

An Innovative Way of Understanding Learning Processes: Eye Tracking

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Abstract. This paper aims to present findings on the use of eye-tracking technology as a new approach from an educational perspective. The studies in this paper on relationship between learning and eye-movements have focused on concept-map formation, learning from multimedia materials, designing materials with different cognitive strategies, multimodal comprehension of language and graphics with and without annotation, computer games and cognitive style effects of computer based interfaces and hypertext environment. The results of the Middle East Technical University (METU) Human Computer Interaction (HCI) research group's eye-tracking based research studies presented and discussed how this approach helps educators to better understand learning processes of humans. Understanding and using this innovative approach is important for both educators and researchers in terms of comprehending learning processes deeply.

Keywords: Eye-tracking, web based learning processes, concept maps, computer games, learning from multimedia.

1 Introduction

Understanding learning processes is still a divisive issue for both researchers and educators. Since the main element in the learning process is “human” and learning process is affected by many factors, researchers are still struggling to find out new techniques for understanding the learning process deeply which may enable them to look from different lenses. At this point, eye-tracking is a new approach that it provides powerful ways of understanding the learning process. Research studies on eye-tracking provide a considerable data on the potential understanding of the cognitive processes of human beings [1; 2; 3] and there occurred theories and hypotheses related with this view as theory of reading with establishing a perspective with using the fixation to comprehension [4] and “eye-mind hypothesis” which deal with the positive relation between the eye behavior and thinking has become an important issue for the researchers [1]. Using these kind of techniques are important since it enables a respectful perspective for researchers that the literature reveal the potential of eye-tracking in terms of the understanding the cognitive processes. The relationship between the eye-behavior and memory in terms of giving clues on learning of the human is become inspiring for the researchers. Moreover, eye tracking has the

potential to give a broader perspective for the researchers providing both application opportunities and the different analysis techniques.

This paper aims to provide information on this new and innovative approach from an educational perspective. Our studies on learning and eye-movements have focused on concept-map formation, learning from multimedia materials and computer games. The results of eye-tracking based research studies [5] were presented and discussed how this approach may help educators to better understand learning processes of humans. Understanding this innovative approach is important for both educators and researchers in terms of comprehending the learning process deeply by using its new techniques.

1.1 Related Eye-Tracking Studies

There are many studies which were conducted by using eye-tracking approach. Eye tracking approach gives researchers opportunity to collect information on user behavior in definite tasks. This device also provides researchers various data related with the user through the process of task; task completion duration, transition number, fixation count, average fixation duration, time to first fixation, hotspot, fixation order, gaze time and gaze replay data [6].

Under METU HCI group, eye-tracking studies have been done by using a usability laboratory environment. Baran, Dogusoy and Cagiltay (2007) conducted an eye-tracking study to understand how adults solve Tangram (Chinese puzzle) based geometry problems [7]. The sampling of this study consists of twenty participants. To analyze the problem solving process, the eye movements of the participants were recorded while they were working on two problems with different levels. The results showed that the participants use different strategies to solve problems given in two different difficulty levels. The researchers indicated that there might be relationship between the task completion duration and the difficulty levels of the problems. Moreover, eye-tracking device enabled the researchers to use the Area of Interests (AOI) option to determine different areas on the screen and these areas were used while analyzing the users' behaviors. In this study, the AOIs were used by dividing the screen into two parts (geometric object screen-the objects given in this screen and problem screen-the solving process is eventuated) in order to determine the different behavior patterns of the participants in problems with two different levels. The researchers argued that there is a relation between the problem complexity level and the focused place on the screen. The participants tended to focus on the problem screen rather than the geometric objects screen. This was explained by the researchers as participants used both inductive and deductive strategies for solving the problems with different levels. This study have potential in terms of giving beneficial clues to educators both using different strategies and support the learners in the development of strategies for solving the problems in different difficulty levels.

User analysis is an important issue for instructional designers and in another study the main issue which was explored is the presumptive effects of cognitive style on the interaction ways while using computer based interfaces [8]. Since cognitive style is frequently researched issue by the researchers especially the potential influence of cognitive style on the interaction with interfaces, they grouped the participants by using Cognitive style test, Group Embedded Figures Test (GEFT) and they were

informed about the process. The process includes studying the predetermined web site and after that the participants were required to take a test about the web site content. The results showed that although there wasn't a statistically significant difference between the participants in terms of the eye-tracking data, there were differences between the two groups in terms of the fixation duration and fixation places. It was suggested by researchers to study with wider groups and using think-aloud protocol during the process, studying the website in further studies.

Another eye-tracking study was related with the multimodal instructional materials and the behavior of the users was conducted [9]. The main purpose of this study was to investigate the potential effects of the instructional environments which were designed by using multimodal information on the participants' behaviors. Fifteen participants' behaviors were recorded and their eye movements were analyzed by using eye-fixation counts and durations. The researchers indicated that the participants used both slide and video presentations in the study. Also, the participants much more focused on the video screen than the slide presentation screen which was obtained from eye-fixation duration data. They suggested replicating the study by using different combinations of the slide and video materials, that it might be possible to offer effective designs for this kind of instructional materials.

Eye-tracking is used as a beneficial approach in terms of observing the general patterns of the participants while completing a specific task. In another study, this approach is used for observing the general pattern of the prospective teachers during the concept map construction [10]. With the aid of eye-tracking device it was aimed to determine whether there was a general pattern among the participants while developing a concept map. Especially the focusing time on concepts, links and cross links were explored. Also, the quality of the created concept maps was considered while analyzing the eye-tracking data on process. Sixteen prospective teachers attended this study from the science education related departments. The results showed that the participants tended to develop hierarchic concept maps, and synchronize strategy while writing the links and concepts. The researchers indicated that with the aid of this study, it may be possible to give some hints to teachers about the effective use of concept maps and their construction process.

Usability is a crucial issue in education that design process is directly affected by the usability related problems. In another research study, the main aim was to gather information on the issues related with the computer games especially usability aspect with the aid of eye-tracking device [11]. They used a computer game which was not familiar for the participants and tracked the behaviors of them during the learning process of a new game. Sixteen participants attended to the study. The researchers pointed that they used not only quantitative but also qualitative methods. Eye tracking approach provided information related with the fixation number, total duration and gaze time of the participants. In addition to this, the comments of the participants were taken for determining the main usability issues related with game. Researchers explained that during the learning process the participants tended to use a trial and error approach. Although there were no gender and level differences among participants in terms of education effect on participants' learning process, the participants marked many usability issues related with the game. Also, they emphasized that the game should be re-designed with the aid of the information gathered from the users.

The researchers in another study aimed to investigate the cognitive style effects on navigation patterns during an interaction occurred within a hypertext environment [12]. The sampling of this study consisted of twenty participants and they were grouped with the aid of the Group Embedded Figures Test (GEFT) and also the knowledge and ability of the participants on computer was another factor. A pre-determined task was given to the two groups (Field-dependent and field-independent) and they were asked to navigate within a hypertext environment. Data was gathered by using eye-tracking device; the fixation duration and gaze points of the participants which were recorded during the task completion process also the navigation complexity, visited and revisited page numbers were traced. The researchers observed the participants and interviewed with them. Also for strengthening the process, think aloud protocol. This protocol was used to comprehend the process. It was explained that these data would help to verify the eye-tracking data. Moreover, the participants took a recall test to understand if there was a difference among groups. According to the results of this study, there was no significant effect of cognitive style on the participants' navigational patterns. The researchers suggested that this study should be done with a wider sampling and this may give more reliable results in terms of the cognitive style differences.

Ozcelik, Arslan and Cagiltay (unpublished manuscript), proposed a study about the effectiveness of signaling the pertinent keywords or sentence on the performance of the participants [13]. In this study, for determining the influence of signaling on reading they used eye-tracking device. The sampling consisted of twenty-eight undergraduate students, one group was given signaled keywords and the other group was given signaled sentence. The results of this study showed that there is no difference between the groups in terms of their performance. The retention and transfer scores were not influenced from the different designs. However, the eye-tracking data contributed the results of the study that signaling affected the students in a positive way, increased attention, less visual search and gave attention to the necessary information from the material.

In the same vein, a similar study on signaling and its impacts on learning was conducted [14]. In this study, the researchers used two groups, one of them is signaled and the other one is non-signaled. They preferred to use color signaling in their study, the transfer test was an indicator of their study in terms of the performance of the participants. The researchers pointed out the inconsistencies in the literature about the retention and transfer. Also, they emphasized the importance of eye-tracking in the study with giving the four main reasons that the signaling contributed to the meaningful learning. First of all, they stated that it was supported by the number of fixations on the necessary information. Secondly, they emphasized that much more time spent on the persistent information given that the gaze duration and average fixation supported this argument. Thirdly, they explained that the time of the visual search was decreased. Lastly, in terms of the effective positioning the relevant information, the data was beneficial since increased fixations gave valuable information about the process.

Yet another study was conducted on the effects of color coding on multimedia learning and visual search of the participants [15]. The purpose of this study is to differentiate whether color-coded split texts and split format text make a change of the participants' recall, transfer, matching performance and their eye tracking data. The researchers explained that color-coded materials enhance the recall and transfer

performance. On the other hand, they found that there was no significant difference between participants in terms of the matching performance. The eye tracking data contributed the results with giving information on the participants' eye fixations on color-coded materials which was longer than the other material. The researchers emphasized the existent literature on the fixation duration and its relation with cognitive processing. Also, they stated that the positive effects were related with the cognitive processing. They suggested that future research should be done on this issue to find out whether there are other reasons or not.

Dogusoy and Cagiltay (2007) studied on another issue by using eye-tracking approach [16]. They pointed out the importance of finding information and search engines' role in this process. In this study, the researchers aimed to examine the possible search behavior of the participants with the aid of eye-tracking approach. An unfamiliar search engine was chosen and nine participants used this search engine for completing four predetermined tasks. According to the results of this study, it was observed that the participants generally had problems during the searching process with the search engine. They tended to behave in a centralized manner while looking for the necessary information that the eye-tracking data supported this result. In addition to this, it was reported that the participants seem to use an "icon-based approach" that the eye tracking data showed that bigger and colored icons were much more focused on the screen than the other icons. They suggested that there needs to be more research on visual based search engines and their formations. Since the sampling is limited, the future studies might be conducted with wider and diverse sampling. They explained that these kinds of studies may give hints about the effective design processes especially the icon and keyword based structures and gathering data from users might help for constructing more effective visual search engines.

Another research study was conducted on an interesting issue, multimodal comprehension of language and graphics graphs with and without annotation [17]. They explained their aim as to determine the function of "annotated textual elements on graphs in multimodal documents" [17]. At this point, eye tracking was used for gathering data on the participants' eye movements and this may help them to have information on the visual attention of the participants. In this study, the sampling consists of thirty-two participants and they were taken verbal and spatial working memory span tests. The results of this study showed that the eye movement characteristics changed in accordance with the annotations on graphs. Also they stated that if the fixation duration data showed the participants' processing difficulties, this was supported by the results of the study that the participants' fixation duration is greater on the Graph AOI in graph-only format than the annotated format. They explained it with the possibility of the cognitive attempts of the participants in the process. Also, it was evidence that the participants' gaze time on the Graph AOI was greater in the graph-only format. They emphasized that the findings of this study is on the same parallel with Split Attention effect [18]. They proposed the future works importance and introduced some of the possibilities. They explained that a detailed analysis of the Graph AOI is essential and with this, it might be possible to comprehend the annotated textual elements function in the process. Moreover, experimental studies might be replicated to have more observable results and lastly post-test might be included to the procedure for determining the individual differences and the connections between the features of the eye-movements of participants.

2 Conclusion and Discussion

The results of the eye-tracking based research studies under the METU HCI group were presented [5] in this paper. Since eye-tracking enables the researchers to study on different dimensions of human and cognitive schema, this may provide beneficial clues for both educators and researchers in order to understand the learning process in depth. The studies which were presented in this paper aimed to show less explored aspects of the educational applications and the attempts on using different techniques and strategies. Learning is a very complex process and it is related with the human beings' complex thinking structure. The main issue which was pointed out in this paper was the design of better learning environments. Many papers focused on this issue and they tried to represent different design possibilities and their effectiveness. It can be seen that eye-tracking approach has a potential to provide information on learning processes and especially the general view on user's behaviors.

Although many studies resulted in with "no significant difference", eye tracking approach has potential to provide information on the process which helps to represent a bigger picture for analyzing the process more easily. Also, new developments in technologies and more studies in this field, especially the analysis process, enable us to use this device more effectively and more accurately. At this point, eye-tracking approach may also give beneficial information on the process of understanding the nature of the cognitive processing. The studies generally focused on the data related with the fixation duration and place which gives information about the visual attention. Moreover, the gaze replay data is beneficial to the researchers to analyze the process deeply which enable them to observe the participants in the task completion process.

Major limitation in eye-tracking studies is related with the small sampling. It is really hard for researchers to generalize the results with limited sampling. Also, in the literature the limitation of the eye-tracking studies were explained as they might give some answers about the users' behavior and their ocular behavior but understanding the reasons under this behavior is not an easily understandable by researchers [19]. Video recordings which provide data on the participants' facial expressions and verbal protocols of participants may help researchers in eye-tracking research studies.

Although there are limitations related with this approach, the potential of these kinds of studies should not be ignored so that they may assist instructional designers and researchers in order to better understanding the learning process of human beings with predicating the deficiencies of the designs and how they can be strengthen.

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