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Eye Tracking and Its Applications

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ABSTRACT: We can measure the eye movement activity using eye tracking technology. We can get information about where we look by using eye tracking. What is overlooked is how the pupil reacts to various stimuli. Although the premise of eye tracking is simple, the technique and interpretation can be quite varied and complex. ET calculates the distance between our eye's gaze points and the top of our head. Eye trackers come in both remote and mobile versions. It keeps track of where we look and how we move our sight. With the use of software, one may analyze, visualize, and interpret this data. We've already known how fingerprint analysis and applications are commonly used, but eye tracking could also be a useful biometric technique for a variety of applications. Eye tracking technology and its varied uses are discussed in this paper. ET is now used in nearly every sector, including psychology, human-computer interface, marketers, designers, academics, medical research, and many more.

Keywords: Fixation, Saccade, Scanpath, Pupil Dilation and Blinking, eye tracking, gaze

INTRODUCTION

Human eyes are one of the excretory organs that we can use to make decisions in our daily lives. Eye tracking is a technology for the measurement of a person's eye movements to determine where they are looking, what they are looking at and how long they are looking in one spot. Because it is the only way to accurately and objectively measure and understand visual attention, eye tracking technology is widely used by researchers and businesses to investigate human behavior.

People constantly explore their environment by moving their eyes. They look around quickly and with little conscious effort but with regard to the well-structured task, the research has shown that people look at what they are working on. The eyes do not wander randomly. Eye tracking research can provide various sources of information the user is using, how often they are sampled and how they affect decisions. The eye is the main gateway to the brain (Brigham et al. 2001; Ellis et al. 1998). A gaze activity reveals cognitive process and provides insights about thought process and intentions (Land & Furneaux 1997). Eye tracking method is useful in many areas, from psychological research and medical diagnostic to usability studies and interactive, gaze-controlled applications.

Eye Tracking

Eye tracking is a sensor based technology that allows a computer or other device to track where a person's gaze is directed. A gaze is nothing but focus at something or someone for a period of time with surprise or attention. A user's presence, attention, and focus can all be detected using an eye tracker. It provides unique insights into human behavior and allows for natural user interfaces across a wide range of devices.

Most importantly, one can trace the fine eye movements several times a second. As its frequency, how quickly an eye tracker is able to capture certain images is named. Eye tracking systems create a dataset by capturing points of eye focusing coordinates several times per second, since every eye data is translated into a set of pixel coordinates. The data can be used to evaluate the eye rotation, and eventually the gaze direction. Eye information such as blink duration, pupil diameter shifts, and other information related to eye movements can also be captured and interpreted to explain users' invisible actions when performing tasks.

Graphs such as heat maps and gaze plots are often generated to visualize the findings. Aside from the visual attention, the eye data can also be used to measure cognitive workload of a participant. Cognitive Activity Index (CAI) is among the most commonly used metrics.

Types of Eye Tracking

Many of today's eye tracking systems contain two specific components: a light source, and a camera. The source of light, infrared, is aimed toward the eye. For example, the pupil is monitored by the eye tracking camera, reflecting the light source along with visible ocular features. Eye tracking systems measure the position of the eye, movement of eye and pupil size to identify areas in which the user has a particular interest at a specific time. This has become a motivational factor to extend eye tracking techniques over several research domains. There are several types of eye tracking devices available but in general principal how they work is the same. There are three main types of eye trackers such as screen based – are stand-alone or individual devices, wearable – include eye tracking glasses and virtual reality (VR) headsets with integrated eye tracking and webcam– consisting of webcam devices attached or built-in to a computer but don't have sensors or cameras. Though there are different types of eye trackers, the most appropriate for the researcher depends

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on the nature of the research. Currently, eye tracking devices are used for attention-based studies in the areas of psychology and neuroscience, clinical research, education, marketing research and user experience (UX) and professional performance, helping them make better business-critical decisions.

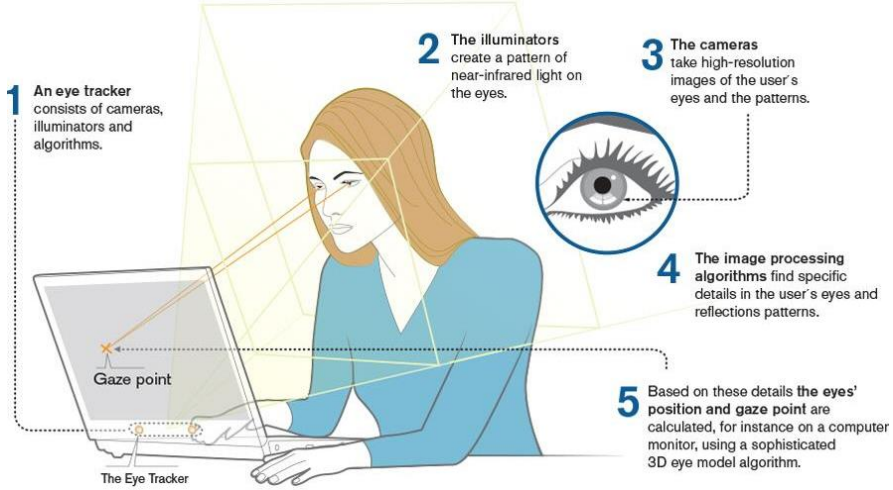

Figure 1 Screen Based Eye Tracking System

Screen based eye trackers (Figure 1) are generally used for research where the participant interacts or is exposed to the stimuli on a screen. These eye trackers come with a broad sampling rate and the trackers with a high frequency can provide a large amount of data with very high-level detailed information about the eye movement. Screen based eye trackers are commonly used when studying people with certain medical conditions and infants who cannot control their movements. It allows the researcher to collect and analyze data in a controlled lab environment. Screen based eye trackers is a device which captures gaze data for research into behavior and eye movements, from fixation-based studies into micro-saccades.

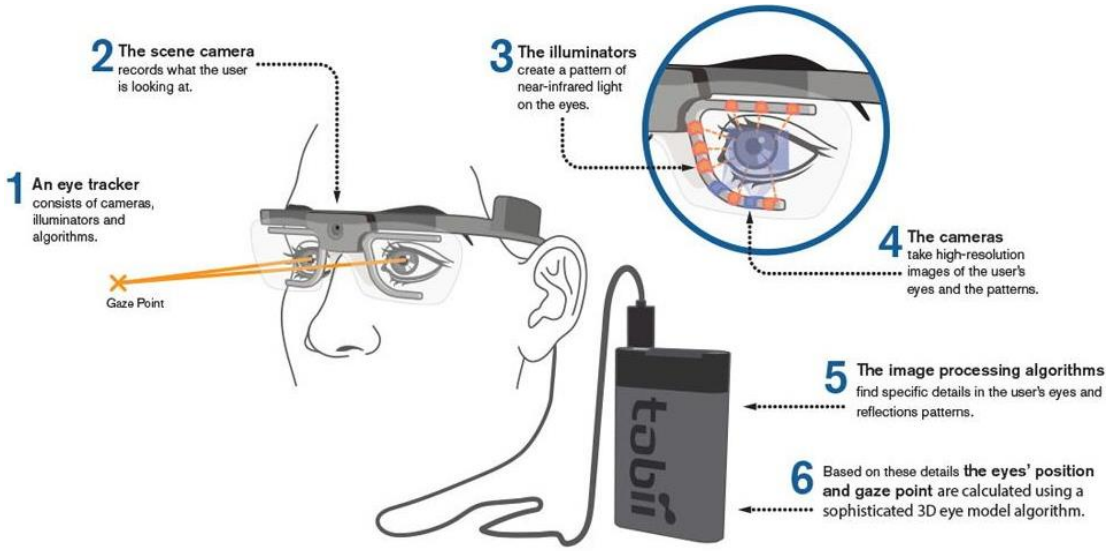

Figure 2 Wearable Eye Tracking System

Wearable eye tracking system (Figure 2) opens up a wide range of opportunities in studying user behaviors. The device allows other devices such as EEG or other biometrics to get deeper insights into human behaviour. Eye tracking glasses are used for conducting research studies in real-world situations that allow natural eye movements and are unobtrusive. They also contain a built-in scene camera and microphone to record the environment.

Portability is a key feature of wearable eye tracking systems for example eye tracking glasses which allows researchers to conduct eye tracking study outside a studio environment. The insights gained from eye tracking study are extremely useful in many fields in commercial as well as in academic research.

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The use of eye tracking technology and metrics for cognitive load measurement seem more scientific and authentic in the field of human-computer interaction. Virtual Reality (VR) headsets with integrated wearable eye tracking systems allow situational interactions to be investigated in multiple environments and the environment need not be physically present. It is very useful for skills and health training and is very dangerous to be in or very hard to set up. Figure 3 displays the VR headsets with built-in eye tracking devices and their use.

Figure 3 Wearable Eye Tracking System with VR HeadSet

Apart from wearable eye tracking systems, Webcam based approach is used for large-scale experiments which are suitable for quantitative investigation. Webcam based research is carried out in the early design of the website or product design. Webcam eye tracker uses the built-in or external camera attached to a laptop or monitor to collect gaze information about where the person is looking as shown in the figure 4. The depth and precision of the obtained knowledge from this approach is not as reliable as the methods above.

Figure 4 Webcam Eye Tracking system

Eye Tracking Metrics

Eye tracking metrics are a valuable set of tools that can be used to uncover insights regarding participant behavior and mindset during various situations. An important first step when choosing metrics is to decide which measures relate to the research questions of interest (Bylinskii & Borkin, 2015). Generally, eye tracking measurements are based on fixations, and saccades, scanpath, pupil dilation, and eye blinking. These tests must be applied to the task when the individual is operating to assess cognitive load. Cognitive load is the total mental effort it takes to process information related to reasoning and decision-making. The pupil size is the most widely used eye measure for assessing cognitive workload of both psychological and human factors (Ahlstrom & Friedman-Berg, 2006; S.P. Marshall, 2002; Muldner et al., 2009; Pomplun& Sunkara, 2003; Stone et al., 2004).

Eye Tracking Visualization

Eye tracking is a method used to track eye movements indicating to the point of the user's visual gaze fixated on the screen. The heat map is a graphical representation of the clustered data and their color values. Heat map gathers visual information regarding the most and the least attention of a visual scene. Heat map is determined as shown in figure 5(a) by number of fixations and duration of fixation. A gaze plot is a diagram showing the motion series of fixations on a visual display in the order in which they occur, as shown in figure 5(b). This is essentially tracking the eye's path

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movement represented by circles as fixations, and the circle areas are proportional to the length of fixation. These two metrics will help the researcher understand how the user's mind works when carrying out a task.

Figure 5: Eye tracking visualization: (a) heat map, (b) gaze plot

Eye Tracking Features – Fixation, Saccade, Scanpath, Pupil Dilation and Blinking

Fixations are the most important factor that eye tracking researchers analyze to make inferences about cognitive processes. It is the stage where the eye essentially stops scanning the scene and sticks to the central foveal vision in place, so that the visual system can focus on what is being looked at. Gaze points are the direct spatial spots of the visual axis landing on the stimulus. The number fixation indicates the number of times the user looked at a specific area as shown in the figure 6. Gaze points show what the eyes are looking at. Gaze points per second are collected based on the sampling rate of the eye tracker. If gaze points are very close in time or space, it denotes that where the eyes are locked and it is an excellent measure for visual attention. Gaze direction is the indication for the interface element for the current cognitive activity.

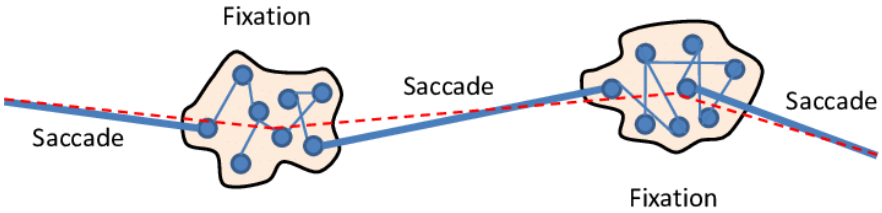

Figure 6: Eye tracking trajectories fixations and saccades

Saccade is another eye tracking measure indicating rapid eye movement, where both eyes move together in the same direction from one point of interest to another as shown in the figure 6. One can measure the velocity and length of saccades to investigate the cognitive load. The higher cognitive rate reflects longer saccades (Victor Manuel et al., 2004). Scanpath is a metric which represents the spatial sequence of eye movements performed by a participant during a task. Eye tracking scanpaths include information regarding how people see. It unfolds visual attention indicating visual context attended and provides information about how users interact with visual scenes. the cognitive load in eye tracking study. Researchers have been using pupil dilation as an important eye metric to investigate cognitive load, information processing and human performance. It is an involuntary reflex and the pupil can range in diameter from 1/16 inch to more than 1/3 inch. Psychologists have acknowledged that a change in pupil dilation indicates effortful cognitive processing. Blinking behavior is another eye tracking metric for measuring cognitive load to a specific layer of information. Blinking is often an unconscious gesture through which the eyelid blocks the illuminator's pupil and cornea resulting in raw data points lacking the details of (x, y) coordinate. The blink rate and latency will provide information for deeper understanding about the state of the attention of the participant.

Eye Tracking Applications

Eye-tracking techniques are used in a broad range of disciplines, including cognitive science, psychology, human-computer interaction (HCI), human factors and ergonomics, marketing research, and medical research. Tracking eye movement in language reading, music reading, human activity recognition, advertisement interpretation, sports play, distraction identification and cognitive load assessment for drivers and pilots, and as a means of running computers by people with extreme motor disability are all examples of specific applications.

The increased sophistication and accessibility of eye-tracking technologies in recent years has piqued the commercial sector's interest. Web accessibility, advertisement, sponsorship, kit design, and automotive engineering are some of the applications.

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CONCLUSION

Eye tracking solutions can be used in a myriad of areas, with the possibilities growing by the day. Pupillary response, blink, and eye movement are the three main types of eye activity that are related to cognitive load. Gaze information is critical because it provides cognitive information from eye movement in a specific task. In the field of cognitive modeling, eye tracking metrics are used to measure cognitive load, which is more scientific and yields promising results. Because human sight is the most complex and important way for people to perceive the world, an eye tracker provides us with information that would be impossible to obtain in any other study.

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