Eye-tracking in psychological research

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Throughout its rich history, the application of eye tracking in science generally and psychology specifically is an important methodological consideration. This is due to the expanding use of the technology in numerous fields, which has provided tremendous insights to the domains of human vision, perception, attention, language, reading and education, physiology, development and neuroscience. In addition, tracking eye movement have recently become an essential marketing and advertisement research tool that improves the understanding of the consumer-product relationship. Further to these issues, this essay will also concentrate on a cognitive use of this technology, drivers and their perception of the environment. Lack of attention is considered a major contributor to traffic road accidents. Understanding attention and perception using eye tracking is therefore a useful addition to scientific efforts and public policy. Practical implications and any limitations related to eye tracking will also be discussed.

Key words

Eye tracking; eye movement; applications; history; Tobii; driver attention; cognitive psychology; developmental psychology; neuropsychology.

History

Interest in tracking eye movements dates back to the late 19th century when in 1879, French ophthalmologist Louis Émile Javal, named the Father of Orthoptics, was thought to be the first to describe eye movements during reading (Rayner, 1998). In the absence of technology, he employed the use of semitransparent occluders during cover testing to examine eye

movements. Later in the century, American reading specialist Edmund Burke Huey developed the very first eye tracking device. Intrusive in its nature, it consisted of a very early form of ‘ lens’ that was attached directly to the eyeball. A thin metal rod that acted as a pointer was connected to the lens and by placing soot dots on a paper drum, recorded the movement of the eye during reading (Edfeldt, 1990). Appendix 1 shows an excerpt from his widely acclaimed book, The Psychology and Pedagogy of Reading, illustrating an image result of the pointer (Huey, 1968). Until Javal’s research, it has been thought that eyes move across text in a continuously smooth manner. Heuy’s work provided further evidence to disclaim the theory. A reader pauses or fixates on certain words while scans or hops quickly through others (Huey, 1968). The eye movement camera, a non-intrusive tracking device that recorded eye motions on film, was later created by Charles H. Judd. The 20th century Opthalmalograph then measured readers’ hops and fixations. Steady rhythms of hops and fixations accounted for efficient readers. A Metronoscope was also developed to help inefficient readers stabilise their rhythm (Young, 1975). For many years, eye tracking tools were exclusive to psychology, education and medical research. Those investigations include: reading, attention, scene perception, spoken language processing, and the physiology of the visual system. But as the methods became less costly, they have spread widely to be used in fields such as marketing to develop effective advertising campaigns, web usability and product designs (Wedel, 2000).

Eye Movements

To understand the theory behind eye tracking one would need to understand what is it that's being tracked, or in other words, how the eye moves. Images of interest to the eye are placed on the fovea, the part of the retina with the highest acuity. Eye movements help try to keep those images stationary on the retina even if the object or head moves. Types of eye movement may be divided into two categories depending on the purpose. Movements that aim to bring and stabilise objects into the fovea are saccades, pursuits, vergences and fixations. Movements whose purpose is to keep the image still on the retina even when the head or the object is in motion are the vestibulo ocular system (VOR) and optokinetic reflex pathway (Rayner, 1979). Three pairs of extraocular muscles rotate the eye. Figure one lists them and shows the direction of rotation of each with respect to the nose. Saccades are very fast jumps from one position to another, pointing the fovea towards the objects of interest, like the words in this sentence. A pursuit, also named a smooth pursuit, is a smooth movement of the eye when following an object, instead of in jumps. Vergence movements are linked to the accommodation reflex, which is responsible for the movement of left eye in opposite directions, convergence (rotation towards each other) and divergence (rotation away from each other), to maintain binocular vision. As the name implies, binocular vision is vision in which both eyes are used to perceive an object. Fixations movements maintain the visual stare on a single location (Paul, 2003). So throughout reading, one will fixate on certain words and saccades through the rest (Pearson, 1984). Eye tracking technology aims to study these movements with respect to the activity in question (Zee, 1999).

Figure Rotation of the left eye by extraocular muscles. (Kaiser, 2010)

Eye Tracking in Psychology

The history of eye-tracking technology and a brief list of its applications were previously mentioned. The processes behind eye movements were also discussed. This essay will now focus on the use of eye-tracking technology in the field of psychology generally and perception specifically by paying special attention to its potential application in studying the driver's perceptions of approaching motorcyclists. The latter is the topic of my research and since there exists a valuable amount of connection between the two, a section will be dedicated to the issue. According to the Tobii Eye-tracker creators, it is possible to ' understand and analyze human behaviour and visual attention using eye tracking' (Tobii, 2010). Tobbi eye trackers and other eye tracking systems have been used in several psychology fields such as neuropsychology, developmental psychology and cognitive psychology.

Neuropsychology

Cognitive neuroscientists may use the eye tracking methodology in observing physiological processes and their influences on cognition and emotions. Eye tracking may therefore be used to study the physiology behind sight. By combining eye tracking with other technologies such as fMRI, functional Magnetic Resonance Imaging, one can examine brain activity while performing cognitive activities and tasks (Duchowski, 2002). So in other words, the regions of the brain that are activated in a certain condition or situation may be identified. The condition in which one's spatial attention is captured may also be measured (Hyona, 2003). In term of

medical diagnostics, eye tracking may be used to study visual changes in patients suffering from neurological diseases and brain damages. These studies of eye movement control may serve as indicators diseases such as Alzheimer's, schizophrenia and autism (Trillenberg, 2004). For example, study by Debbane et al found that ' children and adolescents presenting autistic traits show patterns of visual processing of social information comparable to those observed in adults with autism' (Tobii, 2010). Developmental psychology is also linked to psycholinguistics, the development of human language and skills (Cooper, 1974). For example a study that compared bilingual and monolingual infants' response to novel and familiar words found that each group used a different processing strategy. This was a result of measuring the speed of the eye gaze shift to the spoken word (Bertera, 2000). Eye tracking also enabled researchers at the Rochester Baby Lab to ' demonstrate that children are able to use speech disfluencies such as " uh" and " um" to infer a speaker's intended referent' (Tobii, 2010).

Developmental Psychology

Robert Fantz's pioneering work in the mid 20th century established the fact that infants show systematic preferences for certain stimuli. Since then, thousands of studies have been carried out to study developmental psychology (Gredeback, 2010). One of the methodologies employed in recent years has been eye tracking which is now used to answer questions such as: how does a two-year-old perceive the world? Eye tracking research may explain developments in cognitive, social and emotional abilities of infants, children and adolescents. By tracking an infant's eye movement, one

may be able to measure his or her ability to recognize motion, vocal and social signals. As one grows up the skill of reading is slowly attained, and during this stage the relationship between control of eye movements and reading skill and comprehension may be examined using eye trackers (Aslin, 2007). Eye tracking in this field is not without its problems. Gredeback et al notes that it may be difficult to relate ‘ looking’ or gaze time to a specific underlying process. Several reasons may influence the resulting time data. Therefore there exists an accuracy challenge in establishing solid relations between and infant’s gaze and any one certain underlying process. This limitation however is overcome by several distinct properties of the eye tracking methodology. One is that eye tracking can be assessed over a long time, allowing researchers to examine variances in attention to a stimulus. Long-term assessment may help decrease the chances of confusing stimuli and their subsequent attentive responses (Duchowski, 2000).

Cognitive Psychology

With the advent of the eye tracking technology, one is able to more easily understand cognitive issues such as the interplay between visual perception and reading, human-computer interaction (HCI), man machine interaction (MMI), media psychology and marketing research (Duchowski, 20020). Eye tracking is also an established technique in human perception and performance labs where processes line attention, learning, memory and other tasks are studied. Those include face perception, face-to-face communication, reaction-time experiments and scene analysis and visual perception experiment (Fantz, 1961). For example, eye movements provide valuable insight into the cognitive mind during performing a strong skill or

making critical decision such as in driving. It is widely accepted by the scientific community that deficiencies in visual attention account for a large proportion of road traffic accidents (Crundall, 1998). Eye movement tracking and analysis therefore provide important insight into the nature of driving as a task. Chapman et al indicated that driver's fixation patterns may be described as ' concentration on a point near to the focus of expansion' (Gredeback, 2010). That refers to the ' point in the visual field in front of the driver where objects appear stationary'. It is thus clear that dangerous events such as traffic road accidents ahead may evoke long fixation durations. Long fixations during driving may not only be owed to dangerous events. Simple scene perception may also allow the driver's attention to drift (Henderson, 1998). One such example is how drivers perceive pedestrians, motorcyclists or cyclists on the road. Scene perception on the road is an important consideration for according to Henderson et al, studying eye movements during scene viewing ' contributes to an understanding of how information in the visual environment is dynamically acquired and represented.' In the case of the driver, understanding the driving environment and the information processing occurring within therefore is contributory to examining the human factor of the road (Rayner, 1992).

Limitations

In addition to the above mentioned disadvantages of the difficulty of identifying the underlying process associated with gaze time data, another data-analysis challenge presents itself. For example, some paradigms simply do not consider attention analysis data sufficient to address the questions of interest, so some researcher have resorted to additional analysis from video

recordings (Gredeback, 2010). Although analysing video recording of subject may seem helpful, it results in the data analysis being a laborious task. Because of these and other limitations, some researchers choose alternative testing methods to eye tracking. Programs such as E-Prime and Matlab, which can generate stimuli, experimental control, data collection and analysis simultaneously, now present themselves as a more favourable option for certain research questions (Duchowski, 2002).

Another concern is cost. Commercially available eye tracking systems are expensive relative to other available methods in psychology such as brain imaging. Some traditionalists suggest that traditional methods ‘ are easy to implement and are virtually free for many researchers who have access to undergraduate assistants’ (Van, 2007).

Conclusion

The literature search conducted for this essay revealed hundreds if not thousands of applications of eye tracking spanning several unrelated fields. The options are endless and equally unending. Studies on using eye movements to detect lying and even to ‘ read the mind’ through eliciting eye movement based memory effects give indication of the dimensions to which eye tracking methodology is heading (Greene, 2001). Applications in psychology are numerous as well as valuable. Though some limitations do exist, the field is promising. For example, by understanding drivers’ visual perceptions, which is a major factor in road accidents, one can ultimately reach a diagnostic use of eye tracking in reducing road accidents and thus fatalities.

Appendix 1