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UPORABA TEHNOLOGIJE SLEDENJA POGLEDA V RAZISKAVAH KULTURNE DEDIŠČINE IN PRAKSI

IMPLEMENTATION OF EYE TRACKING TECHNOLOGY ON CULTURAL HERITAGE RESEARCH AND PRACTICE

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IZVLEČEK

Sledenje pogleda (angl. eye tracking) je raziskovalno orodje, ki temelji ne merjenju premikanja oči in podaja informacije o zaznavanju in vizualnem procesiranju nekega predmeta. Zato analiza procesov pozornosti opazovalca ponuja uvid v razumevanje povezave med kognitivnim procesom in premikanjem oči ter informacijo o tem, ali premikanje oči lahko razkrije človekovo zaznavanje. Tehnologija sledenja pogleda postaja v zadnjih letih vse bolj dostopna, uporablja se lahko tudi pri raziskavah kulturne dediščine. Beleženje in merjenje premikanja oči dajeta dovolj podatkov o območjih, ki najbolj pritegnejo vizualno pozornost opazovalcev, in strokovnjakom omogočata vzpostavitev strategij za prilagodljivo ponovno uporabo objektov dediščine. Članek se osredotoča na uporabo tehnologije sledenja pogleda za boljši vpogled v človekovo dojemanje in zaznavanje kulturne dediščine.

KLJUČNE BESEDE
kulturna dediščina, sledenje pogleda, raziskave, vizualna pozornost

ABSTRACT

Eye tracking is a research tool that is based on measuring the eye movements which provides information about the cognition and visual processing of the subject. Therefore, analysing observer's attentional processes can be both instructive for understanding the correlation between the cognitive process and eye movement, and furthermore whether the eye movements can reveal and disclose the perception of people. The technology of eye tracking is more accessible in recent years, and it is possible to implement this technology in cultural heritage studies. Recording and measuring the movements of the eye can give sufficient information about the areas which are catching the visual attention of the observers the most and that can help the specialists on the establishment of adaptive reuse strategies of the heritage buildings. In that regard, this paper is focusing on the usage of eye-tracking technology for understanding the perception of people regarding cultural heritage.

KEY-WORDS
cultural heritage, eye tracking, research, visual attention

1. INTRODUCTION

The Encyclopaedia of Neuroscience defines the term visual attention as a set of cognitive operations that intervene in the selection of the relevant and irrelevant information from cluttered visual scenes (McMains, 2009). Without a cognitive distinction, people would not be able to reach the data set they require or aimed at since they would receive and process a large amount of data on a daily basis. According to Kastner et. al (1999), when people direct their attention to a certain object, or a particular location at a visual scene, their responses regarding the stimulus strengthen, and the distractions around the direct attention are fading in regard of importance. Therefore, visual attention helps people to collect valuable information in the process of perception and cognition.

In behavioural science research, visual attention is being measured by three non-intrusive methods such as electrocardiography (ECG) sensors, electroencephalography (EEG) sensors, or eye trackers. While the ECG and EEG can give information about the electrical activity of the body, eye tracking would give information on the movements of the eye. Recording the movement of the eye is an important research tool since it can provide insights and information about where the observer is looking at and what is the duration of the examination. Furthermore, it can also store the data about the path where the observer's eyes are following in this process. In this regard, eye tracking can generate valuable information about the observer, which makes this technology to be mostly implemented in user experience research regarding human-computer interaction, and marketing in the present days.

However, eye tracking technology can also be implemented in the field of cultural heritage. The decision process of people regarding identification an artefact as cultural heritage is an intriguing and at the same time an ambiguous subject. The indicators which are affecting this process or helping people to make their decisions are not clear. In that regard, tracking the movements of the eye can give sufficient information about the areas which are catching the visual attention of the observers the most. Ascertaining the points of visual attention and identifying these areas can help the specialists on the establishment of adaptive reuse strategies of the heritage buildings. Therefore, this paper is an attempt on the usage of eye-tracking technology for understanding the perception of people regarding cultural heritage.

The paper begins with the definition and explanation of the history of eye tracking technology. The first chapter gives brief information about the development of eye tracking and the different applications in history. In the second chapter, the concept of perception and how it can be implemented towards cultural heritage by the usage of eye tracking technology is explained. The following chapter in this paper gives information about an applied experiment on cultural heritage buildings and analyses the results. In the last chapter of the paper, the application opportunities of this technique are discussed.

2. HISTORY OF EYE TRACKING

The first experiments which were aiming to observe the movements of the eye were applied by French ophthalmologist Javal in the late 1800s, who focused on the saccades and the fixations during text reading. As Drewes (2010) states, Javal applied a mechanical connection between the eyes and the ears by a rubber band, which makes sounds during eye movements. However, Ahrens, Delabarre, and Huey were the first researchers who tried to record the eye movements. According to Bergstrom and Schall (2014), the devices which were used in eye tracking in the late 1800s were not that pleasant and furthermore, they were not practical. One of the first eye-tracking experiments involved attaching levers to the lenses on the eyes which would transfer the movements to a surface covered by soot. Hereof, the experiment enabled to record the information about the place that the observer is looking at during the eye movements. However, the technique involved physical contact with the eye while recording the movements. Therefore, it was not comfortable for the observer.

As Holmqvist et al (2011). state, even though the usage of eye trackers can be traced back to the late 19th century, the principle of photographing the reflection of an external light source from the fovea has been introduced at the beginning of the 20th century by the research of different scientists with different methods. One of the methods which were applied the most in eye tracking is recording the fixations of the observers. People tend to move their eyes in the field of vision when they are gazing around, however, when they divert their attention towards a specific spot, their eye would focus on this region which would establish the fixation. The spot or the region which catches the attention can be identified as the area which the observer found the most interesting or that the observer tries to gain more information about. Therefore, if it would be possible to track the eye movements of an observer in the process of gazing and focusing, it might also be possible to identify the process which people's attention are shaped. As Duchowski (2003) states, recording what the observer found exciting or what drew the attention of the observer might provide a clue to how that person perceived the scene that he/she is viewing. Furthermore, according to Helmholtz (2005), visual attention is a crucial part of the visual perception of people. In that regard identifying the fixations of the eye movements can help to have more information about the attention and perception of the people.

The elements which are affecting the attention of the subject or the observer can be measured by two main movements of the eye. These movements are fixations and saccades. Fixation is a short and relative pause of the eye when a person consciously processes information from the point that it is observing. As Tatler (2014) states, especially when people are viewing complex scenes, fixations are allocated preferentially to specific locations, while other locations receive little or no scrutiny by foveal vision. Moreover, fixations can also demonstrate that the observer is engaged in that location. When the period of the fixation is more extended, the observer would observe and process more information. Therefore, fixations would be longer on the areas which are valued more on the information scale. On the other hand, a saccade is a quick movement of the eye between fixations. In this period of the eye movement, information is also processed; however, most of the time, this sequence is unconscious. Consequently, both fixations and saccades are essential elements for measuring the eye movements, and furthermore for analysing and understanding the information gathering methods of people either consciously or unconsciously, which have an impact on the perception of people.

One of the founders and furthermore the pioneers of the modern eye movement research is Alfred Yarbus. In his book called Eye Movements and Vision, which was published in Russian in 1965 and translated into English in 1967, Yarbus influenced most of the recent approaches on the study of eye movements and vision. According to Tatler et. al (2010), the last chapter of Yarbus's book, which was called "Eye movements during perception of complex objects", is the most important addition to the field of studies related to eye tracking. His research involved measurements of eye scanning paths of observers on a picture painted by Ilya Repin. When the scan paths of the observers are analysed, the eye scans differ regarding the question that Yarbus asked the participants. According to Yarbus (1967), when people are examining complex objects, the eye fixates mainly on certain elements of these objects. Therefore, the eye rests much longer on some of these elements than on others, while some elements may receive little or no attention when people are looking at objects which contain different elements. Moreover, according to Williams et. al (1997), when the analysis regarding the movement of the eye observed in the parallel and serial search conditions, it supports that eye movements are correlated with the attentional processes of underlying performance on such tasks. Therefore, the eye movements are highly related to visual attention and also with the questions which are asked to the participants. As it has been stated by Findley and Gilchrist (2012), the objects which are salient might differ from moment to moment, and from individual to individual, therefore the eye scan would be able to reflect the interests, expectations and biases of each individual. In that regard, analysing the eye-movements and recording those movements can help to identify the elements which are attracting the attention of the subject or the observer, and furthermore, it can contain useful information on the perception of people and the elements which are affecting or influencing the perception.

3. PERCEPTION OF CULTURAL HERITAGE AND EYE TRACKING TECHNOLOGY

According to the survey which was implemented in the United Kingdom by the Department of Culture, Media and Sport in 2014, cultural heritage and the historical landscapes contribute with the mental health and the happiness of the people. As it has been stated at key findings of the report people who have been in an environment which contains heritage or people who had visited a heritage site in the last 12 months before the survey took place are significantly happier than those who had not visited, even when other factors are controlled. Psychological benefits derived from the interaction between the individual and the environment can give the possibility to understand the effect of the environment and specifically historical landscapes on people.

Over the last fifty years, the studies about the environment and the impact of it on people's perception and psychology gained a greater value by the researches in environmental psychology and behavioural geography. The studies, which are analysing the evaluation of the landscape, established in the outlines of the disciplines which are related to the design by the analysis of the scenic beauty in environments that have an impact on the design approaches. However, according to Gold and Goodey (1983), the models of society which have been widely used while analysing the landscapes in geographical studies developed the first impulse for the behaviouralist research. The appraisal of the landscape by the behaviouralist perspective added another constraint for the research field by including the emphasis on individuals as someone who shaped and responded to the limitations of the physical and social environment by highlighting the emotional and aesthetic considerations on the perception and behaviour. As a result, the interest in the perceived notions by the non-experts and society started to be researched under the preference studies.

As Holohan (1986) states, preference studies and the curiosity towards the environmental psychology gained momentum by the development and consolidation of a specialised field in psychology which is dealing with the analysis of the interaction between individuals and their environment. The shift which has been gained by analysing the human-environment interaction established four main paradigms in the field of landscape and environment research. According to Zube et. al (1982), the main paradigms based on this interaction in landscape perception are the expert paradigm, psychophysical paradigm, cognitive paradigm and experiential paradigm.While the expert paradigm, which is called formal aesthetics by Daniel, includes assessment of landscape quality by skilled and trained observers which are the experts, the psychophysical paradigm involves evaluation through testing public or selected populations. Therefore, this second paradigm combines and measures the perception of society. However, as Daniel (1990) states, the main concern in psychophysical measurement methods is the relation between the indicator responses and hypothesised underlying psychological processes, such as perceived scenic beauty. On the other hand, the cognitive paradigm involves research on the meanings that people are associating with the environment by their past experiences and their prior knowledge. Therefore, cognitive paradigm and the theories established by this approach are connected with the biological and habitat theories, where preferences for specific types of environments were explained by their contribution to human survival and continuity of human life. The experiential paradigm is also based on the experience of human–landscape interaction, however, in this paradigm, the process is believed to be on-going, and that human and landscape can both shape each other. All these different paradigms are essential for understanding the interaction between individuals and their environment, and furthermore, they can help in describing the preferences and perception of the people for landscapes and environment.

In this regard, in relation to research connected to cultural heritage and its perception, the cognitive approach can be implemented, because it is directly related to the judgement of the people and their preferences. The visual attention people have is not only related to the ability of the eye regarding seeing, but it can be described as the sum of both overt and covert data collection of the eye and its processing. Therefore, measuring or identifying visual attention can be practical and informative regarding understanding the perception of people when they are evaluating cultural heritage. Accordingly, implementing the eye-tracking technology can be convenient and advantageous for the identification of the indicators, and furthermore, eye tracking as the research tool can provide the additional data which can help to limit the area for conceiving the decision processes of people regarding the selection of cultural heritage. Identification of the indicators can obtain data on the perception of society which should not be omitted in the consideration and decision-making process of adaptive re-use.

4. EXPERIMENT

4.1 Method and apparatus:

As it has been stated at the article 'Yarbus, eye movements and vision' by Tatler et. al (2010), according to the research of Yarbus, when people observe a complex scene for an extended period of time, it is likely that people would follow a repeated cycle of examination. Furthermore, the analysis demonstrates that during these cycles the eye stops and inspects the most important elements of the picture determined by the nature of the object and the problem the observer is facing at the moment of perception. Therefore, the recordings which have been composed in this experiment for tracking the eye and measuring the fixations and saccades have been ceased when the cycles appear to repeat frequently on the indicators. On the other hand, the Scanpath Theory, which established by Noton and Stark (1971) suggests that the scanning paths pursued by the eye during extended viewing are the most important part of people's perception and evaluation of objects. In that regard, repeated cycles on the fixations have also been marked as the more important fixations of the observer during the analysis of the recordings.

In this experiment, wearable eye trackers were used as the research tool. The eye movements of the right eye were recorded with a monocular eye tracker which has a high-speed world camera that contains the sensor with frame rates of 1920x1080 @30fps, 1280x720 @60fps, 640x480 @120fps and diagonal FOV lenses which are 60 and 100 degrees with a latency of 5.7 ms. The Eye camera which is used in this experiment contains the sensor with a frame rate of 200x200 @200fps, 400x400 @120fps with the latency of 4.5 ms. Therefore, the experiment contains two cameras. The eye camera is aimed at the eye pupil, while the world camera is recording the area that the subject is observing. With the help of the two cameras, the eye movements and gaze points were recorded while the subject was observing a set of photographs with 11 different buildings. In the experiment, two different sets of photographs were used.

The photographs which were demonstrated in the experiment contain various façade images which were taken by the author by Nikon D3400 camera with 24.2 Megapixels effective pixels, 23.5mm x 15.6mm sensor size, and 6000 x 4000 maximum resolution. The buildings were chosen from the structures that were listed on the UNESCO nomination file of Kaunas which were selected by the experts, and from contemporary buildings in Kaunas. The photographs were projected by a projector with the native resolution of 1024 x 768 and a maximum resolution of 1600 x 1200 to a screen with the size of 160cm x 200cm. The usage of eye trackers provided the possibility to analyse the fixation points and the indicators where the participants are examining while they are evaluating an artefact as cultural heritage. In that regard, the experiment also provided valuable information regarding the difference by the choices of experts and non-experts as well.

After the experiments were performed, the reason for the decisions and what were the characteristics of the façades which were affecting the participant's decision process were also asked verbally to the participants.

4.2 Participation and procedures:

In the design of the experiment, a qualitative approach and a non-probability sampling method have been applied. The reason for adopting a non-probability sampling method was related to the ability to apply purposive sampling which matches with the goal of the experiment. The goal of the experiment was not on achieving objectivity or generalisation, but it is on identifying indicators which can be implemented in a model. Therefore, the experiment was a pilot study.

As part of the purposive sampling, criterion case sampling method has been adopted in the research. According to the first experiment of the author (Doğan, H.A. 2019), prior knowledge has an essential role in the appraisal of the artefacts. Furthermore, cultural memory and the meanings people attach to the environment and the buildings have an impact on the perception and interpretation. Therefore, this experiment adopts this knowledge as the origin. Consequently, if older generation, which has the prior knowledge and cultural memory, cannot perceive the artefacts which are demonstrated to them as cultural heritage, it is implausible of the younger generation to evaluate these artefacts as cultural heritage. On the other hand, it is possible that the older people would perceive some of the buildings which are demonstrated to them as cultural heritage due to cultural memory and prior knowledge without the need of the indicators. In that regard, selecting the participants from younger generations can give the ability to determine more physical indicators in their evaluation process.

In the selection procedure of the participants, a convenience sampling approach has been adopted by a sequential sampling method. Therefore, the experiment finalized when the indicators got repetitive, and the estimated means in the sample reached saturation in a pre-specified range of confidence interval.

According to this method, the participants were selected from bachelor and master students of Faculty of Architecture and Faculty of Social Sciences, Arts and Humanities of the Kaunas University of Technology. The participants were informed about the experiment and asked for their participation. As a result, 39 students with age ranging between 18 and 30 years old participated. However, there were 2 invalid recordings, therefore, in the experiment, the data of 37 students were used. The invalid recordings were caused by the makeup of the female students or by the darker eye colour of the students which did not allow the eye tracker to record accurately. The distribution was fairly equal between females (n = 18) and males (n = 19).

The course of performing the experiment preceded with the calibration of the eye tracking glasses for each participant. Both manual marker calibration and natural feature calibration methods were adopted in the experiment depending on the conditions. Furthermore, in both methods, a 9-point monocular calibration operated for central fixation accuracy and for a full calibration. The calibration process also served as a cue for the participant for acclimating the procedure and the experiment.

After checking for a central fixation, the experimenter manually triggered the start of each trial. The experiment lasted approximately 12 seconds for each building and 2 minutes in total. The data of eye tracking has been recorded by the wearable eye-tracker and a laptop computer. The participants located approximately 4 meters away from the photograph of the building where the whole façade can be visible for the participant.

4.3 Data analysis:

The overall quality of the data which was recorded by the eye tracker was calculated as the average deviation between the calibrated point of regard (POR) and 9 validation points. The average horizontal and vertical deviation was 0.62 and 0.75° respectively. The number of missing samples due to blinks are approximately 13%. The eye movement data from each participant were extracted, and eye movement events such as fixations, saccades and blinks were detected by the software called Pupil Capture. The analysis of the data which have been recorded by the wearable eye trackers performed on the computer with the help of the software called Pupil Player. Both of the software which is mentioned is the default software of the eye tracking glasses. However, during the analysis, the need for examining the recordings frame by frame emerged due to the recordings containing the whole test, and the photographs needed to be analysed one by one. In that regard, the free software called QGIS used for the analysis.

The Pupil Player software allows to replay the recordings and furthermore, gives the possibility to track the counts of the fixations and saccades of the gaze. Furthermore, the software can provide the data of the start, end and the duration of the fixations, the coordinates of the gaze position in x and y as surface-gaze distribution, confidence and dispersion. According to the data which has been extracted by the Pupil Player, the data has been represented by two main methods. The first method is transferring the fixation counts to a static image. The transfer process has been achieved by manually analysing the video in every frame. The second method is establishing heatmaps. However, the movement of the head, which is constantly changing the position of the observer's coordinates in the recording process, establishes complications in the creation of the heatmaps. Therefore, the heat maps were attempted to be created by the help of markers which identify the area of interest. The markers which have been applied in the experiment were A4 sized and previously defined marker patterns by the Pupil Labs. In the course of the experiment, the markers are attached to the four corners of the screen where the photographs are projected to.

4.4 Results of the analysis:

The experiment suggests that there are various indicators which affect the participant's decision process. One of the indicators which are acknowledged by the experiment is the interventions that were added to the constructions subsequently. According to the results of the analysis of the data, participants had the tendency to fixate on the parts of the buildings which were added postliminary, or which demonstrated the contemporary living norms. 80% of the participants who have specifically focused on these interventions evaluated the artefacts as not being cultural heritage. However, if there are ornaments on the surface, the impact of the interventions is lower, and in most cases, ornaments are strong stimuli for participants. 91% of the participants who were fixated on the ornaments evaluated the buildings as cultural heritage. In that regard, ornaments can be considered as active indicators, while interventions can be recognised in a more passive manner. (Figure 1.)

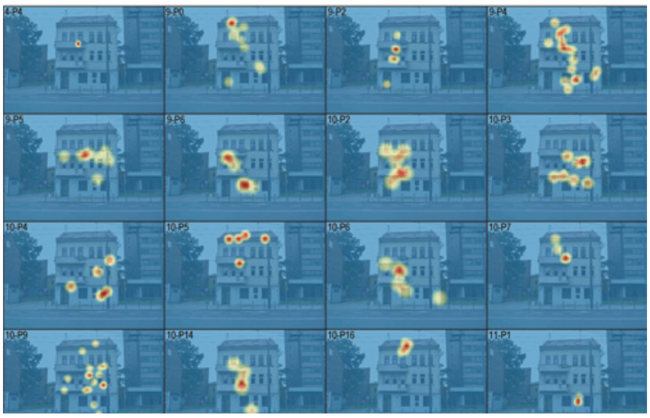


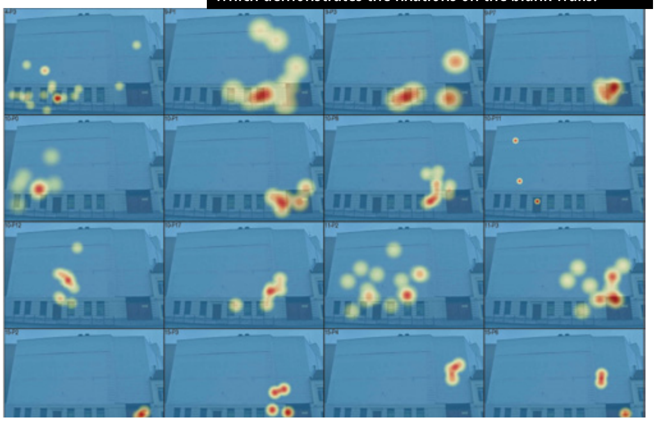
Figure 1: An example sheet of the eye tracking experiment which demonstrates the fixations on the intervention.

Another indicator which was determined by the eye-tracking experiment is the expressive architectural elements such as pediments, towers, portholes or bandings on the plaster. According to the analysis, participants assessed 87% of the buildings as being cultural heritage when they had their gaze fixated on these elements (Figure 2). However, when their gaze was fixated on the surface of the buildings which are covered by plain plaster 83% of the participants determined the buildings as not cultural heritage. In that regard, as it has been also demonstrated by the former research of Dogan (2019), material can also be considered as an indicator.

Figure 2: An example sheet of the eye tracking experiment which demonstrates the fixations on the expressive architectural elements.

The analysis of the heatmaps demonstrates that, when there is a different element on the façade of the building such as an ornament, banding on the plaster, pediment, curved lines or a tower, the fixation of the participants move towards these areas which are giving unique characteristics to the surface. Furthermore, differently shaped windows such as porthole windows or corner windows, or architrave on the entrance door also attract the attention of the observer. However, when the façades contain blank surfaces, most of the gaze does not scan these areas (Figure 3).

Figure 3: An example sheet of the eye tracking experiment which demonstrates the fixations on the blank walls.



5. CONCLUSION

When adaptive re-use is considered, most of the time, its social aspect is disregarded, and the socio-cultural benefits which can be obtained by the adaptive re-use are omitted. However, it might not be due to giving less priority to this aspect, but because social benefits and the impacts are harder to measure. In that regard, there is a new approach needed in adaptive re-use strategies which can measure the impact on the society and also the perception of the people regarding cultural heritage.

The experiment which was presented in this research is based on measuring the eye movements of the participants for identifying and analysing the indicators which might have an impact on their evaluation of cultural heritage by the usage of an eye tracker as a research tool. In this research, recording and measuring the movements of the eye managed to give information about the areas which are catching the visual attention of the observers the most when they are observing the façade of a building. A better understanding of the indicators which are affecting people's perception when they are evaluating cultural heritage can allow specialists to proceed from a more informed perspective regarding adaptive re-use of immovable cultural heritage and comprehend the perception of the society towards it. Furthermore, this approach can also be implemented in practice, especially on the façade lighting of the heritage buildings, so that the parts which are going to be emphasised by the help of light can match with the areas where people are focusing the most. This technology can help the specialists on the establishment of adaptive reuse strategies of the heritage buildings in a broader context, and it can be an important research approach for the future in the cultural heritage field.

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