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The Effect of Reading Strategies and Prior Knowledge on Cognitive Load and Learning with Hypertext

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Abstract: Reading strategies, prior knowledge and cognitive load are some variables that have been related with comprehension and learning with hypertext systems. In this study we analyze the effect of two different hypertext reading strategies – coherence and interest – and two prior knowledge levels – low and high - on cognitive load, and their relation with learning. For low prior knowledge readers, data reveal that following a coherence strategy leads to lower cognitive load during reading and better learning. For high prior knowledge readers, following an interest strategy produce higher cognitive load during reading than a coherence strategy, but they learned equally from both strategies. These results are discussed taking into account the implication of two different components of cognitive load (extraneous and germane cognitive load).

INTRODUCTION

Hypertext is currently widely used as an essential component in formal learning (e.g. higher education e-learning systems) as well as informal or incidental learning (e.g. Wikipedia). Hypertexts have the advantage of fostering learner control, which is performed through *sequencing* (the order in which the learner want to access the different information units) and *selection or content control* (which contents to read from a set of documents) [1]. The specific rule that a hypertext user follows for sequencing and content control are known as reading strategies [2, 3].

Fostering learner control should lead to better motivation, learner engagement and, subsequently, a better learning. However, in a recent review on learner control and hypermedia learning [1] the authors have claimed that the effectiveness for learning of learner control has been shown not to be general and it could be affected by both system and learner characteristics. For example, there is summative evidence showing that low prior knowledge learners have problems with hypertext, and it may be more suited for expert learners [4].

Additionally, the authors also reviewed studies that suggest that cognitive resources needed for learner control will not be available for learning, and if they are high it can lead to cognitive overhead and impairment in learning. Therefore, the question is under which circumstances, learner control leads to high cognitive load and impairment on learning.

In this study, we will examine the effect of two different reading strategies - used by both low and high prior knowledge learners - on cognitive load and learning.

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READING STRATEGIES AND PRIOR KNOWLEDGE

The C-I model of text comprehension [5-7] consider text coherence and prior knowledge as the main variables affecting text comprehension. Text coherence is a complex construct that depends on several factors, but it can be defined in a simple way as the extent to which a reader can understand the relations between ideas expressed in a text [8]. In some linear text reading studies it has been shown a learning reverse effect [9-11]. Low prior knowledge (LPK) readers find high coherent texts beneficial since they don't have the necessary background knowledge to infer information that is not directly stated in the text. However, high prior knowledge (HPK) readers learn more with a less coherent text. The explanation of this reverse effect is that HPK readers are less likely to use their prior knowledge if the text is highly coherent, and reading a less coherent text activates their prior knowledge through inferential processes leading to better learning.

In hypertext comprehension studies, text coherence has been also shown to be important for learning, with the difference that it can be modified through the reading strategies that readers follows [2, 3, 12]. Reading strategies are general navigation rules that users follow to select what hypertext contents to read (selection or content control) and in which order (sequencing). Several strategies have been examined, but the main ones seem to be coherence, interest and link location [3, 13].

In two experiments, Salmerón, Kinstch & Cañas [3] examined the effects on comprehension of different criteria for selecting links, being the main ones coherence and interest:

a) *Coherence strategy* consists in selecting the link most related with the text just read, and therefore it promotes high reading text coherence. As stated before, reading text coherence in hypertext depends also on learners' control, since the reading order selected by the readers determines the coherence of the reading sequence [12].

b) *Interest strategy* is based in selecting first the links that seems most interesting to the reader, delaying the reading of the less interesting ones. Therefore the interest strategy should produce a less coherent reading sequence than the coherence strategy.

The results of the experiments conducted [3] showed that readers following these different reading strategies obtained different comprehension outcomes: LPK readers achieved better comprehension with the coherence strategy than with the interest strategy, but readers with higher knowledge comprehended the contents equally well using the coherence or the interest strategy. Moreover, the results suggested that the effects of reading strategies on comprehension are achieved through two different mechanisms. The first is *text-induced*, as in linear text reading a high-coherence text is better for LPK readers than reading a low-coherence one. On the other hand, readers with some knowledge can obtain benefits from reading low-coherence texts since this process helps them to avoid the shallow processing caused by high-coherence texts [9, 14]. The second mechanism is a *strategic influence*: for readers with some prior knowledge following a strategy to select the reading order activates their prior knowledge and automatically mobilizes cognitive resources for learning. On the contrary, LPK readers did not get benefits from the strategic influence and they don't achieve better learning compared with reading a linear text with the same coherence level. In summary, HPK are affected both by the text-induced and the strategic influence mechanism, and they learn equally both from the coherence or from the interest strategy, while LPK readers are affected only by the text-induced mechanism and they achieved a better learning when they used a coherence strategy.

COGNITIVE LOAD DURING HYPERTEXT READING

The Cognitive Load Theory (CLT) is directed to guide instructional design decisions based on the way in which cognitive resources are used during learning [15-17]. The theory distinguishes between three types of cognitive load (CL): intrinsic CL, extraneous CL and germane CL. Intrinsic CL is related with prior knowledge and the nature of the materials to be learnt (interactivity between elements). Extraneous CL (ineffective for learning) is the effort required by poorly designed tasks, while germane CL (effective for learning) concerns activities related with the construction of schemas and automation leading to higher levels of comprehension. For an instructional design (e.g. educational hypertext) to be effective for learning, extraneous CL have to be reduced and germane CL have to be enhanced.

In the context of hypertext reading, CL has been also analyzed to study their relation with learning [18, 19]. From the point of view of the human cognitive system characteristics, hypertext navigation requires a large amount of cognitive resources. Cognitive resources are needed to plan navigation, to assess the relevance of the information found and to comprehend the information and to integrate it with prior knowledge. In a recent review, DeStefano & LeFevre [18] claimed that, compared with traditional printed text, hypertext tasks requires extra working memory resources to be allocated to decision and comprehension processes. This increment could lead to comprehension problems, mainly for low knowledge readers. They predicted that this CL increment comes from two sources: First, from the decision-making processes needed to perform navigation (and therefore, if more links are offered the CL would be higher); second, from the difficulty of reading and comprehending the information when links followed leads to information semantically unrelated with the previously read contents that can hinder the construction of situation models (and therefore, offering only links to closely related information would reduce CL).

To test these prediction, Madrid, Van Oostendorp & Puerta Melguizo [20], run an experiment in which different types of hypertext presentations (3 *vs* 8 links menus, showing or not link suggestions based on semantic relatedness) were used by LPK readers to test their CL level and learning. The participants were instructed to follow a coherence strategy, selecting the link that they thought that were more related with the previously read text. Participants had to read all the contents, and therefore learner control in this experiment is reduced to sequencing (they were not allowed to select what contents to read). The results showed that CL during hypertext reading and learning were mediated by the reading order that readers followed. Their achieved reading text coherence was measured, and two groups of low and high text coherence reading orders were constructed. Participants selecting a high text coherence reading order suffered less CL both during reading and during link selection, and achieved a better learning than those selecting a low text coherence reading order. This experiment only partially supported DeStefano & LeFevre's [18] predictions, but confirmed the role of text coherence both in CL and learning, at least with LPK readers.

Moreover, the experiment [20] showed that readers' activities are more important for learning than hypertext design characteristics. In a similar way, Gerjets & Scheiter [21] proposed an extension of the CLT based on the assumption that instructional design is not directly determining cognitive load, but that learning activities are important moderators between instructional design and cognitive load.

As have been showed before, readers' prior knowledge is a main variable affecting learning with hypertext systems. However, there is little research concerning the role of prior knowledge on CL during hypertext reading. An exception is the study carried out by Amadieu, Tricot & Marinee [22] who conducted two experiments exploring the relation between prior knowledge, CL, navigation and learning. Although one of the experiments failed to find differences between low and high knowledge readers in CL, the results of the other experiment suggested that prior knowledge could have a negative relation with CL (i.e. the higher the prior knowledge, the lower the CL).

Summarizing, the studies described above suggest that certain features of reading strategies (as reading text coherence, i.e. text-induced mechanism) and readers' prior knowledge determine CL and therefore they could affect learning. However, it is needed to notice that the relationships between CL and learning would be misunderstood if we don't take into account the nature of CL. In this sense, studies as [18] focused in the idea that the more CL invested in hypertext, the worse the performance. This should be only true if the CL exceeds the limits of working memory [23]. But, on the contrary, if CL remains within the limits of working memory, a higher investment of mental effort could also produce better learning when the extra resources are used for active processing [24].

RESEARCH OBJECTIVES

This study is an extension of the line of research started by Madrid, Van Oostendorp & Puerta Melguizo [20]. Their experiment had two main limitations concerning the role of cognitive load in hypertext reading.

First, only low prior knowledge readers participated in the experiment, who following a previous study [3] are only influenced by the text-induced mechanism (i.e. there is not a strategic influence). Since readers who performed a less coherent reading order got higher CL and worse learning, we can reach the conclusion that the increase in CL was mainly composed of extraneous CL. However, for readers with some prior knowledge, following a less coherent reading order could lead to better learning. Moreover, the strategic influence mechanism could produce germane CL for HPK readers that are not available for LPK readers. Therefore, to test the hypothetical effects of the strategic influence mechanism on CL, new experiments are needed in which learners with higher prior knowledge are also included.

Second, to control for the effect of different strategies all the participants were instructed to follow the coherence strategy. However, trying to achieve high reading text coherence is not the only reading strategy that readers could perform, and following different reading strategies may have differential effects on CL as it does on learning [3]. This effect could be mainly relevant during link selection, since different reading strategies could need different amount of resources to assess the relevance of link labels for their goals, but also during reading, since different reading strategies could lead readers to focus in different aspects of the text. Supporting these ideas, evidence coming from the field of cognitive ergonomics shows that people that use alternative strategies for doing a task differ in the amount of mental effort needed for task performance [25, 26].

To solve these limitations, in this study we tested the effect of different reading strategies at different levels of prior knowledge on CL and learning. As in the experiment from Madrid, Van Oostendorp & Puerta Melguizo [20], the participants read all the contents and they could only control sequencing. The aim of this experiment was two-fold:

1) The effect of reading strategies on CL: We examined the way in which two different reading strategies – coherence and interest - could affect the CL that low prior knowledge (LPK) readers and high prior knowledge (HPK) readers experience with hypertext. For both LPK and HPK readers, we predicted that the coherence strategy would produce higher CL during link selection than the interest strategy, since performing the coherence strategy requires several semantic relatedness judgments to select the most related link, while the interest strategy only needs of personal preferences decisions which a priori would consume less cognitive resources. Conversely, we expected that both LPK and HPK readers following the interest strategy would experience higher levels of CL during reading - because of the lower reading text coherence achieved using this strategy - than those following the coherence strategy.

2) The relation between reading strategies, CL and learning: We tested the effect of reading strategies and prior knowledge on learning, and putting together with CL, we used the overall pattern of results to analyze the relation between CL and learning. According with Salmerón, Kintsch & Cañas [3] and the Cognitive Load Theory [15], we expected that the increase on CL during reading for LPK readers using an interest strategy in relation with those using the coherence strategy would be mainly composed of extraneous CL, and therefore their learning would be lower. On the other hand, for HPK readers both strategies could be good for learning: Using the interest strategy they could obtain reading orders with lower text coherence and a higher overall CL, but they could transform the extra processing into germane CL during reading. Additionally, through the strategic influence mechanism, HPK readers could invest extra germane CL if they follow a coherence strategy, and therefore they could avoid the shallow processing induced by high coherence texts.

METHOD

Participants

Fifty-two students of the University of Granada participated in the experiment. Half of them were second-stage Psychology students (at least 3 years studying Psychology), and the other half were Psychology freshmen (less than one semester studying Psychology) or students from other disciplines (Education, Language or Sport Sciences) with only an introductory course on Psychology. They received course credits for their participation.

Design

The study followed an experimental 2x2 design with type of reading strategy (coherence *vs* interest) and prior knowledge level (low *vs* high prior knowledge) as independent variables. We used two kinds of dependent variables: reading processes measures and learning measures. As reading processes measures we used reading text coherence (mean LSA cosines between text transitions), average reaction times to a secondary task (both when reading texts and when selecting links) and reading and link selection times. As a learning measure we used the score on an inference questionnaire.

Materials

Participants read a text in Spanish about Neuropsychology, extracted from a General Psychology introductory e-book. The text had 4599 words and was divided into 21 pages.

After reading each text page, readers went to the link selection menu, where they had to select the next text to read within 8 links. The menu was constructed by showing the two most related links with the text just read, and six links more that were extracted randomly from the list of link labels.

Participants had to select the next text to read following the specific instructions for their type of strategy condition. Participants in the coherence condition had to select the link that they assessed as the most similar to the text just read. Readers that were assigned to the interest condition had to select the link that they assessed as the most interesting to them.

Measures

Process Measures

Reading Text Coherence: Based on the reading order followed by the participant, we computed the mean LSA cosine of their text transitions (see [12] for a detailed explanation of this method). This measure can be used as an index of the coherence of the reading order followed by the readers [3, 12, 20].

RTs to Secondary Task: This technique has been widely used to measure the CL associated with different experimental treatments [27-30]. It requires participants to perform the main task or primary task while responding to random beeps as quickly as possible (secondary task). RTs to beeps are slower when the cognitive requirements of the primary task are higher, and therefore can be used to measure the CL associated with it. This measure has showed sensitive to extraneous CL and to inefficient learning [20, 31, 32].

In our experiment, at the beginning of the session participants had to react as quickly as possible to 10 beep sounds presented randomly to obtain their RT baseline. During hypertext reading, participants had to press the ‘‘z” key as soon as possible when a beep was presented through the headphones. Their data was corrected by subtracting the baseline RTs. Variations in RTs reveal the cognitive capacity allocated to the primary tasks: reading or selecting links. Consequently, we computed the corrected RTs separately when selecting links and when reading the text fragments.

Several measures of cognitive load derived from RTs can be computed [23]. In our analyses, we will use the average RTs both for reading and selecting links which reflects the intensity of the cognitive load carried out during the task. However, some authors have claimed that not only the intensity but also the duration of the CL is relevant [33, 34].

Reading and Link Selection Times: To cope with the duration aspects of CL, the time spent when reading and when selecting links was measured and analyzed separately. Time has been used to test the cognitive load required both in reading [35] and in menu navigation tasks [36]. Link selection times were recorded in seconds for each page, starting when the link menu was shown and finishing when a link label was clicked. Reading times were measured in seconds for each hypertext page. A total reading and total link selection time was computed for each subject by adding the times spent for each task in each page.

Learning Measure

Inference questions score: Several mental representations are constructed in the process of learning from text [37]. The situation model is considered the deepest mental representation, formed when the textbase propositions are integrated with prior knowledge. It this experiment, a questionnaire composed of ten inference questions was administered to all participants after they completed the hypertext reading task. It was constructed in such manner that the questions and the answers appeared in different hypertext pages. The score in this questionnaire was used as a measure of situation model acquisition. Chance performance was at 25%.

RESULTS

All results were considered significant when $p < .05$, and marginally significant when p values were between .05 and .10. The data of one participant was excluded from the analyses as extreme outlier. Therefore the following results are based in a sample of 51 participants. According with Salmerón, Kintsch & Cañas [3] and Cognitive Load Theory [15].

Process Measures: Reading Text Coherence, Cognitive Load and Reading and Link Selection Times

A set of 2x2 ANOVAs was performed using prior knowledge and type of strategy as independent variables, and reading text coherence, mean RTs and reading and link selection times as dependent variables. See Table **1** for a summary of mean and SD results per group.

Reading Text Coherence

Results showed a main effect of type of strategy ($F(1, 51) = 48.177$; $p < .001$). Participants in the coherence condition selected a more coherent reading order (higher mean LSA cosine, $M = 0.317$; $SD = 0.047$) than those in the interest strategy ($M = 0.211$; $SD = 0.011$). There were not significant differences for prior knowledge, and no interaction effect.

Table 1. Mean and SDs (Between Parentheses) on Reading Processes Measures

	Low Knowledge		High Knowledge	
	Coherence	Interest	Coherence	Interest
LSA cosines	0.309 (0.049)	0.206 (0.059)	0.324 (0.046)	0.216 (0.068)
Average reaction times (link selection)	202 (61.5)	216 (105.7)	198 (82.4)	276 (73.8)
Average reaction times (reading)	150 (29.7)	135 (68.6)	151 (59.4)	180 (68.5)
Link selection times	293.77 (127.74)	162.86 (65.88)	225.14 (90.20)	147.86 (60.08)
Reading times	1561.92 (361.33)	1783.35 (306.01)	1199.429 (300.47)	1340.661 (419.08)

Reaction Times to Secondary Task

Average reaction times during reading: Contrary to our expectations, the 2x2 ANOVA results on mean reaction times during reading did not reach statistical significance (all p's > 0.1).

Average reaction times during link selection: Results showed a significant main effect of type of strategy (F(1, 51)=4.25; p < .05). Readers using the interest strategy got higher reaction times (M = 246; SD = 94) than those using the coherence strategy (M = 200; SD = 72). There were not main effects of prior knowledge or interaction effects.

Fig. (**1**) shows the results both for link selection and reading.

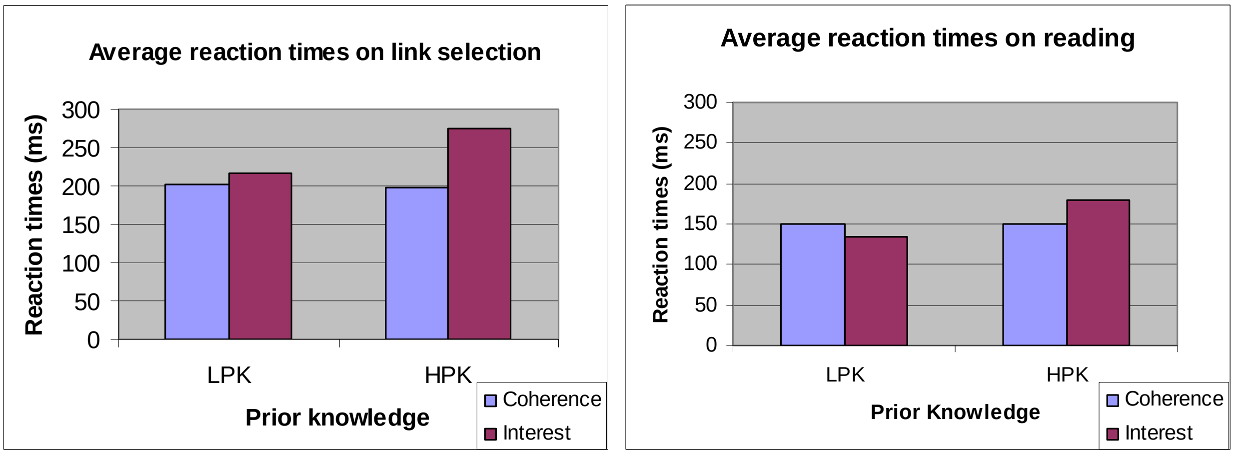

Fig. (1). Average reaction times during reading and during link selection.

Reading and Link Selection Times

Fig. (**2**) show the graph for results both on link selection and reading times.

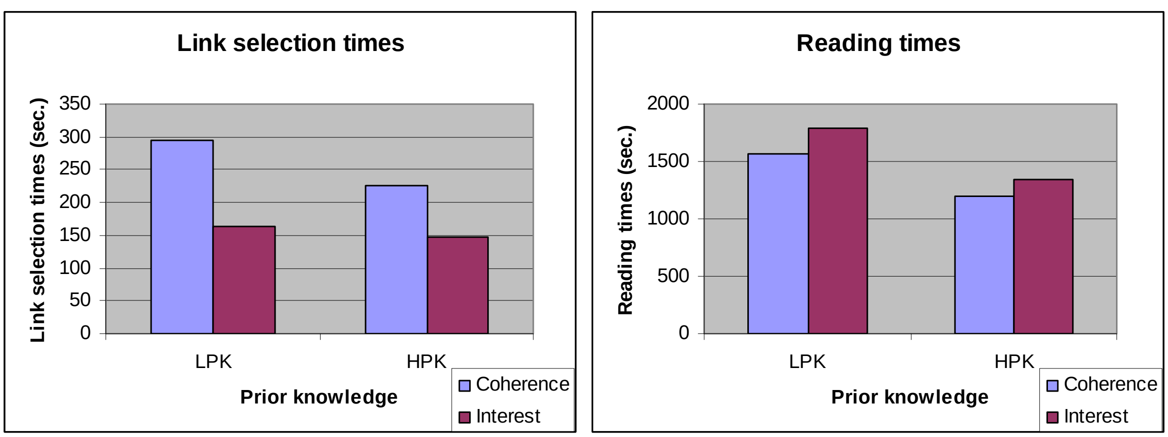

Fig. (2). Link selection times and reading times.

Link selection times: Time devoted to link selection was higher for those using the coherence strategy (M= 259.46; SD = 17.16) than for those using the interest strategy (M = 155.36; SD = 16.84), (F (1,51) = 18.75; p < .001). A main effect of PK was found marginally significant (F (1, 51) = 3.02; p < .09), LPK readers seems to expend more time selecting links (M = 228.31; SD = 17.16) than HPK (M = 186.50; SD = 16.84). The interaction did not reach significance (p > 1).

Reading times: Results showed a main effect of prior knowledge (F(1,51) = 18.19; p < .001), LPK readers devoted more time to reading (M = 1672.64; SD = 67.37) than HPK readers (M = 1270.05; SD = 66.11). The analysis also showed a marginally significant effect of type of strategy (F(1,51)=3.69; p = 0.06), the interest strategy group devoted more time to reading (M=1562; SD = 66.11) than the coherence strategy group (M=1380.68; SD = 67.38). The interaction did not reach significance (F < 1).

Learning Measure: Score on Inference Questions Questionnaire

A 2x2 ANOVA was performed using prior knowledge and type of strategy as independent variables, and inference questions score as dependent variable. Mean and standard deviation are showed in Table **2**. See also Fig. (**3**) for a graphical representation.

Inference Questions

Results showed a main effect of prior knowledge (F(1, 51) = 13.70, p = .001), and a significant interaction effect (F(1, 51) = 5.14 ; p < .05) (See Table **2** and Fig. **3**). Pairwise comparisons showed that LPK readers acquired a better situation model when using the coherence strategy (near significant, $F(1,51) = 3.82$; $p = 0.56$), but no differences were found for HPK. Comparisons also showed that HPK readers got better situation models than LPK readers when they used an interest strategy ($F(1,51) = 18.16$; $p<.001$), but there learnt equally when they use the coherence strategy ($F < 1$).

Table 2. Average RTs Per Condition (Standard Deviations Between Parentheses)

	Low Knowledge		High Knowledge	
	Coherence	Interest	Coherence	Interest
Inference questions	4.15 (1.91)	2.79 (1.37)	4.86 (1.99)	5.71 (1.94)

DISCUSSION AND CONCLUSIONS

The main objective of this experiment was to analyze the effect of reading strategies and prior knowledge on cognitive load, and their relation with learning.

First of all, we assumed that the interest reading strategy would lead to a less coherent reading order than the coherence strategy. Confirming that assumption, mean LSA cosines were quite lower for those following the interest strategy.

The Effect of Reading Strategies and Prior Knowledge on Cognitive Load

We predicted that following a coherence strategy would result in higher CL during link selection both for LPK and HPK readers. This assumption relays in the cognitive processes underlying link selection, since interest is an "a priori" automatic and motivational process while coherence requires several semantic similarity comparisons to be performed which would consume cognitive resources. Contrary to our expectations, the intensity of the CL (measured with RTs to secondary task) was higher for the interest strategy. In addition, we expected that both LPK and HPK readers using the interest strategy would experience higher CL during reading than those using the coherence strategy. However, both groups experienced the same intensity of CL. This last prediction was based on the study from Madrid, Van Oostendorp & Puerta Melguizo [20] that showed that those LPK readers following a reading order with lower coherence got higher intensity of CL. Although the reading text coherence for the interest strategy group was considerably lower than for the coherence strategy group their mean RTs were similar.

These results could seem difficult to reconcile with our hypotheses. However, before discussing results on the intensity of the CL we have to take into account also the duration on the CL. The notion of "volume of attention" can be relevant here: both the intensity and duration of the CL are important for learning [38, 39]. The "volume of attention" hypothesis shows the dynamics of CL: task A can be more cognitive demanding than task B, but it can be performed using the same intensity of CL if more time is devoted to it. Therefore, to discuss our results we also have to take into account reading and link selection times.

On the one hand, analyses of link selection times reflected that the time requirements are higher for the coherence strategy than for the interest strategy, both for LPK and HPK readers. Therefore, those readers following the coherence strategy showed higher duration but lower intensity of CL than the interest group. This pattern of CL results prevents us to make any conclusion about which strategy required higher CL, although it can be interpreted as an evidence for a different tradeoff between intensity and duration for both strategies.

On the other hand, the analyses of reading times showed that the interest strategy required more time than the coherence strategy both for LPK and HPK. Since no differences were found on the intensity of CL, it can be concluded that higher reading and link selection times mean higher cognitive requirements for the interest condition. Conversely, in the experiment from Madrid, Van Oostendorp & Puerta Melguizo [20], higher reading text coherence led to

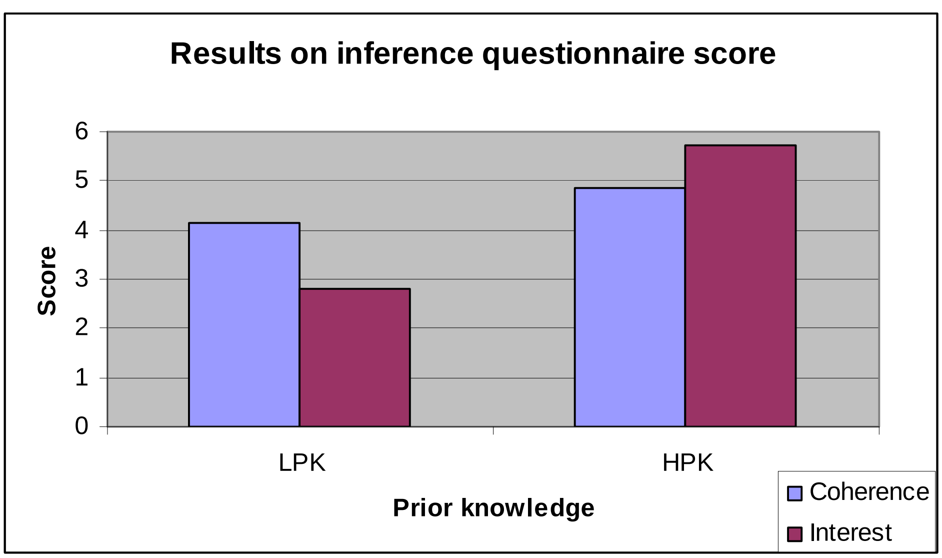

Fig. (3). Inference questions score per condition.

higher intensity of CL (average RTs) but no differences were found on reading times.

As a summary of this section, it can be argued that our prediction on the role of reading strategies on CL is partially supported. Both LPK and HPK readers who followed the interest strategy had higher CL during reading than those who followed the coherence strategy. Regarding the effect of reading strategies on link selection, those who followed a coherence strategy had not higher requirement than those who followed an interest strategy, but they showed a different tradeoff between intensity and duration of CL.

The Effect of Reading Strategies and Prior Knowledge on Learning

In general, learning outcomes confirmed our predictions. Learning outcomes has been shown to be affected by the strategy used, and to be different for both LPK and HPK readers. The score on inference questions was higher for LPK readers that used the coherence strategy than for those that used the interest strategy. Otherwise, HPK readers learn equally either using the interest or the coherence strategy.

These results also support the widespread idea which argues that reading hypertext in a semantically unrelated order is harmful for LPK readers' learning [3, 18, 20, 40].

The Relation Between CL and Learning

As this pattern of results shows, the relation between cognitive load and hypertext reading are far from being simple. Following the Cognitive Load Theory [15], there are three components of cognitive load that are additive (intrinsic, extraneous and germane cognitive load). Intrinsic cognitive load depends on the complexity of the materials and learner expertise. Extraneous cognitive load is related with inefficient learning. Finally, germane cognitive load are related with deeper learning. This distinction between different dimensions of CL is very useful from a theoretical point of view, but it has some methodological problems. First of all, experimental manipulations can influence more than one type of cognitive load at the same time, and it could have different effects on learning for LPK and HPK learners [41]. Second, the techniques used to measure CL do not clearly distinguish between these load components since they offer a global measure of CL [34]. If different measures were sensitive to different CL components, we could predict learning results based on the balance between intrinsic, extraneous and germane CL.

Recently, DeLeeuw & Mayer [32] have discussed some research findings in the field of multimedia learning suggesting that different measures of CL (RT to secondary task, mental effort during learning and difficulty ratings) could be sensitive to different types of CL. In two experiments, participants (mainly low knowledge learners) watched different versions of a 6-minutes multimedia lesson, in which the three measures of CL were obtained. Results showed that RT to secondary task was mainly sensitive to manipulations in extraneous CL, whereas mental effort and difficulty ratings were sensitive to intrinsic and germane CL respectively. Regarding extraneous CL, the measurement method (RT to secondary task), participant characteristics (low prior knowledge) and task timing features (no differences between conditions in relation to duration of the session) were similar to those in the Madrid, Van Oostendorp & Puerta Melguizo experiment [20] in which the group with higher RTs also achieved less learning. Comparisons with the current experiment are difficult since participants had different levels of prior knowledge and we used also reading and links selection times as measures of CL, which a posteriori appeared as more sensitive to complexity variations than RTs. Unfortunately, the duration of the session in the DeLeeuw & Mayer experiment [32] was kept constant for all participants and therefore the results did not offer information on which component of CL could be related with performance time. Additionally, the authors pointed out some limitations on their study and they proposed replication with different learners and materials.

In spite of this lack of distinctive CL measures, in order to explore how reading strategies, CL and learning are related, the pattern of results on CL measures and learning measures can be analyzed. However, in this discussion we will exclude CL during link selection, focusing in CL during reading. The main reason to do this is that we did not obtain a clear measure of CL during link selection that could be used for the comparison, but it can be also argued that reading is the main task for learning with hypertext and therefore the effect of CL during link selection on learning could be overshadowed by the influence of CL during reading.

In line with prior research [18, 20], low knowledge participants that read the hypertext in a high coherent order - by following a coherence strategy - got lower cognitive load when reading and better comprehension than those in the interest condition (who read the hypertext in a low coherence order). This is a support for the idea that low reading text coherence leads to extraneous CL, at least with LPK readers. Conversely, the pattern of results on learning and cognitive load when reading for HPK readers was different: those participants in the interest condition (who performed a less coherent reading order) got higher cognitive load than those in the coherence condition, but they achieved the same learning outcomes than those using the coherence strategy. Contrary to LPK readers, HPK readers can get higher germane CL with the interest strategy by activating prior knowledge and investing extra cognitive resources in learning. Moreover, the coherence strategy leads to follow a high coherence reading order which would hamper the activation of prior knowledge and would lead to extraneous CL for HPK readers, but the active selection of the reading order in the coherence strategy helps them to avoid the shallow processing induced by high coherent texts. Therefore, it seems that for HPK readers there are a balance in the coherence condition between extraneous CL and germane CL, and a higher investment of germane CL in the interest strategy. This balance of CL components helps them to learn equally from both strategies.

Practical Implications

In the preceding sections we have argued that using different reading strategies affect differently cognitive load, and subsequently learning with hypertext. Thus, by determining which strategy is better for a certain level of prior knowledge it is possible to match readers and strategies to enhance learning. Following this argument we can draw two practical implications of this experiment.

First, novices learn better when they follow a strategy that maximizes text coherence. Indeed, some authors argue that, to maximize learning, linear text is a better instructional design than hypertext for low prior knowledge readers [18]. However, maximize learning could be not the only reason to use hypertexts instead of linear text, and ease of access, interactivity, teacher control or economic factors could also recommend the use of an educational hypertext. Under these situations, it is important to support the learner in reading the materials in a coherent manner. In this sense, McNamara & Shapiro [42] have proposed that it can be done with reading strategy training or including hypertext design features for user support.

Second, both low prior knowledge and high prior knowledge readers requires more time to perform an interest strategy. However, this increment is not related with a benefit in learning compared with the coherence strategy. Therefore, under instructional conditions in which duration is an important factor (e.g. educational programs defined on an hourly basis), to select a coherence strategy will be more time-saving.

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