Why should we use Eye Tracking for Hypertext Design?

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1. Introduction

Information is very much an important concept of the 21st century and an important resource in our society. Currently electronic media, for instance hypertext, plays an influential role in the distribution and storing of information. Hypertext is an electronic text that allows users to navigate through an information space by using electronic links included in the text.

It can't be denied that hypertext currently holds a great fascination. At the present time, much specialized knowledge is being offered in media form, as media learning programs. The World Wide Web itself can be seen as a gigantic hypermedia system where different media such as text, sound, and film can be connected to each other through electronic links. The number of registered Web sites has risen above the three billion mark according to "Google" (http://www.google.de/). In January of 2003 according to NUA, a source for internet trends and statistics, more than 605 million people worldwide were online (http://www.nua.ie/surveys/). These numbers show the importance of hypertext for the distribution and storage of information. Information can be flexibly linked with hypertext, making it easy to activate and, with the available software, easy to access. Hypertext acts as network-like information storage and meets our society's need for information.

A problem in the structuring of hypertext is that barely adequate rules exist for the design of hypertext. Many standards are enforced by the market (Nielson, 2000). Design errors, how it should never be done, are currently described more differentiated and thoroughly than positive design maxims (http://www.useit.com/alertbox/; http://www.karzaunikat.com/Goldhtml/). Therefore, the aim of designing hypertext is to develop criteria for a user oriented information presentation.

2. Problem of Disorientation in Hypertext

A still unanswered question is how hypertext based information units should be presented and structured. Almost everyone has had the frustrating experience of totally losing his or her orientation in a hypertext system or not being able to handle the navigation help. Disorientation is one of the major problems that hypertext readers experience. Readers of hypertext cannot find the information they seek. They have difficulties getting an overview of the material, they don't know where to go or where they are (Edwards & Hardman, 1989). Disorientation has a negative impact on the effective usage of hypertext systems. First of all, the huge volume of information on the Web is one reason for the occurrence of orientation loss. A second reason is the still unsatisfactory navigational support provided in hypertext. Above all, in association with hypertext the user has more freedom to navigate the information, which also infers added cognitive cost through structuring work (Lacroix, 1999). The user, when he is maneuvering through hypertext, has to master two tightly intertwined tasks. For one, he has to understand the presented content. For the other, the user must navigate through the text to get to the relevant information since the information in hypertext is divided into different text nodes. Besides the comprehension task, the task of navigation and orientation within the text must also be mastered (Waniek, 2002). The processing of one task interacts with the processing of the other task. Naumann, Waniek, & Krems (2001) report in a hypertext study that orientation problems correlated negatively with participants' knowledge acquisition. The more orientation problems occurred the less knowledge participants could acquire.

In the individual reconstruction and interpretation of Internet supported information, the individual inference processes must be performed with more strength and in turn, cognitive resources are more intensely required. The simple transfer of information from the printed to the digital form is for this reason unsatisfactory. With regards to the characteristics of new media, new forms of text organization, processing and supplementation need to be developed.

3. Cognitive resources

The interaction of the navigational task and the comprehension task could be repeatedly found in hypertext studies (Moeller & Mueller-Kalthoff, 2000). Thus, the question arises what role do cognitive resources have in hypertext environments. The users' cognitive resources must be divided for the processing of both tasks. However, the availability of cognitive resources is restricted. Therefore, the assignment of cognitive resources plays an important role for the successful processing of both tasks. Baddeley (1986) describes in his working memory model a central executive which is responsible for the assignment of cognitive resources. The central executive manages the assignment of cognitive resources depending on task requirements. A balance must be established between the demands of the task and the cognitive resources of the user. The more cognitive resources are required for a specific task the less cognitive resources can be provided for the processing of a parallel task. As a result of that, the comprehension task will be affected by the navigational task when reading hypertext.

A problem for the design of hypertext is that the course of cognitive processes is still unclear. The cognitive demands that the hypertext system imposes on the user should be analyzed in order to better the unity of man and system (Norman, 1987). The user must process the information offered in hypertext in order to judge correctly the state of the system, to plan his actions and to be able to control the system. In the information search in hypertext the user chooses the link, for example, because he expects this link to lead to the appropriate information and he must be able to calculate if the task has been accomplished or if the search must continue. In order to work effectively with the hypertext system the user must be able to understand how the system is structured. He has to have an adequate mental representation of the system. At the same time, the hypertext must be so designed that it supports the user's cognitive tasks (Williges, Williges & Elkerton, 1987). Above all it is influenced by the manner information is presented to the user. Furthermore, the hypertext should be so designed that the cognitive demand is reduced through a reasonable interplay between the demand on the user and the user's cognitive abilities (Muthig, 1990).

4. Eye tracking

The cognitive processes which are involved in using hypertext have to be taken more into consideration in research in order to understand how users handle the given information and to adjust the design to the needs of the user. For this reason, the usual offline assessments, such as knowledge tests, must be complemented with on-line assessments. In most studies, the user is asked about hypertext after he has immersed himself in the text. Often the users' subjective assessment does not concur with their actual performance. In addition, offline assessments are often too inexact to reveal the difference between user strategies and design advantages (Fukuda, 2002). Offline assessments are too undistinguishing and do not allow for exact inferences about which hypertext elements support the user and which information provided is ultimately used by the user. The recording of log-file protocols is one possibility for obtaining more detailed behavioral data of the user. Though the user's navigational path can be reconstructed, his or her reason for choosing a specific navigational strategy is not made clear. It happens quite often that users do not take the shortest route to the information he or she was seeking, because the user could not find the appropriate link or navigational button. Users easily overlook graphics used as links or text links which are not displayed in the standard link colors.

Since the information tasks in hypertext are exclusively visual, it seems natural to analyze the eye-movements of the user when using hypertext. When a person uses a computer the person's eye-movements convey a continual stream of information about his or her mental state. The study of eye-movement patterns delivers a contribution to the understanding of how information in the visual environment is actively acquired and represented (Underwood & Radach, 1998). Eye-movements are valid data and can show how users deal with the given information; which parts of the provided information are actually used and if there exist special viewing patterns when acquiring information in hypertext. With this data, conclusions could be made about the effective presentation and structuring of information in hypertext. Also, problems can be avoided that arise in the recording of offline data.

Furthermore, the recording of eye-movements should move beyond merely asking where a person's eyes are focused, but aim to infer high-level behaviors from observing various patterns of eye-movement. Therefore, connections between behavior data (eye-movement and navigational behavior) and subjects' performance should be investigated. A main question here is, how far does the observed online data correlate with the performance and the subjective assessment of the subjects? Can eye movement data provide reliable predictions of users' performance?

An important point should not be forgotten when analyzing eye movement data for hypertext design: not every object that is looked at is also processed cognitively. On the other hand objects that are not directly fixated can also be comprehended. Also, peripheral vision does take in information; especially graphics and photos can be absorbed without eye fixations registering. Therefore, special care needs to be taken when interpreting eye movement data.

5. What can be analyzed?

The analysis of eye movements takes time, but it is worth doing. The cost of analysis can be much reduced by a homogenous design of pages. Since most analysis software cannot yet deal with scrolling, the scrolling of pages should be avoided.

Each hypertext page should be divided into several regions of interest in preparation for the eye movement analysis. Afterwards, the dwell time, amount of fixations, duration of fixations and amount of refixations can be analyzed for each region separately. These data allow conclusions about the interest and the attention directed at a specific region or object. Besides these summarized data, eye movement data facilitate the analysis of the process of information acquisition. The scan path reveals information about the order of viewed objects. Conclusions about the occurrence of orientation problems can be drawn on the basis of specific eye movement patterns. For instance the overlooking of relevant links or navigational aids or search patterns with repeated refixations can be an indication of users' disorientation. In some research context it is also of interest which object or which region is viewed first when a new page has been opened.

Eye movements have already been examined in a few hypertext studies. Results show that hypertext pages are usually looked at very briefly. Readers spent less time reading the pages than would be necessary for a full comprehension of all the presented information (Scott, 1993). Hence, this information was not regarded with the necessary attention. Scan paths reveal that many readers need a longer orientation phase when they encounter a page for the first time. Important navigational aids or buttons were often not found or were only found with great effort (Fukuda, 2002).

As has been argued before, usability questions do concern the cognitive demand made by the system on the user. The attention given to the processing of specific tasks, such as the reading task and the navigational task, are of particular interest. The comparison of dwell time, number of fixations and duration of fixations between actual text and navigational aid provide data about the assignment of the users' attention. Naumann et al. (2001) compared eye movement data at navigational aids and at the actual text in a hypertext condition with a linear text condition. Participants spent more time for navigational aids in the hypertext condition than in the linear text condition. At the same time, participants spent less time for the actual text in the hypertext condition than in the linear text condition. The navigational aid in the hypertext condition was cognitively more demanding on the user. Interestingly, users did not compensate for this higher demand but assigned less attention to the actual text. Active and passive navigational aids were compared in a further hypertext study

(Waniek, Brunstein, Naumann, & Krems, in press). The navigational aids were presented parallel to the text. Participants had to use the navigational aid actively for navigation within the hypertext in the active condition. Participants had to use links embedded in the text in the passive condition, so that the passive navigational aid supported only the users' orientation within the text. Eye movement data could show clearly the higher demand made by the active navigational aid compared to the passive navigational aid. In addition, participants experienced more orientation problems in the conditions which put a higher cognitive demand on the user. Beyond this, orientation problems and knowledge acquisition correlated negatively. The more orientation problems occurred the less knowledge could be acquired. The observed eye movement data support the assumption that users' cognitive resources have to be divided for the fulfillment of the navigational task and the comprehension task. The more demand is made by the system on the user the more affected is the users' performance.

Summarizing, it can be said that navigational aids should guide and support the user instead of putting an even higher cognitive load on him or her. Navigational aids must be easy to understand and easy to use. The design of navigational aids has to have the goal to establish a balance between the cognitive demands of the system and the cognitive abilities of the user. The task of navigation and of comprehension should form a unit. Therefore, aspects of text comprehension must be considered when designing navigational aids. The navigational aid should reflect the thematic structure of the hypertext. Semantic relations of the content of different hypertext pages can be mirrored in the arrangement of items in the navigational aid. For example, the spatial array of items expresses the semantic relatedness between topics, with items being close together in the spatial array or far apart (Wickens & Hollands, 1999).

6. Conclusion

In order to analyze the visual and cognitive information processes in hypertext, the user's eye movements should be recorded. These eye movements convey a continual stream of information about the mental state of the user. When human cognition necessary for the handling of hypertext is better understood, then the course of the cognitive process could also be adequately supported by the appropriate information design. A balance has to be established between the cognitive demands of the system and the cognitive abilities of the user. It should be investigated whether or not information that is dependent on the task should be presented differently, if the information design must be tailored to the user and, if there are forms of information presentation that generally assure an effective handling within the hypertext system.

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