made to the other sections. For each hypertext there was a highly coherent version, which was presented as follows: introduction, topic issue 1, example of topic issue 1, topic issue 2, example of topic issue 2; and a less coherent version, which read as follows: example of topic issue 2, example of topic issue 1, topic issue 2, topic issue 1, introduction. In addition, each hypertext was displayed with a graphic overview that depicted the hierarchical structure of the hypertext (Fig. 1).

3.1.2.2. Text-based questions. For each hypertext we constructed one open-ended question that referred to a single statement presented in one section and did not require the reader to infer information (see Appendices I and II for sample questions).

3.1.2.3. Inference questions. For each text we constructed one open-ended question, the answer to which was related to at least two ideas presented in two or three separate sections. This task was thus intended to assess non-verbatim comprehension (Kintsch, 2005).

3.1.2.4. Graphical overview usefulness ratings. For each text, participants rated to what extent they thought the graphical overview was useful for comprehending the hypertext, on a scale from 1 (not useful at all) to 5 (extremely useful).

3.2. Procedure

Before carrying out the experiment, the eye tracker was calibrated for each participant. Students were instructed to read each hypertext carefully enough to answer a series of open-ended questions after reading all the hypertexts. They first read a practice hypertext and were told that an overview displaying the hypertext structure would be always displayed on the upper part of the screen. Afterwards, they read the 16 experimental hypertexts, with a small pause after reading half of the hypertexts, which was used to perform a second calibration of the eye tracker. The overview was available during the entire study session on the upper part of the screen, and each hypertext was presented one section at a time on the bottom part of the screen. Participants indicated when they wanted to move to the next section by pressing a key. The preceding section disappeared when a new section was shown. Before the presentation of each hypertext section, a

fixation cross pointing to the first word of the hypertext was displayed on a blank screen for 500 ms. The presentation of the hypertext was self-paced. After each hypertext, participants rated the extent to which they had found the overview useful for comprehending the hypertext. After all the hypertexts had been read, questions were presented in the same sequence in which the hypertexts were read. Finally, the participants rated their background knowledge on the text topics prior to the experiment, on a scale of 0 (no prior knowledge) to 10 (high prior knowledge). These self-report data were only used to check the validity of the experimental grouping of hypertexts' topic prior knowledge. The complete experimental session lasted for around 1 h.

3.3. Results

The experimental grouping of topic prior knowledge was compared to the participant-rated prior knowledge. Supporting the experimental grouping, the participants declared having more prior knowledge of the psychology hypertexts ($M = 6.99$, $SD = 1.62$) than of the hypertexts on other disciplines ($M = 3.14$, $SD = 1.01$), $t(52) = 8.74$. Nevertheless, we did not split students into high and low prior knowledge groups. Only the experimental grouping of high- and low-knowledge hypertexts' topics was included in the following analyses.

Two main zones were considered for the reading time data: the text and the graphical overview. For the text zone, we first analyzed fixations on the sentences in the text, considering them to be either first-pass (fixation on a sentence when first reading it, before moving on or moving back to a different sentence) or second-pass (additional fixation on a sentence that occurred (a) after that sentence had already been fixated and (b) after at least one other sentence had been subsequently fixated). For the overview zone, we analyzed fixations on the five regions corresponding to the section headings displayed in the overview. These analyses were repeated for each of the five sections (i.e. pages) of each text. Eye-movement data were weighted on the basis of the number of characters in each critical zone. In addition, individual distributions were analyzed to detect outliers (fixation times of 2 *SD* above or below the participant's mean). For the text zone, these values (between 1.2% and 2% of data) were replaced by the participant's mean fixation time. For the overview zone, most of the outliers corresponded to zones that had not received any fixation (recall that reading the overview was not compulsory, and participants could read it at the very beginning and ignore it for the following pages). Thus, zone outliers were ignored for calculating the reading time of the overview, and we computed the sum of the weighted fixation times on any of the five sections corresponding to the graphical overview for each page. Then, the data were collapsed into a single 'Text zone' and 'Overview zone' value for each page. To avoid problems related to a positive skewness of the reading time values, we used the logarithmic transformation of the eye-movement data. Finally, eye-movement data were collapsed across pages, to obtain the mean reading times of the text and of the overview for the first pages (first and second page read) and for the last pages (fourth and fifth pages read). The dependent variables were the scores on text-based and inference questions, and the overview usefulness ratings.

3.4. Preliminary analyses

We conducted ANOVAs with topic knowledge and coherence as factors, for each type of question (text-based and inference). The first analysis with text-based questions revealed no effects for topic knowledge, $F(1, 26) = 1.45$, $MSe = 0.04$, $p < 0.25$, text coherence, $F < 1$, or the interaction of both variables, $F < 1$. Participants had similar scores when reading high-knowledge highly coherent texts ($M = 0.41$, $SD = 0.23$), high-knowledge less coherent texts ($M = 0.42$, $SD = 0.24$), low-knowledge highly coherent texts ($M = 0.37$, $SD = 0.25$), or low-knowledge less coherent texts ($M = 0.37$, $SD = 0.26$). The second analysis with inference question scores revealed no effect for topic knowledge, $F(1, 26) = 1.71$, $MSe = 0.03$, $p < 0.25$, text coherence, $F(1, 26) = 2.08$, $p < 0.2$, or the interaction, $F < 1$. These analyses revealed that there were no significant differences for high-knowledge highly coherent texts ($M = 0.28$, $SD = 0.22$), high-knowledge less coherent texts ($M = 0.37$, $SD = 0.26$), low-knowledge highly coherent texts ($M = 0.23$, $SD = 0.22$), or low-knowledge less coherent texts ($M = 0.33$, $SD = 0.24$). These results might not be surprising, given that the participants could use graphical overviews to overcome comprehension difficulties due to lack of prior knowledge or low text coherence. These issues are addressed in the following two sections.

3.5. Question 1: what impact does the time spent reading the graphical overview at the beginning of the hypertext have on comprehension?

For each condition resulting from the combination of prior knowledge (high and low) and text coherence (high and low) we performed three multiple regression analyses. The models included the reading times of the text and graphical overview on the first pages as predictors, and text-based question scores, inference question scores, and overview usefulness ratings as dependent variables. These regression models are summarized in Table 1.

Reading times of the graphical overview at the beginning of the hypertext did not predict scores on objective comprehension measures (scores on text-based and inference questions) for low-knowledge or low-coherence hypertexts. This variable was not related to objective measures of comprehension on any of the four conditions (see Table 1, top and middle rows). Nevertheless, a different outcome was obtained for the subjective measure of comprehension: perceived usefulness of the graphical overview. Participants reading the graphical overview for longer at the beginning of the hypertext only found it more useful when reading low-knowledge or low-coherence hypertexts (see Table 1, bottom rows). When reading high-knowledge and high-coherence hypertexts, the time spent reading the graphical overview did not predict overview usefulness.

3.6. Question 2: what impact does the time spent reading the graphical overview at the end of the hypertext have on comprehension?

To test our second research question we performed similar regression models to the previous section. The only changes introduced were the predictors, which in this case were the reading times of the text and of the graphical overview in the last pages. The dependent variables were again the text-based question scores, inference question scores, and overview usefulness ratings. These regression models are summarized in Table 2.

The reading time of the graphical overview at the end of the hypertext predicted comprehension (scores on inference questions) for high-coherence hypertexts (both high- and low-knowledge). Eye-tracking data showed that the longer the participants read the graphical overview at the end of the hypertext, the less they scored on inference questions for high-coherence hypertexts. This relation did not occur

Table 1
Summary of multiple regression analysis for the effects of reading times of the text and the graphical overview on the first pages for the different dependent variables of experiment 1 (scores on text-based questions, scores on inference questions, and perceived overview usefulness) by prior knowledge (high and low) and text coherence (high and low).

	High know. – high cohe.			High know. – low cohe.			Low know. – high cohe.			Low know. – low cohe.		
	B	SE_B	*t*	*B*	SE_B	*t*	*B*	SE_B	*t*	*B*	SE_B	*t*
Text-based questions												
Intercept (B_0)	−0.52	0.42		0.07	0.41		−0.18	0.63		0.68	0.74	
Text reading time	1.57	1.58	0.99	0.51	1.96	0.26	2.06	1.85	1.12	2.44	1.67	1.45
Overview												
Reading time	0.28	0.25	1.08	0.11	0.26	0.42	0.02	0.33	0.06	−0.40	0.39	−1.01
Model fit	$R^2 = .19, R^2_{corr} = .12$			$R^2 = .03, R^2_{corr} = -.0.5$			$R^2 = .08, R^2_{corr} = .00$			$R^2 = .08, R^2_{corr} = .01$		
Omnibus test	$F(2, 24) = 2.91$			$F(2, 24) = 0.36$			$F(2, 24) = 0.99$			$F(2, 24) = 1.06$		
Inference questions												
Intercept (B_0)	0.29	0.46		0.42	0.43		−0.12	0.57		0.25	0.71	
Text reading time	0.21	1.73	0.12	2.81	2.02	1.39	−1.82	1.67	−1.09	0.96	1.59	0.60
Overview												
Reading time	−0.02	0.28	−0.09	−0.33	0.27	−1.23	0.34	0.30	1.14	−0.07	0.37	−0.18
Model fit	$R^2 = .01, R^2_{corr} = -.08$			$R^2 = .08, R^2_{corr} = .00$			$R^2 = .06, R^2_{corr} = -.02$			$R^2 = .02, R^2_{corr} = -.02$		
Omnibus test	$F(2, 24) = 0.01$			$F(2, 24) = 1.05$			$F(2, 24) = 0.79$			$F(2, 24) = 0.21$		
Perceived overview usefulness												
Intercept (B_0)	−1.90	2.41		−3.83	1.73		−3.77	2.57		−5.06	2.98	
Text reading time	10.70	9.16	1.17	5.60	8.35	0.67	5.68	7.93	0.72	9.42	6.46	1.46
Overview												
Reading time	1.21	1.46	0.82	2.79	1.08	2.59*	2.38	1.42	1.97*	2.60	1.55	2.24*
Model fit	$R^2 = .19, R^2_{corr} = .12$			$R^2 = .43, R^2_{corr} = .38$			$R^2 = .26, R^2_{corr} = .19$			$R^2 = .34, R^2_{corr.} = .29$		
Omnibus test	$F(2, 24) = 2.72$			$F(2, 24) = 8.63^{**}$			$F(2, 24) = 4.02^{*}$			$F(2, 24) = 6.01^{**}$		

* $p < .05$.
** $p < .01$.

Table 2
Summary of multiple regression analysis for the effects of reading times of the text and the graphical overview on the last pages for the different dependent variables of experiment 1 (scores on text-based questions, scores on inference questions, and perceived overview usefulness) by prior knowledge (high and low) and text coherence (high and low).

	High know. – high cohe.			High know. – low cohe.			Low know. – high cohe.			Low know. – low cohe.		
	B	SE_B	*t*	*B*	SE_B	*t*	*B*	SE_B	*t*	*B*	SE_B	*t*
Text-based questions												
Intercept (B_0)	−0.27	0.31		0.34	0.41		−0.16	0.39		0.05	0.39	
Text reading time	2.60	1.49	1.74	1.36	1.99	0.69	3.13	1.92	1.63	2.12	1.82	1.16
Overview												
Reading time	0.12	0.06	1.86	−0.15	0.12	−1.28	−0.12	0.09	−1.30	−0.10	0.19	−0.52
Model fit	$R^2 = .16, R_{corr} = .13$			$R^2 = .07, R^2_{corr} = -.03$			$R^2 = .11, R^2_{corr} = .04$			$R^2 = .05, R^2_{corr} = -.02$		
Omnibus test	$F(2, 24) = 3.12$			$F(2, 24) = 0.89$			$F(2, 24) = 1.51$			$F(2, 24) = 0.68$		
Inference questions												
Intercept (B_0)	0.09	0.28		0.08	0.44		0.50	0.33		0.33	0.37	
Text reading time	1.91	1.37	1.40	1.88	2.14	0.87	−0.27	1.65	−0.16	0.98	1.70	0.57
Overview												
Reading time	−0.21	0.06	−3.72**	−0.08	0.13	−0.61	−0.16	0.08	−2.10*	−0.13	0.18	−0.72
Model fit	$R^2 = .37, R^2_{corr} = .32$			$R^2 = .04, R^2_{corr} = -.04$			$R^2 = .19, R^2_{corr} = .12$			$R^2 = .02, R^2_{corr} = -.06$		
Omnibus test	$F(2, 24) = 7.03^{**}$			$F(2, 24) = 0.46$			$F(2, 24) = 3.08^{*}$			$F(2, 24) = 0.29$		
Perceived overview usefulness												
Intercept (B_0)	−1.90	2.41		−2.03	2.03		−0.21	1.72		−0.66	1.61	
Text reading time	10.70	9.16	1.17	20.57	10.02	2.00	14.84	8.61	1.72	18.77	7.60	2.06
Overview												
Reading time	1.21	1.46	0.82	0.47	0.57	0.82	0.05	0.41	0.12	−0.13	0.78	−0.17
Model fit	$R^2 = .07, R^2_{corr} = .03$			$R^2 = .23, R^2_{corr} = .17$			$R^2 = .15, R^2_{corr} = .08$			$R^2 = .24, R^2_{corr} = .17$		
Omnibus test	$F(2, 24) = 0.93$			$F(2, 24) = 3.15$			$F(2, 24) = 2.05$			$F(2, 24) = 3.42$		

* $p < .05$.
** $p < .01$.

for low-coherence hypertexts (see Table 2, middle rows). Finally, our model did not predict scores on text-based questions or perceived overview usefulness.

3.7. Discussion

The results from experiment 1 provide clear insights into the impact of graphical overviews on hypertext comprehension, depending on the time when the overview is read initially or at the end of the study session, and the hypertext difficulty.

Firstly, we discuss the results related to overview reading times at the beginning of the hypertexts. After controlling for text reading times, the amount of reading time devoted to the overview at the beginning of the hypertexts did not affect comprehension. Nevertheless, the participants who read the graphical overview for longer early in the hypertext perceived the overview as highly useful for their comprehension of the more difficult texts (i.e. those which were presented in an incoherent order, or those for which the participants did not have much prior knowledge). Interestingly, this relation does not occur for easier texts (i.e. highly coherent texts or those for which the participants possessed a high level of knowledge).

The results showing no relation between reading behaviour at the beginning of the hypertext and comprehension do not mach the predictions of either the Assimilation Theory (i.e. facilitative effect for difficult hypertexts) or the Active Processing model (i.e. detrimental effect). Nevertheless, the data relating overview reading times and overview perceived usefulness fit well with the Assimilation Theory (Mayer, 1979): reading the graphical overview early in the hypertext is perceived as useful for those hypertexts for which readers may have more difficulty (i.e. because of a lack of prior knowledge or because of an incoherent presentation of the text). From the viewpoint of this theory, these participants rate graphical overviews as useful for their comprehension because the overviews help them in the difficult task of constructing the hypertext structure for unfamiliar or low-coherence materials. In contrast, the Active Processing model may not explain why those participants reading the overview for longer at the beginning of the text perceived them as useful for their comprehension. From the viewpoint of this model, the participants reading a graphical overview at the beginning of the hypertext may not consider it useful once they realize they have not properly understood the hypertext, due to the passive processing induced by the graphical overview.

Secondly, we discuss the results related to overview reading times at the end of the hypertexts. After controlling for text reading times, the amount of reading time devoted to the overview at the end of the hypertexts is related to poorer inferential comprehension of the easier hypertexts (i.e. those presented in a highly coherent order). In this case, the reading order in which the hypertext sections are presented clearly mimics the hypertext structure, thus facilitating the integration of information between the related sections. On the one hand, the Assimilation Theory cannot explain the negative relation between overview reading time and comprehension at the end of easy hypertexts. From the viewpoint of this model, after having already encoded most of the hypertext information, the graphical overview cannot be used to encode information already processed. On the other hand, the Active Processing model interprets this pattern of results in relation to a participant's effort during reading the hypertext (Hofman & van Oostendorp, 1999; Shapiro, 1998). For this model, reading the overview for a long time at the end of easy hypertexts suggests that readers may not have invested much effort in constructing the hypertext structure during the greater part of the text reading (Nilsson & Mayer, 2001; Salmerón et al., 2006).

Experiment 2 tries to replicate the results from experiment 1 using a longer and more difficult hypertext, which includes a navigable graphical overview. In this learning situation, the Assimilation Theory only predicts a facilitative effect of reading the overview at the beginning of the hypertext for those participants who may find the text more difficult (i.e. those without prior knowledge on the hypertext topic). In addition, the Active Processing model predicts a negative effect of reading the overview at the end of the hypertext mostly for those participants who may find the hypertext easy to process without support (i.e. those with prior knowledge on the hypertext topic).

4. Experiment 2

In experiment 2, participants of varying background knowledge on Biodiversity read a chapter of an undergraduate textbook on that topic. A navigable graphical overview depicting the text structure was visible throughout. As in experiment 1, we tested the hypothesis that the impact of graphical overviews on hypertext comprehension depends on when the student reads the graphical overview and on the text difficulty.

4.1. Method

4.1.1. Subjects

Thirty-two psychology undergraduates from the University of Granada participated to fulfill a course credit. All participants were native speakers of Spanish with normal or corrected-to-normal visual acuity.

4.1.2. Apparatus

Eye movements were recorded by an EyeLink II head-mounted eye-tracking system. The system recorded data binocularly at a sampling rate of 500 Hz. Participants were seated approximately 60 cm from the presentation screen. Calibration of the eye tracker was performed prior to the reading phase and a drift-correction was performed each time the participant moved to a new hypertext section.

4.1.3. Materials

4.1.3.1. Hypertext. We constructed a hierarchical hypertext starting from an expository text from an undergraduate level textbook on 'Diversity and conservation of the Mediterranean river fauna' (Tierno de Figueroa & Luzón-Ortega, 2002). The hypertext was 1813-word long, and was divided into 10 sections. The hypertext was structured in a hierarchical fashion, consisting of an introductory text and three main sections (Classification of aquatic mediums, fauna associated with aquatic mediums and the ecological state of Mediterranean rivers). Each main section consisted of an introductory text and two other texts developing particular topics relevant to that section. We developed an overview containing the hierarchical structure of the text (see Fig. 2), taking special care to assure that each node title represented its

content as clearly as possible. For that purpose, section titles were rewritten following a procedure for analyzing the macrostructure of the text using Latent Semantic Analysis (LSA) (Kintsch, 2002), a corpus-based technique for natural language processing. For each section, all sentences were compared with each other using the matrix comparison analysis (document to document) for a general Spanish corpus. The sentence with the highest cosine value was selected as the central sentence of the text. For each central sentence, every phrase was compared to the whole text on the node. The phrase with the highest cosine value was chosen as the central idea of the text and was used as the title for that particular node.

4.1.3.2. Prior knowledge questions. Participants were given a pre-test of 15 true/false questions to determine individual differences in domain knowledge prior to the reading phase. The test assessed the general knowledge on the topic 'Biodiversity' rather than information specific to the text itself. Samples of prior knowledge questions and of the other types of questions are provided in Appendices I and II.

4.1.3.3. Text-based questions. We developed a test consisting of 10 true/false questions for which the answer appeared in a single section and did not require the reader to infer information. Each question referred to the content of a different section.

4.1.3.4. Inference questions. We created 9 true/false questions that required the participant to think and relate information located in at least two different sections. This task was thus intended to assess non-verbatim comprehension (Kintsch, 2005).

4.2. Procedure

First, participants went through the test assessing their domain knowledge. Then, the eye tracker was calibrated. Participants practiced with a sample hypertext, and they were instructed on how to access the sections by clicking with a mouse on the titles provided on the overview. Once they were confident on the use of the hypertext, they were required to read the hypertext carefully with the aim of answering a series of questions about it afterwards. No instructions were given on how to process the overview. The first section presented was the introductory section on "Biodiversity and conservation of Mediterranean rivers", and the participants were then free to choose the reading order by clicking on the overview titles. There was no time limit and the task finished once the participants had read all 10 sections. They were not allowed to reread any section. After the reading phase, they answered the test questions.

4.3. Results

We followed the procedure used in experiment 1 to analyze eye-movement data to get mean reading times of the text and the overview for the first pages (first to fifth page read) and for the last pages (sixth to tenth page read). Individual distributions were analyzed to detect outliers (fixation times of 2 *SD* above or below the participant's mean). For the text zone, those values (between 1.8% and 2.6% of the entire data set) were replaced by the participant's mean fixation time. The dependent variables were scores on text-based and inference questions.

4.4. Question 1: what impact does the time spent reading the graphical overview at the beginning of the hypertext have on comprehension?

For each dependent variable (text-based question scores, inference question scores), we performed multiple regression analyses with interaction terms (Aiken & West, 1991). We entered as predictors: prior knowledge, reading times of the text and of the graphical overview in the first pages, and the interaction between prior knowledge and reading time of the graphical overview in the first pages. These regression models are summarized in Table 3 (left columns).

Table 3
Summary of multiple regression analysis for the effects of prior knowledge and reading times of the text and the graphical overview for the different dependent variables of experiment 2 (scores on text-based and inference questions) by text pages (first and last pages).

	First text pages			Last text pages		
	B	SE_B	*t*	*B*	SE_B	*t*
Text-based questions						
Intercept (B_0)	0.85	0.01		0.85	0.01	
Prior knowledge	0.03	0.01	2.21*	0.03	0.01	2.23*
Reading time text	−0.02	0.01	−1.28	−0.02	0.01	−1.22
Reading time overview	−0.03	0.02	1.64	−0.01	0.01	−0.22
PK × RT overview	0.04	0.02	−1.99*	0.01	0.02	0.85
Model fit	$R^2 = .29, R^2_{corr} = .18$			$R^2 = .21, R^2_{corr} = .09$		
Omnibus test	$F(4, 27) = 2.71$*			$F(4, 27) = 1.81$		
Inference questions						
Intercept (B_0)	0.66	0.07		0.75	0.08	
Prior knowledge	0.04	0.02	1.97*	0.03	0.02	1.66
Reading time text	0.01	0.01	1.52	0.01	0.01	0.13
Reading time overview	0.02	0.02	0.88	−0.01	0.02	−0.27
PK × RT overview	0.01	0.03	0.01	0.02	0.03	0.75
Model fit	$R^2 = .20, R^2_{corr} = .09$			$R^2 = .11, R^2_{corr} = -.02$		
Omnibus test	$F(4, 27) = 1.73$			$F(4, 27) = 0.83$		

* $p < .05$.
** $p < .01$.

Table 4
Summary of main hypotheses of the Assimilation Theory and the Active Processing model regarding the effect of reading graphical overviews on comprehension, by time of overview reading (at the beginning or at the end of the hypertext) and hypertext difficulty; and summary of the results from experiment 1 and 2 related to each hypothesis.

		Overview is read at the beginning of the hypertext				Overview is read at the end of the hypertext			
		Easy hypertext[a]		Difficult hypertext[b]		Easy hypertext[a]		Difficult hypertext[b]	
Assimilation Theory	Exp. 1	No effect	✓	Facilitates	✓	No effect	×	No effect	✓
	Exp. 2		✓		✓		✓		✓
Active Processing model	Exp. 1	Hinders	×	Hinders	×	Hinders	✓	Hinders	×
	Exp. 2		×		×		×		×

Notes: Hypotheses supported by data from the reported experiments are indicated with the ✓ symbol, whereas those not supported by data are signalled with the × symbol.
[a] Hypertexts are considered easy either if a reader possesses high prior knowledge on the topic, or due to a high coherent presentation order of the hypertext sections.
[b] Hypertexts are considered difficult either if a reader possesses low prior knowledge, or due to an incoherent presentation order of the hypertext sections.

Congruent with prior research, prior knowledge positively predicted comprehension (scores on both text-based and inference questions) (Chen, Fan, & Macredie, 2006). In addition, the model included the interaction between prior knowledge and the reading time of the graphical overview in the first pages as a significant predictor of scores on the text-based questions. To interpret the interaction effect, we computed simple slopes for each group separately (according to Aiken and West (1991)). Participants with low prior knowledge (1 *SD* below the mean) scored higher on text-based questions, as they spent longer reading the overview in the first pages, $t(27) = 2.04$, $B = 0.06$, $SE_B = 0.03$, $p < .05$. Participants with high prior knowledge (1 *SD* above the mean), in contrast, scored equally, regardless of the time devoted to reading the overview in the first pages, $t(27) = -0.57$, $B = -0.01$, $SE_B = 0.01$, $p < .60$.

4.5. Question 2: what impact does the time spent reading the graphical overview at the end of the hypertext have on comprehension?

As in the previous section, we performed two regression models with interaction terms with text-based and inference question scores as dependent variables. The predictors were prior knowledge, reading times of the text and of the graphical overview in the last pages, and the interaction between prior knowledge and the reading time of the graphical overview in the last pages. These regression models are summarized in Table 3 (right columns).

The results revealed a significant effect of prior knowledge for scores on text-based questions. No other effects reached significant levels. Participants with either low or high prior knowledge comprehended equally, independently of the time they spent reading the graphical overview in the last pages.

4.6. Discussion

The results from experiment 2 complement those found in experiment 1 with a different set of materials, and help in clarifying the effect of graphical overviews on hypertext comprehension, in relation to when the overview is read and to hypertext difficulty.

First, we comment on the analyses that relate the overview reading times at the beginning of the hypertexts and comprehension. After controlling for text reading times, the amount of reading time of the overview at the beginning of the hypertext is only related to higher comprehension at the text-based level for participants with low prior knowledge. The interpretation of this effect from the viewpoint of the Assimilation Theory may be to consider that participants with low prior knowledge use the overview at the beginning of the text to build a preliminary text structure, which, in turn, allows them to link the incoming information for the subsequent sections into a coherent representation (Mayer & Bromage, 1980). For this theory, a graphical overview for high-knowledge readers may be redundant with their existing knowledge and thus useless (Lorch & Lorch, 1996). Indeed, this lack of effect of graphical overviews on comprehension for high-knowledge readers corroborates the results found in previous studies (Hofman & van Oostendorp, 1999; Moeller & Mueller-Kalthoff, 2000; Mueller-Kalthoff & Moeller, 2003; Potelle & Rouet, 2003; Shapiro, 1998). The Active Processing model, in contrast, cannot easily account for the facilitative effect of graphical overviews for low-knowledge readers. From the viewpoint of this model, readers with low prior knowledge who read the overview thoroughly at the beginning of the study session engage in a less active processing of the information, which should lead to poorer comprehension.

Second, we discuss the analyses relating overview reading times at the end of the hypertexts and comprehension. The time devoted to reading the graphical overview at the end of the hypertext is not related to comprehension for either low- or high-prior-knowledge participants. These effects apparently contrast with those found in experiment 1, where longer reading times for the overview at the end of the hypertext are associated with lower comprehension. However, the effect for experiment 1 only appears for easy hypertexts (i.e. short hypertexts presented in a highly coherent order), and not for more difficult texts (i.e. short hypertexts presented in a less coherent order). Thus, the lack of effect in experiment 2, using a rather difficult hypertext (i.e. longer undergraduate-level hypertext), may be comparable to the null results found in experiment 1 for more difficult hypertexts (i.e. presented in a less coherent order). The Assimilation Theory interprets this lack of effect of graphical overviews as being due to the ineffectiveness of overviews in supporting comprehension once most of the information has been already processed (Mayer & Bromage, 1980). From the viewpoint of the Active Processing model we could expect a negative impact of overview reading times on comprehension (Hofman & van Oostendorp, 1999; Shapiro, 1998).

5. General discussion

We report two studies that examine the effect of graphical overviews and comprehension in hypertext depending on when the overviews are read and the hypertext difficulty. Following this, we will summarize the results that provide clear insights into these relations. Next we will discuss future research issues that could be undertaken to clarify the effect of graphical overviews on hypertext comprehension. Finally, we will discuss important instructional and design implications of our results for educational hypertexts.

5.1. Graphical overviews and hypertext comprehension

The results from the two experiments suggest that graphical overviews depicting the text macrostructure are useful if read at the beginning of a study session for difficult hypertexts, but discourage further learning once the students have read several sections of easy hypertexts. Existing theoretical models for the role of graphical overviews in hypertext comprehension, Assimilation Theory and the Active Processing model can only partially account for these results (see Table 4 for a summary of the main hypotheses and the results found in the two experiments reported). The focus of our discussion is the issue of whether the effect of graphical overviews on comprehension is moderated by the moment of reading the overview (initially or later in the hypertext) and hypertext difficulty. Regarding the first issue, the Assimilation Theory (Mayer, 1979) states that graphical overviews provide an organizational framework prior to reading that facilitates reading of difficult texts, because in this situation students will not be overloaded by the need to build a macrostructure for the text (Lorch & Lorch, 1996). Alternatively, the Active Processing model (Hofman & van Oostendorp, 1999; Shapiro, 1998) states that overviews explicitly representing the text macrostructure may inhibit the use of comprehension strategies by readers, thus hindering comprehension. The data from the two experiments reveal that graphical overviews of difficult hypertexts are found useful by readers (experiment 1) and are related to better comprehension (experiment 2) only if read at the beginning. In addition, overviews of easy hypertexts are linked to lower comprehension if they are read at the end of the reading session (experiment 1).

The complex pattern of results found suggests that each of the theories is well suited to one of two different learning situations. On the one hand, the Assimilation Theory may well explain learning situations where students read hypertexts in order to learn difficult information (e.g. where students do not possess prior knowledge on the topic). In this scenario, the material will be challenging for the students, thus requiring most of their cognitive resources to comprehend the information. Students could make use of overviews initially to easily construct a mental representation of the text macrostructure, which will free up some resources that may be devoted to other comprehension processes (cf. Lorch & Lorch, 1996).

On the other hand, the Active Processing model may well explain a learning situation where students are reading easier hypertexts (e.g. because the text is highly structured, or because students possess a high level of background knowledge on the topic). In this scenario, readers will not be overloaded by the task of building the hypertext macrostructure, thus they will not necessarily need to free up cognitive resources by reading the overview. If students do indeed read the overview, it may be a sign that they have engaged in a shallow processing of the text, which could be induced by the belief that the text will not be challenging (cf. McNamara, Kintsch, Songer, & Kintsch, 1996). As a consequence of this shallow processing, their comprehension will drop compared to if they had actively read the hypertext. Previous literature on text coherence and prior knowledge support this claim. For example, when students with high previous knowledge read a highly coherent text, which includes global and local explicit relations between ideas, they comprehend the information to a lesser extent than when they read a less coherent version of the same information (McNamara, 2001; McNamara & Kintsch, 1996; McNamara et al., 1996). Further research will be required to fully understand these effects of graphical overviews on hypertext comprehension.

5.2. Future research

How do the results from the present studies help to clarify the inconsistent results found in the literature on the effect of graphical overviews on hypertext comprehension? Our findings suggest that future research on hypertext learning might consider controlling for the relation between overview reading times and comprehension, because it could be responsible for hidden effects on learning results. For example, two similar experiments could produce different comprehension results if the participants in each one use different strategies for processing overviews. A possible solution for controlling these effects might be the use of on-line measures of processing, such as eye-tracking methodology (Rouet & Passerault, 1999).

In this work we have focused on one of the key roles played by graphical overviews, as an explicit representation of the text macrostructure. As mentioned above, graphical overviews are also intended to guide students' navigation through the hypertext link structure. Future research should clarify the interplay between these two aspects of overviews. For example, reading an overview (i.e. structure of themes) initially may induce students to passively follow the structure drawn in the overview. In this case, students are guided by the overview and this guidance may facilitate text representation (Salmerón et al., 2005). In this sense, students who rigidly follow the hypertext overview may behave as when reading traditional print text (i.e. linearly). In contrast, and paradoxically, if students choose by themselves how to read a hypertext (i.e. without rigidly following the path suggested by the overview), this would require a higher level of attentional processing, due to the increased cognitive demands for the task, which would probably hamper their comprehension (DeStefano & LeFevre, 2007; Madrid, van Oostendorp, & Puerta Melguizo, 2009). In order to clarify these issues, further studies will require methodologies that are able to capture the different influences of both components associated with overviews (i.e. text representation and navigation guidance), such as methods combining eye movement and verbal protocols (Kaakinen & Hyöna, 2005).

Considering the results from the two experiments, one critical issue for low-knowledge readers using hypertexts with graphical overviews is to identify which individual characteristics induce students to read the overviews at the appropriate moment (i.e. initially). A key variable that may well explain such strategic behaviour is self-regulation, or the process of planning, controlling and monitoring strategies intended to improve comprehension during hypertext learning (Greene, Moos, Azevedo, & Winters, 2008; Salmerón, Kintsch, & Kintsch, in press). Future research could explore whether students with higher levels of self-regulation do indeed read graphical overviews strategically (i.e. early on in the reading).

5.3. Implications for instruction and design

From a practical point of view, the results of the experiment suggest that the use of overviews in hypertext systems might be helpful for readers with no background knowledge. However, just including a graphical overview for a hypertext might not be useful, and could even be harmful, if it is not read properly (i.e. early on in the hypertext). In a classroom setting, readers might be instructed to process the overview early on in the reading to learn the structure of the current hypertext and to link new information to this representation (Bernard,

1990). Special care might need to be taken in independent learning situations, such as on-line courses, because if readers merely use the overview for navigational purposes, it might not be sufficiently useful to foster their learning. In this case, the hypertext itself could encourage readers to actively process the overview by providing cues that explicitly direct readers to turn their attention to the overview accompanying the text (Hayes & Reinking, 1991), especially while the first sections are being accessed.

In addition, web designers should carefully check the design of the overviews in order to ensure that students will indeed read it. Spyridakis, Mobrand, Cuddihy, and Wei (2007) describe one successful and one unsuccessful design solution for overviews. They performed a study in which participants read a hypertext with a home page, including either a textual overview with embedded links to the hypertext sections or a textual overview with a separate list of links. Participants using the overview with embedded links showed a better comprehension of the material. The authors' interpretation of this effect was that the overview with a separate list of links "discouraged thorough reading of the preview and instead allowed participants to skim and use just the list of hyperlinks" (p. 255). In summary, it is particularly important that the design of a graphical overview should capture the readers' attention at the beginning of the learning task, to ensure that they will benefit from it.

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Appendix I

A.1. Sample materials of experiment 1

A.1.1. Sample of an unfamiliar text

The organization of hypertext sections is identified in brackets.

[Introduction] The Romantic Movement: Literary Romanticism flourished in England and Germany around 1795. Their use of the fantastic and the nature renewed and amplified the whole panorama of European literature. The Romantic Movement looked for a direct and original expression of Romantic themes.

[Topic 1] Victor Hugo: Victor Hugo is a representative writer of the Romantic Movement. Like other Romantic writers, he loved nature and exoticism, and liked to be seen as an outsider of Society. He thus put the poet and the prophet in the same category. He succeeded better than any other writer in capturing the complexity of French vocabulary. The richness and variety of his works is astonishing.

[Topic continuation] Author's life: The author wrote poetry, novels, literary essays and political pamphlets. During a long period he supported Absolute Monarchy. Indeed, he became friend of Louis-Philippe who crowned him lord of France. He was against death penalty, and he always defended liberty and human rights.

[Topic 2] Alphonse de Lamartine: Alphonse de Lamartine was born in Macon in 1790. He lived most of his childhood in a small French town. In his adulthood, he travelled around Italy. He started writing after joining the court of Louis XVIII. His first book, "Poetic meditations", was the first book of the Romantic movement of French literature.

[Topic continuation] The writer's life: Religious topics played an important role in his poetry. However, the dead of his daughter Julia in 1832, and his increasing politic engagement, changed the nature of his religious believes. The poet finally became supporter of a liberal Christianism.

A.1.2. Sample of a text-based question of the 'The Romantic movement' text

'Cite one characteristic of the 'Romantic' movement', Possible correct response: 'They focused on previously neglected topics such as nature or the fantastic'. Sample inference question: 'Apart from being part of the same literary movement, which intellectual characteristic do Hugo and Lamartine share?' Possible correct response: 'They both were engaged in political activities'.

Appendix II

B.1. Sample materials of experiment 2

Example of a prior knowledge question (correct responses are underlined): "The basins of Mediterranean rivers are one of the world's richest biodiversity hotspot" (True/False).

Example of a text-based question: "Rain characteristics under the Mediterranean climate cause rivers and streams to have little annual flow variability" (True/False). To answer this question, participants had to recall the following information from the section "Mediterranean type rivers": "[Mediterranean type rivers] share a series of biological characteristics [...] such as the existence of droughts and predictable seasonal swellings".

Example of an inference question: "fauna's life strategies in the Iberian Mediterranean rivers, such the use of refuges against the current, are similar to those used by the fauna of the Mediterranean rivers outside Spain (such as those in South-west Californian and South Australia, among others) (True/False). To correctly answer this question participants might relate the information from the section "Life adaptations in aquatic mediums": "Some of the strategies developed [by the fauna from the Mediterranean rivers] consists of using refuges against the current [...], morphologic adaptations [...] or, in the case of amphibious, the active displacement by earth or air", with the information from the "Mediterranean type rivers" section: "We consider Mediterranean rivers not only those that drain directly or indirectly to the Mediterranean Sea, but also those from regions with a Mediterranean climate [...], which includes part of the south-west of California, south of Australia, south-west of South Africa and part of central Chile".

References

Aiken, S., & West, G. (1991). *Multiple regression: Testing and interpreting interactions*. Newbury Park, CA: Sage.

Amadieu, F. (2007). *Structures des hypertextes et diversité des connaissances dans les apprentissages*. Unpublished doctoral dissertation, Université de Toulouse-Le Mirail, Toulouse, France.

Baccino, T., Salmerón, L., & Cañas, J. (2008). La lecture des hypertextes. In A. Tricot & A. Chevalier (Eds.), *Ergonomie des documents électroniques* (pp. 9–34). Paris: PUF.

Bernard, R. M. (1990). Effects of processing instructions on the usefulness of a graphic organizer and structural cueing in text. *Instructional Science, 19*, 207–217.

Björnsson, C. H. (1983). Readability of newspapers in 11 languages. *Reading Research Quarterly, 18*, 480–497.

Britton, B. K. (1994). Understanding expository text: Building mental structures to induce insights. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 641–674). San Diego: Academic Press.

Chen, S. Y., Fan, J., & Macredie, R. D. (2006). Navigation in hypermedia learning systems: Experts vs. novices. *Computers in Human Behavior, 22*, 251–266.

DeStefano, D., & LeFevre, J.-A. (2007). Cognitive load in hypertext reading: A review. *Computers in Human Behavior, 23*, 1616–1641.

Dillon, A., & Gabbard, R. (1998). Hypermedia as an educational technology: A review of the quantitative research literature on learner comprehension, control, and style. *Review of Educational Research, 68*, 322–349.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 101*, 371–395.

Greene, J. A., Moos, D. C., Azevedo, R., & Winters, F. I. (2008). Exploring differences between gifted and grade-level students' use of self-regulatory learning processes with hypermedia. *Computers & Education, 50*, 1069–1083.

Hayes, D. A., & Reinking, D. (1991). Good and poor readers' use of graphic aids cued in texts and in adjunct study materials. *Contemporary Educational Psychology, 16*, 391–398.

Hofman, R., & van Oostendorp, H. (1999). Cognitive effects of a structural overview in a hypertext. *British Journal of Educational Technology, 30*, 129–140.

Jacobson, M. J., & Spiro, R. J. (1995). Hypertext learning environments, cognitive flexibility, and the transfer of complex knowledge: An empirical investigation. *Journal of Educational Computing Research, 12*, 301–333.

Kaakinen, J., & Hyöna, J. (2005). Perspective effects on expository text comprehension: Evidence from think-aloud protocols, eyetracking, and recall. *Discourse Processes, 40*, 239–257.

Kester, L., Kirschner, P. A., & van Merriënboer, J. J. G. (2004). Timing of information presentation in learning statistics. *Instructional Science, 32*, 233–252.

Kester, L., Kirschner, P. A., van Merriënboer, J. J. G., & Bäumer, A. (2001). Just-in-time information presentation and the acquisition of complex cognitive skills. *Computers in Human Behavior, 17*, 373–391.

Kintsch, W. (2002). On the notions of theme and topic in psychological process models of text comprehension. In M. Louwerse & W. van Peer (Eds.), *Thematics: Interdisciplinary studies* (pp. 157–170). Amsterdam, Netherlands: John Benjamins Publishing Company.

Kintsch, E. (2005). Comprehension theory as a guide to the design of thoughtful questions. *Topics in Language Disorders, 25*, 51–64.

Lorch, R. F., & Lorch, P. E. (1996). Effects of organizational signals on free recall of expository text. *Journal of Educational Psychology, 88*, 38–48.

Madrid, R. I., van Oostendorp, H., & Puerta Melguizo, M. C. (2009). The effects of the number of links and navigation support on cognitive load and learning with hypertext: The mediating role of reading order. *Computers and Human Behavior, 25*, 66–75.

Mayer, R. E. (1979). Twenty years of research on advance organizers: Assimilation theory is still the best predictor of results. *Instructional Science, 8*, 133–167.

Mayer, R. E., & Bromage, B. K. (1980). Different recall protocols for technical texts due to advance organizers. *Journal of Educational Psychology, 72*, 209–225.

McNamara, D. S. (2001). Reading both high-coherence and low-coherence texts: Effects of text sequence and prior knowledge. *Canadian Journal of Experimental Psychology, 55*, 51–62.

McNamara, D. S., & Kintsch, W. (1996). Learning from text: Effect of prior knowledge and text coherence. *Discourse Processes, 22*, 247–288.

McNamara, D. S., Kintsch, E., Songer, N., & Kintsch, W. (1996). Are good texts always better? Interaction of text coherence, background knowledge, and levels of understanding in learning from text. *Cognition and Instruction, 14*, 1–42.

Moeller, J., & Mueller-Kalthoff, T. (2000). Lernen mit hypertext: Effekte von navigationshilfen und vorwissen [Learning with hypertext: The impact of navigational aids and prior knowledge]. *Zeitschrift für Pädagogische Psychologie, 14*, 116–123.

Mueller-Kalthoff, T., & Moeller, J. (2003). The effects of graphical overviews, prior knowledge, and self-concept on hypertext disorientation and learning achievement. *Journal of Educational Multimedia and Hypermedia, 12*, 117–134.

Nilsson, R. M., & Mayer, R. E. (2001). The effects of graphic organizers giving cues to the structure of a hypertext document on users' navigation strategies and performance. *International Journal of Human–Computer Studies, 57*, 1–26.

Pilgrim, C. J. (2007). Trends in sitemap designs – A taxonomy and survey. In W. Piekarski, & B. Plimmer (Eds.), *Proceedings of the eight Australasian conference on user interface* (Vol. 64, pp. 95–102).

Potelle, H., & Rouet, J.-F. (2003). Effects of content representation and readers' prior knowledge on the comprehension of hypertext. *International Journal of Human–Computer Studies, 58*, 327–345.

Rouet, J.-F., & Passerault, J.-M. (1999). Analyzing learner–hypermedia interaction: An overview of online methods. *Instructional Science, 27*, 201–219.

Salmerón, L., Baccino, T., & Cañas, J. (2006). How prior knowledge and text coherence affect eye fixations in hypertext overviews. In R. Sun & N. Miyake (Eds.), *Proceedings of the 28th annual conference of the cognitive science society* (pp. 715–719). Hillsdale, NJ: Lawrence Erlbaum Associates.

Salmerón, L., Cañas, J. J., Kintsch, W., & Fajardo, I. (2005). Reading strategies and hypertext comprehension. *Discourse Processes, 40*, 171–191.

Salmerón, L., Kintsch, W., & Kintsch, E. (in press). Self-regulation and link selection strategies in hypertext. *Discourse Processes*.

Salmerón, L., Kintsch, W., & Cañas, J. J. (2006). Reading strategies and prior knowledge in learning with hypertext. *Memory & Cognition, 34*, 1157–1171.

Scheiter, K., & Gerjets, P. (2007). Learner control in hypermedia environments. *Educational Psychology Review, 19*, 285–307.

Scott, B. M., & Schwartz, N. H. (2007). Navigational spatial displays: The role of metacognition as cognitive load. *Learning and Instruction, 17*, 89–105.

Shapiro, A. M. (1998). Promoting active learning: The role of system structure in learning from hypertext. *Human–Computer Interaction, 13*, 1–35.

Shapiro, A. M., & Niederhauser, D. (2004). Learning from hypertext: Research issues and findings. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (2nd ed., pp. 605–620). Mahwah, NJ: Lawrence Erlbaum Associates.

Spyridakis, J. H., Mobrand, K. A., Cuddihy, E., & Wei, C. Y. (2007). Using structural cues to guide readers on the internet. *Information Design Journal, 15*, 242–259.

Tierno de Figueroa, J. M., & Luzón-Ortega, J. M. (2002). Diversidad y conservación de la fauna de los ríos mediterráneos [Diversity and conservation of Mediterranean rivers fauna]. In J. M. Barea, E. Ballesteros, J. M. Luzón-Ortega, M. Moleón, J. M. Tierno de Figueroa, & R. Travesi (Eds.), *Biodiversidad y conservación de fauna y flora en ambientes mediterráneos* (pp. 271–295). Granada, Spain: Sociedad Granatense de Historia Natural.

Unz, D. C., & Hesse, F. W. (1999). The use of hypertext for learning. *Journal of Educational Computing Research, 20*, 279–295.