Eye movement and environmental affordances in an emergency egress task: A pilot study

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ABSTRACT

Understanding and predicting people’s displacement movement is particularly important to avoid wayfinding problems as well as to improve egress in emergency situation within complex buildings (e.g., hospitals, convention centers, subway stations and university campus). Environmental cues (i.e., affordances) can act as attractiveness factor which can influence some decisions taken by the visitors while choosing what route to follow. The study of eye movement can be an interesting approach to examine the influence of environmental cues about people’s decision-taking. Therefore, this pilot study aims to investigate the use of eye movement analysis to understand the association between decision-taking during an emergency egress and environmental affordances. For this, a non-immersive virtual-reality (VR)-based methodology was adopted, involving the projection of images in a wall-screen. To collect the users’ responses, a constant stimulus method combined with a two-forced choices method was used. The results obtained, allow us to conclude that eye movement analysis may be used to investigate the association between decision-taking in an egress task and environmental affordances.

Keywords: Eye movements, decision-taking, affordances, wayfinding, virtual reality
1 INTRODUCTION

When complex buildings (e.g., hospitals, convention centers and train stations) are the focus of intervention by professionals involved in planning these structures (e.g., architects, designers, managers), the ability to predict people’s movement is particularly important to avoid wayfinding problems within these built environments. According to Conroy (2001), architects and designers are often unable to determine how people navigate through complex buildings, so they either neglect this information altogether or make judgments based solely on intuition. Additionally, as settings grow larger and more complex, emergency evacuation emerges as a key problem, and wayfinding becomes a matter of life and death (Arthur and Passini 2002).

The importance of signage for wayfinding problem solving is generally recognized among researchers; however, Arthur and Passini (2002) point out that sometimes people are often as lost with the signs present as they are without them. Thus, an important issue to consider when studying human wayfinding is the influence of the external information when it is presented in a lower level of awareness, which sometimes is implicit in the overall configuration of the building. Some studies suggest that in ordinary conditions (e.g., where relatively symmetrical intersections have the same environmental characteristics on both sides) there is a tendency for the public to bear to the right (Robinson 1933; Scharine and McBeath 2002; Vilar et al. 2012). The influence of lighting on people’s decision about what path to choose in an everyday situation was also examined (Taylor and Socov 1974; Vilar et al. 2012). They found that when paths had the same intensity of light on both sides, about 60% of the subjects chose the path on the right side. However, when there was a noticeable difference in the light intensity on one of the sides, subjects preferred to follow the brighter path. An approach to study this implicit external information can be based on the affordances that the environment furnishes or affords the observer (Gibson 1986). Some authors state that affordances are environmental properties that have some meaning to guide the observer’s behavior (Turvey 1992; Stoffregen 2003). The conscious use of this concept in architecture is based on the definition of a set of variables, which express the different priorities and capabilities of users under various conditions, creating congruence between what people realize they can do and the activities they can really perform.

According to Wiener, Büchner, and Hölscher (2009), eye-tracking studies have primarily investigated the role of gaze for the control of locomotors behavior, considering the context of navigation and wayfinding. They also stated that very few eye-tracking studies investigated the processes related to spatial memory, path planning, and decision making at choice points, and this approach can be very useful for answering questions related to human wayfinding.

In this way, the main objective of this pilot study is to investigate the use of eye movement analysis to understand the association between decision-taking during an emergency egress and environmental affordances. For this, a non-immersive VR-based methodology was adopted, involving the projection of images in a wall-screen. To collect the users’ responses, a constant stimulus method combined with a
two-forced choices method was used.

2 METHODOLOGY

For this study, a set of static images of virtual indoor hallways was presented to participants using a projector. Eye-movement data was acquired through the use of an eye-tracker system. To collect the participants’ responses, the images’ sequence was presented using a constant stimulus method combined with a two-forced choice method.

The participant’s decision-taking (i.e., path selection) at the corridors’ intersection points along simulated corridors (i.e., escape routes) was the study’s main focus. As such, these concerns have conditioned the architecture of the experimental VE designed for this study.

For this pilot study, data were collect from a female participant, with 24 years old, who participated as volunteers in this study. She was right-handed and had normal sight or had corrective lenses and no color vision deficiencies. Color blindness was screened by the Ishihara Test (Ishihara 1988). She also reported no physical or mental conditions that would prevent her from participating in a VR simulation.

2.1 Design of the experiment

In order to assess the influence of the independent variables – corridor width and lighting – on the path’s selection, by participants in a simulated emergency egress, three situations were considered (i.e., corridors width with same bright, lighting in wider corridors and lighting in narrower corridors). Considering this, nine experimental conditions representing indoor situations formed by two corridors linked by a “T-type” intersection were designed, providing two alternative arms or directional choices, (Figure 1). Thus, the participant was assigned to a setting which was composed of a main corridor that ends in a perpendicular corridor with two side corridors (i.e., an alternative hallway to where the user could turn), offering two alternative paths (i.e., to turn left or to turn right).

The width of the side corridor was manipulated to test the influence of the corridor’s width on the route decisions. Thus, the main corridor’s width was fixed at 2 m wide, but the perpendicular alternative corridors (left and right) had their width varying between 2m and 3.5m wide each, corresponding to the corridors C2 and C3 in Figure 1.

The existence of lighting was also manipulated to test the influence of this variable on participants’ decision about the path to follow. Thus, lighting was added in the wider corridors and two stimuli were obtained through this (i.e., corridors C5 and C6 in Figure 1). In order to verify which variable had more influence in participant’s decision, two stimuli were created with lighting in narrower corridors,
designing a situation that confronts narrower and brighter vs. wider and darker corridors. These stimuli can be seen in Figure 1 as corridors C8 and C9. Neutral condition was defined as corridor C1 in which all corridors have the same width (2m) and bright.

Considering light positioning, corridor C4 and C7 were designed with lighting at the corridors of the left and right sides.

An example of the virtual environments developed from those conditions can be seen in Figure 2.

The stimuli were organized according to the method of constant stimuli, and a method of forced choice, between two alternatives, was used to collect answers. All the participants were exposed to 2 blocks of 135 trials, in a randomized sequence, in which all of the stimuli were repeated 15 times. The second block had the trials organized in the inversed order used in the first block. To exclude an eventual sequence effect, each half of the sample was assigned, in first place, to one of the blocks.

The inter-stimulus interval varied from 800 to 1000 ms and the stimulus maximum duration was 1400 ms, but it could be less, because in the moment that the participant pushed the button to select an answer (i.e., a direction), the corridor’s image disappeared and an inter-stimulus screen was presented. The inter-stimulus screen was a gray screen with the image of a black cube in the center.

Figure 1 Nine different corridors according to the studies’ independent variables.

Figure 2 Examples of the images of corridors presented to the participants. In the left image there is an example of the narrower corridor with more lighting vs. the wider and darker corridor. The middle image has an example of a situation in which the lighting is in the wider corridor. The right image show the situation where left and right corridors have the same width but the right corridor has more lighting.
The participant was unaware of the real objective of the experiment and was asked to act in a realistic/natural manner in order to evaluate a new system for VR simulation. She was told that she should choose one of the available paths as fast as possible, since she was in an emergency situation.

2.2 Virtual Environment

The VE used in this study was a simplified version of those used for Vilar et al. (2012). Later, a free plugin (OgreMax v1.6.23), exported the environment which were presented by the ErgoVR system (Teixeira et al. 2010), developed by the Ergonomics Laboratory at FMH – Technical University of Lisbon.

2.3 Experimental settings

A Lightspeed DepthQ 3D video projector and a MacNaughton Inc’s APG6000 active glasses comprised the VR system used for the experimental tests. A Thrustmaster FireStorm Dual Analogue 3 Gamepad was used as an input device, in order to collect the participants’ answers. Participants were asked to press the Gamepad’s functional buttons on the right, according to the chosen direction (i.e., left and right).

The projected image size was 1.72 m (horizontal) by 0.95 m (vertical) with an aspect ratio of 16:9. The observation distance (i.e., the distance between the observers’ eyes and the screen) was 1.50 m resulting in a 35.2º of vertical field-of-view (FOV) and 59.7º of horizontal FOV. All participants remained standing during the experimental session at the same location (marked on the floor) to ensure the same observation distance.

Data for eye- movement analysis was collected using the eye-tracker system Mobile Eye v. 1.33 from Applied Science Laboratories (ASL).

2.4 Procedure

The participant was asked to sign a form of consent and advised she could stop the experimental session at any time. The duration of the experimental session was 15 minutes.

The experimental session started with a training stage, in which some explanations about the experiment and the equipment involved were given to the participant. She also saw images of the intersection type and received instructions regarding to the task she was requested to fulfill. Participant received task-related instructions such as “You are in an emergency situation, the building is on fire. You have to choose between two alternative paths to find the building egress”. The training stage also comprised of two trials using a sequence of images like those used in the experimental test. In the first trial, the participant was asked to point, with her hands, to each alternative corridor that she could see in the image. This
procedure intended to ensure that the participant realized the alternative paths that she had in front of her. The second trial intended to make participants familiar with: i) the command buttons in order to choose the direction and, ii) the time available for the answers.

After the training stage, the calibration of the eye-tracker system was done asking the participant to look at five points projected.

The experimental test started after participant had given the required answers, in the time available, and had declared she felt confident and comfortable with the command buttons. For the experimental test, participant was assigned to the first sequence of 135 trials. When the first sequence was fulfilled, and after a five minute break, in the absence of simulator sickness symptoms, participant was assigned to the second sequence of 135 trials. At the end of the experimental test, a demographic questionnaire was applied to collect information such as age, gender, occupation and dominant hand. The participant was also asked to answer questions related to the experimental test.

3 RESULTS AND DISCUSSION

The main objective of this pilot study is to investigate the use of eye movement analysis to understand the association between decision-taking during an emergency egress and environmental affordances.

All data obtained with the eye tracker were analyzed using the ASL Results and the Captiv L-2100.

Table 1 Percentages of participants’ directional choices and percentage of first eye-gaze coincident with the choice for the experimental conditions.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Condition</th>
<th>% Choice</th>
<th>% First Eye Gaze</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Bright Same Width</td>
<td>Neutral</td>
<td>66.7 (%Left)</td>
<td>76.7</td>
</tr>
<tr>
<td>Different Bright</td>
<td>Width</td>
<td>98.3 (%Wider)</td>
<td>38.9</td>
</tr>
<tr>
<td>Same Bright Same Width</td>
<td>Bright</td>
<td>100 (%Brighter)</td>
<td>98.3</td>
</tr>
<tr>
<td>Different Bright</td>
<td>Bright Vs. Width</td>
<td>95 (%Brighter)</td>
<td>100</td>
</tr>
<tr>
<td>Different Bright</td>
<td>Bright + Width</td>
<td>100 (%Both)</td>
<td>88.3</td>
</tr>
</tbody>
</table>

The participant’s choice in what concerns the direction, for each experimental condition, considering that the subject was escaping from a building in an emergency situation, is presented in Table 1, as well as the first eye-gaze for each directional choice. The results encompass the participant’s directional choice, by
experimental condition, for all trials, (30 observations for each stimulus). All missing answers were considered invalid.

Regarding to the neutral condition, where both alternative corridors had the same width and bright (C1), 66.7% of choices were favoring the left corridor. When this choice is made, the analysis of the eye-gaze show that the first eye-gaze was coincident with the directional choice in 76.7% of the trials related to this stimulus (30 trials).

The situation where the corridors had the same bright but different widths, 98.3% of choices were favoring the wider path. The first eye-gaze was coincident with the wider corridor only in 38.9% of the cases.

Others conditions had the majority of the directional choices favoring the brighter corridors. In these situations also the first eye-gaze was near 100% favoring chose option.

Nine categories related to the strategies of image exploration were defined considering the three main areas of interest, left, center and right, as shown in Figure 3. Exploration patterns were analyzed only based on the presence of the eye-gaze in each area. Thus, up, center and down eye-gazes into the same area were classified as same (i.e., they were not discriminated).

In this way, the image exploration categories defined were:
1. Choice area: the participant looked only to the area which is the same of her directional choice;
2. Choice area – Opposite area: the participant looked first to the area coincident with her choice and after she looked to the opposite area of her directional choice;
3. Choice area – Center area- Choice area: the participant looked first to the area coincident with her choice, after she looked to the center area and returned to look at the choice area;
4. Choice area - Opposite area - Choice area: the participant looked first to the area coincident with her choice, after she looked to the opposite area of her directional choice and looked again for the choice area;
5. Opposite area: the participant looked only to the area which is the opposite of her directional choice;
6. Opposite area - Choice area: the participant looked first to the opposite area of her choice and after she looked to the Choice area;
7. Opposite area - Center area - Opposite area: the participant looked first to the opposite area of her choice, after she looked to the center area and looked again for the opposite area;
8. Opposite area - Choice area - Opposite area: the participant looked first to the opposite area of her choice, after she looked to the choice area and looked again for the opposite area;
9. Opposite area - Center area - Choice area: the participant looked first to the opposite area of her choice, after she looked to the center area and looked to the area which is coincident of her choice.

Table 2 Percentages for each eye-movement category according to the participants’ directional choices.

<table>
<thead>
<tr>
<th>Eye-movement categories</th>
<th>C1 %Neutral</th>
<th>C4 + C7 %Light</th>
<th>C2 + C3 %Width</th>
<th>C5 + C6 %Bright + Width</th>
<th>C8 + C9 %Bright Vs. Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51.7</td>
<td>76.3</td>
<td>36.2</td>
<td>75.0</td>
<td>93.0</td>
</tr>
<tr>
<td>2</td>
<td>17.2</td>
<td>20.3</td>
<td>1.7</td>
<td>5.0</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>3.4</td>
<td>1.7</td>
<td>0.0</td>
<td>5.0</td>
<td>3.5</td>
</tr>
<tr>
<td>4</td>
<td>6.9</td>
<td>0.0</td>
<td>1.7</td>
<td>3.3</td>
<td>1.8</td>
</tr>
<tr>
<td>5</td>
<td>3.4</td>
<td>0.0</td>
<td>13.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>10.3</td>
<td>1.7</td>
<td>39.7</td>
<td>8.3</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>3.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>3.4</td>
<td>0.0</td>
<td>0.0</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td>9</td>
<td>0.0</td>
<td>0.0</td>
<td>6.9</td>
<td>1.7</td>
<td>0.0</td>
</tr>
</tbody>
</table>

When bright is higher in one of the alternative corridors, the exploration pattern is more concentrated in the areas of choice, with few variations among other areas. Nonetheless the condition bright vs. width had opposite cues, the eye-gaze exploration was very focused in the brighter areas.
In Neutral and Width situations, there were more variability in the eye-gaze strategies as can be seen in the Table 2.

4 CONCLUSION

The main objective of this pilot study was to investigate the gaze behavior during spatial decision taking to assess the influence of cues, which may increase the affordance of interior hallways in complex buildings during an emergency situation. In this paper we present an eye-tracking experiment investigating the relation of gaze behavior and spatial decision-taking.

Generalizations about eye movement’s strategies in emergency egress task, are not possible since we used only one participant. Nonetheless, results regarding the choice of the path in the intersection in our participant, was similar to previous studies (Vilar et al. 2012).

Regarding eye movement analysis, results are according to previous studies that show that light is a factor of eye-gaze attraction (Taylor and Socov 1974). In our study, in conditions where one of the intersections was brighter, first gaze was in majority of cases directed to that intersection. In the corridors that light was equal (C4+C7 “neutral” and C2+C3 “width”) there was no such clear eye-gaze pattern.

Conjointly the results obtained, allow us to conclude that eye movement analysis may be used to investigate the association between decision-taking in an egress task and environmental affordances.

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