A Review of Eye-Tracking Methods in Tourism Research

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Abstract Technological advancement provides opportunities for improvements in the methods academics use in their research. Traditional studies of advertising and interpretive material effectiveness typically use self-report surveys that are subject to subjectivity and data validity bias. Eye-tracking technology provides researchers with an alternative, objective research method to study the processes involved in visual attention to and interest in such stimuli. Psychological research on eye movements began around one hundred years ago, but the recent development of cheap and reliable eye-tracking equipment makes it more accessible to tourism researchers, both for laboratory and in-situ data collection. Application of such eye-tracking methods may enlarge our understanding of our tourists' attention and perception as cognitive processes. This chapter provides a review of eye-tracking methods, its theoretical basis, advantages and disadvantages, data collection and analysis procedures. Gaps in knowledge and topics for future research are provided.

Keywords Eye-tracking · Attention · Marketing effectiveness · Tourism marketing

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1 Introduction

Early humans hunting dangerous animals or living in close social relationships who were able to direct their visual attention to relevant environmental stimuli rapidly were more likely to survive and reproduce. Thus to avoid information overload, human brains and sensory systems have evolved the capacity for selective attention and processing of goal-relevant visual stimuli (Davenport and Beck 2001). Consumers today use these same attentional processes to evaluate the saliency of the thousands of pieces of information in their environment, whether they are viewing television, social media or just walking down the street.

As a case in point, a person thinking about taking a holiday is unable to process in detail all the information they may observe and collect during their extended search process. Instead, their attentional processes allow them to focus on only a few of many possible stimuli in the environment (Scott et al. 2019). Therefore, only marketing messages that attract the audience's visual attention are processed and influence tourists' behavioural intentions. Understanding and managing the audience's visual attention is a key factor in designing effective and persuasive marketing messages (Wang and Sparks 2016). This applies to both traditional stimulus materials such as print advertisements, brochures or guidebooks, as well as websites, blogs, videos and augmented reality and virtual reality applications (Lee and Gretzel 2012; Schlosser 2003).

Eye-tracking research methods offer valuable opportunities to explore tourists' attentional process. Psychologists have conducted research on eye movements since the early twentieth century and due to the recent development of unobtrusive and wearable eye-tracking devices and sophisticated analysis software programmes, marketing, computer science, neuroscience and tourism researchers can apply the methods they developed (Duchowski 2002). A number of tourism studies used eye-tracking methods to explore how tourists perceive tourism advertisement (Berenbaum and Latimer-Cheung 2014; Li et al. 2016a; Potocka 2013; Scott et al. 2016; Wang and Sparks 2016). Further applications of eye-tracking equipment for research in tourism marketing and tourist behaviour research appear useful.

This chapter provides an introduction for researchers who want to use eye-tracking methods for studying tourist behaviour. The chapter is organised into three main sections. First, the authors summarise the theoretical basis of eye-tracking research, its advantages and disadvantages. Second, eye-tracking equipment, data collection methods and analysis are discussed. Third, the chapter reviews the applications of eye-tracking methods in tourism research and proposes topics for future studies.

2 Theoretical Basis for Eye-Tracking

Understanding how the eyes function to perceive the environment is necessary if we are to measure attention (Land 1999). Even though our vision appears to be continuous and stable, it is built from a thousand pieces of information collected through the eyes. Our eyes are in constant motion of two main types; one that directs the fovea to a stimulus (e.g. saccades and smooth pursuits), and another that maintains the eye fixed on a stationary stimulus (e.g. fixations). The eye senses light through rod and cone photoreceptors located in the retina. The density of these receptors varies across the retina with the greatest density in the fovea (fovea centralis). The greatest detail (highest resolution) about the visual field is when the lens of the eye focuses light on the fovea (Schütz et al. 2011). Peripheral vision is due to light falling on the lower density of photoreceptors surrounding the fovea. Eye muscle movement (EM) combined with re-orientation of the head and body serves to align the fovea (foveation) with potentially relevant locations in the visual scene. The human visual system combines a series of rapid foveations on different parts of the visual field and information from peripheral vision to build a detailed map of a scene (Rayner 1998). EM, therefore, is essential to the operation of the human visual system, but to be effective, it must allow those small areas of the visual field that are most salient to prioritised for inspection.

Attentional processes drive the EM that allows our fovea to collect the highest resolution image about the most salient part of the visual scene. Attention can be defined as “focused mental engagement on a particular item of information. Items come into our awareness, we attend to a particular item, and then we decide whether to act” (Davenport and Beck 2001, p. 20). Two different attentional mechanisms direct EM. These two mechanisms are termed bottom-up and top-down (Rosa 2015) or exogenous and endogenous attention (Posner 1980; Wedel and Pieters 2008). Bottom-up or exogenous attention is caused by elements of the visual field (e.g. contrast, luminance, movement), while top-down or endogenous attention is initiated from higher cortical centres and driven by affective states, goals, memory or context (Rayner and Castelhano 2008). “Bottom-up” or exogenous attention functions subconsciously and is rapid compared to top-down attention (Cheal and Lyon 1991) which is assumed to be under the overt control of consumer goals (Rosa 2015). An example of top-down is that a person who is thinking of a holiday in Greece is more likely to notice Greek holiday advertisements. Bottom-up attention may be biased towards viewing faces and body parts (Ro et al. 2007).

The combination of top-down and bottom-up mechanisms provides a basis for understanding eye movements. Top-down attention explains why task instructions during an eye-tracking study affect the object fixated (Duchowski 2002, pp. 458). Task relevance is a primary driver of attention in natural tasks (Orquin and Loose 2013). While most tourism research to date has only investigated the bottom-up attention and tested different marketing stimuli, future research could examine what naive viewers look at compared to those who have had an instruction (provided with a goal).

3 Data Collection and Analysis Procedures

Due to their close relation to attentional mechanisms, researchers study eye movements to learn about the perception of visual stimuli and how such stimuli relate to an individual's needs. This section discusses the procedures used for eye-tracking research data collection and analysis.

3.1 Eye-Tracking Technologies and Devices

There are two generic types of eye-tracking data collection equipment: fixed and mobile (Scott et al. 2019). The leading eye-tracking method for fixed eye-tracking equipment is called video-based infrared oculography (VIROG). This technique uses relatively low-cost cameras and image processing hardware to estimate the point-of-regard (POR) or point-of-gaze, that is, the (x, y) coordinates of the user's gaze on the displayed stimulus in real time (Holmqvist et al. 2012). The POR is determined from the images of a (usually infrared) light source reflected from the surface of the cornea or lens. The position of these light reflections, known as the Purkinje Reflections (Cornsweet and Crane 1973), can be measured relative to the centre of the pupil. Many commercial eye-trackers identify and measure only the first Purkinje reflection (glint) off the front of the cornea, which can provide appropriate accuracy and precision. Such eye-tracker systems use one camera and one or two infrared light sources and use a five- or nine-point calibration procedure. Recently, mobile eye-tracking equipment (similar to a normal pair of glasses) has been developed for non-laboratory research studies, e.g. driving research and outdoor visual perception research. These operate using similar methods as fixed data collection equipment. There are a number of data collection issues related to the use of mobile eye-tracking. Real-world conditions such as the sunshine reflected from the sand can overwhelm the infrared camera sensors. Moreover, the visual stimuli observed by the participant can be changing and the scene that each participant view may be different. This can make data analysis complicated, but new eye-tracking software can address this issue to produce heat maps (Scott et al. 2019).

3.2 Data Collection Procedure

An eye-tracking system should be unobtrusive to users. Advanced eye-tracking glasses are lightweight and have good ecological validity (Johansen and Hansen 2006) similar measurement errors to fixed eye-tracking equipment. It is important that the equipment is calibrated for each participant before the experiment starts (Blignaut and Beelders 2012; Holmqvist et al. 2012). Typically, calibration is done by displaying fixation targets on a screen, which the participant follows with their eyes. An experiment should consist of discrete, short tasks followed by a break to avoid boredom or fatigue (Goldberg and Helfman 2010). In a laboratory setting, ambient lighting, noise, distractions and temperature can be controlled to provide a reproducible evaluation environment. In order to get accurate eye measurements, users should perform the experimental tasks without interruption. Asking users to think aloud, asking probing questions or even allowing participants to ask questions interferes with data accuracy. Researchers should obtain data instead from post-experiment questionnaires to interpret eye-tracking outcomes.

A fixed eye-tracking system uses a monitor connected to a computer, where the monitor frame contains an unobtrusively integrated sensor (e.g. high-resolution camera and near-infrared light-emitting diodes). Such equipment can determine the position of the participant's eyes at 50 Hertz (50 times per second) or higher. A typical eye-tracker's measurement error when viewing a screen 50 cm away has been estimated at less than half a centimetre (less than 1 degree) but maybe greater towards the edge of the monitor (Goldberg and Helfman 2010). Mobile eye-tracking equipment consists of a set of glasses connected to a small data processing and storage unit. This system measures eye movements in real time and then allows downloading of the data for analysis. Both mobile and fixed equipment can be used with skin conductance or other types of monitoring equipment.

Due to the huge amount of data collected through eye-tracking methods, the sample size of eye-tracking studies is small and similar to psychophysics or physiology studies (Goldberg and Wichansky 2002). Usability experiments using goal-directed searching tasks require a smaller sample than undirected browsing. Representative scan paths may be determined for search tasks using 27 participants (Eraslan et al. 2016). A meta-analysis of eye-tracking research on differences between experts and novices found an average cell size of 11. Table 1 summarises the sample size used in previous eye-tracking studies. Overall, designs have used between 12–63 participants.

3.3 Data Analysis Procedure

Data analysis begins by the use of software to identify fixations and saccades and extract this data. The software algorithms use various techniques, such as the number of gaze points within a defined radius, or eye movement velocity, to identify a fixation (Salvucci and Goldberg 2000). Typically, a fixation time of around 200 ms is used, and small changes in this value may change the number of fixations identified. Researchers should, therefore, report choices of this parameter in their papers. Analysis of data may be based on hypotheses and psychological theory or entirely on describing patterns of activity. Defining an area of interest (AOI) is often an important step in the eye-tracking data analysis procedure. Researchers define AOIs according to their research interests. For example, in brand awareness research, the AOI can be defined around the brand logo. This step can be done

Table 1 Eye-tracking study topics and sample size

Study	Topic	Sample size
Atalay et al. (2012)	Location of material on brochure racks	63/84
Bebko et al. (2014)	Advertisement effectiveness	63
Chua et al. (2005)	Effect of culture on image recognition	52
Eghbal-Azar and Widlok (2013)	Attention to displays in museums	16
Hernandez-Mendez and Munoz-Leiva (2015)	Online tourism advertising effectiveness	30
Marchiori and Cantoni (2015)	Online tourism website navigation	28
Green et al. (2011)	Olympic website advertising effectiveness	21
Hao et al. (2015)	Online advertising effectiveness	53
Kiefer et al. (2014)	How long to people look at a view	12
Li et al. (2016a, b)	Effect of text on attention	37
Pan et al. (2011)	Online travel agency user search strategy	41
Pan et al. (2013)	Online travel agency user choice strategy	16
Pan et al. (2004)	Website viewing	30
Scott et al. (2016)	Advertising	25
Wang and Sparks (2016)	Cultural effects on image evaluation	30
Yang (2012)	Restaurant menus	27

Source: Scott et al. (2019)

after data collection, and eye-tracking participants should not be aware of the boundaries of AOIs.

Eye movements within an AOI are measured by fixations and saccades. Fixations are defined as a "relatively stable eye-in-head position within some threshold of dispersion (typically ~2°) over some minimum duration (typically 200–300 ms), and with a velocity below some threshold (typically 15–100 degrees per second)" (Jacob and Karn 2003). Fixations are usually extremely short but can be mapped to specific *X* and *Y* coordinates on a grid are then matched with a picture of the visual stimuli (Scott et al. 2019). While a fixation is the estimated location of the eye gaze at a particular moment in time, saccades are the rapid eye movement between two consecutive fixations (Lai et al. 2013).

Fixations and saccades can be measured based on three scales of measurement (temporal, spatial, count). The most frequently used eye-tracking measures are fixation count, the proportion of time spent on each AOI, average fixation duration, fixation count on each AOI, gaze duration mean on each AOI and fixation rate (count) (Jacob and Karn 2003). Fixations are valid measures of visual attention (Wedel and Pieters 2008). For example, a fixation count (i.e. the number of times an AOI is fixated upon) reflects the importance of the objects within that AOI since salient parts of the stimuli are fixated more frequently (Fitts et al. 1950). Search efficiency is correlated with total fixations (Goldberg and Kotval 1998). Time to first fixation can be used to evaluate the salience of an AOI. The shorter the time taken to first fixate on an AOI the more impressive or salient it is (Bebko et al. 2014). The first total gaze duration indicates interest in the stimulus, and repeatedly gazing at an AOI may indicate its influence on attention (Bebko et al. 2014).

Based on measuring fixation and saccades, eye-tracking software helps to create outcome visualisations such as scan path and heat map. A scan path shows the sequence of fixations and saccades. The longer scan paths length or duration, the less efficient the organisation of website elements are (Goldberg and Kotval 1999). A heat map that is colour coded to separate areas more or less intensively viewed is useful in visualising the elements that attract the audience's attention (Bojko 2009). Researchers can create a heat map for one participant or a number of participants depending on their research purpose. For example, heat maps created for two different groups of participants (Chinese vs Australian) help to easily compare the differences in their visual attention and perception (Wang and Sparks 2016). The data analysis procedure of mobile eye-tracking research requires one more step that is to import background images. This is because participants in mobile eye-tracking research may view different scenes and the software needs reference images for data analysis. The software maps each individual gaze data onto these reference images by applying image recognition technology to create scan paths and heat maps.

3.4 Advantages and Disadvantages of Eye-Tracking Methods

Eye-tracking methods offer objective measures of participants' attention and interest. In comparison to self-report questionnaires that rely on individual reflection and memory, eye-tracking methods help to measure both conscious and unconscious attention. Self-report instruments, used to infer cognitive and attentional processes, are highly susceptible to exogenous influences, sustaining the use of complementary measurements (Schwarz 1999). Eye-tracking can help to avoid bias and validity issues in data collection (Scott et al. 2019). In addition to screen-based eye-tracking that is designed for laboratory research, there is also the possibility of using mobile eye-tracking equipment in a real-world setting. Tourism researchers can use mobile eye-tracking to collect real-time tourist perception and attention data that would be more reliable and valuable for research findings.

However, there are several challenges that tourism researchers should be aware of in using eye-tracking methods. First, it takes a considerable amount of time and effort to design and conduct eye-tracking research. Also, there is often only one participant involved in the eye-tracking experiment at once time (due to the cost of eye-tracking equipment), and it generates a huge volume of data for each participant (the eye-tracking measures will be discussed in the next section). Therefore, the sample size of eye-tracking research is quite limited. Second, there are from 10% to 20% of the population that are illegible for eye-tracking research because of their eye issues. More time is needed to recruit and test the eligibility of participants. Third, analysing eye-tracking data requires the use of specific software, and the analysis outcome must be carefully interpreted. For example, a lack of attention to a visual object does not necessarily mean that the respondent is unaware of it. This assumption is only true if the object is unfamiliar (Orquin and Loose 2013). Researchers using eye-tracking methods must have a good understanding of perception and attention as cognitive processes in data analysis (Kuhl and Chun 2014). Despite their reliability and low cost, recent eye-tracking systems, and especially eye-tracking 2.0 systems, can be more demanding and require more technical skills.

Eye-tracking does not record any measure related to peripheral vision, which makes up 98% of the human visual field (Land 1999). However, the rationale of using eye-tracking is that covert attention is followed by overt attention because peripheral vision allows choosing where to fixate our fovea next. In other words, we can see (process) some specific visual element in our visual field without directly fixating on it. For instance, banner ads can be seen on the right side of a page, using peripheral vision. Information from their position, visual appearance or previous web experience, is gathered and used to identify them as ads, and potential consumers frequently choose not to fixate on them.

4 Eye-Tracking Applications in Tourism Research

Eye-tracking methods are powerful means for the study of cognitive processes and are widely used in many research areas such as consumer behaviour (Rosa 2015), education (Lai et al. 2013), information technology (Duchowski 2002), landscape studies (Dupont et al. 2014), marketing (Hui et al. 2009; Wedel and Pieters 2008), psychology (Mele and Federici 2012), reading (Rayner 1998) and scientific studies of attention and eye movement control (Orquin and Loose 2013; Tatler 2009). However, the application of eye-tracking in tourism is still limited. A systematic literature review identified only 17 papers applying eye-tracking methods (Scott et al. 2019, Accepted). This section reviews how eye-tracking has been employed in current tourism research to suggest future research directions.

4.1 Tourism Research Using Eye-Tracking

Tourism research applies eye-tracking mostly to explore how tourists pay attention to and perceive marketing materials such as labels, advertisements and websites. By defining how the audience pays attention to different visual elements, eye-tracking research suggests better ways to design attractive marketing messages. Eye-tracking is effective in evaluating the audience's attention to specific elements of marketing materials such as calorie information on food labels (Nelson et al. 2014; Wolfson et al. 2017), sustainability-related labels (Samant and Seo 2016), nutrition labels (Antúnez et al. 2015) or sponsor information in sports telecasts (Breuer and Rumpf 2012). By applying objective measurements like eye-tracking, researchers can also detect attentional bias including duration bias and direction bias when participants view neutral versus gambling-related pictures (Grant and Bowling 2015).

Eye-tracking has been employed in studying the effectiveness of marketing advertisements. Research reveals that photographic images are more effective than textual advertisements in attracting and retaining attention (Scott et al. 2016) but the addition of text in the advertisement increases attention, especially when it is written in the audience's native language (Li et al. 2016a, b). Eye-tracking is used to measure the influences of textual versus graphical presentation on judgements (Hellmann et al. 2017), image characteristics (Wang and Sparks 2016), gain-framed messages versus loss-framed messages (Berenbaum and Latimer-Cheung 2014) and alcohol consumption (Ellert et al. 2014) on perception. Furthermore, eye-tracking helps tourism researchers to investigate how tourism images can be perceived differently by participants from different cultural backgrounds (Wang and Sparks 2016).

Web utility is one of the central topics in tourism eye-tracking message. The interaction between tourism websites and users has been explored by applying eye-tracking methods (Benbunan-Fich 2001). In addition to eye-tracking web studies in marketing and computer sciences (Bergstrom and Schall 2014; Djamasbi et al. 2010; Drèze and Hussherr 2003; Ert and Fleischer 2016; Goldberg et al. 2002; Hao et al. 2015; Hernandez-Mendez and Munoz-Leiva 2015; Lorigo et al. 2008; Marchiori and Cantoni 2015; Pan et al. 2004), tourism researchers have examined how websites should be designed for better web visit experience. Different types of websites such as online travel agency web (Pan et al. 2011), online sports event web (Green et al. 2011), accommodation choice (Pan et al. 2013) and destination website (Mariussen et al. 2014) have been examined. The structural and visual complexity of the website (Pan et al. 2004), information supply channel characteristics (Mariussen et al. 2014), pictures such as brand image and symbols (Noone and Robson 2014), online hotel reviews (Aicher et al. 2016), price incentives (Tzuaan et al. 2014; Xie and Lee 2015) and consumer evaluations (Noone and Robson 2016; Xie and Lee 2015) are found to affect web users' attentional processes. Mobile eye-tracking has been used in sports management to improve player performance (Steciuk and Zwierko 2015). This is the pioneering study in using mobile eye-tracking for tourism research, but it provides evidence of the potential of mobile eye-tracking for future tourist behaviour studies.

4.2 Future Research Directions

Even though eye-tracking is a powerful tool in studying tourist behaviour, the applications of eye-tracking methods in tourism research to date are only limited to web utility and advertisement effectiveness. The dominant use of fixed eye-tracking methods also limits research possibilities in investigating real-world tourist behaviour or their experiences of augmented and virtual reality. In order to explore the full potential of eye-tracking, areas for future research are proposed in this section.

Mobile eye-tracking can be further explored to study tourist experiences in non-laboratory settings such as natural scene viewing, museum visit, exhibition or event participation. Thanks to recent advancements in portable eye-tracking technologies, today it is easy to collect eye movements in more natural situations—usually requiring unconstrained eyes, head and hand movements—with full freedom of movement in indoor and outdoor settings (Duchowski 2002). By means of wearable eye-tracking technologies, researchers can obtain reliable and unobtrusive online measures of eye movements and parameters to study eye behaviour during complex visual cognitive tasks, analyse the way in which subjects acquire environmental information and investigate how information in visual environments is dynamically processed (Henderson and Hollingworth 1999).

The use of fixed eye-tracking equipment limits tourism researchers to investigate traditional marketing materials such as tourism websites, advertisements, labels on the computer screen in laboratory settings. However, tourists expose to a variety of digital devices every day such as augmented and virtual reality. Eye-tracking studies have been used to measure participants' experiences of augmented reality (Naspetti et al. 2016), virtual cultural heritage contexts (Gena et al. 2016), virtual museums (Bastanlar 2007), virtual tours (Potocka 2013) and hotel virtual tours (Pan et al. 2011) in the computer science and marketing research. Tourism researchers may employ eye-tracking in similar research settings to understand tourist behaviour in the virtual world.

Tourism marketing research to date has only focused on bottom-up attention process by testing different marketing stimuli; there is a gap in investigating how top-down attention influences tourist behaviour in visual search. In the investigation of human behaviour related to visual search tasks, subjects are traditionally asked to search for a given target and discriminate it among several non-targets that differ from the target. Previous research showed that task relevance is the primary driver of the viewer's attention (Orquin and Loose 2013). Individual purpose (e.g. natural or targeted, expect or non-expert) (Li et al. 2016a; b; Naspetti et al. 2016; Sang et al. 2016) affect their attention to and interaction with their environment. Therefore, future research using eye-tracking should consider top-down attention in investigating tourist gaze and viewing experiences (Rayner et al. 2001). Response times, eye-gaze parameters and accuracy of responses are relevant measures to be taken into account in visual search studies (Duchowski 2002).

Eye-tracking can also be applied in conjunction with other emotional measurement methods to provide a more comprehensive picture of tourist experiences. The combination of these objective research methods can provide new insight into tourist behaviour research and avoid bias due to the subjectivity of self-report questionnaires. A number of objective measurements of emotional responses such as skin conductance, heart rate or EEG have been suggested by tourism researchers (Li et al. 2015; Ma et al. 2016; Sivaji et al. 2014).

4.3 Eye-Tracking for Tourism Marketers

Eye-tracking methods offer tourism marketers an objective and advanced tool to understand tourist attentional reactions to marketing materials. This allows them to improve tourism advertisement effectiveness because tourism marketing is not very effective in promoting a destination (Govers et al. 2007) or evoking emotions (Li et al. 2016b). Tourism marketers can employ eye-tracking techniques to test different designs of tourism promotions such as print ads, videos, websites. One the one hand, eye-tracking devices allow them to identify eye-catching elements and suggest ways to enhance tourist attention to tourism promotions. On the other hand, tourism marketers can also verify whether tourists are aware of key messages and hence try to refocus viewers' attention to these important messages. For example, a research project was conducted by the research team at Griffith University in Australia in collaboration with the marketing department of Mantra hotel group. Eye-tracking experiments were used to compare tourist attentional reactions to different designs of Mantra's new website.

Moreover, tourism marketers can also apply mobile eye-tracking methods to enhance tourist experiences. The use of eye-tracking equipment in real-world situations will provide important information about how tourists pay attention to different elements exhibited at a place. This helps tourism marketers to redesign artificial attractions such as museums, exhibition centres in an attractive way to tourists. Based on eye-tracking research outcomes, marketers are able to modify marketing stimuli for the purpose of better staging tourist experiences and increasing their satisfaction. For example, architecture is of less interest to active travellers, while animated signs attracted attention (Afrooz et al. 2014).

This chapter provides a useful guide for tourism researchers who are looking for applying more objective measurements of tourist behaviour. The chapter has discussed theoretical basis, data collection and analysis procedures, advantages and disadvantages of eye-tracking methods. By reviewing how eye-tracking methods have been applied in tourism research, the authors suggest future research directions to exploit this powerful tool in tourism studies. The technological advancement is making objective measurements such as eye-tracking, skin conductance, heart rate and EEG more accessible to researchers and offers promising research opportunities to replace the traditional way of researching with self-report questionnaires.

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