Web-Based Eye-Tracking for Neuromarketing

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The increasing popularity of neuromarketing has led to the emergence of various measurement methods, such as webcam-based eye-tracking technology. Webcam-based eye-tracking technology is noteworthy not only for its use in laboratories but also for its ability to be applied to participants online in their natural environments through a link. However, the complexity of e-commerce interfaces necessitates high performance in eye-tracking methods.

Keywords: web-based eye tracking ; neuromarketing ; e-commerce ; human computer interaction ; lighting conditions

1. Introduction

Visual stimuli constitute the primary source of information from the environment and occupy a broader cognitive space in the brain compared to other sensory inputs [1][2][3][4][5][6]. As a reflection of the intricate workings of the mind, the processing and interpretation of visual data have become significant factors in various aspects today. In this context, visual perception has become a focal point both academically and commercially [7]. Eye tracking is an experimental research method that has emerged at the intersection of psychology, neuroscience, and marketing with the aim of better understanding human behaviors. It involves tracking and recording a user's eye movements [8]. This technology, which allows the measurement of visual attention [9], enables the examination of where, when, for how long, and in what order a user focuses, as well as the intensity and distribution of this focus [10]. Eye-tracking technology is increasingly being used for purposes such as understanding responses to visual stimuli, evaluating advertising effectiveness, optimizing product designs, understanding consumer behaviors, making marketing strategies more effective and personalized [11], and ensuring customer satisfaction [12] (p. 64), and its usage has been on the rise [13][14]. These studies, which are a critical tool for the analysis of visual attention, can be conducted both in laboratory settings and in natural scenarios [15]. With the increasing interest in eye-tracking technology and its expanding range of applications, the devices and techniques used in this field have also evolved. Eye-tracking technology has evolved over time, offering various options ranging from non-user-friendly contact lenses [16][17][18][19] to wearable devices and video-based methods [20][21][22][23][24][25]. During this process, the cost of eye-tracking technologies has decreased, making these technologies more accessible. Webcam-based eye-tracking technology, in particular, has gained attention due to its low cost, lack of additional hardware requirements, absence of physical contacts, and its ability to be applied anywhere through a simple link. The ability to apply this method anywhere allows participants to take part in the experiment from various positions with natural and artificial lighting sources with the light coming from different directions (from the right, left, and center). When evaluated in conjunction with the information density and complexity of e-commerce interfaces, this situation has raised questions about how the direction and type of lighting affect webcam-based eye-tracking performance.

2. Eye-Tracking in the Field of E-Commerce

The sense of vision serves as a primary conduit for a plethora of information derived from the surrounding environment. One-quarter of the brain's volume is allocated to visual image processing and its integration. Visual image processing occupies a broader area in the brain compared to other senses, indicating the significance of the sense of vision [1][2][3][4][5][6]. Comprehending the fundamental physiological structure of the eye and the process through which vision is formed is essential for eye-tracking studies [26][27].

The process of image formation begins with the arrival of light signals reflected from objects to the eye. Within the brain, there exist millions of neurons that transform these luminous signals into encoded electrochemical signals. This group of neurons, also known as photoreceptors, constitutes the retina. Continuous movements of the eyeballs allow the light inputs from the object of interest to fall onto this region [4] (p. 13). Contrary to popular belief, eye movements are not smooth. The process of vision involves two distinct eye movements known as saccades and fixations [15]. Saccades are rapid eye movements lasting approximately 20–40 milliseconds (occurring at an average rate of three to four times per second) and are recognized as the swiftest motions within the human body. Fixations, on the other hand, occur following

these rapid eye movements, during which the eyes remain relatively stable (approximately 200–500 milliseconds) and focused on the object of interest [28][29][30][31]. Due to the inability of the eye to process the target image with high quality in a single fixation, it necessitates frequent movements. Consequently, most fixations are relatively short, and this duration can vary depending on factors such as the nature of the visual stimulus, the purpose and complexity of the task, the individual capabilities of the observer, and the focal point of attention [32]. During fixations, although perception may appear static, the eye is actually engaged in continuous movements, including tremors, drifts, and microsaccades [33] (pp. 3–13). However, saccades and fixations are the most frequently discussed eye movements, particularly capturing the attention of user experience (UX) researchers in e-commerce and marketing research [31] (p. 12).

Eye tracking is an experimental method wherein the eye movements and gaze position of a user are tracked and recorded over a specific period and task duration, enabling the measurement of visual attention [9]. This method is frequently employed in areas where the focus and distribution of visual attention are crucial [14][27][34]. This method allows for the investigation of where, when, for how long, and in what sequence a user directs his focus, thus making it a versatile research technique across various disciplines [9]. From fundamental studies of perception and memory [34][35][36] to game strategy development [37][38], from marketing and advertising [7] to industrial engineering [39], and from driving behaviors [40] to the professional development of educators [41], eye-tracking studies find application in almost every facet of life. Eye tracking, a tool for the analysis of visual attention, is garnering increasing attention in the relevant literature [9] [27][42][43].

The growing interest and significance of eye tracking have been reflected in the variety of devices and techniques developed. The eye-tracking methodology originated with attempts to monitor the pupil externally and evolved into its present form through the development of after images, attachment devices, optical devices, remote devices, electro-oculographic devices, and portable eye-tracking techniques throughout history [20] (pp. 14–28).

Many early-stage eye-tracking techniques employed devices such as contact lenses [16] and electrodes [44], which necessitated physical intervention, making them impractical and discomforting for the user. Later, wearable eye-tracking devices that were less intrusive were developed, but these devices did not achieve the desired practical impact either [18] [19]. In contrast, video-based eye-tracking techniques that are more suitable for daily use and do not cause discomfort to the user have begun to be developed [22][23].

Jacob and Karn [45] pointed out that despite the promising advancements in eye-tracking research, the utilization of such technologies had yet to proliferate to its potential level. They attributed this to the limitations related to eye-tracking hardware and software, as well as a lack of knowledge in interpreting the acquired data. In addition to these factors, the nature of the calibration process, requiring meticulous work and the shortage of competent experts in interpreting the acquired data [46] (p. 5), as well as factors like the cost of laboratory equipment and hardware, can be attributed to the limited proliferation of eye-tracking technology to the desired extent [47][48]. Nevertheless, the high-cost hardware and software in eye-tracking technology are gradually being replaced by more affordable alternatives [49]. The development of open-source software for data analysis [50], the production of wearable eye-tracking devices [51], the utilization of web cameras for eye-tracking [21][22][24][48], and the creation of eye-tracking software driven by artificial intelligence technology [52] are among the efforts aimed at making research in this field more accessible and widespread.

Eye tracking, based on the assumption of a direct relationship between where an individual looks and what they are cognitively attending to [31][43][53], can be conducted both in laboratory settings and in users' natural environments. During the data collection process, users can be instructed to observe a variety of predetermined stimuli, which can be either static or dynamic, living or non-living [15]. Eye-tracking hardware can be categorized into two main groups: desktop-based devices and mobile devices. Desktop-based devices, which are mounted in a fixed location, record users' eye movements from a stationary and relatively distant position, requiring users to sit in front of a screen. Mobile devices, as the name implies, allow users movement and capture images using wearable eye-tracking devices [25]. Eye-tracking technologies can measure various variables, including the position, number, and duration of fixations, the sequence and speed of saccades, pupil diameter, blink frequency, and many other factors [10].

While traditional marketing methods aim to decipher consumers' approaches towards specific products and develop suitable sales strategies, they may not fully reflect consumers' attitudes at the moment of purchase. Misunderstanding or misinterpreting these attitudes could lead to adverse outcomes for businesses, thus leading to an increasing focus on neuromarketing tools [54]. Neuromarketing has introduced a novel area where both cognitive and emotional aspects of consumer behavior can be studied together [8]. Research in this field has shown that individuals might not always express their preferences and intentions clearly, and they might not always be aware of the underlying reasons for their choices.

This phenomenon is a crucial factor for both researchers in the field and relevant businesses to understand how the consumer's brain responds to specific stimuli [55].

The number and variety of commercial stimuli that consumers are exposed to in daily life are increasing. Visual advertisements are among the marketing stimuli that businesses most commonly resort to in order to closely monitor their target consumer groups. From the consumer's perspective, individuals engage in an information search process throughout their purchasing journey to fulfil various desires and needs, and visual search is the most effective tool in this process [56]. The field of marketing, as both a philosophy and an organizational strategy, centers on achieving customer satisfaction and conducting the most suitable purchasing actions by focusing on these information-searching behaviors [12] (p. 64). As a result, with the increasing significance and scope of visual marketing, the growing utilization of eye-tracking technology in commercial settings has also become an expected progression. It is known that numerous companies such as PepsiCo, Pfizer, P&G, and Unilever have employed this technology to formulate sales strategies in both America and Europe [7]. These developments are further supported by the reduction in the costs associated with eye-tracking tools and research.

With the increasing prevalence of e-commerce, consumers' shopping experiences have diverged from their experiences in physical stores [13]. There exist numerous studies in the literature that compare physical and virtual stores [57][58][59]. In physical stores, the store atmosphere influences consumer behaviors [60][61][62]. In e-commerce and digital marketing processes, many significant variables used in the store atmosphere become obsolete. Factors that affect the atmosphere like scent, lighting, and ventilation cannot be controlled in the e-commerce process. This aspect sets e-commerce apart from physical stores.

Due to its inherent nature, e-commerce is unable to convey elements such as the scent, taste, and texture of a product to consumers within the current technological infrastructure [63] and, therefore, cannot address consumers' sensory characteristics. In e-commerce, the most crucial and fundamental variable is the power of visual presentation. These reasons highlight the significance of eye-tracking in the field of e-commerce.

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