Cognitive Aspects of Web-based Hypertext: An experimental approach

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Abstract: - This paper reports on a pilot study that is concerned with the cognitive aspects of reading in an electronic environment. The study focuses on text based electronic documents. A cognitive model for hypertext document reading proposed in an earlier work is here developed and validated with the use of think aloud protocols. The model is concerned with the general cognitive processes that take place during reading a hypertext. Navigational strategies that readers employ in hypertext reading and hypertext links' selection are also under study along with the effect of different reading goals on comprehension. The preliminary results from the think aloud protocols show that 100% of the task related data correspond to the components of the cognitive model, allowing us to conclude that the proposed model sufficiently describes the cognitive processes involved in hypertext reading. In addition, three navigational strategies are revealed, *linear*, *mixed*, and *mixed review*. The quantitative data show no significant differences between different reading goals on comprehension and on the amount of text read.

Key-Words: - Hypertext, Think Aloud Protocols, Electronic Learning, Locating Information, Text Understanding.

1 Introduction

The emergence of hypertext and the widespread use of the WWW have changed the way we approach information. An increasingly amount of information are delivered on the WWW and the time people spend to read online increased considerably. Understanding the nature of hypertext reading is vital in order to improve hypertext design, reading strategies, and users' performance in educational settings. It is also important in order to illustrate the full potential of the medium. But in spite of the increasing attention towards this area, there are still many questions unanswered.

Hypertext systems allow users to navigate between nodes that connect multiple units of information and select the ones they are interested in. This multilinearity [1] challenges the way people read information and even improves it according to some scholars [2-5]. However, empirical research in the field has shown little or no advantage of hypertext over traditional printed media [4, 6, 7]. Users, especially the novice ones, may experience disorientation and navigational problems while reading [8-10]. Besides, they may have difficulties following the overall structure of information and relating it to their prior knowledge or cognitive schemata [11].

One of the reasons that hypertext has not demonstrated its full potential as an information vehicle is the lack of understanding of the cognitive process that takes place during reading. Neither a general theory of hypertext nor a model of the cognitive process involved in reading exists [9, 11]. Much of the research has so far focused on design, engineering, and information retrieval principles [9, 12, 13]. Further, very little attention has been paid to strategies readers employ in traditional printed documents and hypertexts [14-16]. Wright argues that any model intending to account for reading process needs to incorporate reading strategies [14]. Additionally, cognitive processes have proved to be crucial in activities such as reading and searching information in an electronic medium [17].

Reading a traditional paper-based document is a complex process that requires a lot of effort and many cognitive recourses. Experimental work to date has been based on the assumption that reading takes place in a sequential manner from start to finish, first at a word level and then at a sentence level. Also, most of the documents used in studies were linear, paper based documents with a beginning, middle and end. Hypertext offers a different approach to reading. Readers can enter the presented information at any point, determine for themselves a path through the information and abandon the hypertext whenever they feel to do so. Hypertext challenges traditional models of sequential reading [3, 5]. Research has demonstrated differences between the electronic and paper media in reading at the psychomotor, perceptual, and cognitive levels [8]. Wenger and Payne [13, 18] argue that hypertext use depends on some additional types of processes that are not always important in linear text. There is need to investigate these cognitive processes in order to understand the nature of hypertext reading [19].

Research on the cognitive processes of reading traditional printed documents can assist us towards this direction. One of the most influential theories about text understanding has been proposed by Kintsch and van Dijk [20, 21]. In addition, theories about locating information in printed documents [22, 23] can assist us to discover how users locate information in hypertext.

Dillon [8, 24] proposed a framework (TIMS) to account as a representation of the human cognition and behaviours central to interaction between reader and document. The framework consists of four interactive elements that reflect the primary components of the reading situation. These elements are, “The Task Model (T)”, “The information Model (I)”, “Manipulation Skills and Facilities (M), and “Standard Reading Processor (S)”. As Dillon [8] points out this framework should not be considered the equivalent of a cognitive model of reading, rather as a framework intended to reflect the human aspects of performance during reading.

In a previous work [25], we proposed a cognitive model to account for hypertext understanding. The model describes the main steps a reader undertakes during hypertext reading and understanding. It combines aspects from Kintsch and van Dijk’s [20, 21] text comprehension model and Guthrie’s locating information model [22].

The purpose of this paper is to continue and expand the work on the cognitive model [25], by examining the strategies hypertext readers use, and study the influence that reading goals may have on them. Using think aloud protocols we were able to obtain rich and valuable data.

2 The cognitive model

The cognitive model is intended to account for hypertext comprehension. The model contains eight components, some of them interconnected to reflect the primary cognitive process of hypertext reading. Fig. 1 shows a schematic description of the components of the model, which are:

1. Formation of a goal or a task.
2. Scan and choose appropriate categories of information.
3. Read the categories of information.
4. Follow the appropriate path.
5. Repeat steps 2, 3 and 4 as many times as necessary.
6. Recycle if you fail.
7. Build the macrostructure.
8. Goal succeeded.

The first component of the model is the setting of the goal. The goal is either formed or given, depending on the aim of reading. If the main goal is complex, the reader could formulate sub goals. The success of the sub goals will gradually lead to the succession of the final goal.

The second component is to “scan and choose” the appropriate categories of information. The reader scans through the hypertext to select the appropriate categories of information in order to precede reading. Not all categories are relevant to the task performance, thus the reader must allocate the most relevant ones. This component is similar to Guthrie’s [22] inspection of appropriate categories, but it includes an additional scanning process.

Having selected an appropriate category, the next step is to read in order to extract the information that is relevant to users’ goal. They establish the local meaning of the presented information and build the microstructure of the document. Microstructure is defined as the restricted meaning of the text, and is narrowed down to the level of individual sentences and paragraphs [21].

The fourth component of the model contains the choice of a path continue, that leads to the rest of the information. The chosen path will most likely match the readers’ goal or sub goals, and coheres with the previously read information.

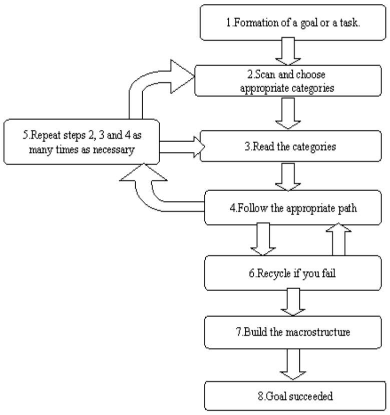

Fig.1 Hypertext model for hypertext comprehension

The next element of the model suggests that readers recycle through other paths or segments of the text, if the followed one is not the right one to accomplish their goal. If they failed to capture the meaning of certain fragments of information or if their understanding is not complete, they can go back and revisit/reread them.

In the sixth component of the model the reader is integrating the newly extracted information with previously extracted information, background information and information about the world. This integration leads to a comprehensive understanding of the presented information, the macrostructure. Macrostructure or situation model refers to reader's understanding of the situation and ideas described in the text. However, this understanding does not contain references to the text base of the text [20, 21, 26].

The last feature of the model is the succession of readers' goal. Having read all the information necessary for fulfilling their goal, readers are ready to proceed to any additional tasks that may be required, such as answering questions.

3 Method

This experimental study was undertaken using the think aloud method [27]. Even though there is some scepticism about this method and its effect, in the processes that are under investigation, it has been proven not to influence the reading process and to provide data that is difficult to obtain with any other method [27, 28]. In addition, the think aloud method has proven to reveal the contents of working memory during reading, which is a very rich source of data [29]. The experiment was a 3 by 1 between subjects, manipulating the reading goals. The reading goals were manipulated by providing different instructions about what they should read in the text.

3.1 Subjects

Eight students participated. All subjects were volunteers. Subjects were screened to ensure that they had not taken any courses in economics and had no reading disabilities.

3.2 Material

An economics paper [30] converted to a hypertext was used. Research findings on usable electronic texts and educational hypertexts were taken into consideration for its development [24, 31, 32]. The aim was to maintain the document format that is widely used in the WWW.

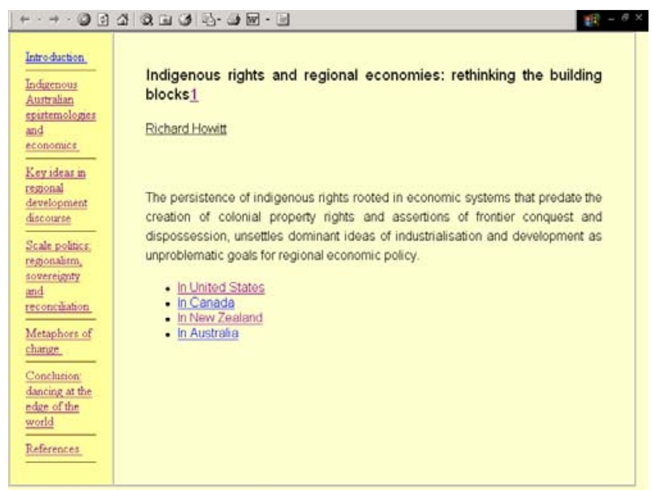

Fig. 2 An example of a hypertext node

The structure of the hypertext was based on the semantic structure provided by the author and it was converted to a hierarchical tree. Each section of the original document was converted to an individual node. A total of 24 nodes were created. There was a welcome page before the main document. A menu for navigational purposes was available at the left hand side of the document. Users had a choice of global and local navigational links. An example of the hypertext nodes can be seen in fig. 2, illustrating the different global and local navigational links offered to readers.

3.3 Procedure

Subjects were randomly assigned to one of three conditions: reading for answering specific questions, reading for answering general questions, and reading with no instructions. A personal computer was used to display the document. A tape recorder was used for the recording of the think aloud protocols. They were briefly told the aim of the study. They read the text until they felt satisfied that they can answer questions on the topic. Warm up exercises were given for practicing the think aloud method until they felt confident with it. After the reading task, subjects received the booklet with the recognition material. All subjects answered the same set of questions. Each session took about one hour to be completed.

3.4 Coding scheme

The coding scheme specifies how elements of the model can be identified in the data [28]. For every process described in the model, the types of statements referring to that process are described in the coding scheme. Nine coding categories were created in total. Six categories are derived from the model and three are "special" [28]. The six categories derived from the model are:

- goal or task
- scan and choose
- read/microstructure
- action
- recycle
- macrostructure

Segments that cannot be coded but do appear in the protocols reflect deviations of the model [28]. Statements allocated to the "read" category were literal reproductions of the information. Statements such as "I'll scan the menu to see where to go to", which indicate brief inspection of the information and choice of a path, were allocated to the "scan and choose" category. For the "action" category the expected utterances were: "I'll click on…" or "I'm going to move to…". The verbalisations that were considered as a match to the "macrostructure" category are reproductions of the information presented to the subjects, which do not represent a literal copy of the original text. Another indication of the "macrostructure" is when subjects produce relevant world knowledge in working memory and express it [33]. All the codes were assigned in a similar way and all the appropriate types of the expected statements were described. An example of a coded protocol can be seen in fig. 3.

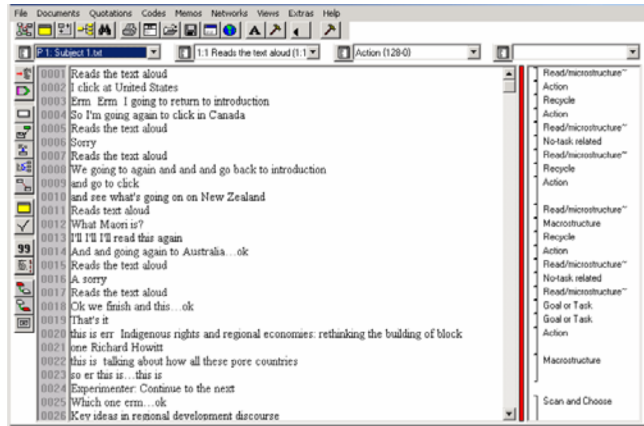

Fig. 3 Example of a coded protocol

Three special coding categories were created for verbalisations that are not covered from the model but may still be anticipated in the protocols. These categories are:

- no-task related
- meta-level evaluation
- comments on oneself

Statements such as, "I'm trying to concentrate on the first paragraph" or "I don't have a clue" were allocated to the meta-level evaluation category. They indicate evaluation of the task or task situation at a meta-level by expressing the understanding or the lack, of a particular phrase or word [34]. To the "no-task related" category the allocated statements were "Oh, must not forget to call…". Again, all the codes were assigned in a similar way and all the appropriate types of the expected statements were described.

3.4.1 Coding scheme evaluation

Essentially, coding entails assigning labels to think aloud protocols following the coding scheme. Making the coding scheme reliable an evaluation is necessary. Two coders evaluated the coding scheme and the correspondence between their coding was 95.6%. After discussion, the two coders reached an agreement about the segments that there was no correspondence.

4 Results

The primary data collected was from the think aloud protocols. The cognitive model and the reading strategies were validated by the think aloud protocols. The think aloud protocols were enhanced by observation and note-taking during the experimental sections. Reading times and answer scores were also obtained. To examine those results a one-way analysis of variance (ANOVA) was conducted.

4.1 Analysis of the cognitive model

To examine the cognitive components of the hypertext understanding model, an analysis of the relation of the coded protocols to the proposed model was performed. All the segments were assigned to a coding category. A total of 668 codes were produced, spread between the 9 coding categories. The number of codes produced by each subject varied from 46 to 134. The mean number of codes per protocol was 82.6. The three special coding categories were allocated with 24% of the codes that count for no-task related statements. These verbalisations often occur during the think aloud process. It is common to ignore cases like those, as they do not influence task performance [28]. Therefore, the analysis of the results was based on the 76% of the codes that refer to task related issues. Fig. 4 presents the codes assigned to each coding category.

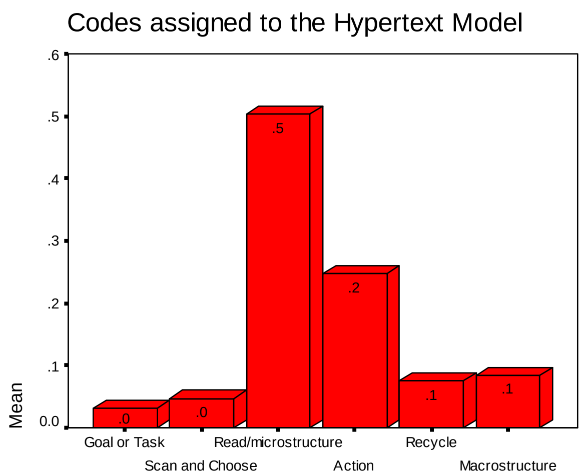

Fig. 4. Codes assigned to each model category

Overall 100% of the task related codes conform to the cognitive model. The majority of the codes, 50.3%, were classified as "read/microstructure", while the "action" category had the second highest percentage (24.8%). The "goal or task" category was assigned with 3.1% of the codes and the "scan and choose" with 4.7%. The "recycle" category counted for 7.5% of the codes and finally, 8.4% of the codes were classified as "macrostructure". There were no statements in the protocols that could not be coded in any of the coding categories.

The results confirm that the proposed model successfully describes the cognitive processes that take place during reading a hypertext. However, there were differences in the way subjects chose to read the hypertext in the initial stage.

Half of the subjects (50%) started reading the hypertext without scanning the document before, and instead they selected the first link that came across. The remaining half scanned the available links before choosing one to follow.

4.2 Analysis of hypertext reading times

The total time to read the hypertext was recorded. The mean time for reading was 26.6 minutes with a standard deviation of 5.3. There was no significant difference between the reading times based on the different reading goals ($F=.883$, $p=.469$).

4.3 Analysis of the hypertext comprehension

The comprehension was estimated through grading the multiple choice and short essay questions. One score for each subject was calculated. The maximum achievable score was 20. There was no significant difference in comprehension based on different reading goals ($F=.485$, $p=.642$).

4.4 Analysis of navigation

The purpose of the analysis of the subjects' navigational patterns is to investigate the strategies readers use while reading in hypertext. Furthermore, it permits examining whether the goal manipulation caused differences in strategies used by the subjects.

4.4.1 Navigation strategies

The analysis of the think aloud protocols revealed three strategies. First, a *serial* or *linear* strategy, where subjects read the hypertext in a linear manner, following the "predefined" order. In other words, subjects followed the first link they came across without scanning the document to see what other links were available. Fig. 2 shows an example of hypertext nodes and the available links. For instance, subject number 5 produced the following verbalisation:

"I'm gonna go for United States first
Ok
Reads the text aloud
All right I'm gonna read that again
Reads the text aloud
Press Canada
Reads the text aloud
(pause)
New Zealand just click on New Zealand"

The subject selected the first link presented and as soon as he/she had to select another one, the subject again selected the first link presented. This pattern was applied throughout the document.

The second strategy that readers used was a *mixed* strategy. Readers chose some links in a linear fashion while others in a random fashion. An example of subject's verbalisation using this strategy is given below:

"I click on the other hand
I don't think is working (the link)
(muttering…unidentified reading) (goes to metaphor of change)
Reads the text aloud
"In particular, admission that indigenous peoples are genuine stakeholders in the arena of regional economic activity -- their transformation…"
I don't gonna read any other than that
Conclusion dancing at the edge of the world…
I look that next
It doesn't work (the link) aa
Conclusion dancing at the edge of the world
it sounds interesting
see what is at the bottom of the page, nothing
it's got links to some (short pause) writers (pause)
I see what they've write about I click on Le Guin
Aa just references to books"

While this subject had started reading the text in a linear fashion, after a while started jumping to different hypertext nodes without following any presented sequence, trying to find the information he/she was looking for.

The third strategy is rather more sophisticated, the *mixed review* strategy. Review because subjects first scanned the document to see what links are available and then chose one to proceed with. Mixed because they chose to follow links sometimes in a linear and others in a random fashion. An example of verbalisation that indicates this strategy is:

"Sorry I'm just curious about Australia
because that's were I'm from
Reads the text aloud
Ok I'm just gonna compare it to New Zealand
Reads the text aloud
Just to see Canada
Reads the text aloud"

While in another phase of the reading produced:

"I'm actually quite taken by these Metaphors of change
"Scale politics, regionalism, sovereignty..."
so I feel already sort of got some ideas of what the politics is
so I'm just gonna have a look of Metaphors of change
Reads the text aloud"

The first example shows the subjects selected links in a non sequential manner, while the second verbalisation presents a change to a sequential manner, because the links in the second example are presented in a sequence.

Strategies were not affected by the different reading goals. Subjects with different reading goals used different strategies.

4.4.2 Factors influencing navigation strategies

One of the most common arguments in favour of hypertext over traditional printed documents is the freedom and flexibility that offers users to construct their own sequence of information. However, there is no extensive study on the factors that influence this choice. Foltz [35] has shown that one factor that influences readers choice of link in hypertext is coherence. He also found that readers made 80%-90% of their transitions in coherent manner. Carter [36] points out that "in hypertext, coherence must be felt no matter in what sequence the text is encounter" (p.90). The notion of coherence is very close to what Landow [37] and Zellweger [38] refer to when they insist on the necessity to help readers' to discover the relation between the source and the destination of a link, and Tosca [39] calls it the bridge metaphor.

The results show that another factor that influences readers' choices is personal interest. For instance one of the subjects gave the following verbalisation on choosing a link about New Zealand: "I click on New Zealand, I am from New Zealand that's why I pick New Zealand". Another subject gave a very similar explanation on choosing another link relevant to Australia: "Sorry I'm just curious about Australia, because that's where I'm from". In both cases the reason for choosing a particular link was related to social factors.

Similarly a third subject mentioned: “Rick Coledge grab my interest…”, and in the same vein said: “reading each title in terms if anything grabs my interest”. There is no justification why the subject’s interest was grabbed on that information or what she/he was looking for in the text. However, it is clear that interests are having a significant effect on reading processes. Scholars suggest that there is a need for more systematic focus on interest and motivational factors - in reading in general and in hypertext environments in particular [40].

However, for the majority of readers the “predefined” sequence of the links seems to be the determinant factor for choosing a hyperlink. Users tend to select the first available link. A possible explanation for this can be the lack of relevant schema referring to hypertext reading and navigation. Similarly, Dillon [8] argues that the lack of standards in electronic documents development means that readers can not acquire skills from one document that could be valuable during the use of another. In addition, Nielsen [41] points out that readers do not read on-line, instead they scan the document picking up individual words and sentences, and printing it out. Nevertheless, this tactic does not allow them to develop the necessary cognitive schema for hypertext reading and may affect the strategies they employ during reading. Moreover, in order to overcome this deficiency readers tend to apply strategies borrowed from reading in traditional paper documents. Troffer [42] argues, for example, that readers feel comfortable with hierarchical structure because many print texts are organised this way. Researchers have argued that in order to improve hypertext performance and reduce readers dissatisfaction and disorientation, structures should be borrowed from traditional paper texts [43].

4.4.3 Amount of text read

Another indication of the readers’ strategies is the amount of text read. A page was clearly identified as “read” from the think aloud protocols when subjects produced literal copies of the information. The results showed no significant difference between the amount of text subjects read on different goals ($F=2.239$, $p=.202$).

5 Conclusion

The analysis of reading times and comprehension showed no significant differences between conditions. Reading conditions neither affect the time subjects spend on the document nor their comprehension. Foltz [44] has obtained similar results in his study of readers’ comprehension and strategies in linear text and hypertext. On the other hand, one can claim that the lack of any significant difference between conditions on reading times and on comprehension could be due to the small number of subjects.

The results showed that 100% of the task related codes generated by the protocols correspond to the model’s components. Moreover, neither unpredicted processes occurred from the protocols nor the model predicted any processes, which have not been in the protocols. Despite the fact that there was a difference in the way subjects chose to start reading the hypertext, the results strongly suggest that the proposed model accommodates the cognitive processes taking place during hypertext reading.

The qualitative analysis revealed three navigation strategies. Readers used a “linear”, a “mixed”, and a “mixed review” strategy. Reading strategies were not affected by different reading goals as subjects with different reading goals used the same strategies. This was also implied from the quantitative results on the reading times and the amount of text read. Subjects read approximately the same amount of nodes for approximately the same time, so their navigational patterns could no be distinctively different.

The strategies used by the subjects in the present study appear to be similar to those used in traditional paper based documents [35, 45, 46]. Hypertext readers seem to borrow reading strategies they are familiar with by their use of paper documents.

In concluding, this paper proposes a cognitive model for hypertext comprehension in order to facilitate the construction of hypertext systems. A cognitive model of information processing can have direct implications on hypertext systems [47]. More precise, findings about the processes required for reading in hypertext could assist hypertext authors, developers, and educators to improve electronic documents. For instance, it can offer information on the best way to structure electronic documents to facilitate users understanding. In addition, the exposure of the factors that influence link selection could provide guiding principles on the most efficient way to link information to each other. The outcome of this study suggests that the model succeeds in accommodating the cognitive processes taking place during hypertext reading.

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