Cognitive economy strategies employed during information seeking in a hypermedia environment: A qualitative analysis

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ABSTRACT
Information search in hypermedia system involves several cognitive resources, which can lead to a cognitive load. We observed the user navigation behavior during information seeking tasks in a hypertext environment. In this paper, we present qualitative results about navigation strategies employed in information seeking in order to reduce the cognitive load caused by the task and the interface.

Categories and Subject Descriptors
H.1.2 [**Models and principles**]: User/Machine Systems– *Human factors, Human information processing.*

General Terms
Experimentation, Human Factors.

Keywords
Information seeking, hypermedia navigation, cognitive load, cognitive economy.

1. INTRODUCTION
Hypertext navigation was defined by Dillon [1] as a dual task needing both semantic and material processing required by manipulation of the interface. Since the 1980s, numerous studies have shown that spatial visualization abilities are involved in information search in a hypermedia environment [2]. Prior knowledge is a factor, which has an equal influence upon interaction with the interface [3]. Several cognitive resources are therefore mobilized in order to successfully achieve a navigation goal.

Indeed, the user must understand the semantic content presented in order to assess whether or not it fulfills the navigation aim. At the same time, he builds up a mental representation of the structure of the interface, in order to be able to plan his navigation (that is to say to know where he has already been and where he might go next). Rouet and Tricot [4] argue that the user also has to construct a mental representation of the strategy he wants to use to find information. The complexity of these tasks can create a cognitive load [5] which is adverse to the success of information seeking. That load is often responsible for the feeling of disorientation which the users might feel when they do not succeed in carrying out a task in an interface [6].

Within the framework of a much larger study [7], we observed subjects' navigation in tasks involving the location of information. We are going to present a section of the results we have gathered here and focus on the navigation strategies employed in order to reduce the cognitive load caused by the task and the interface. These observations come from qualitative analyses of the strategies developed by twenty-four subjects to navigate a hierarchical hyperdocument designed for the purposes of the study [7]. This article therefore presents four navigation behaviors employed by the users in order to reduce the cognitive load caused by the navigation task.

2. Mental representation of environment
The human brain is capable of mentally representing an environment which is far too large to be seen from one viewpoint alone. Edward and Hardman [8] show that hypertext users construct a representation of that environment as they would for a physical environment (such as a town for example). Rouet et al. [9] show that individuals assimilate the structure of the hyperdocument they are trying out and are capable of reproducing it more or less exactly after the navigation (according to the level of their visuospatial abilities). Dillon [1] maintains that perception of the informational environment is always based (regardless of its size) upon physical and semantic properties. This dynamic combination of spatial and semantic information forms what Dillon refers to as Shape, that is to say, the mental model which the hypermedia user construct of the informational space he is trying out [1]. This mental construction of the environment is the result of cognitive collages of mental images which we build up in order to deal with a particular task [10], [11] and which are integrated to form a whole. These representations are fragmented, placing the parts of the environment we show ourselves end to end. They are hierarchically encoded [12] and certain parts can be highly detailed while others might not be. These mental representations are therefore biased in relation to the real environment, but these biases can be beneficial as they allow for a simplified cognitive construction, reduced to concentrate upon the elements, which are relevant and necessary to completion of the task.

3. Cognitive load theory
Sweller [5] proposes the cognitive load theory as an explanation for failures in learning. The working memory's limited capacity [13] can suffer from cognitive overload when processing a task which is too complex. In cases where information is searched in a hypermedia environment, this load can be due to several factors; the complexity of the seeking task (intrinsic load), the complexity of the semantic content (intrinsic load) or the complexity of the

interface itself (extraneous load). These loads can occur simultaneously. The cognitive load due to the hypertext navigation has been studied for many years [14]: the hypermedia interface results in a cognitive load which, in certain situations, causes a feeling of disorientation and urges individuals to make particular navigation choices, such as using the back button.

We believe that establishing strategies such as using the back button might be a means of managing the cognitive load inherent to the task and the device, so that it is not too cumbersome. The individual choses strategies allowing him to lighten the cognitive process. These cognitive economy strategies allow the user to complete his task successfully without overloading his working memory. The individual can move forward in the task while sparing his cognitive functions.

4. Experimentation

We created a 45-page hypertext, structured in three hierarchical levels and containing transverse links. The semantic content related to animals, was presented like an encyclopedia and organized according to the continents on which the animals evolve. A non-clickable site map could be accessed from any page, via a tab.

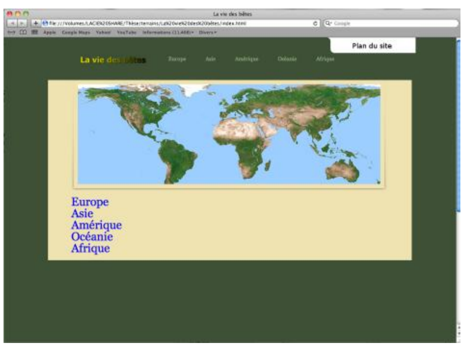

Figure 1. Home Page

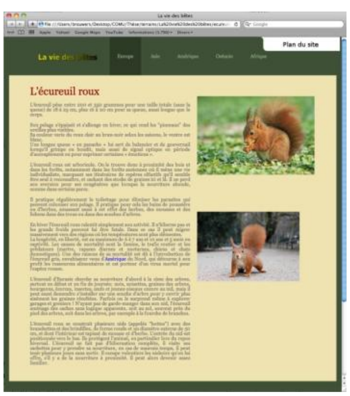

Figure 2. Animal Page

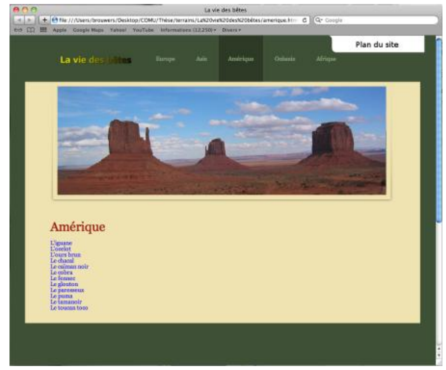

Figure 3. Continent Page

We observed the navigation of 24 subjects, fifteen women and nine men all university graduates, aged between 22 and 30. We asked them to locate seven pieces of information in the interface. The first two questions, as well as the final four questions, were characterized by the fact that the individuals knew what they were looking for. For example; how much does the giant panda weigh? The participants had to find the panda page and read the information they found there in order to be able to respond to the question. The third question (One omnivorous animal's young are nicknamed "*bêtes rousses*", which animal is this?), on the contrary, did not state on which animal's page the information would be found. The participants were in a situation where they did not know what they were looking for.

We asked the subjects to verbalize their actions while navigating. The subjects' navigation was registered thanks to the Morae software suite which enabled the gathering of videos of the navigations, but also, the number of clicks, the number of pages visited and the time taken to complete each task.

4.1 Data processing

We watched all the videos and coded each navigation behavior. Identical behaviors were quickly observed in several individuals. Using these behaviors, we have constructed indicators which allow us to detect a strategy or the effect of a capacity. This coding was carried out using Nvivo software.

4.1.1 Indicator and cognitive economy strategies

4.1.1.1 Mental representation indicator

The Mc. Donald et Pellegrino [15] model maintains that direct experience of the environment, what they refer to as primary learning, allows the individual to acquire spatial knowledge enabling him to construct a mental representation of the environment. In this way, a prolonged experience of the system allows the user to construct a representation of it for himself. We defined an indicator to tell us whether the subject had been able to construct a mental representation of the interface. This indicator is the number of tasks which the subject was able to complete effectively (by directly clicking on the correct page) out of the final four tasks. We chose the final four tasks because task three was defined by the fact that the individual did not know what he was looking for. A large number of the participants therefore navigated all over the interface and thoroughly experimented the system, which, according to the Mc Donald and Pellegrino [15] model, allows a mental image of the interface to be constructed. This indicator therefore allowed us to identify the subjects who were able to construct a mental representation of the interface, by observing whether they were able to find the correct location for the four final pieces of information searched, without making an error (clicking on an incorrect page).

4.2 Observed strategies

We believe that an individual can put strategies in place in order to manage the cognitive load inherent in the task so that it is not too cumbersome. The individual choses strategies allowing him to lighten the cognitive process. These cognitive economy strategies allow the user to complete his task successfully without overloading his working memory. Here we are going to present four navigation strategies which we have interpreted as cognitive economy strategies.

The most frequently observed economy strategy is systematic navigation (observed in 13 of the 24 participants): from a continent's page, they click on all the referenced links in turn and then move on to the next continent until they find the information. This strategy is extremely undemanding from a cognitive point of view since it means that the individual does not have to contemplate making a choice. It is rather the interface which makes the navigation choices, so the individual can concentrate on the semantic content provided to him in order to locate the information he is looking for.

Among the individuals who chose to undertake a systematic navigation we also observed that some used the back button, even though when they knew what they were looking for or were exploring the environment (i.e. that they are performing additional navigation with the aim of having an idea of how the interface is organized), they navigated using the continent tabs directly. Use of the back button has often been categorized as an indicator of inefficiency or disorientation [16]. Just like Tauscher et Greenberg [17], we believe that this kind of navigation behavior is more an indicator of management of the cognitive load. In fact, using the back button allows the user to avoid burdening his memory with the location of the page he is consulting. It is sufficient to go back, and to click on the link which follows the one he has just visited. Furthermore, we noted that these individuals are not aware of the structure since when they visit the final link suggested on a continent's page, it is only when they click the back button and see that they have clicked on all the links that they then move to the next continent. We observed that these individuals had not constructed any representation of the environment at all via primary learning [15]. Indeed, these participants were not able to find the four final pieces of information without making mistakes which, in our view would have been possible if they had constructed a mental image of the document's structure.

Among the subjects who had not constructed a mental representation of the environment (on the basis of their capacity to find the four final pieces of information without making an error), we find subjects who decide to return "to the beginning" when they do not find the information they are looking for. The fact that they have a concept of the "beginning" is a reference to a basic or partial mental representation of the interface. In fact it is an answer to a precise function: to be able to return to a point of reference from which a new strategy can be implemented (such as a systematic strategy, for example). This partial representation allows the cognitive load to be lightened. These individuals know that once they are "at the beginning" they can plan a navigation choice.

Finally, certain subjects directly consult the (non-clickable) site map while others prefer to browse the continent tabs, without clicking on their content, purely in order to have a view of the entire structure of the interface. Consultation of navigational tools allows a global view of the environment but most of all an externalization of the interface representation, which avoids the need to remember it.

Certain strategies can be combined. Of the nine participants who consult a navigational tool, four opt for systematic navigation at any moment. Likewise, of the five subjects who decide, during the navigation, to "return to the beginning", four then decide to undertake a systematic navigation. Nevertheless, the strategy of "returning to the beginning" is almost never (save in the case of one subject) combined with the strategy of consulting a navigational tool. The users are more likely to choose one or the other.

5. Conclusion

During information seeking in a hypertext environment, the individual faces a dual task, both material and semantic [1], which can lead to a cognitive load and a feeling of disorientation [6]. We observed the navigation behavior of 24 subjects in a hyperdocument designed for the purposes of our study. Hence, our results need to be considered carefully. The qualitative analysis of information seeking by our subjects has allowed us to identify four cognitive economy strategies; systematic search, using the back button, returning "to the beginning" and using external representations of the environment. It is important to emphasize that these strategies aren't always indicators of lostness and that they can allow the users to successfully complete a task without burdening their memory with an overly cumbersome mental representation of the interface. Although these observations come from a small sample of subjects using a specific interface, which precludes any premature generalization of our results, the typology of the four strategies of cognitive economy appears to be an interesting frame for larger subsequent analyses in other interfaces.

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