Exploratory Study of Eye-Tracking Path: A Case Study from Switzerland

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Abstract. It is known that due to the nature of 360° videos, a user only utilizes about 20 % of the transmitted data, so understanding how the viewer actually watches them, is very crucial for the scenario of the video, and for stimulating the viewer for a certain action, like taking a real trip. We conducted the experiment using the 360° videos produced by the tourist bureau of the Canton of Vaud in Switzerland, on 16 viewers. This study was conducted in January 2023, and therefore, this paper is the initial step for the eye-movement path description from this experiment. The paper consists of 4 parts – introduction, theoretical background for eye-tracking path data, eye-tracking data analysis and conclusion.

Keywords: video 360° VR, eye-tracking path, fixations, saccades, viewing behavior

1 Introduction

In recent years, especially during and after the Covid-19 outbreak, the use of VR/AR technologies for such industries as manufacturing and design, health care, transportation, retail and tourism is on the rise, because it helps to improve productivity and well-being of users. For consumers, VR/AR provides immersive experiences and personalized content [1].

This paper addresses the under researched issue of viewer orientation in video 360° VR traveling environment. The purpose of this paper is to propose the framework based on behavioral and environmental variables, which can be tested using the eye-tracking data obtained from the recent experiment, which took place in January 2023 in Switzerland.

The paper is organized as follows. In the second section, we describe the theoretical backgrounds for the viewer behavior in travel environment from two main standpoints in environmental psychology and neuroscience - the spread of the experiment participant's view of the video, and the density of the experiment participant's looks at the video. In the third section we give some descriptive statistics for the data. In the fourth

section we conclude with proposing managerial implications and direction for future research.

2 Theoretical Background for Eye-Tracking Path Data in Environmental Psychology and Neuroscience

2.1 General Theory related to Human Movements Tracking of Individuals

In the past three decades there have been numerous studies in the fields of environmental psychology and neuroscience, the results of which shed light on viewer behavior while watching video 360° VR. There are two approaches in environmental psychology: emotional (affective) and cognitive. Emotional approach analyzes emotional reactions in different environments [2]. One of the main theory which can be used in investigation of how to use of video 360° VR in order to motivate humans to take real tours is stimulus–organism–response (S–O–R) theory [3]. In order to test for such reactions, the survey has to be conducted. However, in this paper we will mainly deal with the dynamics of the eye-movement itself, which comes first before the investigation of any emotional reactions. The second main approach is cognitive approach which analyzes perception and remembering of the environment, "mental maps". In our case, moving within the virtual environment as the "heat maps" show. Lots of research related to the influence of mental maps on orientation behavior of viewers were conducted, however, the issue of the eye-tracking paths stays somewhat under researched. [4] In the next section we investigate in more details related to the theoretic definitions of the eye-tracking movements.

2.2 Theoretical Background for Eye-Tracking Movement

As for the definition of "eye-tracking", it is a method that provides objective data on where and why viewers are looking. In other words, the method determines the gaze coordinates: points of intersection of the optical axis of the eyeball and the plane of the observed object or screen with some visual stimulus (in our case – video 360°).In the context of video 360° method is used in different purposes related to visual system: to get the gaze coordinates on all 15 scenes of the video 360° of canton Vaud (Switzerland), to evaluate the landscape attention of the viewer by evaluating density of the gazes, to what elements of the scenes the viewer is more attracted, in what sequence of elements the viewer's attraction is moving and how often this happens, and finally to evaluate the efficiency of video 360° as the stimulus for real traveling.

It is known that the pupil of the eye moves unevenly. Rapid (till 800°/sec.) pupil movements are called *saccades*, and focusing the pupil on any object are called *fixations*. Saccades move the eyes to a new position for fixation. During fixations, perception and storage of information happens. Saccades and fixations distribution on the image is called the landscape attention. As for saccades, they are extremely fast jumps, moving the eyes to a new position for fixation. Fixations vary in amplitude and speed. There are 3 types of saccades: macrosaccades (abrupt changes in the position of the

eye, characterized by high speed and accuracy, with amplitude 40'– 50' till 50– 60º), tracking movements (smooth eye movements accompanying smooth movement of objects in the field of view (scenes in the case of video 360°), ensuring the preservation of the image fixed object in the zone of the best vision (on central fossa), microsaccades (rapid eye movements of 10–20 ms in duration, with amplitude range 2'–50').
The fixed state of the eyes - fixations. During fixations, objects are recognized (when reading during the time of fixations, word recognition occurs). Fixations by durations are divided into explicit (from 250 to 450 ms) and implicit (150-250 ms).

3 Eye-Tracking Data Collection and Analysis

3.1 Description of Eye-Tracking Paths through the Scenes

Eye-movement data collection experiment was conducted in January 2023 with 16 participants from one of the Swiss universities. The idea of the experiment was to let the participants of the experiment watch the video 360°, track and record the movements of their eyes and record their pupils positions with Tobii Pro Glasses 3. The glasses have the ability to record at 50 or 100 frames per second, and the concept automatically adjusts to saccade to maintain accuracy of data measurement. The video 360° was produced by the Tourism Bureau of the Canton of Vaud in Switzerland.
The main value of technology lies in the fact that in eye-tracking studies participants' attitude to the object of the research comes to naught. This means that the accuracy of the research and the veracity of the data obtained are not distorted by motivation of the experiment participants during the research.

3.2 Description of Eye-Tracking Paths through the Scenes

During the experiment the following information was collected: event number (the same for 1 person); absolute start time of the event (microseconds), absolute end time of the event (microseconds); gaze point X as X-coordinate (screen pixels), gaze point Y as Y-coordinate (screen pixels); variance in X (screen pixels), variance in Y (screen pixels); gaze point 3D X, gaze point 3D Y, gaze point 3D Z; gaze direction left/right X, gaze direction left/right Y, gaze direction left/right Z; pupil position left/right X, pupil position left/right Y, pupil position left/right Z; pupil diameter left (right), pupil diameter filtered; eye movement type; gaze event duration (microseconds); eye movement type index; fixation point X, fixation point Y; gyro X, gyro Y, gyro Z; accelerometer X, accelerometer Y, accelerometer Z.

For the purpose of this research, we use the data on event number (the same for 1 person); absolute start time of the event (microseconds), absolute end time of the event (microseconds); gaze point X as X-coordinate (screen pixels), gaze point Y as Y-coordinate (screen pixels).

Firstly, the absolute start time of the event is used in order to break the video into the scenes and thus, we divided the video 360° into 15 scenes (Vallee de Joux, Mon- treux (Rochers-de-Naye), Lausanne (Cathedrale), Lausanne (Ouchy), Morges, Nyon,

Montreux (Chateau de Chillon), Lavaux-les-Bains, Jura Vaudois, Avenches, Aigle, Chateau-d'Oex, Leysin (Kuklos), Les Diablerets (Glacier 3000)).

The absolute gaze point X as X-coordinate (screen pixels) and gaze point Y as Y-coordinate (screen pixels) are used in order to visualize viewer's eye-movements.

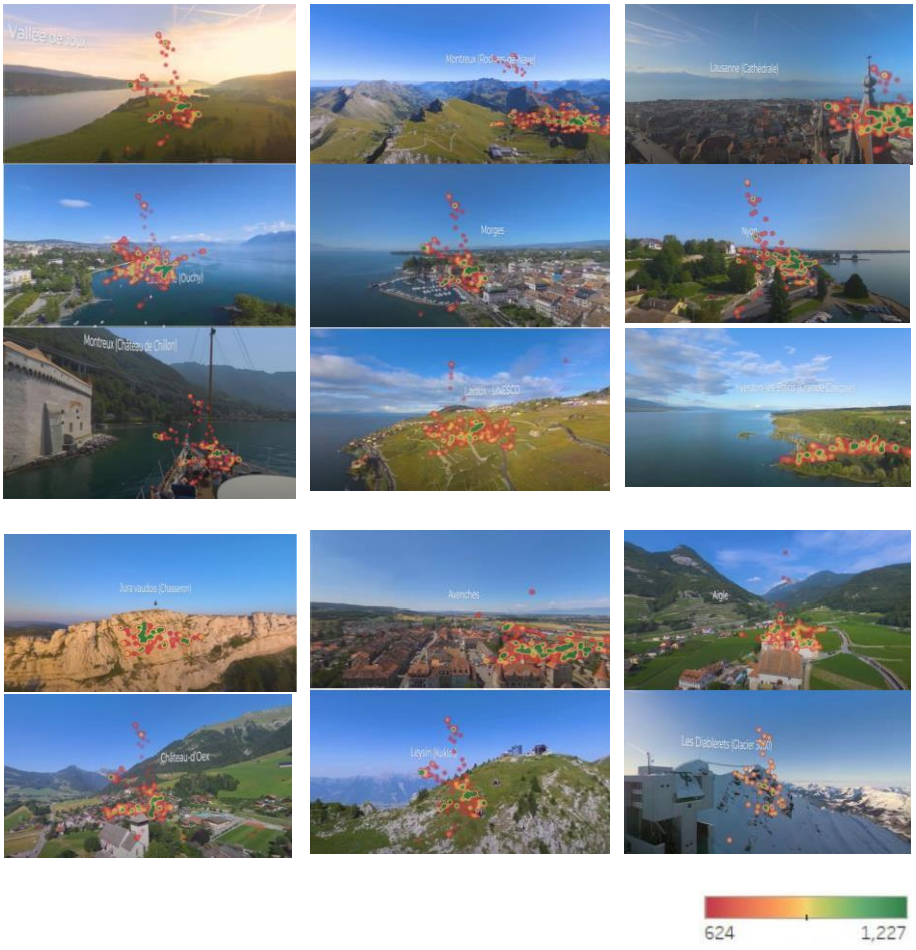


Fig. 1. Heat maps of eye-movements on 15 scenes of the video 360° of the Canton of Vaud

(the order of the scenes in Fig.1 corresponds to the order of the scenes in the video, namely Vallee de Joux, Montreux (Rochers-de-Naye), Lausanne (Cathedrale), Lausanne (Ouchy), Morges, Nyon, Montreux (Chateau de Chillon), Lavaux-les-Bains, Jura Vaudois, Avenches, Aigle, Chateau-d'Oex, Leysin (Kuklos), Les Diablerets (Glacier 3000))

The problem of such visualization is that if the scenes change order, the measurements of gaze points Xs as X-coordinates (screen pixels) and gaze points Y as Y-coordinate (screen pixels) will also change.

Secondly, we computed the descriptive statistics of the trajectory path. From the Table 1 we can see that the most attractive scene for the viewer is Les Diablerets (Glacier 3000) with the number of fixation points 2105 and the number of saccade points 154, the second attractive scene for the viewer is Montreux (Rochers-de-Naye) with the number of fixation points 1776 and the number of saccade points 106, the followingare LausannLaysin (mountains) and Montreax (riviera) drew the most of attention of the viewer while the most active saccades were at the glacier and Montreax (riviera) scenes. The frequencies give the certain characteristics of the touristic preferences of the viewer.

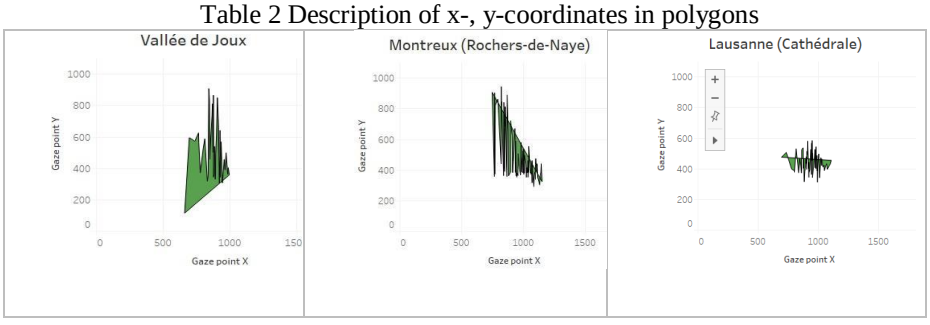
Table 1. Descriptive statistics of fixations and saccades depending on the scene

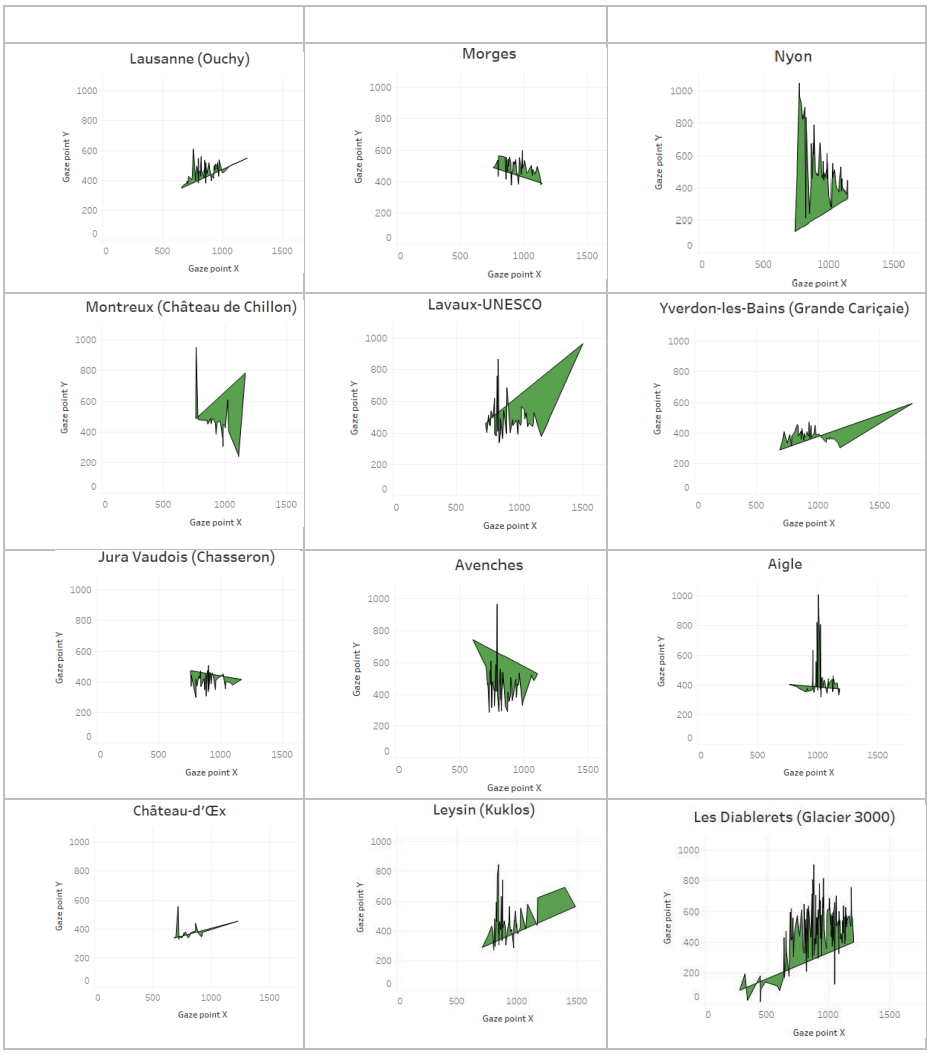
	Eye movement type			
Scene_Idx	Fixation	Saccade	Unclassified	EyesNotFound
Aigle	856	42		0
Avenches	862	50	1	0
Château-d'Œx	785	22		0
Jura Vaudois (Chasseron)	560	36		
Lausanne (Cathédrale)	1 435	70	3	0
Lausanne (Ouchy)	1 462	56		0
Lavaux-UNESCO	1 187	50		0
Les Diablerets (Glacier 30..	2 105	154	3	0
Leysin (Kuklos)	1 125	52	5	0
Montreux (Château de Chi..	508	28		0
Montreux (Rochers-de-Na..	1 776	106	1	0
Morges	760	48		
Nyon	609	57		
Vallée de Joux	689	46		
Yverdon-les-Bains (Grand..	496	41		0

3.3 Description of Eye-Tracking Paths through the Scenes

The description of the spread of the coordinates is given in the Table 2. From the Table 2 we see that the widest spread in eye movement is the characteristic for the wide natural scenes such as Valee de Joux, Montreux (Rochers-de-Naye), Nyon, Montreux (Chateau de Chillon), Lavaux -UNESCO, Avenches, Leysin, Les Diablerets (Glassier 3000).

Table 2 Description of x-, y-coordinates in polygons





Mani results based on the analytics above are that 1) the viewers eye-movements are more wide in the natural and broad scenes, 2) the viewers eye-movements are more intensified in the scenes with some objects in them, i.e. the house in the mountains, the ship in the lake, the cathedral in the city.

4 Conclusion

While it is a bit challenging to make an immediate conclusion for the application from the exploratory study, it is definitely very helpful to observe the whole eye-movement path of the viewer of the video 360° in order to make a basic description of the viewing behavior. It is known that due to the nature of 360° videos, a user only utilizes about 20 % of the transmitted data, so understanding how the viewer actually watches them,

is very crucial for the scenario of the video, and for stimulating the viewer for a certain action, like taking a real trip.

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