Self-Regulation and Link Selection Strategies in Hypertext

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The present paper explores the role of self-regulation in strategies that readers use to decide the order in which to read the different sections of a hypertext. We explored three main strategies for link selection based on 1) link screen position, 2) link interest, and 3) the semantic relation of a link with the section just read. We followed Winne's (1995, 2001) model of self-regulated learning to try to explain why some readers select hyperlinks based on strategies that lead to lower levels of comprehension (i.e., screen position and personal interest). Results from two studies revealed that readers with low prior knowledge base their decisions on what to read next on a default screen position or on link interest more often if they are instructed to set a low learning goal, if they regularly use shallow learning strategies (e.g., memorizing), or if they are poor at calibrating their comprehension. Reader's link selection strategies mediated the effect of the self-regulation variables studied on comprehension.

Hypertext documents are a non-linear network of linked text chunks, which allow the reader to decide their particular reading sequence. Prior research has found that hypertext readers use different strategies to decide the reading order of a document, and that different strategies support dissimilar levels of comprehension (Salmerón, Cañas, Kintsch, & Fajardo, 2005). Therefore, a critical issue for understanding and improving the comprehension of hypertext readers is to identify what makes students select a particular link. Despite increasing empirical evidence relating strategy use to learning in hypertext, little is known about the mechanisms by which readers select a particular strategy (Alexander, Graham, & Harris, 1998). In the present paper, we aim to explore the role of self-regulation as a potential factor affecting the selection of hyperlinks.

Self-regulated learning and Hypertext Comprehension

Although there are important differences between different theoretical models, self-regulation is generally characterized as the effective management of the own learning process through monitoring and strategy use (Greene & Azevedo, 2007). Most of the research on hypertext and self-regulation has been conducted from the perspective of Winne's (1995, 2001) model of self-regulated learning (SRL) (e.g., Moos & Azevedo, 2008). Winne's model of SRL considers readers as active participants in the learning process, as reflected by the different cognitive and metacognitive activities in which readers engage in a cyclic and recursive manner. Based both on task conditions (e.g., an assigned goal) and on cognitive conditions (e.g., how much prior knowledge of the topic readers possess), readers set a goal or standard to guide learning. This phase generally takes places at the beginning of the learning session, but may be reviewed during reading depending on the outcome of the following phases. Once readers have set a goal, they apply study tactics to attain their goal. During the execution of these process, readers monitor their comprehension and the effectiveness of the strategies used. A perceived mismatch between the goal and current comprehension could lead to adjustments to the learning goal or to the study strategies used.

Although Winne's SRL model was first developed for traditional linear text, it has been successfully applied to the study of reading in hypertext and hypermedia (a format that includes non-textual information such as images and sounds). Indeed, several authors have proposed that the need to select the appropriate hyperlinks at each moment during reading require hypertext and hypermedia students to self-regulate their reading to a degree far greater than in regular linear text (Goldman, 1996; Rouet, 1992). Hypermedia readers are confronted with the additional tasks of selecting relevant pictorial information and of integrating it with the text. Further self-regulation may be required in hypermedia to avoid potential distractions such irrelevant images and videos, features that can hamper comprehension if they distract reader's attention from relevant text content (Lawless & Kulikowich, 1996, 1998).

Empirical support for the relation between hypertext/hypermedia and self-regulation comes from intervention studies that promote the use of self-regulation in hypertext and hypermedia tasks. Several studies have shown that instructing students to engage in various self-regulation activities during hypertext/hypermedia reading improves their comprehension. Training college students on how to regulate their learning in a 30 minutes course boosts their use of self-regulation processes (measured by a think aloud procedure) in a hypermedia system, which improves their comprehension compared to a control group (Azevedo & Cromley, 2004), especially if they possess high working memory capacity or high reading skills (Naumann, Richter, Christmann & Groeben, 2008). College and high-school students who are provided with a human tutor prompting them to deploy specific self-regulatory processes at various stages of learning are more eager to verbalize optimal self-regulation processes (such as monitoring and knowledge activation), and improve their comprehension of the hypermedia materials (Azevedo, Greene, & Moos, 2007; Azevedo, Moos, Greene, Winters, & Cromley, 2008). Simpler interventions may also be effective in promoting self-regulation in hypertext. Prompting college students to regularly monitor their learning while reading a hypertext through the use of adjacent questions increases the use of self-regulation processes measured by think aloud protocols (Bannert, 2003), and improves recall compared to a no-prompts group (Kauffman, 2004; Stadtler & Bromme, 2007). Another type of prompting, providing students with guiding questions during navigation, induces hypermedia readers to use a higher amount of planning activities as revealed by think aloud (Moos & Azevedo, 2008), especially when guiding is flexible (Azevedo, Cromley, Winters, Moos, & Greene, 2005). Finally, instructing readers to reflect aloud on their navigation behaviour while reading benefits their comprehension on problem solving questions (Bannert, 2006; Bannert & Mengelkamp, 2008). Similar effects are found in teenagers, who may improve their comprehension of science hypermedia by being instructed on how to generate questions while reading (Johnson-Glenberg, 2005).

In addition, support for the effect of self-regulation on learning from hypertext and hypermedia comes from studies that relate individual differences in the use of self-regulation activities and learning in hypertext. College student's use of monitoring and evaluation utterances, as revealed by a thinking aloud procedure, is positively related to knowledge acquisition in a hypermedia learning task (Azevedo & Cromley, 2004; Azevedo, Guthrie, & Seibert, 2004; Stadtler & Bromme, 2004). A similar effect is found when self-regulation activity is measured by an SRL questionnaire (such as the MSLQ, Pintrich, Smith, Garcia, & McKeachie, 1993) (McManus, 2000; Schmidt & Ford, 2003). Teenagers' and undergraduate students' self-reports on the use of planning, controlling and monitoring strategies reveals a higher use of SRL strategies in a science hypermedia system compared to a linear version, which is reflected in higher levels of comprehension (Green & Azevedo, 2007; Stiller, 2007; exp. 6). Analogous effects with similar populations have been found in highly non-linear hypermedia and hypertext compared to more restricted ones (Schwartz, Andersen, Hong, Howard, & McGee, 2004; Scott & Schwartz, 2007).

As we have described above, research reveals a clear effect of self-regulation factors on hypertext and hypermedia comprehension. In addition, a different line of research has shown that comprehension in hypertext and hypermedia can also be related to the way readers decide their selection of hyperlinks.

Link Selection Strategies and Hypertext Comprehension

Hypertext readers follow different strategies to select the reading order of the sections, an activity that has proven to be influential in hypertext comprehension (see Salmerón, Cañas, Kintsch, & Fajardo, 2005, for a review). Recent studies have identified three main criteria for selecting a link sequence followed by hypertext readers: coherence, interest and default screen position (Protopsaltis, 2008; Salmerón, Kintsch & Cañas, 2006). The coherence strategy consists of selecting hypertext sections that are semantically related to the one just read (Foltz, 1996; Goldman & Saul, 1990); the interest strategy consists of selecting first those sections considered more interesting, delaying the selection of the less interesting ones (Ainley, Hidi, & Berndorff, 2002); and the default screen position consists of selecting links based on their position in the hypertext (e.g., selecting the link that is presented at the top of the screen). The coherence strategy is clearly more demanding than the other two, because it requires the reader to actively process the text to identify the semantic relations between hypertext sections. However, this effort leads to better comprehension, especially for those readers without prior knowledge on the studied topic (Madrid, van Oostendorp & Puerta Melguizo, 2009; Salmerón et al., 2006).

We interpret the effects of link selection strategies on hypertext comprehension from the lens of the Construction-Integration (C-I) model of text comprehension (Kintsch, 1988; 1998). The C-I model conceives of comprehension as a process of relating the ideas of a text into a coherent representation. The model distinguishes between two of the mental representations that a reader forms from the text: the textbase, a hierarchical propositional representation of the information within the text; and the situation model, which integrates that information with reader’s prior knowledge. As we described above, the coherence strategy supports better formation of the situation model of the hypertext for low knowledge readers. The nature of this effect seems to rely on the improvement of text order coherence induced by this strategy, contrary to what happens by using the interest or default screen position strategies (cf., Schnotz, 1982). In contrast, for knowledgeable readers, each of the three strategies considered improves comprehension equally. In the case of the coherence strategy, this benefit might be supported through the active processing induced by the selection of the high coherence links. In the case of the interest and default screen position strategies, the learning benefit could be associated with active processing induced by coherence breaks in the reading order (Salmerón et al., 2006; cf. McNamara et al., 1996; McNamara & W. Kintsch, 1996).

An open question raised by the study of link selection strategies is what makes a reader follow a particular reading order, especially when a strategy leads to non-optimal comprehension, such with the link interest or default screen position criterion. The main hypothesis of the current study is that self-regulation may indeed play an essential role in determining which strategy to employ to select hyperlinks.

Self-regulation Learning and Link Selection Strategies

Several studies have shown that reader's efficient use of self-regulation is associated to the use of several cognitive strategies during learning in hypertext and hypermedia. College students trained on how to self-regulate use more cognitive strategies in hypermedia systems, such as summarizing, taking notes, and coordinating informational sources, than a control group with no training (Azevedo & Cromley, 2004). Similar results are obtained by providing students with an adaptive human scaffolding compared to a non scaffolding version of a hypermedia (Azevedo, Cromley, & Seibert, 2004). These studies, however, do not assess the strategies followed by participants to select hyperlinks. Thus, the present paper extends prior research by focusing on the relation between self-regulation and link selection strategies.

Following Winne's (1995, 2001) SRL model, we predict readers' use of link selection strategies based on critical individual difference factors: learning goal, prior knowledge, learning strategies use and comprehension calibration. As described above, a main phase of the SRL model is the setting of a learning goal or standard, which may depend on both task demands and prior knowledge. If the task is highly demanding (e.g., the instructor demands answers to questions that require an active processing of the text), and the students do not posses high prior knowledge on the to-be-studied topic, they will generally set a high learning goal. To attain a high standard for learning, readers need to apply strategies that guarantee an optimal learning, such as rereading or summarizing (Mazzoni & Cornoldi, 1993; Thiede & Dunlosky, 1999; Pelegrina, Bajo, & Justicia, 1999; Zumbach & Reimann, 2002). Thiede and Dunlosky (1999, Exp. 1) exemplify this possibility in a study of paired associates. Participants read thirty pairs of words and afterwards were instructed either to memorize them in order to be able to recall at least twenty-four pairs (high goal), or just to learn six pairs (low goal). Participants in the high goal condition selected a high demanding strategy useful for attaining their goal: they chose for restudy mainly those pairs rated as more difficult to memorize. In contrast, participants in the low goal condition selected a low demanding strategy: they restudied mainly pairs rated as less difficult to memorize. Consequently, hypertext readers will use demanding although optimal link selection strategies (e.g., link coherence) if they are given high task demands. When faced with low task demands, readers may just decide to apply less challenging strategies, such as link interest and default screen position. With respect to prior knowledge, readers who are familiar with the text topic may find the task not challenging and thus set a lower learning goal (cf. McNamara, E. Kintsch, Songer, & W. Kintsch, 1996; McNamara & W. Kintsch, 1996). Conversely, low knowledge readers may find the task difficult and thus be more likely to set a high learning goal.

Two other important features of the SRL model that participate mainly during reading are the calibration of comprehension and the learning strategies used by a reader. Given the case that hypertext readers set a high study goal (either based on task demands or on their prior knowledge), we expect those more accurate on their calibration and those who generally use optimal learning strategies to more often select link strategies leading to higher comprehension. An accurate calibration of comprehension is necessary to detect a mismatch between the comprehension induced by applying non-optimal strategies (i.e., link interest and default screen position) and a high learning goal (Coiro & Dobler, 2007). In other words, an inability to accurately calibrate comprehension prevents readers from using a more appropriate strategy. Regarding the use of important learning strategies during reading (such as summarizing, identification of important ideas), we expect skilled readers to have more knowledge about link selection strategies and to be more likely to use optimal link paths (i.e., based on link coherence) (e.g., McNamara & O'Reilly, in press). In contrast, less skilled readers may be more likely to either lack knowledge about strategies or mainly engage in shallow link selection strategies (i.e., link interest and default screen position).

The general hypothesis of this paper is that there is a strong relation between self-regulation learning and link selection strategies, two factors that, as described above, have a robust impact on comprehension. If both factors are indeed related, the question is how they interact to affect comprehension? Prior research has not considered this question in depth; therefore we will briefly consider three possible models that will be tested in the two experiments reported in this paper. The first model that represents the relations between self-regulation and link selection strategies may be called the Pure Self-Regulation model. This model regards classical self-regulation factors such as goal setting and prior knowledge as the unique factors that contribute to comprehension. The fact that in previous studies link selection strategies were related to comprehension is due from this perspective to the fact that self-regulation factors predict the use of these strategies (e.g., learners who activate their prior knowledge during reading follow as a consequence a semantically coherent link sequence). The second model, referred to as the Pure Textual model, predicts the opposite. From this perspective, the coherence strategy for link selection leads to better comprehension because it maximizes text cohesion, which facilitates readers incorporating two or more related ideas into working memory at the same comprehension cycle (e.g., Budd, Whitney, & Turley, 1995). Prior results showing a relation between self-regulation and comprehension in hypertext are due from this model to the assumption that good regulators benefit just by applying the coherence strategy for choosing hyperlinks. Finally, a Mediation model may consider the fact that self-regulation influences comprehension through the benefits obtained by diverse adjustments to the reading behaviour, such as rereading a difficult section. From this perspective, one of these adjustments is the selection of hyperlinks based on a particular strategy. Therefore, the benefit associated to the coherence strategy due to its effect on text cohesion may be just one of the several possible factors linked to self-regulation that improve comprehension.

Hypertext Systems and Link Selection Strategies

Before describing the two experiments designed to test the relation between SRL and link selection strategies, we will discuss the use in our experiments of an unusual hypertext system. Real-life hypertexts consist of several nodes including information and links to other nodes, which may be embedded in the text or in a separated menu. Moreover, they often include a content map depicting the hypertext nodes and their structural relations. Although the use of this kind of hypertext guarantees a high external validity of the experiments, they pose a series of difficulties for the assessment of link selection strategies. First, readers faced with a large set of links to follow at every node as in real hypertexts may not evaluate all the possible links before deciding which one to pick (Zhu, 1999). Thus, there is a high risk of misinterpreting links not evaluated by participants as links rejected. Second, participants who decide which link to follow using the content map may reach their decision in at least two different ways. They may select a link that better fits their learning objectives after inspecting several links, or they may just passively follow the order proposed by the overview (Salmerón et al., 2005). Thus, a transition between two high related nodes may be interpreted as an indicator that readers are using either a coherence strategy or a default screen position strategy. In order to overcome these potential problems, several research strategies may be used. One possibility is to keep using complex hypertexts combined with on-line measures, such as the methodology of think aloud (Protopsaltis, 2008) or the recording of eye-movements (Salmerón, Baccino, Cañas, Madrid & Fajardo, 2008). The use of on-line methods allows registering which links are evaluated by readers before deciding which one to pick. However, it does not solve the fact that readers may not evaluate all possible links before moving ahead in the hypertext. Another possibility is the use of a simplified hypertext version that presents only two links at the end of every node (Salmerón et al., 2006). This method increases the probability that readers evaluate all possible links before making a decision, and allows the inclusion of experimental manipulations related to link semantics. However, this method may pose a threat to the external validity of the results, as we discuss in the conclusion.

We designed two experiments to test the hypotheses regarding the interactive effects of certain features of the SRL model (Winne, 1995, 2001) on the use of link selection strategies. In experiment 1 we instructed participants that varied on their regular use of learning strategies to set either a low or a high learning goal during their navigation, and evaluated its effect on their link selection patterns and on comprehension. In experiment 2, we evaluated the use of link selection strategies by participants that varied on their prior knowledge and accuracy of comprehension calibration.

Experiment 1

Experiment 1 tested the hypotheses that readers who set a high learning goal and that generally apply good learning strategies during reading select more often an optimal link selection strategy (i.e., link coherence). It also explores the effect of those variables on comprehension.

Method

Participants

Sixty-two volunteers from an introductory psychology course at the University of Colorado participated in the experiment. All were native speakers of English. The sample consisted of 30 females and 32 males ranging in age from 18 to 23 years, with an overall mean age of 19 years (SD = 1.26). All participants were Caucasian. Volunteers received course credit for their participation.

Materials

Hypertext. We used an expository text on the historical event of ‘The Black Plague’ constructed from different sources (on-line encyclopaedias), and adapted it for use in hypertext format. We selected this topic considering that most participants would be unfamiliar with it (see prior knowledge analyses below). The text was 2,614 words long (including section titles) and was divided in 32 sections (Average words per section = 81.9, *SD* = 17.7). Text readability was as follows: *Flesch Reading Ease* = 48.4; *Flesch-Kincaid Grade level* = 11. Each section of the hypertext was presented one at a time on the screen, and after finishing reading it, participants could choose between only two other nodes. These two nodes corresponded to the section with the highest coherence and to the section with the lowest coherence with the previously read text. Coherence between texts was computed by comparing LSA cosines for the node just read with the rest of unread nodes (the whole text of each node was used for the matrix comparison analysis, document to document test). LSA cosines provide a measure of the degree of argument overlap between texts that is assumed to reflect the level of coherence between texts (Foltz, Kintsch, & Landauer, 1998). The selection of the two nodes was done automatically by choosing the one with the highest and the lowest LSA cosines. Links were presented one below the other. The position of the high and low coherence link was randomized across selections. Participants were not aware of the distinction between links. Each text section was presented only once and it was not possible to backtrack and reread it. For example, after reading the section entitled "The three forms of the Black Death", participants could be presented with a highly related section like 'The septicemic type of the epidemic" (with an LSA cosine of .52) and with a poorly related section such as "Interruption of philosophical and scientific development"' (LSA cosine of .08). Another example including an entire hypertext-section can be seen in Appendix A.

Prior knowledge questions. Participants were given a pre-test consisting of 5 open-ended questions to determine individual differences in domain knowledge prior to the reading phase. Each question required 1 to 3 idea units to be answered correctly, for a total of 11 idea units. The test assessed general historical knowledge about the culture and events during the time of The Black Plague, for example, "Describe two characteristics of European art during the period in which the Black Death took place (14th century)."

Comprehension test. Participants' comprehension of the hypertext at both the textbase and situation model level was assessed by means of written responses to a set of open-ended text-based and inference questions, constructed according to the guidelines described by E. Kintsch (2005). Eight *text-based questions* targeted content explicitly stated in the text, including prompts to summarize a paragraph or section as well as requests for specific story content. All together complete answers to the textbase questions comprised 22 idea units. An example of this type of question was: "How were the three forms of Black Death, bubonic, pneumonic and septicemic transmitted?" The eight *inference questions* required answers that went beyond what was explicitly stated in the text in order to measure the participants' understanding of the situation being described. All together the inference questions required 22 idea units to answer completely. An example of this type of question was: "How did the big differences in depopulation between West and East Europe influence the changes in the social structure of each area after the plague?" As a count measure, the total number of idea units for both types of questions was skewed to the left. For this reason, we transformed the variables by applying a logarithmic transformation that normalizes the distribution (Cohen, Cohen, West, & Aiken, 2003).

Learning strategies questionnaire. We used the 'Learning goals and strategies measurement' questionnaire (Taylor, 2004) to capture the quality of the learning strategies generally used by our participants during reading. This test consists of eight items describing learning strategies that are representative of what efficient self-regulators do (e.g., "Connecting the various facts and ideas to each other"; "Connecting the material to things that you already knew about") or of what non-efficient self-regulators do (e.g., "Skimming the material for the main points"; "Memorizing the material"). For every item, readers have to answer to the question "Typically, when you're reading, what goals do you have and what reading strategies do you use?" using a six-point likert scale (1= almost never, 5 = almost always). An overall learning strategy value for each participant was computed by subtracting average scores of the items representing efficient strategies from those of the items representing non-efficient strategies.

Apparatus. All materials were programmed using Real Basic(R) software with reliable millisecond timing. The experiment program ran under Apple Power Mac G4(R) computers.

Procedure

In order to assess the participants' prior knowledge, they first answered a pre-test questionnaire consisting of eight multiple-choice questions. They then used a practice hypertext while they were instructed on how to use the system. Participants were told that the hypertext presented only two links after each node, but they were not told that links differed on their coherence with respect to the node content. Afterwards, they were asked to read the text without time restrictions. The instructions stressed that they would have to read all sections of the text but that they could choose the order in which to read them. Participants in the high learning goal group were instructed to "read the sections and select the order carefully to fully understand the text, since you will have to summarize the text and answer a set of open-ended questions about the content after reading the entire text." Participants in the low learning goal group were told to "read the text and select the order simply for entertaining yourself, as if you were reading a magazine" (R. Lorch, E. Lorch, & Klusewitz, 1993). The reading procedure was as follows: first, participants were presented with an introductory node with an overall description of the text. After reading that section, participants had to press a button announcing that they had finished reading it. Next, a new screen appeared presenting two links pointing to unread nodes. Here, participants had to click on a link to read one of the sections. The selected text section was presented on the screen with a button announcing the completion of the reading, but with no further links. When only one node remained to be read, a single link corresponding to that text section was presented for selection. After reading all the nodes, participants were asked to answer the comprehension questions. Next, participants were asked about the criteria they had followed for selecting the links by means of a retrospective debriefing method (Poulisse, Bongaerts, & Kellerman, 1987). For each selection made (n = 30 because the first and last texts could not be chosen), they were presented with the title of the section they had read before selecting it together with the two links available after reading it (the selected link was marked). For each selection participants had to answer why they had chosen that particular link from a set of reasons. The most frequently mentioned reasons, identified in previous experiments (Salmerón et al., 2006), were: “the link seemed the most interesting”, “the link seemed the easiest”, “the link seemed related to the previous text read”, “the link was the one on the top”, or “other reason” (in that case participants had to explain their criteria). They were restricted to reporting one reason per choice. Finally, participants filled in the ‘Learning goals and strategies measurement’ questionnaire.

Results

Preliminary analyses

Before testing our hypotheses we validated the results of the use of link selection strategies obtained with the debriefing method against data from the reading process (Grotjahn, 1987; Taylor & Dionne, 2000). For that purpose we computed Spearman correlations between declared percentage of use of strategies (coherence, interest and default screen position) and different objective measures of participants’ reading activity (selection of the high coherence link, selection of the link on the top, together with mean time spent on the link decision process). Only correlations significant at $p < .05$ are described. The objective selection of the high coherence link was positively correlated with the *declared use* of the coherence strategy ($r = .61$), and negatively correlated with the *declared use* of the interest and default screen position criteria ($r = -.41$ and $r = -.34$, respectively). The objective selection of the link on the top was only significantly correlated with the *declared use* of the default screen position ($r = .38$). (Note that in both experiments we lack of an objective measure of link interest.) Finally, mean time on the link decision process was not significantly correlated with any of the three strategies. Taken together, these analyses support the data from the retrospective debriefing method. The use of the coherence strategy was positively related to the selection of the coherent link, a relation that reversed for those using the interest and default screen position strategies. Finally, the use of the default screen position strategy was also positively correlated with the selection of the link presented at the top.

In addition, we analysed scores on the prior knowledge test to assure that participants were unfamiliar with the topic. The mean prior knowledge score was .12 (percentage of correct responses), $SD = 0.09$. The maximum score was .32, which was achieved by only two participants. These results suggest that most of the participants lacked high knowledge about the topic.

Finally, we conducted additional analyses to identify possible differences on the time spend reading the sections. Mean reading times did not vary either by learning goal , $t(58) < 1$, or by learning strategies use, $t(58) = 1.75$, $p = .090$.

Question 1: Do Learning Goal and Learning Strategies predict the use of Link Selection Strategies?

For each set of the dependent variables (percentage of use of each link selection strategy, and comprehension scores), we performed multiple regression analyses with interaction terms (Aiken & West, 1991). Learning goal (low and high) and learning strategies use were entered simultaneously with the interaction of both variables into the regression model. Learning goal was entered as a contrast-coded dummy variable (low coded with -0.5 and high with 0.5). Both variables were entered as z-standardized variables.

Coherence strategy. The regression model for percentage of use of the coherence strategy is summarized in Table 1 (left columns). Results showed a main effect for learning goal. A high learning goal was positively related to the use of a coherence strategy. In addition, the main effect for learning strategies use was close to significant, $p = .065$. Participants who usually apply good learning strategies tended to select more often a strategy based on link coherence. Effects were qualified by a significant interaction. To interpret the interaction effect, we computed simple slopes for each experimental group separately (according to Aiken & West, 1991). There was an effect of learning goal for participants who use poor learning strategies (1 *SD* bellow the mean) ($B = 0.09$, $SEB = 0.03$, $t(56) = 3.25$, $p = .002$) but there was no effect of learning goal for participants that use good learning strategies (1 *SD* above the mean) ($B = -0.01$, $SEB = 0.03$, $t(56) = -0.08$, $p = .934$.

Interest strategy. The results of the regression model for percentage of use of the interest strategy are summarized in Table 1 (middle columns). There was a main effect of learning goal, revealing a positive relation between a low learning goal and the selection of links based on their interest. No other effects resulted in significant differences.

Default screen position strategy. The results of the regression model for percentage of use of the default screen position strategy are described in Table 1 (right columns). There was a main effect of learning strategies use. The use of poor learning strategies was positively related to the employment of a default screen position strategy for selecting links. No other effects resulted in significant differences.

Table 1

Question 2: Do Learning Goal and Learning Strategy Use predict Comprehension scores?

We first analyzed participants’ responses to the comprehension questions as follows: Each text-based and each inference question required an answer comprising up to four idea units. For example, the inference question “How do you think international trade influenced the spread of the Black Death?” required participants to include these three main ideas: “Without trade the plague would probably have remained within Asia”, “Trade with ships through the Mediterranean was fast enough to transport the virus from one continent to another” and “Cargos introduced the virus into highly populated port cities.” For every complete idea included in their responses participants received one point. Incomplete but correct ideas were given half a point. Comprehension scores for each type of question (inferential and text-based) were averaged by the total number of possible idea units for that question type.

Similar to what was done to answer question 1, we performed multiple regression analyses with interaction terms including learning goal (low and high), learning strategies use and the interaction term as independent variables. We conducted two separate analyses for scores on inference and text-based questions as dependent variables.

Inference questions. The results of the regression model for inference question are described in Table 2 (left columns). There were main effects of learning goal and learning strategies use. Both a high learning goal and the use of good learning strategies was positively related with scores on inference questions. The interaction between variables did not reach significance levels.

Text-based questions. As results summarized in Table 2 (right columns) reveal, none of the effects resulted in significant differences.

Table 2

Question 3: To what extent do Link Selection Strategies moderate the relationship between Learning Goal, Learning Strategies Use and Comprehension outcomes?

Regression models used to answer questions 1 and 2 revealed that the two self-regulation variables assessed in Experiment 1 (learning goal and learning strategies use) were related to both link selection strategies use and comprehension scores. Because prior research has stressed the relation between link selection strategies and comprehension (Madrid et al, 2009; Salmerón et al., 2006), it was necessary to clarify to what extent do link selection strategies moderate the relationship between self-regulation and comprehension. To examine this issue we performed a set of hierarchical regression analyses starting from the regression model used to answer question 2, in which learning goal (low and high), learning strategies use and the interaction term were entered as independent variables and scores on inference and text-based questions as dependent variables (we refer to this model as Self-regulation model). Next, percentage of link selection use of each strategy (coherence, interest and default screen position) was entered in a second step into the model, which retained all factors entered in the first step (we refer to this model as Mediation model).

Inference questions. The resulting model after including percentage of use of the coherence strategy significantly improved the variance explained in the regression model, $R^2 = .28$, $R^2_{corr} = .23$, $F(4,57) = 5.5$, $p < .001$. Simple effects showed that percentage of use of the coherence strategy predicted scores on inference questions, $t(57) = 2.19$, $B = .05$, $SE_B = .02$, $p = .033$, which indicates a mediation effect on the relationship between learning goal and scores on inference questions.

Moreover, the mediation model retained the two significant factors of the self-regulation model (learning goal, $t(57) = 3.84$, $B= .19$, $SE_B = .05$, $p < .001$; learning strategies use, $t(57) = 1.79$, $B= .05$, $SE_B = .02$, $p = .078$). Data revealed that learning goal had an additional direct effect on scores on inference questions, independent from the indirect effect mediated by its effect on the utilization of a coherence strategy. Finally, the mediation model for the variables percentage of use of the interest and default screen position strategy did not add additional variance to the self-regulation models (F_{change} (1,57) = 2.12, $p = .150$; F_{change} (1,57) = 1.21, $p = .275$, respectively).

Text-based questions. As was the case with the original regression models analyzed in the previous section, the inclusion of the variables percentage of use of the coherence, interest and default screen position strategy in a second step did not reach significance for the mediation model (F_{change} (1,57) = 2.56, $p = .115$; F_{change} (1,57) = 2.67, $p = .108$, $F_{change} < 1$, respectively).

Discussion

The results from Experiment 1 address important issues concerning the inter-relationships among self-regulation, link selection strategies and comprehension in a hypertext environment. We will first focus on the role of learning goal and learning strategies use on link selection and then discuss on the effects of those variables on hypertext comprehension.

The Role of Learning Goal and Learning Strategies use on Link Selection

The results from Experiment 1 highlight the significance of two important components of self regulated learning, namely the importance of the learning goal and learning strategies use (Winne, 1995, 2001), for choosing how to go across the hypertext sections. Participants who set a low learning goal are more likely to choose non-optimal link selection strategies (link interest and default screen position, respectively) (cf. Mazzoni & Cornoldi, 1993; Thiede & Dunlosky, 1999; Pelegrina et al., 1999; Zumbach & Reimann, 2002). In contrast, participants who set a high learning goal more often used an optimal link selection strategy (i.e., link coherence). This effect of learning goal is particularly beneficial for those readers who by default use poor learning strategies. To accomplish a high goal for learning requires a careful selection of hyperlinks based on the semantic relation between sections. This strategy prevents cohesion breaks in hypertext (Salmerón et al., 2006). However, this selection comes with a high cost, because the reader has to actively process the text to identify possible semantic relations between sections. Thus, readers who set a low goal may find it more efficient to employ less demanding link selection strategies, such as link interest. This strategy contributes to achieve the comprehension level required by a low learning goal, without the cost associated with the coherence strategy.

Data also reveal that the quality of the learning strategies that readers generally apply during reading (i.e., summarizing vs. memorizing) predicts the type of link selection strategy used. Readers who generally apply appropriate learning strategies are more eager to use optimal strategies for the selection of hyperlinks such as link coherence. Readers who usually employ shallow learning strategies, in contrast, tend to use more often non-optimal link selection strategies, such as selecting hyperlinks based on a default screen position (McNamara & O'Reilly, in press). A possible explanation for this effect is that readers need declarative and procedural knowledge of the strategies before using them (Winne, 1995). Readers who generally use poor learning strategies may lack the knowledge for applying optimal but sophisticated strategies for selecting hyperlinks (i.e., link coherence). However, this explanation can not account for the result showing that those readers do actually follow a coherence strategy for link selection to some degree when they are instructed to attain a high learning goal. An alternative justification may consider the fact that readers who usually apply shallow learning strategies require external guidance or support to deploy appropriate strategies (Winne, 2001), such as the learning goal instructions in our experiment.

The effect of Learning Goal, Learning Strategies use and Link Selection on Comprehension

Regarding comprehension outcomes, the results indicate that hypertext comprehension is constructed from a combination of self-regulation and link selection strategies effects. Participants construct a better situation model of the hypertext (as measured by inference questions) if they set a high learning goal and if they regularly employ good learning strategies, which is in line with previous research on self-regulated learning (Green & Azevedo, 2007). In addition, the results show that the selection of links based on the coherence strategy also improves comprehension at the situation model level (Madrid et al, 2009; Salmerón et al., 2006). Contrary to previous studies which focused on either self-regulation or link selection factors, the present experiment identifies the joint contribution of these factors. After controlling for the effects of two key self-regulation variables on comprehension (i.e., learning goal and learning strategies use), percentage of use of a coherence strategy adds a small but significant amount of variance to the model. Considering that a high learning goal and learning strategies use is associated to the utilization of the coherence strategy, we may conclude that these two key self-regulation factors have both a direct positive effect on comprehension, and an indirect positive effect mediated by their impact on the selection of the coherence strategy. Thus, data can not be explained by a pure Self-Regulation or a pure Textual model of the interrelation between self-regulated learning and link selection strategies. The Mediation model outlined in the introduction describes better this pattern of results: self-regulation affects comprehension during reading through diverse adjustments of the reading behaviour due to the use of tactics and strategies. A particular kind of adjustment that takes places after setting a high learning goal or if a reader generally apply good learning strategies is the selection of hyperlinks based on a particular strategy, which affects comprehension because it leads to changes in the textual cohesion of the hypertext (Budd et al., 1995; Salmerón et al., 2006). These results converge with previous studies that have identified several other key learning strategies used by hypertext readers that have a direct effect in comprehension: coordinating informational sources, summarizing, or taking notes (Azevedo & Cromley, 2004; Azevedo et al., 2004). Indeed, the two self-regulation factors studied in experiment 1 may well be related to the use of those strategies, which explains the positive effect of learning goal and learning strategies use on comprehension independently of the link selection strategy used.

Experiment 1 stresses the importance of learning goal and learning strategies use on the selection of hyperlinks and in comprehension. Experiment 2 extends these findings by exploring the role of two other components of the self-regulation model (Winne, 1995, 2001), prior knowledge and calibration of comprehension, on the use of link selection strategies and comprehension.

Experiment 2

According to our theoretical rationale, readers' prior knowledge is expected to affect the relationship between their calibration of comprehension and link selection strategies. Predictions are made considering that all participants are given the same high learning goal (i.e., they are required to read the text carefully in order to take a test). On the one hand, we expect that readers with no prior knowledge will differ in their link selection due to their accuracy on calibration of comprehension: links semantically related will be selected more often by more accurate readers, whereas interesting links and those in a default screen position will be selected mostly by readers less accurate on their calibration. On the other hand, we expect that readers with prior knowledge will no differ on the pattern of link selection with regards to their calibration accuracy.

Method

Participants

Eighty-two volunteers from an introductory psychology course at the University of Colorado participated in the experiment. All were native speakers of English. The sample consisted of 26 females and 56 males ranging in age from 18 to 24 years, with an overall mean age of 19.41 years (*SD* = 1.25). The majority of participants (98.78%) were Caucasian. All volunteers received course credit for their participation.

Materials

In experiment 2 we used the same materials as in Salmerón et al. (2006) except for the inclusion of a judgment of learning task.

Hypertext. We adapted an expository text on atmospheric pollution for use in a hypertext format. The text was 4,033 words long (including section titles) and was divided in 27 sections (Average words per section = 148.5, *SD* = 57.3). Text readability was as follows: *Flesch Reading*

Ease = 34.6; *Flesch-Kincaid Grade level* = 12. As in Experiment 1, each section of the text was presented one at a time on the screen, and after finishing reading it, participants could choose between two other nodes (one with the highest coherence and one the lowest coherence with the previously read text). For example, after reading the section entitled ‘Sources of air pollutant emissions’, participants could be presented with a highly related section like ‘Ground level ozone in metropolitan cities’ (with an LSA cosine of .73) and with a low related section such as ‘Effects of climate change in agriculture’ (LSA cosine of .22).

Prior knowledge questions. Participants first answered a pre-test consisting of eight multiple choice questions to determine individual differences in domain knowledge prior to the reading phase. The test assessed general knowledge of the topic ‘Atmospheric pollution,’ rather than information specific to the text itself. Chance performance was 33%. An example of this type of questions and the rest of comprehension materials of Experiment 2 can be seen in Appendix B.

Comprehension Test. Two sets of questions were constructed to assess participants’ understanding of the text content after reading all the hyperlinks. The 22 multiple-choice text-based questions and 10 multiple-choice inference questions were randomly mixed for presentation. The text-based questions targeted information that occurred in a single section and did not require the reader to make inferences. Thus, these questions provided a measure of participants’ understanding of the propositional textbase. The text-based questions covered 22 of the 27 text sections; no questions were constructed for five sections that covered general topics whose content was elaborated more specifically in subsequent sections. The inference questions, which were designed to assess participants’ comprehension at the level of the situation model, required participants to pull together information across two or more different sections of the hypertext. For both type of questions chance performance was at 33%.

Relatedness judgment task. We used a relatedness judgment task as an additional assessment of situation model comprehension. Participants were given a list of the 14 most important concepts in the text and were instructed to rate the degree of relatedness of pairs of concepts (the combination of all concepts resulted in 91 pairs). Participants had to respond using a scale from 1 to 6, in which 1 meant highly related and 6 poorly related. A Ph.D. in Atmospheric Science provided expert ratings after reading the original text. We used these scores in order to compare the participants' solution with the expert score. The final score was obtained by applying the Pathfinder algorithm (Schvaneveldt, 1990) to each matrix using $r = \infty$ and $q = n$-1, and comparing the resulting Pathfinder network to the expert one. Pathfinder is a graph theoretic technique that derives network structures from proximity data. This algorithm provides a measure of the similarity between two networks called *C*. This value reflects the degree to which the same node in the two graphs is surrounded by a similar set of nodes. A *C* value of 0 corresponds to two complementary graphs and a value of 1 corresponds to equal graphs (see Dearholt & Schvaneveldt, 1990, for a detailed discussion of the Pathfinder algorithm; Acton, Johnson, & Goldsmith, 1994, and Goldsmith, Johnson, & Acton, 1991, for its use as a tool for assessing learning). The relatedness judgment task has been used successfully to assess situation model comprehension (e.g., Britton & Gülgöz, 1991).

Judgment of learning task. A judgment of learning task was used to assess the participants' accuracy on their calibration of comprehension. For each section of the text, participants judged their perceived comprehension by answering the question "How likely is it that you will be able to correctly answer a test question about the section you just read in about 25 minutes?' 0 (definitely won't be able to), 10 (10% sure I will be able to), 20..., 30…, 100 (definitely will be able to)." For each participant, a gamma correlation between judgments and test performance across sections[1] was computed (for rationale on using gamma as a measure of calibration accuracy, see Nelson, 1984). The Gamma correlation represents the degree to which a person's judgments correlate with his or her own test performance across text sections. The correlation ranges from -1 to +1, with correlations near or below 0 indicating poor accuracy. This is represented in two possible cases: either a reader thought she will be able to correctly answer most of the questions and then failed most of them, or she thought she will not correctly answer most of the test and then succeed on it. A correlation of 1 indicates a perfect match between participants' judged comprehension during reading and their actual comprehension as measured by post-test questionnaires. Again, this corresponds to two possible scenarios: either a reader thought she will be able to answer most of the questions and then succeed on most of them, or she thought she will not correctly answer most of the test and then failed on it.

Apparatus. All materials were programmed using Real Basic(R) software with reliable millisecond timing. The experiment program ran under Apple iMac G3(R) computers.

Procedure

The procedure used in Experiment 2 followed that of Experiment 1 except for the instructions provided to participants and the inclusion of a judgment of learning task. All participants were told to "read the sections and select the order carefully because you will have to answer some questions about the content after reading the entire text." In addition, after reading a section, participants performed a judgment of learning for that section.

Results

Preliminary analyses

We first checked the link selection strategies data obtained with the debriefing method against objective data from the reading process (Grotjahn, 1987; Taylor & Dionne, 2000). For that purpose we computed Spearman correlations between declared percentage of use of strategies (coherence, interest and default screen position) and different objective measures of participants' reading activity (selection of the high coherence link and selection of the link at the top of the screen). Only correlations significant at $p < .05$ are described. Declared use of the coherence strategy was related to higher selection of the most coherent link ($r = .67$) and to lower selection of the link on the top ($r = -.58$). Declared use of the interest strategy was not correlated either with the selection of the high coherence link ($r = -.03$), or with the selection of the link at the top ($r = -.13$). Finally, declared use of the default screen position criteria was related to lower selection of the most coherent link (*r* = -.55), and higher selection of the link on the top (*r* = .68). Finally, no significant relation was found between the declared use of each type of strategy and amount of time devoted to reading the text sections. In sum, participants that reported a high use of a coherence strategy differed from those reporting a high selection of interesting links, in that the former objectively selected the high coherence link more often and the link on the top less often. Compared to those strategies, participants reporting a high use of the default screen position strategy selected the upper link more often. Thus, these analyses support the data from the retrospective debriefing method on the use of link selection strategies. Following we will use these data to answer our experimental questions.

<u>Question 1: Do Prior Knowledge and Calibration of Comprehension predict the use of Link Selection Strategies?</u>

For each set of the dependent variables (percentage of use of each link selection strategy), we performed multiple regression analyses with interaction terms (Aiken & West, 1991). Prior knowledge and calibration of comprehension were entered simultaneously into the regression model together with the interaction term. Both variables were entered as z-standardized variables.

Coherence strategy. Results of the regression model for percentage of use of the coherence strategy are summarized in table 3 (left columns). Data revealed no significant main effects of prior knowledge or calibration of comprehension. The interaction between both variables was significant. To interpret the interaction effect, we computed simple slopes for each variable separately. As expected, there was a positive effect of calibration of comprehension for participants with low prior knowledge (1 *SD* below the mean) (*B* = 0.05, *SEB* = 0.02, *t*(78) = 2.72, *p* = .008) but no effect for participants with high prior knowledge (1 *SD* above the mean) (*B* = -0.01, *SEB* = -0.72, *t*(78) < 1, *p* = .472).

Interest strategy. The results of the regression model for percentage of use of the interest strategy are summarized in Table 3 (middle columns). There was a main effect of calibration of comprehension, showing a negative relation between calibration of comprehension and the selection of links based on their interest. No other effects resulted in significant differences.

Default screen position strategy. The regression model for percentage of use of the default screen position strategy is described in Table 3 (right columns). None of the effects resulted in significant differences.

Table 3

Question 2: To what extent do Prior Knowledge and Calibration of Comprehension predict Comprehension outcomes?

For each dependent variable measuring comprehension, we performed multiple regression analyses with prior knowledge, calibration of comprehension and the interaction term as independent variables.

Pathfinder similarity scores. The results of the regression model for Pathfinder similarity scores are summarized in Table 4 (left columns). There was a main effect of prior knowledge (positive shape), but not of calibration of comprehension. These results are qualified by a significant interaction between variables. Simple slope analyses indicated that for participants with low prior knowledge (1 *SD* bellow the mean), accuracy of calibration of comprehension positively predicted Pathfinder similarity scores, $B = 0.06$, $SEB = 0.02$, $t(78) = 2.57$, $p = .012$. For participants with high prior knowledge (1 *SD* above the mean), calibration of comprehension did not predict Pathfinder similarity scores, $B = -0.01$, $SEB = 0.02$, $t(78) < 1$, $p = .643$.

Inference questions. The regression model is described in Table 4 (middle columns). Prior knowledge resulted in the only significant predictor (positive shape).

Text-based questions. None of the effects resulted in significant differences for this variable (see Table 4, right columns).

Question 3: To what extent do Link Selection Strategies moderate the relationship between Prior Knowledge, Calibration of Comprehension and Comprehension outcomes?

In order to explore this issue we followed the same rationale as in Experiment 1. We started from the regression model used to answer question 2, which included prior knowledge, calibration of comprehension and the interaction term as independent variables, and comprehension scores as dependent variables (Self-regulation model). In a second step, we entered in three separate analyses percentage of link selection use for each strategy (coherence, interest and default screen position) while retaining all the variables entered previously (Mediation model).

Pathfinder similarity scores. The model resulting after including percentage of use of the coherence strategy significantly improved the variance explained in the self-regulation model, R^2 = .31, R^2_{corr} = .28, $F(4,77) = 8.72$, $p < .001$. In the mediation model percentage of use of the coherence strategy predicted Pathfinder similarity scores, $t(77) = 1.99$, B= .28, SE_B = .14, $p = .049$. In addition, the mediation model retained the two existing significant predictors: prior knowledge, $t(77) = 4.84$, B= .07, SE_B = .01, $p < .001$; interaction: $t(77) = -1.97$, B= -.03, SE_B = .02, $p = .050$. The remaining effect did not reach significance levels: calibration of comprehension: $t(77) = 1.13$, B= .02, SE_B = .01, $p = .262$.

The mediation model for the variable percentage of use of the interest strategy did not add additional variance to the self-regulation model (F_{change} (1,77) < 1, $p = .657$).

Finally, the regression model resulting after including percentage of use of the default screen position strategy significantly added explained variance to the self-regulation model, R^2 = .32 R^2_{corr} = .29 $F(4,77) = 9.23$ $p < .001$. Percentage of use of the default screen position strategy predicted Pathfinder similarity scores, $t(77) = -2.34$, B= -.31, SE_B = .13, $p = .022$. Moreover, the mediation model retained prior knowledge as predictor, $t(77) = 4.73$, B= .07, SE_B = .02, $p < .001$. The remaining effects did not reach significance levels: calibration of comprehension: $t(77) = 1.58$, B= .02, SE_B = .02, $p = .118$, interaction: $t(77) = -1.69$, B= -.03, SE_B = .02, $p = .094$.

Inference questions. The resulting model after including percentage of use of the coherence strategy significantly improved the variance explained by the self-regulation model, R^2 = .17, R^2_{corr} = .13, $F(4,77) = 3.89$, $p = .006$. Simple effects revealed that percentage of use of the coherence strategy predicted scores on inference questions, $t(77) = 2.46$, $B= .39$, $SE_B = .16$, $p = .016$. Moreover, the mediation model retained the only significant factor of the self-regulation model (prior knowledge, $t(77) = 2.83$, $B= .05$, $SE_B = .02$, $p = .006$)

The mediation model for the variable percentage of use of the interest strategy did not add additional variance to the self-regulation model (F_{change} (1,77) < 1, $p = .403$)

Finally, the regression model resulting after including percentage of use of the default screen position strategy added new variance to the self-regulation model, $R^2 = .18$ $R^2_{corr} = .14$, $F(4,77) = 4.31$, $p = .003$. Percentage of use of the default screen position strategy predicted scores on inference questions, $t(77) = -2.74$, $B= -.41$, $SE_B = .15$, $p = .008$. The mediation model kept the only predictor of the self-regulation model (prior knowledge, $t(77) = 2.66$, $B= .05$, $SE_B = .02$, $p = .009$)

Text-based questions. The inclusion of the variable percentage of use of the coherence strategy significantly improved the variance explained by the self-regulation model, $R^2 = .18$ $R^2_{corr} = .13$, $F(4,77) = 4.12$, $p = .004$. Percentage of use of the coherence strategy resulted in the only significant predictor of the mediation model, $t(77) = 2.96$, $B= .35$, $SE_B = .12$, $p = .004$).

Percentage of use of the interest strategy did not help improving the variance explained by the self-regulation model, (F_{change} (1,77) < 1, $p = .439$).

Finally, the inclusion of percentage of use of the default screen position strategy added extra variance to the self-regulation model, $R^2 = .14$, $R^2_{corr} = .09$, $F(4,77) = 3.07$, $p =< .021$. Percentage of use of the default screen position strategy resulted in the only significant predictor of the mediation model, $t(77) = -2.22$, $B= -.26$, $SE_B = .12$, $p = .029$)

Table 4

Discussion

The data from Experiment 2 allows clarifying the role of two key variables of self-regulation, prior knowledge and calibration of comprehension, on the selection of hyperlinks and comprehension in hypertext.

The Role of Prior Knowledge and Calibration of Comprehension on Link Selection

Data from Experiment 2 support a strong relationship between prior knowledge and calibration of comprehension in regards to hyperlink selection, as predicted by the SRL model (Winne, 1995, 2001). After setting a high study goal (as requested by the instructions of Experiment 2), participants calibrate their comprehension against their goal while reading, and regulate their strategies to adjust actual comprehension to their learning goal. Indeed, data from Experiment 2 indicate that low knowledge participants who accurately calibrate their comprehension select strategies compatible with a high learning goal (a coherence strategy, i.e., selection of links based on the semantic relatedness of sections) more often than participants who are less precise on their calibration. The latter participants are more likely to select strategies that do not lead to optimal comprehension, such as the selection of links based on link interest. Their inaccurate calibration of comprehension prevents them from using a more advantageous strategy to achieve a high learning goal (Winne, 2001).

Furthermore, the data indicate that high knowledge readers choose criteria for selecting links independently of their calibration accuracy. Two possible explanations can be considered for this null result [3]. Given that high knowledge readers learn to the same extent regardless of the link selection strategy used, calibration of comprehension might not be a decisive factor in regulating their reading behaviour (Alexander & Jetton, 2000; Alexander et al., 1997; Borkowski et al., 1987; Pressley & McCormick, 1995; O'Reilly & McNamara, 2002). In other words, for high knowledge readers there is no optimal strategy that those with better calibration accuracy might have followed more often than other non-optimal strategies. A second explanation might take into account the fact that knowledgeable readers may not be challenged by the task of comprehending a text on such a familiar topic and thus set a low learning goal. In that case, they might process the text in a more superficial manner (McNamara & Kintsch, 1996; McNamara et al., 1996).

Finally, contrary to our expectations, results show a null effect of prior knowledge and calibration of comprehension on the choice of the default screen position, a non-optimal strategy for link selection. But why did even readers accurate in their calibration of comprehension still decide to use this non-optimal strategy? A possible factor that could explain this selection by accurate readers is a lack of motivation to accomplish a goal (Moos & Azevedo, 2006; Rheinberg, Vollmeyer, & Rollett, 2000). Readers can decide to choose a less demanding strategy, such as the selection of links based on a default screen position, even when they realize that their comprehension is not optimal, if they lack the necessary motivation to accomplish the study goal. This issue will require further research.

The effect of Prior Knowledge, Calibration of Comprehension, and Link Selection on Comprehension

The results of Experiment 2 reveal an interesting picture regarding the inter-relationship between prior knowledge, calibration of comprehension, hyperlink selection and comprehension outcomes. Participants' prior knowledge is positively related with the construction of a good situation model (as measured by Pathfinder similarity scores and inference questions), as found repeatedly in the literature (e.g., Kintsch, 1998). In addition, low prior knowledge readers with accurate calibration of comprehension also learn better at the situation model level (as measured by Pathfinder similarity scores). Together with these effects, link selection strategies also influence comprehension in different ways. Whereas selecting links based on their coherence has an extra positive effect at the situation model level, choosing links based on a default screen position has an additional negative effect (Madrid et al, 2009; Salmerón et al., 2006). This pattern of results can hardly be explained either by a pure Self-regulation or by a pure Textual model (as outlined above). Concretely, a self-regulation factor, calibration of comprehension for low knowledge readers, affects comprehension directly and indirectly through its effect on a mediator variable: 'use of a link coherence strategy'. As in Experiment 1, a Mediation model stressing the diverse effects in comprehension of self-regulation due to the associated adjustments on the reading behaviour may account for the results. In this case, the two self-regulation factors analyzed benefit comprehension, but through different mechanisms, not necessarily involving link selection strategies (Azevedo &

Cromley, 2004; Azevedo et al., 2004). Prior knowledge may have improved comprehension due to the activation of existing mental representations of the topic during reading, without affecting link selection strategies. In addition, readers with accurate calibration of comprehension, especially those without prior knowledge, can detect during reading the benefit on comprehension of choosing only links semantically related. Those with less accurate calibration, in contrast, may be unable to precisely detect this link and may be tempted to use a less demanding strategy for link selection as link interest (Coiro & Dobler, 2007). As we have already discussed, different link selection strategies have opposite effects in comprehension. Thus, calibration of comprehension mostly affects comprehension in hypertext, especially for those readers without prior knowledge, through its influence on the mediator variable hyperlink selection.

Regarding textbase construction, results of text-based questions show that link selection based on link coherence improves comprehension, whereas a link selection based on a default screen position decreases it. This pattern of results contrast to the null effects found previously in Experiment 1 (see also Madrid et al., 2009; Salmerón et al., 2006). Interestingly, this conflicting result might help us understand how link selection strategies affect the construction of a textbase representation and can be explained by the differences in the procedure used in the two studies. In Experiment 1 (as in Salmerón et al., 2006) participants finished reading a section, then chose between two nodes, and were immediately presented with the selected section. However, in the current study participants performed a judgment of learning task between the end of a section and the selection and presentation of subsequent sections. On average, each judgment of learning took participants 5.13 seconds (*SD* = 1.1) to make. The introduction of this task may have interfered with the construction of a coherent textbase representation, for which readers must relate relevant propositions in the current section to those in the following one (e.g., Budd et al., 1995). Similarly, prior studies have found that interruptions during reading are likely to decrease readers' comprehension (Lorch, 1993). In the current experiment, the use of the default screen position strategy severely affects comprehension at the textbase level because after the interruption by the learning judgment task they had to reinstate propositions from the previous section that were mostly unrelated to the subsequent section (Levy et al., 1995). The use of the coherence strategy, in contrast, facilitates this process because it maximizes the semantic relation of the propositions to be combined.

Conclusion

The two studies reported here support the hypothesis that efficient readers regulate their hyperlink selections in order to optimize their learning from hypertext. Using Winne's (1995, 2001) model of self-regulated learning, we evaluated the hypothesis that self-regulation factors may be critical to the use of hyperlink selection strategies, which in turn may lead readers to different comprehension gains. In this section, we summarize the results from the two experiments that provide new insights concerning this relationship and we discuss some limitations of the studies and possible future directions.

What Makes a Reader Select a Particular Hyperlink?

The starting point for this research was evidence relating the use of different link selection strategies with comprehension outcomes in hypertext (Madrid et al., 2009; Salmerón et al., 2005; Salmerón et al., 2006). Low knowledge readers who select hyperlinks in a semantically coherent sequence better understand the situation described by the text, as shown by their superior performance on inference tasks. Other two commonly used strategies for selecting links, based on a default screen position or on personal interest, hamper comprehension of low knowledge readers. Results from the two experiments reported conclude that self-regulation factors from the Winne's SRL model (1995, 2001) are critical in regards the use of link selection strategies. The use of optimal strategies for link selection (i.e., link coherence) is predicted by a high learning goal (Exp. 1), by a regular use of appropriate learning strategies (Exp. 1), and by an accurate calibration of comprehension for low prior knowledge readers (Exp. 2). In contrast, the use of non-optimal strategies for link selection (i.e., link interest and default screen position strategies), is related to setting a low learning goal (Exp. 1), to a regular use of poor learning strategies (Exp. 1), and to an inaccurate calibration of comprehension (Exp. 2). This pattern of results suggests that readers are aware of different strategies for selecting hyperlinks and their effect on comprehension, and thus can adapt their reading tactics to attain their learning goals. Indeed, results clearly show that more efficient readers follow optimal strategies for link selection whereas less efficient readers apply less optimal strategies.

We obtained analogous patterns of results using two texts from completely different disciplines: history and science. These two knowledge domains are typically structured quite differently (McCarthy, Lightman, Dufty, & McNamara, 2006). For example local cohesion is significantly greater in science texts than in history texts. Thus, we can conclude that the effects of self-regulation on link selection strategies are not restricted to a particular domain.

How Self-Regulation and Link Selection affect Comprehension in Hypertext?

As we have described in the introduction, prior research reports robust effects of self-regulation factors and link selection strategies on comprehension in hypertext systems (e.g., Moos & Azevedo, 2008; Madrid et al., 2009). However, a new question arises from the finding that self-regulation predicts link selection strategies: is any of these factors alone responsible for the effect on comprehension –what we described as a pure Self-regulation and pure Textual model, or do they interact to affect comprehension conjointly –what we described as a Mediator model-?

Some of the self-regulation factors analyzed have a direct effect on comprehension even though they do not predict link selection strategies, such as prior knowledge (Exp. 2). Also, some of the link selection strategies identified, such as the use of a default screen position (Exp. 2), affect comprehension although its use is not predicted by any of the self-regulation factors measured (i.e., prior knowledge or calibration of comprehension). These data may be well explained by a pure Self-regulation and a pure Textual model respectively. However, critical tests for these models are the mediation effects in which self-regulation factors predict link selection strategies, and both variables account for distinct portions of the variance of comprehension outcomes. For example, in

Experiment 1 setting a high learning goal predicts the use of a coherence strategy, and both factors independently affect comprehension positively at the situation model level. In experiment 2, calibration of comprehension for low knowledge readers predict the use of a coherence strategy, and both variables account for distinct portions of the variance of comprehension outcomes (Pathfinder similarity values). These results are better explained by a Mediation model, which considers that self-regulation factors (such as learning goal or calibration of comprehension) command diverse adjustments to the reading behaviour (e.g., summarizing at the end of a section), and that are these and not self-regulation factors per se the responsible for influencing comprehension. From the lens of this model, one of these adjustments is link selection strategies. Other adjustments not directly identified in our experiments such as summarizing, taking notes, and coordinating informational sources may well be responsible of additional improvements in comprehension associated to key self-regulation factors (Azevedo & Cromley, 2004; Azevedo et al., 2004).

Limitations and Future Directions

Even though we believe that the present study contributes to the literature on hypertext comprehension by identifying the relation between self-regulation and link selection strategies, it should be acknowledged that our investigation comes with certain limitations. First, in the current work we use a simplified hypertext system which consists merely on a multi-section text in which readers can only choose between two particular links after reading each section. That is to say, this system does not include several other features typical of educational hypertexts such as graphical overviews or embedded links, and restricts reader's selection behaviour. By using this simplified system we try to clearly isolate the process of selecting a particular link sequence from other task influences such as the use of overviews to move through the hypertext. Hence, a concern may arise over how the data related to self-regulation and link selection strategies reported in this work apply to more realistic hypertext systems. Recent studies with naturalistic hypertexts describe a strategic behaviour of hypertext readers regarding link selection similar to that found in our experiments (Protopsaltis, 2008). In this study, participants read through a structured hypertext of 5075 words, divided in 23 nodes. The hypertext included a navigational menu, and participants could choose between global and local hyperlinks. Participant's strategies were identified using a non-intrusive methodology (think aloud procedure). Results from an experiment replicate the finding that hypertext readers mainly use coherence, interest or a default screen position as main criteria to select hyperlinks (Protopsaltis, 2008). Further studies will evaluate if self-regulation also relates to strategic decisions regarding link selection in more naturalistic environments.

Second, we should note that the experiments reported here involve only university undergraduate students, and thus the results may not be valid to interpret younger readers' behaviour in hypertext environments. Analogous hypertext comprehension studies with college and high school students reveal that younger readers usually employ less number and less effective self-regulation processes than older readers (e.g., Green & Azevedo, 2007). Future research should evaluate if selecting hyperlinks is also a regulated behaviour for high school students.

In addition, the results from the reported experiments suggest several challenges for researchers who are currently examining the role of strategic behaviour in hypertext and hypermedia. Future research might address how self-regulation affects readers' use of other key strategies besides the selection of reading order, such as the selection of sections and the allocation of study time. Shapiro and Niederhauser (2004) have suggested that self-regulation may well be related to the process of deciding which sections, images or videos to access (and which to ignore), an important task that can also affect comprehension (Lawless & Kulikowich, 1996, 1998). Indeed, we have found that for low knowledge readers, the more sections they read, the higher the number of text-based questions they answer correctly (Salmerón et al., 2005). Reader and Payne (2007) have studied the strategies readers use for allocating study time in particular hypertext sections. They have found that prior knowledge, a key factor in self-regulation, is positively related to the study time devoted to more difficult sections. In sum, researchers might consider the SRL model

(Winne, 1995, 2001) as a starting point for further understanding of the diverse strategic behaviours in hypertext comprehension.

Future research might also explore techniques to improve readers' self-regulation with the aim of facilitating students' decisions in hypertexts, such as choosing the sections relevant for a task or selecting an optimal reading order for the selected sections. Along these lines, Puntambekar & Stylianou (2005) describe a hypertext system that analyses on real time the reading sequence of students, and prompts them to assess their comprehension whenever transitions between low semantically related sections are made. Thus, this systems aims to improve calibration of comprehension during reading, under the assumption –corroborated in our Experiment 2- that better calibration is related to more optimal link selection strategies. Such a system may benefit by incorporating a recent technique to improve calibration accuracy, which consists on instructing students to judge their understanding of specific ideas (e.g., On a text of elementary statistics: *'How well will you be able to recall the definition of ordinal measurement on an upcoming test?'*) and not of an entire section of the text (Dunlosky & Lipko, 2007). Readers are required to attempt to recall the definition before the actual judgment of comprehension, and are subsequently provided with feedback on their response. Thus, readers know immediately if they really understood the text at the level they thought. We might expect that an advance on readers' calibration accuracy would reflect on an improvement on their reading decisions in hypertexts (e.g., selection of a coherent reading order, allocation of study time, etc.) Further research will be required to evaluate this issue.

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Footnotes

1. Only scores on text-based questions were considered, because they were the only ones that allowed correlating learning judgements for a text section with actual comprehension of that particular section. In contrast, the inference questions and the similarity rating task asked for information contained in different text sections.

2. Due to the few responses on the retrospective debriefing for the ‘easiest link’ and ‘other’ criteria, these data were not included in the analyses.

3. An alternative explanation for the different pattern of results for low and high prior knowledge readers may consider the presence of a confounding between calibration of comprehension and prior knowledge. High knowledge participants may have overestimated their comprehension whereas low knowledge may have been more precise on their assessment (Glenberg & Epstein, 1987), which might have been reflected on their link selection patterns. In order to test this possibility we computed a Spearman correlation between amount of prior knowledge (assessed by the pre-test questionnaire) and calibration of comprehension (computed using Gamma correlations between JOL and the post-test comprehension questionnaire). Ruling out this interpretation, the correlation between variables was not significant, $R = -0.03$, $p < .8$, i.e., in our experiment prior knowledge was not related to calibration accuracy (cf. Jee, Wiley & Griffin, 2006).

Table 1

Summary of multiple regression analysis for the effects of Learning Goal and Learning Strategies use on criterion followed for link selection in Experiment 1.

	Coherence (log)			Interest (log)			Default screen position (log)		
	B	SE_B	*t*	*B*	SE_B	*t*	*B*	SE_B	*t*
Intercept (B_0)	0.19	0.01		0.1	0.01		0.03	0.01	
Learning goal [a]	0.05	0.02	2.26 *	-0.07	0.02	-3.54 **	0.01	0.01	0.54
Learning strategies [b]	0.02	0.01	1.88	0.01	0.01	0.49	-0.02	0.01	-2.59 *
Interaction	-0.05	0.02	-2.32 *	0.02	0.02	1.12	0.02	0.01	1.34
Model fit	R^2 = .19, R^2_{corr} = .15			R^2 = .2, R^2_{corr} = .15			R^2 = .12, R^2_{corr}.= .07		
Omnibus test	$F(3,58)$ = 4.48**			$F(3,58)$ = 4.69 **			$F(3,58)$ = 2.63 *		

Note. [a] Dummy-coded, High learning goal = 0.5, low learning goal = -0.5, [b] z-standardized.

* p < .05, ** p < .01, *** p < .001.

Table 2

Summary of multiple regression analysis for the effects of Learning Goal and Learning Strategies use on comprehension scores in Experiment 1.

	Inference scores (log)			Text-based scores (log)		
	B	SE_B	*t*	*B*	SE_B	*t*
Intercept (B_0)	-0.59	0.02		-0.42	0.02	
Learning goal [a]	0.16	0.05	3.37 **	0.02	0.03	0.72
Learning strategies [b]	0.05	0.02	1.98 *	0.03	0.02	1.69
Interaction	0.07	0.05	1.43	0.04	0.03	1.37
Model fit	$R^2 = .24$, $R^2_{corr} = .2$			$R^2 = .1$, $R^2_{corr} = .05$		
Omnibus test	$F(3,58) = 6.04$ **			$F(3,58) = 2.03$		

Note. [a] Dummy-coded, High learning goal = 0.5, low learning goal = -0.5, [b] z-standardized.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 3

Summary of multiple regression analysis for the effects of Prior Knowledge and Calibration Accuracy on criterion followed for link selection in Experiment 2.

	Coherence (log)			Interest (log)			Default screen position (log)		
	B	SE_B	*t*	*B*	SE_B	*t*	*B*	SE_B	*t*
Intercept (B_0)	0.13	0.12		0.06	0.01		0.11	0.01	
Prior knowledge [a]	-0.04	0.12	-0.31	0.01	0.01	-0.42	-0.01	0.01	-0.33
Calibration [a]	0.02	0.12	1.32	-0.02	0.01	-2.09 *	0.01	0.01	0.49
Interaction	-0.03	0.13	-2.27 *	0.02	0.01	1.86	0.02	0.01	1.27
Model fit	R^2 = .09, R^2_{corr} = .06			R^2 = .11, R^2_{corr} = .07			R^2 = .03, R^2_{corr} = -.01		
Omnibus test	$F(3,78) = 2.66$ *			$F(3,78) = 3.02$ *			$F < 1$		

Note. [a] z-standardized, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 4

Summary of multiple regression analysis for the effects of Prior Knowledge and Calibration Accuracy on compreh

	Pathfinder scores (log)			Inference scores (log)			Text-based scores (log)		
	B	SE_B	*t*	*B*	SE_B	*t*	*B*	SE_B	*t*
Intercept (B_0)	-0.57	0.02		1.62	0.02		1.14	0.01	
Prior knowledge [a]	0.07	0.02	4.69 ***	0.05	0.03	2.66 **	0.02	0.01	1.16
Calibration [a]	0.02	0.02	1.41	0.02	0.02	1.36	0.02	0.01	1.56
Interaction	-0.03	0.02	-1.99 *	0.01	0.02	0.39	-0.02	0.02	-1.55
Model fit	$R^2 = .28$, $R^2_{corr} = .25$			$R^2 = .10$, $R^2_{corr} = .07$			$R^2 = .08$, $R^2_{corr} = .05$		
Omnibus test	$F(3,78) = 9.9$ ***			$F(3,78) = 2.99$ *			$F(3,78) = 2.33$		

Note. [a] z-standardized, * $p < .05$, ** $p < .01$, *** $p < .001$.

Appendix A

Example of a text-section and its associated nodes used in Experiment 2

Text-section “The severe seasonal ozone depletion”

The most dramatic depletion of ozone occurs over the polar regions. A seasonal (spring) decline in stratospheric ozone levels over Antarctica has been apparent since the late 1970s. Since the late 1980s, the seasonal ozone depletion has been severe and associated with a rapid rise of ozone depleting substances levels in the stratosphere. Satellite data indicate that now more than 60% of the total ozone over Antarctica is being destroyed in spring, when climatic conditions are most favorable for ozone destruction. Ozone levels have been observed to drop under a 25% of the considered normal levels.

Associated links

Influence of wind in the air quality (low related, LSA cosine = .20)

Greenhouse gases concentrations in the troposphere (high related, LSA cosine = .51)

Appendix B

Example of comprehension materials used in Experiment 2

Prior Knowledge Question

The Montreal Protocol is accepted by nations agreeing to restrict the release of:

A. Ozone depleting chemicals. (correct)

B. Greenhouse gases.

C. Climate change chemicals.

Text-based Question

Human activity especially affects:

A. The four layers of the atmosphere.

B. The two layers of the atmosphere closest to the earth’s surface. (correct)

C. The two intermediate layers of the atmosphere.

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 especially 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.

Inference Question

Ozone in the higher and lower levels of the atmosphere…

A. Are chemically different.

B. Differ greatly in its environmental effects. (correct)

C. Can cause skin cancer.

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.