Overview of the Use of Eye-Tracking Technology for Monitoring Consumer Views

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Abstract

Eye-tracking technology has become increasingly popular in studying consumer behavior and decision-making as a part of the marketing research area. The paper highlights the importance of eye tracking in the study of consumer behavior including the use of eye tracking in virtual reality environments, the integration of eye tracking with other physiological measures, and the development of more sophisticated analytical techniques. By observing eye movements and fixations researchers can gain insight into the visual and cognitive processes underlying consumer choices. For this reason, a literature review of relevant studies provides a detailed synthesis of the development of eye-tracking experiments. This apaper contributes to the latest findings on consumer behavior in the field of eye-tracking technology.

Introduction

Visual attention is the cognitive process of concentrating on one aspect in the multitude of stimuli detected by our senses for further processing, resulting in long-term memories and ignoring the others. Attention also involves awareness of stimuli in the conscious mind and is driven by top-down (endogenous) and bottom-up (exogenous) processes. Bottom-up processes occur when vital information from the external world draws our attention, while top-down processes draw attention to information based on internal knowledge, beliefs, expectations, and goals. Attention filters most of the sensory stimuli a person faces, reducing it to a level that can be processed to fulfil whatever goal or task currently directs our activity and is extremely important in forming long-term memory (Huddleston et al., 2018).

However, attention represents a neutral function that is difficult to measure with traditional methods. Eye-tracking systems measure eye position, eye movement, and pupil size to detect zones in which the user is interested at a specific time. Several methods exist for measuring eye movement (Fakhrhosseini & Jeon, 2017). Eye-tracking technology is based on decades of research on oculomotor behavior. A typical eye movement model applied to eye tracking consists of two basic concepts: fixation and saccade. The difference between fixations and saccades is in the behavior of the eyes. Human gaze at stationary objects is characterized by jumpy gazes in saccades, stopping at shorter or longer fixations. Information is processed only during fixations since the brain blocks information acquisition processes during saccades (Holmqvist et al., 2011). Empirical evidence supports that fixation on a particular item indicates that attention is being paid. Also, attention and eye movements, as well as information processing and fixation, are thought to co-occur (Sickmann & Le, 2016). This represents the operational basis for using eye tracking as a reliable tool for measuring attention.

Different eye-tracking tools allow researchers to observe and analyze subjects' visual attention and decision-making processes in real time, providing insight into how people process information and make decisions. Eye-tracking technology has the potential to shed light on how individuals direct their attention to different features of a product or service, how they process complex information, and how they integrate that information into their decision-making process. With the increasing availability and affordability of eye-tracking technology, researchers in marketing are increasingly using this method to investigate various research questions related to consumer behavior (Debertin, 2012; Sickman, 2016; Huddleston et al., 2018) This paper aims to synthesize the literature on eye tracking in applied microeconomics, highlighting its advantages and limitations and discussing its potential application in business. This review tried to demonstrate the usefulness of eye tracking in applied microeconomic research and provide guidance to researchers interested in including this method in their studies. Also, this paper represents the first phase of literature research as an introduction to the second phase, which will include a scientific experiment using eye tracking on a focus group.

The work is structured as follows: the first part provides a basic introduction to attention processes and eye-tracking technology; the second part describes the methodology, the technological background of eye-tracking is presented in part three; the fourth chapter gives a historical overview of eye-tracking, in chapter five is a literature analysis of usage eye-tracking research in retail and online; in the sixth part is conclusion and discussion given. The shortcomings of the conducted eye-tracking studies are investigated.

Methodology

For the eye-tracking review, we researched available scientific and professional articles in the fields of marketing, market research, consumer behavior, and technology development in the field of eye-tracking. Literature was searched using an advanced search with keywords (TITLE-ABS-KEY (“eye tracking“OR “eye-tracking“ OR “gaze tracking“) AND (consumer behavior OR economic behavior OR decision making OR choice OR attention OR applied microeconomics)). Web of Science, Scopus, Google Scholar, Science Direct, and APA Pysc Net databases were searched. We have narrowed our search to a time frame between 2000 and 2022. Furthermore, we found two papers from 1898, when the first device for recording eye movements was invented (Delabarre, 1898). The obtained data set consisted of 1854 works. The first stage of the data cleaning process was to remove papers based on title and abstract. After screening, we received a sample of 80 papers. The next phase involved looking at the discussions and conclusions. Excluded are articles from the field of finance, accounting, education etc. After that, a sample of 39 acceptable studies and sources that use eye-tracking (ET) as the methodology of choice in the field of consumer behavior, as well as several review papers from that field, was gained.

The Technological Background of Eye-Tracking

Eye tracking technology is the most promising in eye movement research, visual perception, and visual attention. The eye tracking device collects data that enable conclusions to be drawn about eye fixations and saccades to a given stimulus. If the eyes stop on a particular stimulus that is captured in the foveal region, fixation occurs. The most important measures related to fixations are fixation position, number of fixations, probability of fixation, time to first fixation, duration of first fixation, and total fixation time (Duerrschmid & Danner, 2018). Conversely, a saccade includes saccade amplitude (saccade length) and saccade velocity (speed of eye movement). Meißner & Oll (2017) further explain that a saccade is a rapid eye movement between two consecutive fixations during which the person is "blind". Therefore, information gathering and actual attention take place during fixation. Different combinations of

fixations and saccades allow researchers to extract specific eye-tracking measurements that represent the visualization of eye movements (Meißner & Oll, 2017). Some other eye-tracking methods can be found, e.g., blink rate, saccades, and pupil dilation (Motoki et al., 2021). Still, all of them are used to examine the visual attention of different consumers.

Eye tracking devices typically use one of two approaches: corneal reflection or pupil center corneal reflection. Corneal reflectance monitoring devices use a camera to capture an image of the eye and its surroundings. An infrared light source is used to create a reflection on the cornea, which can be tracked as the eye moves. The position of the reflection relative to the camera can be used to calculate the gaze direction. This technology is also known as the Purkinje eye-tracking method. Center-of-pupil corneal reflection tracking devices use a similar approach, but instead of tracking the reflection at the cornea, they track the position of the center of the pupil. The corneal reflection is used to calculate the position of the center of the pupil which is then used to determine the direction of gaze. Eye trackers can be used in various applications, such as user interface design, virtual and augmented reality, and market research (Bulling et al., 2014). A very intuitive visualization of eye-tracking data is a heat map that shows areas of visual interest at different thermal intensities. It shows several participants' accumulated fixations (numbers or lengths) on each stimulus area using a colour code: often red indicates many long fixations, orange-yellow for medium, and green for a few short fixations. An important tool for analyzing eye movement data is AOI (*area of interest*), which defines essential areas of the image which should be analyzed separately. AOI can be plotted on the image using eye-tracking software, and then the eye-tracking data related to the defined areas can be statistically analysed. Another option for visualizing eye-tracking data is to display fixations on a timeline. Such view diagrams show the participants' scan path and search behavior. Each fixation is shown as a dot, the number in it indicates the order in which the fixation appeared, and the diameter of the dot represents the length of the fixation (Duerrschmid & Danner, 2018).

There are usually two types of eye-tracking devices – one in the laboratory and mobile that could be used in open space. Eye tracking in the laboratory or on a computer can ensure the reliability of measurements in a controlled experimental environment. On the other hand, mobile devices offer the advantage of measuring views while shopping in a physical environment (Motoki et al., 2021).

Historical Development of Eye-Tracking

The first eye tracker was developed at the end of the 19th century by Edmund Huey, who used iris-hole contact lenses that were connected to aluminum indicators. This method was unpleasant to the eyes. (Huey, 1898). Delabarre (1898) invented a plaster cap that adhered to the moist surface of the eye. Attached to the cap was a wire leading to a lever that plotted the horizontal movements of the eye on the surface of the cinematographic cylinder. The subject could read the text through a hole made in the plaster cover. The plaster cap did not detach from the eye until it began to fill with tears (Płużyczka, 2018). In 1901 Dodge and Cline (1901) invented non-invasive optical eye-tracking devices. They were the first to use light that reflects from the cornea's surface and falls through the optical system onto a moving photosensitive photographic plate, thus leaving a record of the eye's movement on that plate. Dodge and Cline's device had two flaws: it registered only horizontal eye movements and required subjects to keep their heads still. US Air Force in the 1960s invented the first eye-tracking device named "oculometer". Thanks to computer algorithms, the iris was recognized on the video screen, and its geometric center and the direction in which the tested person was looking were determined (Płużyczka, 2018).

For more than 70 years, researchers have been building their systems, and it was not until the 1970s that new technologies such as infrared cameras and computers enabled the development of more sophisticated eye-tracking systems. In the 1980s, researchers began using head-mounted eye-tracking systems, allowing greater freedom of movement and more natural experiments (Duchowski, 2002). In the 1990s, the development of remote eye-tracking systems allowed researchers to monitor eye movements from a distance without needing participants to wear any equipment (Holmqvist et al., 2011).

Over the years, eye trackers have become cheaper and smaller and several commercial eye trackers are available on the market today. The most famous manufacturers of eye-tracking technology are Tobii Pro, CRG Global, MSW Research, Fieldwork Network, etc. (GreenBook, 2023). Eye-tracking technology is used in various applications, from medicine, market research, and advertising to cognitive psychology and human-computer interaction (Duchowski, 2002).

The Use of Eye-Tracking in Applied Microeconomics

Gaze tracking is becoming an increasingly popular way to understand consumers' visual attention in retail. In this way, researchers try to gain insight into the sale of specific products or help consumers make decisions. One of the primary uses of eye tracking in retail is to optimize store layout and product placement. A study by Orquin and Loose (2013) found that eye tracking can provide valuable insights into how consumers move through a store and which products they pay the most attention to. By analyzing fixation patterns, retailers can identify which areas of the store are most likely to attract customer's attention and can use this information to place products and promotions strategically. For example, a retailer may display high-margin items in areas with high traffic levels and fixation rates, to increase the likelihood of purchase. By analyzing gaze behavior, researchers can identify which product features are most important to consumers and which factors influence their purchase decisions. A study by Wedel and Pieters (2008) found that eye-tracking can be used to predict consumer preferences with a high degree of accuracy and can even be used to design more effective product packaging and labelling.

Also, product characteristics in the store, such as brand and popularity, influence consumer attention. The previously described experiments prove this, and in most cases, popular products are more attractive and more present in supermarkets (Bialkova et al., 2019). Meißner et al. (2019) propose the creation of virtual reality and mobile eye tracking for researching consumer behavior in retail. Eye tracking in virtual reality enables a level of control that can usually only be achieved in laboratory environments while simultaneously providing a realistic 3D experience and the freedom of movement typical of real store environments. The main argument they make for using mobile eye tracking in real-world retail settings is that attentional processes can differ significantly between the laboratory and the real world. Supermarket shoppers often make choices within seconds and consider only a few options, suggesting that retail research should investigate attentional processes at the point of sale (Meißner et al., 2019).

The main application of eye-tracking in studying consumer behavior on digital devices is to improve user interface design. A study by Thüring and Mahlke (2007) found that eye tracking can optimize website navigation, improve search functionality, and reduce user errors. They also found that eye-tracking can identify user preferences for different types of menus and navigation systems, which can help design more effective user interfaces. Another application of eye tracking in studying consumer behavior on digital devices is understanding how users process information and make decisions. A study by Tuch et al. (2012) found that gaze tracking can measure the influence of different design elements, such as colour, font, and layout, on users' perception of a website's usability.

In online shopping, consumers' perceptions of products depend solely on their visual attention to the purchase information displayed on the screen. Consumers lack service encounters or tangible product experiences. For this reason, research into the visual behavior of consumers during online shopping is essential to help online retailers design appropriate purchase information for display on screens. Furthermore, Hwang and Lee (2020) found in their research that the small screen of a mobile device affects users' visual behavior by imposing greater visual complexity and higher cognitive load. Also, Chen et al. (2022) investigated the impact of online reviews on consumer purchases using gaze tracking. The results showed that the respondents' attention was greater for negative comments than positive ones, especially among female respondents. It was also established that consumers could not recognize false comments. The researchers suggest that marketers should pay special attention to negative comments and address them immediately.

How do consumers decide to spend their income? Which goods are bought and which remain on the shelves? The economic theory of consumer choice helps explain why consumers behave in certain ways. Different applied microeconomics studies in the marketing field try to find the best approaches to satisfy the infinite desires of modern consumers that are very demanding in this era (Debertin, 2012). Understanding consumer behavior is a central concern of microeconomics, as it plays a vital role in allocating economic resources. One of the most important aspects of consumer behavior is making purchase decisions. Eye tracking has become a valuable tool for analyzing decision-making processes in recent years. Eye tracking allows researchers to measure consumers' visual attention, providing insight into the factors influencing consumer behavior. Most eye-tracking research in this scientific field examined fixation as a primary measure of visual attention (Wedel & Pieters, 2008). Fixation can inform researchers about participants' focus, memory, preference formation, choice, and sales (Orquin & Mueller-Loose, 2013). Using eye tracking technology, Amasino et al. (2023) found that

higher budgets accelerate the purchase decision process, increased attention to higher budgets increases their influence on choice, and higher budgets justify higher spending, while lower budgets reduce purchases.

One of the most prominent areas of research using eye-tracking technology in applied microeconomics is product placement. Researchers have investigated the effects of product placement on consumer attention and choice in different retail environments. Orquin et al. (2020) investigated the impact of prominence, surface size, and product center distance on the visual attention of packaging elements. In their research, fixation is a binary variable representing whether attention appears on certain package elements. Results showed that more prominent, larger, and centrally placed package elements were more likely to be fixed. In addition, they found that images and logos on larger packages were more prominent and more centrally positioned than sustainability and nutritional information. Earlier studies have found that consumers are likelier to pay attention to and remember visually salient features, such as colours, shapes, or logos (Pieters & Warlop, 1999). Also, in their work, Puccinelli et al. (2009) investigated the influence of the environment in which products are presented on the decision-making process. They found that consumers pay more attention to prominently or centrally located products in a store or website.

Furthermore, the presence of other stimuli, such as sales promotions or competing products, also affects the allocation of visual attention and the consumer's decision-making process. This suggests that packaging and product design can significantly attract consumers' attention and influence their decision-making process. Furthermore, Bogomolova et al. (2020) tested whether the salience of a unit price label (displaying prices per unit of volume or weight) affects viewing behavior. A prominent unit price label (e.g., larger font size, colours) increased the number of fixations on the price label. Moreover, the number of fixations can be primarily attributed to highlighting the unit price in yellow and for less price-conscious consumers (Bogomolova et al., 2020). These findings suggest that visual salience is key to attracting exogenous attention.

On the other hand, gaze tracking technology has proven to be a reliable tool for measuring attention focused on a goal. Wansink and Park (2001) demonstrated that the goals and motivation of consumers can influence visual attention and the decision-making process. For example, consumers may pay more attention to features relevant to their goals or needs, such as the nutritional content of food products and environmental awareness. In their work, Chiu et al. (2023) found that reusable packaging and a monotonous logo can attract consumers' attention faster than original packaging. A uniform logo has the subtle effect of helping consumers shift their attention to the type of packaging, indirectly stimulating and enhancing the impact of visual perception on environmental awareness and brand image. This study suggests that the company should use reusable packaging to support environmental protection and improve its brand image.

Some studies have also investigated the role of emotions on visual attention and consumer decision-making processes. Studies have found that emotional cues, such as images or slogans that evoke positive or negative emotions, can capture consumers' attention and influence their decision-making process (Pham et al., 2001). Motoki et al. investigated how random emotions affect the visual processing of food packaging (Motoki et al., 2019). Participants were randomly assigned to emotion elicitation conditions; anxiety, anger, and neutral state. In each condition, participants wrote personal experiences associated with anxiety, anger, or neutral to elicit each emotion. Afterwards, participants saw packages of healthy and unhealthy products with eye tracking. The results show that participants who felt anxious (vs. angry) showed a longer total fixation time on the junk food packages. In addition, Wedel and Pieters (2000) found that consumers tended to fixate on product features relevant to their decision, such as price and brand name. However, they also found that consumers tend to ignore features that are not relevant, such as product colour. This study demonstrated the importance of understanding which features are relevant to consumers and how visual attention can influence their decision-making.

Conclusion and Discussion

In conclusion, examining eye-tracking technology for monitoring consumer perspectives presents a comprehensive understanding of its applications across various domains. An extensive review shows that eye-tracking technology offers invaluable insights into consumer behavior, preferences, and decision-making processes. The diverse range of studies showcased in this overview underscores the versatility and effectiveness of eye-tracking technology in capturing nuanced aspects of consumer engagement. As technology continues to evolve, it is foreseeable that eye-tracking will play an increasingly integral role in understanding consumer behavior and shaping decision-making processes in the marketplace.

In essence, this overview underscores the significance of eye-tracking technology as a powerful tool for monitoring consumer views, offering researchers and businesses alike the opportunity to gain deeper insights into the intricacies of consumer perception and behavior. Exploring its potential applications and refining methodologies, eye-tracking stands poised to remain at the forefront of consumer research, driving innovation and informing strategic decision-making in the dynamic landscape of consumer markets.

Like any research method, eye tracking has limitations that researchers must know. One of the primary limitations of eye-tracking technology is its potential for inaccuracy. Eye-tracking technology assumes that the gaze point corresponds to the visual stimulus being looked at, but this is not always the case. Several factors can affect the accuracy of eye tracking, such as head movements, blinks, and pupil size, which can result in erroneous information (Holmqvist et al., 2011). In addition, the calibration procedure used to determine the relationship between gaze position and screen position can also introduce inaccuracies if not performed correctly (Duchowski, 2002).

Another limitation of the eye-tracking method is the spatial resolution of the equipment. Although modern eye trackers are capable of very high sampling rates and spatial resolutions, there are still limitations to their accuracy. For example, some eye trackers may have difficulty resolving small saccades or fixations, especially when the user moves quickly or in low-light conditions (Bulling et al., 2011).

Eye tracking is sensitive to artefacts that can affect the quality of the collected data. Artefacts can arise from various sources, such as reflections from glasses, contact lenses, or corneal irregularities, which can distort the eye's image and introduce inaccuracies in the collected data (Duchowski, 2002). In addition, lighting conditions can affect data quality, as changes in ambient light can affect pupil size and iris-pupil contrast, which can affect tracking accuracy (Bulling et al., 2011). Furthermore, eye-tracking technology cannot reveal precisely why subjects position their eyes on a particular element. Therefore, this technology is often supplemented with additional methods, such as the interview method (Rajapake, 2018). Another disadvantage of eye tracking is bias. When users are aware that researchers are interested in certain product elements, they may be more cautious than they would be if that element were just one of many they encountered during their search. In their research, Krajina and Mladenović (2018) supplemented the quantitative value of eye-tracking data with the qualitative value of retrospective interviews. Also, it is necessary to pay great attention to the correct coding and analysis of the obtained data to avoid reaching incorrect conclusions. Another precaution concerns concluding cognitive processes. For example, visual attention is not perfectly correlated with awareness, so the focus of the gaze is not always a direct mirror of what is being processed. Furthermore, the gaze is influenced by various factors such as memory, colour, and saliency. This could confirm the influence in experimental eye movement research and, therefore, must be properly controlled.

Table 1
Eye-tracking technology – main findings, limitations and solutions

Technology	Main findings	Limitations	Solutions
Eye-tracking	Give invaluable insight into consumer behaviour preferences Decision-making process in different areas	Rather expensive technology Technology still in progress (e.g., fast moves of the eye cannot be tracked) Potential for inaccuracy (head movement, blinks etc.) Quality of the collected data Private protection issue	SW price will fall in the next few years Technology is constantly improved Conducting additional tools, such as interviews with consumers, focus groups, filling out questionnaires, etc. Education of eye-tracker professionals and/or AI Consumer legal privacy issues should be solved before the experiments

Source: Authors' compilation.

Although this is a valuable literature review, it also acknowledges certain limitations. Namely, by reviewing only a certain number of databases, we omitted research available from other sources. Furthermore, by including only articles from the English-speaking area, we skipped valuable research written in other languages. To avoid

these limitations in future studies, conducting a more extensive study on this topic would include a larger number of databases, and using tools to translate the article into other languages is recommended.

Before conducting any experiment with eye-tracking technology, it is necessary to ensure the ethicality of the procedure in the direction of privacy and data protection. Future research should also address some of the limitations of eye-tracking technology and investigate other factors influencing consumer behavior, such as tracking devices connected to the customer's skin. All these technological innovations for monitoring consumer behavior need to be supplemented with traditional techniques used in marketing, such as conducting interviews with consumers, focus groups, filling out questionnaires, etc. to scientifically and in practice support the usefulness and effectiveness of the used techniques for monitoring decision-making during consumption, voting and all other activities of human behavior. It also remains to be investigated how AI techniques can be used for better and faster processing of data obtained by applying eye-tracking in different areas of human activity.

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Pregled uporabe tehnologije sledenja očem za spremljanje pogledov potrošnikov

Izvleček

Tehnologija sledenja očem postaja vse bolj priljubljena pri preučevanju vedenja in odločanja potrošnikov v okviru področja trženjskih raziskav. V prispevku je poudarjen pomen sledenja očem pri preučevanju vedenja potrošnikov, vključno z uporabo sledenja očem v okoljih virtualne resničnosti, povezovanjem sledenja očem z drugimi fiziološkimi meritvami in razvojem bolj izpopolnjenih analitičnih tehnik. Z opazovanjem gibanja oči in fiksacij lahko raziskovalci dobijo vpogled v vizualne in kognitivne procese, na katerih temeljijo odločitve potrošnikov. Zato pregled literature o ustreznih študijah zagotavlja podrobno sintezo razvoja eksperimentov s sledenjem očem. Ta članek prispeva k najnovejšim ugotovitvam o vedenju potrošnikov na področju tehnologije sledenja očem.

Ključne besede: vizualna pozornost, sprejemanje odločitev, tehnologija sledenja očem, vedenje potrošnikov, izbira potrošnika