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HCI and Eye Tracking Technology for Learning Effect  
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Abstract  
The utilizing of interactive teaching and integrated application in technology has revolutionalized ways of teaching and learning. By making use of the interactive input and output devices that users are able to control the learning information from stem to stem. According to the research in Sander & McCormick (1987), it indicated that more than 80% that human beings manage to process cognitive information through visual operation. That is to say, the eye movement is an essential source of information in the cognitive processes. In combination with the human-computer interaction and eye movement processes, only if the eye obtain the correct teaching message which will generate the greatest effect for the content delivery in the digital learning industry. Therefore, the experiences of human-computer interaction and the eye tracking technology have been widely used in usability testing for different digital learning contents. This article will review the representative theory of interactive behaviour, eye tracking technologies and related studies. In addition, we will also discuss teaching operation and other basic data analysis in the use of eye tracking technology.

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1. Introduction

In the process of using E-learning products or even as information receivers that these people perform a self-control behaviour in the manipulating procedure. In other words, users have the authority to select which products they want to use. Therefore, it is different that learners process information from tradition to modern technological education. However, the education way we use still in the same position but to teach students in accordance with their aptitude. Due to this situation, the effectiveness of education is still in the same place without progress. Thanks for the development of technology, in order to enhance the effectiveness thoroughly that we should take the information processing behaviour into account. Besides, the acceptance of learners is also a key factor to improve education.

The scholars developed eye movement monitoring technique which provides a nature and real-time instrument to explore the cognitive thinking of users. This method is widely applied in the understanding of the learning process and other related issues such as the perceptual span, the integration of information processing and the eye movement characteristics. Furthermore, the eye movement information recorded to examine the cognitive processes under different cognitive tasks.

The eye movement data is so important but people could only observe the eye movement through the eyes in the past which are not objective enough, low accuracy and unable to grasp the subtle changes of the eye movements. Consequently, it was difficult to accumulate and provide convincing research under such condition. Nevertheless, the scholars began to use the characteristics of the eyes to record eye movements. With the progress of science, making the eye tracking technology more advanced and diversified. Nowadays, the eye tracking technology is a technique which using the image processing technology and collocate mini-camera that enable to focus the eyes and capture the infrared which reflect from the cornea and pupil; then, to record the changes of eye movements continuously and analyze the result of eye tracking process.

In the past, learners receive the learning message passively; however, since the development of technology that the education way has been changed. It is not merely one-sided to supply the message on the journey of education. Therefore, we must apply the appropriated and accepted learning methods to learners by observed the characteristics of them in order to enhance the quality of education. Combining the design of human-computer interaction with understanding the operation of eyes and the way that human manage the cognitive information which have considerable relevance when improving the education. Through reviewed the studies which included human-computer interaction, information processing model, as well as eye tracking technology that we can thoroughly improve the education and provide practical advices to the development of learning.

2. Human-Computer Interaction

The design of human-computer interaction has been an important issue for the process of developing information technology. Based on the research of Venkatesh & Davis (1996) in Technology Acceptance Model (TAM), they pointed out that the perceived usefulness and perceived ease of use will affect the users’ behavioural intentions. Simultaneously, the perceived usefulness will also affect perceived ease of use which will influence the final decision on the actual users’ behaviour. Well-designed human-computer interface will help users be more receptive to new forms of technology services. As for education, due to the appearance of new technology that changes the way of learning. According to the extent of intervention of information technology, Urden & Weggen (2000) proposed the new types of
learning that included computer-based Learning (CBL), web-based learning (WBL), digital learning, distance learning.

The research and theory of Human-computer interaction (or human-computer interface, HCI) has gradually been taking seriously nowadays. Hence, the key designing factor of human-machine interaction will change eventually from the computer to human. With the extension of the fields in computer science, and the software, system functions became more complex that the interaction patterns between people and computers has become even more diverse when it compared with the past. Human-computer interaction is an interdisciplinary subject; it is the innovative object from two scholarships which included computer science and cognitive engineering. When it comes to human-computer interaction, it also includes numbers of popular computer technologies, such as artificial intelligence, natural language processing, multimedia systems, as well as the operation of human factors engineering, linguistics, and sociology.

A well-designed human-computer interface requires covering a wide range of designed principles and there are a number of different theories that announced from domestic and foreign researchers. Beside, in the past two decades, the development of computer science has been gradually varied from the focus on the standard function of mechanics to consider the user experience, usability and the Human-oriented perspective. Kristof & Satran (1995) indicated that as for the designing of computer product that it should be mainly based on user experiences. In other words, users have considerable control authority to decide the speed of receiving information, the direction, and make decisions on whether to accept the learning or using message or not. For users, a good human-computer interface design should combine the user experiences with the ideas of designers that will make the systems more useful and play a teaching role for learners. In addition, a well-designed product will attract students' attention and the digital learning products will achieve the desired effect as well. In the correlative analysis of human-computer interaction, Nielsen (1993), announced in a published book of Usability Engineering in order to test the usability that he designed several different testing methods to measure the systems, and that users will be assigned to complete the task through the system. The evaluators will analyze the testing results to understand the usability of the user interface. The detective method is through the people that included experts, software developers, users and other experts to test the systems directly. In the detective situation, the heuristic evaluation can be applied to evaluate the system. Nielsen proposed the method to evaluate the systems in order to provide practical recommendations to improve the design of the user interface and solve the difficulties of the systems.

3. Information Processing Model

The main theoretical framework for cognitive psychology is information processing model. The model indicates that people have the initiative to manage massages and receive massages, storage massages, extract information, and manipulate massages by sense organ. The information processing illustrates that how people process massages, deal with conceptual information, explain the reasoning skills, and the way people learning by descript the stimulus of the inspiring motive and response within the mechanism of mantel activity and characteristics. Sperling & Melchner (1978) pointed out that the human cognitive system is a limited resource allocation system, not only the working memory, but the concentrated resources are limited. People do not notice the whole massages when facing a large number of information, not to mention to place the massages into the level of consciousness. As for receiving information, the brain can only capture a small part of massages and lay the other part of information into the subliminal of memory part. That is to say, individual will select the most economical or most preferred way to capture the required visual information into the consciousness level when facing a large number of information. It is an active process of construction and which combined two different direction
into the cognitive processes when human beings face the real things outside of the world. One of the
direction is the physical signals from outside to attract our attention from the process of bottom-up, and
the other is an existing knowledge systems in the brain which already know how to capture and interpret
external messages in the top-down process.

Recently, scholars concentrate on the development and research on the information processing model, and
one of the researchers, Gagné Ellen, announced a model that made the educators and psychologists feel
interested. Gagné Ellen integrated the concept of behaviour and psychology into one model and
emphasizing the importance of the cooperation between teachers and students in the learning process. He
announced a theory about the learning point of view in the information processing mode is the most
suitable theory to explain the inherent learning process of human beings. The Gagné Ellen’s theory in
information processing mode includes receptors, immediate memory, working memory, long-term
memory, reflecting organization, and reactor. Short-term memory refers to the memory that receives by
the sense organ and extended the time up to 20 seconds. The capacity of long-term memory is extremely
large, due to the existence of the message in the long-term memory have been well managed, once they
have been stored in long-term memory which can be retained in perpetuity. In Gagné Ellen’s theory, the
process of retrieving memory or massages is called search. Message retrieval and activation of short-term
memory depends on the appropriate "probed messages" that individual have and to activate associated
message in long-term memory. The control process in long-term memory system is an individual part, by
executing the control process that learners can select or decide the information processing in completing
the learning process. The procedure will control the entire information processing steps and affect the
learning quality of the thinkers.

4. Eye-Tracking and Measurement

Under the premise of achieving the attainment of educational effectiveness, we must realize the learning
process of the learner and which may encounter several unconscious learning problems, or learning
defects, and obstacles. Several visual psychologists found that the eye tracking movement is an objective
indicator and one can monitor the whole cognitive processes of the learners (Baker & Loeb, 1973;
sometimes the eye using strategy will also reflect the automatic operation of oneself. In addition, Sander
& McCormick (1987) pointed out that more than 80% that human beings manage to process cognitive
information through visual operation. That is to say, the eye movement is an essential source of
information in the cognitive processes. Through recording and analyzing the data of eye movement that
can help us to realize the variety of cognitive processing in different courses.

To the eye construct, the photosensitive cells which in the retina are not evenly distributed, and only the
fovea on retina have higher density of photosensitive cells which can receive the visual information from
the outside world for about two-degree visual angle. The characteristics of eye movements can be divided
into six motions that included saccade, pursuit, vengeance movements, vestibule-ocular reflex (VOR),
optokinetic nystagmus (OKN), and fixation. According to Kandel et al. (2000) that they illustrated the
movement of fixation is much more static when compared to other five types of eye movements. In order
to comprehend the relationship between eye movement and external messages, it must be retrieved the
information of the time and space from eye movement and external messages. In most of the eye
movement studies, researchers look forward to getting quantitative information which means the gaze
location and stay time for eyes on gazing at a graph or a paragraph of text. Moreover, based on the study
of Henderson & Hollingworth (1999), as for the time dimension that researcher understand the depth of
the visual perception system to process the messages by analyzing the gazing times and fixation duration;
on the spatial dimension, which puts emphasis on the fixation position and saccade length.
There are three types of methods have been used to measure the eye movements. First, the special lens equipped with a built-in induction coil and be able to be worn on eyes to record the eye rotation, such as scleral search coil; secondly, using optical non-contact way to measure eye movements, such as video-based eye tracker. The third equipment is electro-oculogram (EOG) which used the change of electromyography to obtain the eye movement data. The eye tracker that used to record the eye movements included the data about time and visual angle. In order to get the correct eye movement information that must be captured the corresponding location of eye rotation angle which relative to the external environment. Therefore, the most important function of eye tracker is that it is able to generate the corresponding equation of eyeball rotation and fixation position by calculate the calibration in the subsequent process. When individual views a visual stimulation included text or image that the eye tracking instrument will record the fixation position in a fixed sampling rate. The measured ways of eye tracking focus on two types of eye movements: fixation and saccade. Each data of fixation contains the message of fixation duration as well as fixation position. Each of the saccade data includes saccade duration, saccade length (saccade amplitude), saccade direction, and saccade velocity. The above information is the original information utilized by eye tracking.

According to Rayner (1984) that he found the average fixation duration for various tasks are: type for 400ms, music reading for 375ms, sees the picture for 330ms, read for 225ms. The saccade sizes for different tasks are: view photos for 4 degrees, read for 2 degrees, read music and typing for 1 degree. From the view of developed direction, Kowler & Martins (1985) found that the saccade length of preschool children is shorter than adults but the fixation duration is longer than adults. Basically, the average of fixation duration may reflect the degree of difficulty of the job to the participants (or the degree of mental resources it required), the more difficult jobs it is the longer the average fixation duration; however, saccade length reflects the density of the message. That is to say, the increasing of the density of massages, the saccade length will become short depending on the length. Apart from a holistic point of view on the data of eye movements, the researchers usually proceed from theories or assumptions, for instance that researchers will set several particular parts which is called area of interest (AOI) and then analyze the eye movement data base on diverse units. For example, by observing pictures from given information and the picture will divide into several different blocks. Based on the study from Chua, Boland, & Nisbett (2005), the study had found that a divided picture which included two parts: foreground and background, it shows that the Chinese readers have to spend much time than those English readers on viewing the part of background.

There are no more than ten standard eye movement indicators for analyzing the information retrieved from eye tracking and researchers usually conduct the statistical analysis based on several area of interest that participants pay more attention than other area. The gaze duration count up when the sight of participants get into the particular area of interest and stop counting when the sight leaves. Besides, the duration may contain one or several fixation time. Long fixation time reflects several possibilities which included: 1. the viewers want or need to spend more time dealing with the messages in the particular region; 2. the contents of this area have a higher degree of difficulty; 3. the area attracts the viewers' attention. However, when facing the complicated visual stimulation that the participants view the parts more than once that can be categories into the first past gaze duration (first run gaze duration), or second past gaze duration (second run gaze duration) till the last past gaze duration (last the run gaze duration), while the sum of the entire time period referred to the dwell duration (dwell time). The dwell time represents the whole required time to fully understand the area of interest, and may also stands for the time that the area attracts individuals to enjoy or read it. Through analyzing the first fixation time that it can be learned the degree of the region which attracts the viewer. In addition, when particular areas attract the readers more than other than which will reflect the shorter time in the first past gaze duration. Moreover, when reading the article that the reader's eyes will not absolutely perform one-way forward
which means the reading path will be from the first word to the last word. Sometimes, the reader will return back to what he already read and this phenomenon called regression.

5. Conclusion

Simply to say, a poor designed user interface will lead users encounter difficulty everywhere when using the systems and after receiving the bad experiences that users will not going to use the system any more. Conversely, a well designed user interface that will increase the pleasure for users to use the system again. Therefore, in discussing how to increase the acceptance of the system as for users that we can easily find the issue about human-computer interaction provides an essential entry point and when designing the new systems without considering the needs of the human factors that the new system suffer the rejection from users.

When emphasized the importance on the well designed human-computer interface that it should combined the measuring instruments in order to thoroughly achieve the principle of human-centered design. Eye tracking technology has the advantage that it does not influence the learners, record the information immediately which is utilized to solve the problems including the learning process for creativity, learning, reading, teaching and other issues. Furthermore, the technique gradually becomes a popular measured instrument but with less related researches and learning applications. The eye tracking technology is still in the initial step as for the education industry in Taiwan, that is to say, there are quite a number of issues needed to be explored, looking forward to attracting more scholars and researchers to join the research and enhance quality of education as well.

In addition, the eye tracking measurement can be seen as a facilitator in learning area. The eye tracking technique can be expected to link directly together with computer and apply the immediate feedback to the learners, or teachers. In other words, through the eye movement teaching feedback system, the computer can directly guide the learner to watch critical areas in order to promote students' ability to solve problems.
6. References


