THE INFLUENCE OF GUIDANCE SYSTEM IN INDOOR WAYFINDING USING VIRTUAL REALITY

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ABSTRACT
This paper has the objective investigate issues related to the Human wayfinding into buildings, particularly the use of guidance systems. It aims, in this way, to present a study related to the use of the horizontal and vertical guidance systems inside a building. The Immersive Virtual Reality (VR) was used as interaction environment for the experimental tests. The human wayfinding performance into a virtual building and the level of presence into the simulation were verified. This study is part of a PhD project in Ergonomics that uses Virtual Reality (VR) as interaction environment to analyze indoor human wayfinding as a way to optimize the design of complex buildings.

INTRODUCTION
The disorientation threatens the welfare and limits people mobility. Not knowing where we are or how to get where we want to go is a very stressful and frustrating experience and it has physical and psychological negative effects. Wayfinding difficulties may lead people to avoid places such as shopping malls, museums and convention centres. It can make people late for important occurrences such as business meetings or flights, which may cause loss of opportunity and money [1].

Additionally, during emergency situations, badly designed buildings and guidance systems for wayfinding are also a potential danger for people due the fact that they can arise as an increased problem to an extreme stress situation [2]. Otherwise, a place with an ease wayfinding can provide good sensations and the wish to visit this place again [3].

During the last years, the indoor wayfinding problems have been considered also by organizational administrators, interior designers, architects and planners as a key to improve well-being. Thus, the study of individual movement to improve indoor wayfinding process may contribute to increase the visitor’s satisfaction, to intensify visitation, to reduce the visitor’s anxiety and producing physical, economical and social benefits.

According to Norman [4], when people try to find their way to a destination in an unfamiliar environment, they look for external information that will complement their orientation and navigation processes in this unfamiliar environment. Many of the information that people
need to reach a destination are in the world (knowledge in the world) and the human's mind is perfectly able to understand this world. It is what made the people able to orientate and navigate themselves in environments that they never interact before.

The analysis of the human interaction with the built environment is beyond of to obtain the users' subjective opinion. It is necessary to understand which the consequences of the aspects related to the orientation and navigation during the human interaction with the building are, in way to promote safety, comfort and effectiveness of the system Human-Environment. Thus, the Human must be considered as integrant and central part of the system, taking in consideration its characteristics, needs and limitations.

The literature suggests that environment's configuration aspects have significant cognitive consequences in human wayfinding [5]. According to some authors, the spatial layout of the built environment can also influence the accuracy of cognitive representations of real-world spatial information [6]. Thus, higher levels of configuration understanding are generally associated with more efficient wayfinding performance. However, buildings where the overall configuration is confusing or hard to imagine can be considered environment where the users are more disoriented [7;8]. The signage is a component with large importance in wayfinding process as many place and situations are presented, at the beginning, as a maze or a complex space (and especially unknown) where the architecture, the lighting and the interior design are not able by themselves be intelligible and usable. According to Costa [9], the signage is part of the visual communication science which studies the functional relations between the guidance systems and the users' behaviors. Our need for signs increases when we are unfamiliar with the environment or when the environment is too complex to get completely familiar with [10].

According to Smitshuijzen [10], the traditional methods of guiding or directing are basically done by grouping and repeating the destinations and adding an arrow to show the right way for all destinations. This method is still far the most used although there is another (slightly archaic) method based on making a more or less continuous line on the floor, the wall, or the ceiling that leads from the starting point to the final destination. Different colors (or types of lines) can be used for different destinations. This method has been applied in a few signage projects for buildings (notably a hospital), but it has far too many limitations to be seriously considered in most cases. These limitations are based mainly in the use flexibility, maintenance and visibility when putted in places with a high flow of people.

Many researches were developed in the wayfinding area, but the studies which are based on the influence of the environment physical conditions on human wayfinding are still few and insufficient [3]. A pertinent methodological issue is the interaction environment. Some studies used the real world as interaction's environment to analyse the user's behavior [5;11-17]. In these studies people who never interacted with a place (urban or building) have to move around the environment in order to reach some established points or to point the direction of some landmarks in the environment. The main advantage of this approach is that the studies' participants have the real perception of the environment mainly regarding to materials, barriers, people's movement in environment, the anxiety in using a space for the first time, sounds, light and many other characteristics related to the reality.

However, interacting with real world has also many constraints. The main problem for a research in human wayfinding is to control the variables that can influence people orientation and navigation processes as: light, people moving around the environment, noise, eye direction, among others. Another problem is related to safety. When interacting with real world people is submitted to constraints that can put human physical a mental integrity in risk. The behavioral data (those related to users feelings and frustrations) is also very difficult to acquire during the interaction with real environments due the fact that most of times users' verbalizations are missed during this interaction process.

Another interaction environment used in human wayfinding research is the bi-dimensional image of interior spaces, which, in many times, are presented as slides projected in a screen, photos and/or video [2;18]. These images are taken from an environment which participants never interacted before and represent decision points in pre-defined routes from where they have many options for choosing a way. Generally a task- where participants must reach a specified destination – is given to the participants.

This methodological approach is useful in way that it represents low financial costs, it does not put in risk the participants' physical integrity and can be applied in any place which few
resources. Thus, it can involve a large number of participants with different characteristics.

However, the realism is very poor and depends of images quality and evaluators choices which may direct the user’s field of view. Thus, the route chosen by users may be conditioned by images elements and view angles, besides the users are being always directed to go ahead due the fact that they do not know what is behind themselves. From psychology point of view, space around is not seen as equal; front is most important, back next most important and sides least important [19].

Another point to consider is that when people interact with an area for the first time they can show some fear or anxiety that may reflect in navigation errors. Interacting with unfamiliar places through photo can exclude this anxiety factor.

Recently, some researches used virtual reality-based environments to study human wayfinding [18;20-25].

The Virtual Reality (VR) is emerging as an important tool to overcome ethical and methodological constraints. One of the main advantages of VR is flexibility. The use of VR allows the researchers manipulate systematically the environment’s layout, and different kinds of interactions can be designed in order to create suitable experimental conditions. It allows changing scenes according to the research’s needs with low time and financial costs. VR also allows monitoring and recording for further evaluation the behaviors through which an explorer gains spatial knowledge [24]. The use of this technology allows registering, in a precise way, the user's path into a building, also making possible to observer short actions as small change directions, hesitations, glaze direction among others that in the real-world will be difficult to acquire.

METHODOLOGY

The main goal of this study is evaluate the human wayfinding performance of users during the accomplishment of a wayfinding task inside a building in way to test two types of guidance system: i) vertical (composed by signage place at the walls with arrows that indicate the way to all destinations) and horizontal (with continuous lines on the floor that leads from the starting point to the final destination). An Immersive VR was used as interaction environment in way to allow simulating the proposed experimental conditions. Thus, the user’s evaluation of the presence level into the simulation was also considered in the study’s objectives.

VIRTUAL ENVIRONMENT (VE)

A VE was developed in way to reach the study’s objectives. It was made from a requirement program generated in brainstorming meetings with experts in Ergonomics, Architecture and Design.

Firstly, a 2D project, which was the base structure if the VE, was designed using software AutoCad 2008® and exported 3D Studio Max®, both from Autodesk, Inc. in order to model the 3D environment. Several objects, such as furniture, and general properties, such as color, texture, light, among others, were created in order to generate a realistic scenario. The scenario was then exported using a free plug-in called OgreMax 1.6.23, to be used by the software ErgoVR.

The VE consists in a symmetric plan formed by a rectangle divided into 8 rooms (12 x 12 meters each) interconnected by symmetrical axes of corridors, 2 meters wide, and circumvented by another corridor (Figure 1).

A small environment with a room and a small corridor was developed the same way as VE for the experimental tests. This environment was used as a training area, where the participants can move themselves freely in order to become familiar with the equipment and with their movements inside the simulation.

APPARATUS

The experimental tests were made using a Head-Mounted-Display (HMD) from Sony, model PLM-S700E with headphones. The body and head movements were controlled separately in way to give the users a higher level of autonomy and to bring near the natural actions. Thus, as a location device was used an USB joystick from Thrustmaster and the head motion was controlled using magnetic motion tracker from Ascension-Tech, model Flock of Birds. (See Figure 2)

The experimenter, seated in the surroundings, visually monitored participants to take notes. All experiments were videotaped. The VE displayed in the HMD was being displayed, simultaneously, in a screen placed on the desk. Thus, the researcher could see the same as the participants.
EXPERIMENTAL CONDITIONS

Three experimental conditions were defined in order to test the human wayfinding performance in two guidance systems.

- Neutral (N): In this condition all information and objects that can help the participant when accomplishing the wayfinding task were extracted from the VE as: pictures, fire-extinguishers, furniture, emergency signs. Only the signs with the information about the rooms’ use were permitted.

- Horizontal (H): In this condition, a horizontal guidance system (with continuous lines that lead to the destinations) was inserted. There were inserted into the environment elements that increase the sense of presence as: pictures, fire-extinguishers, furniture, emergency signs. (See Figure 3)

- Vertical (V): In this condition, a vertical guidance system (signs on the wall with the name of all destinations and with arrows that points the way to all destinations) was inserted. There were inserted into the
environment elements that increase the sense of presence as: pictures, fire-extinguishers, furniture, emergency signs. (See Figure 3)

Figure 3. A user’s view of the horizontal guidance system (left image), and of vertical guidance system (right image).

PARTICIPANTS
Eighteen subjects, 11 males and 7 females, aged between 15 and 53 years (mean age = 26.44 years) participated in the study. Five (27.77%), all men, were videogame players (VGP) and thirteen (72.22%) were non-videogame player (NVGP). The selection criteria were that they had played action videogames at least twice a week for a minimum of 1 hour per day, and had done it so in the previous 2 months. The participants were randomly assigned to each of three experimental conditions as a function of the guidance system (without signage, horizontal system and vertical system).

PROCEDURE
The experiment used a between-subjects design. The experiment consisted of one preliminary practice trial and three experimental conditions (neutral, horizontal and vertical). The participants, randomly assigned to one experimental condition, were unaware of the real objective of the experiment and were asked to evaluate new software for VR simulation. They were told that they ought to fulfil some tasks as accurate and fast as possible.

The participants received a brief explanation about the experiment and they were asked to sign a form of consent and advised they could stop the simulation at any time they wanted to.

After, they were introduced to the equipment and started in a practice trial.

The main objectives of the practice trial were: i) Present a simulation to the participants, in order to get them acquainted with the setup and with their movement inside the simulation; and, ii) Check for eventual simulator sickness case.

For this practice trial, participants were encouraged to freely explore and navigate the virtual room as quickly and efficiently as they could. When they felt they were able to control the navigation devices and felt relaxed or comfortable with the equipment they should declare it, in order to begin the experimental session. The trial VE was composed by a room with some obstacles (an object in the middle and narrow corridors) and was developed in the same way of the experimental VE.

After the practice trial, participants were assigned to one of the three experimental conditions. The same wayfinding task was given for all experimental conditions. The participants were asked to reach the lockers-room as quick as possible and when they find their destinations they must say it aloud. A post task questionnaire was given, requesting subjects to evaluate their sense of presence and immersion level while in simulation.
MEASUREMENTS

ErgoVR software automatically measured: **distance**: distance travelled inside the VE, **time**: time spent in the simulation, **pause**: number of times that participant stays at the same place during, at least, 2 seconds, **average velocity**: participant’s average velocity inside the VE and **path**: path taken by the participants (not analyzed in this paper). The researcher registered, by observation, if participants had successfully fulfilled the required wayfinding task.

Part of the questionnaire was adapted from Witmer and Singer (1998) presence evaluation questionnaire. The participants were also asked to estimate the duration of the time interval they spent in the simulation (in minutes and seconds). In addition, they were asked to rate their level of disorientation and enjoyment doing the VR simulation.

RESULTS

- **Distance**: The mean distances travelled inside the VE, from each experimental condition, are displayed in Table 1.

<table>
<thead>
<tr>
<th>EXPERIMENTAL CONDITION</th>
<th>N</th>
<th>MEAN</th>
<th>STD. DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>6</td>
<td>564.53</td>
<td>318.85</td>
</tr>
<tr>
<td>Horizontal</td>
<td>6</td>
<td>143.41</td>
<td>54.61</td>
</tr>
<tr>
<td>Vertical</td>
<td>6</td>
<td>164.19</td>
<td>90.58</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>290.71</td>
<td>270.11</td>
</tr>
</tbody>
</table>

The mean distance travelled by the entire sample inside the VE was 290.71m. The participants engaged in Neutral condition travelled a greater distance (564.53m) than the two other conditions. In the Horizontal Condition participants travelled a smaller distance (143.41m) than in the Vertical condition (164.19m).

In order to evaluate if the distance travelled into the simulation had a significant influence in the 3 experimental conditions, a non-parametric Kruskal-Wallis test and LSD – Fisher test were carried out. We used an error probability type I (α) of 0.05. The Kruskal-Wallis was made using the software SPSS (v.17, SPSS Inc. Chicago, IL). The results revealed that there is a statistical significant difference among 3 experimental conditions. The LSD-Fisher test revealed that the distance travelled into Neutral condition presents a significant difference for the horizontal (p-value = 0.001) and vertical (p-value = 0.005) conditions. The results revealed no statistical significant differences between the distances for the horizontal and vertical conditions (p-value = 0.558).

- **Time**

The simulation mean time (estimated time and real time), from each experimental condition, are displayed in Table 2.

<table>
<thead>
<tr>
<th>Simulation real time (duration)</th>
<th>Duration estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Neutral</td>
<td>6</td>
</tr>
<tr>
<td>Horizontal</td>
<td>6</td>
</tr>
<tr>
<td>Vertical</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
</tr>
</tbody>
</table>

According to these data that participants were able to estimate, in an accurate way, the time they spent inside the VE (real time mean = 03:52; estimated time mean = 04:01). The mean time for simulation length was longer in Neutral condition (07:32) than in the Horizontal and Vertical conditions. The participants had fastest times (02:00) for the Horizontal condition.). However, according to the Kruskal-Wallis and LSD- Fisher tests, the results revealed no statistical significant differences between the times for horizontal and vertical conditions (p-value = 0.914).

The participants were asked to classify the duration the duration of the simulation, in a 7 points scale (1 - very short to 7 - very long), participants (N 18) classified it as being medium (Mode = 5). The participants who interacts with the vertical condition had considered the duration as being shorter (Mode = 4).

- **Pauses**
The mean number of pauses from each experimental condition is displayed in Table 3.

Table 3. Comparison of the mean number of pauses inside the VE in each experimental condition.

<table>
<thead>
<tr>
<th>EXPERIMENTAL CONDITION</th>
<th>N</th>
<th>MEAN</th>
<th>STD. DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEUTRAL</td>
<td>6</td>
<td>13.33</td>
<td>9.07</td>
</tr>
<tr>
<td>HORIZONTAL</td>
<td>6</td>
<td>4.00</td>
<td>3.95</td>
</tr>
<tr>
<td>VERTICAL</td>
<td>6</td>
<td>4.17</td>
<td>4.79</td>
</tr>
<tr>
<td>TOTAL</td>
<td>18</td>
<td>7.17</td>
<td>7.46</td>
</tr>
</tbody>
</table>

The mean number of pauses by the entire sample inside the VE was 7.17. The participants engaged in Neutral condition made the highest number of pauses (13.33). In order to evaluate if the number of pauses into the simulation had a significant influence in the 3 experimental conditions, a non-parametric Kruskal-Wallis test and LSD – Fisher tests were carried out. We used an error probability type I (α) of 0.05. The Kruskal-Wallis was made using the software SPSS (v.17, SPSS Inc. Chicago, IL). The results revealed that there is no statistical significant differences between the times for horizontal and vertical conditions (p-value = 0.07).

• Average Velocity

The average velocity from each experimental condition is displayed in Table 4 in meter per second (m/s).

Table 4. Comparison of the mean number of pauses inside the VE in each experimental condition.

<table>
<thead>
<tr>
<th>EXPERIMENTAL CONDITION</th>
<th>N</th>
<th>MEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEUTRAL</td>
<td>6</td>
<td>1.30</td>
</tr>
<tr>
<td>HORIZONTAL</td>
<td>6</td>
<td>1.38</td>
</tr>
<tr>
<td>VERTICAL</td>
<td>6</td>
<td>1.67</td>
</tr>
<tr>
<td>TOTAL</td>
<td>18</td>
<td>1.45</td>
</tr>
</tbody>
</table>

According to these data the average speed into the simulation for the entire group was 1.45 m/s. The participants were faster in the Vertical condition (1.67 m/s) than in the Horizontal (1.38 m/s) and Neutral (1.30 m/s) conditions. However, according to the Kruskal-Wallis and LSD- Fisher tests, the results revealed no statistical significant differences between the times for horizontal and vertical conditions (p-value = 0.567).

• Post-Task Questionnaire

The post-task questionnaire used a seven-point scale format. Therefore, the scale included a midpoint anchor and the anchors were based on the content of the question (e.g. 1 - not compelling, 4 - moderately compelling, 5 - very compelling). The instructions asked respondents to place an “X” in the appropriate box of scale. This questionnaire was formulated in order to investigate questions related to sense of presence evaluation and enjoyment.

Regarding to the levels of presence the entire group presented high presence level. The Vertical condition displayed higher levels of presence, than Neutral and Horizontal conditions. In question (that was: what degree did you feel confused or disoriented at the beginning of breaks or at the end of the experimental session?), participants reported more disorientation in Neutral condition (Mode 4). When asked if they felt themselves inside the VE during the simulation, participants reported higher level of presence in Vertical (Mode 6) and Neutral (Mode 6) conditions than in Horizontal condition (Mode 3). When asked about the visual aspects of the environment participants reported higher levels in Horizontal condition (mode 6) than in vertical (Mode 5) and Neutral (Mode 4) conditions.

Kruskal-Wallis Tests were carried out on each question, with experimental condition (Neutral, Horizontal and Vertical) factor. The results revealed only the Question 16 (Were you involved in the experimental task to the extent that you lost track of time?) presented a statistical significant difference, in function of experimental condition (p-value = 0.012).

CONCLUSIONS

The main objective of this study was to analyze the difference between two types of indoor guidance systems. The use of the VR as
interaction environment and the level of presence into the simulation were also considered.

VR technology allows researchers to control and manipulate characteristics of the physical environment. Designers and planners can use the technology to test and refine designs and thus to understand the physical, environmental requirements to ease wayfinding difficulties for different populations. The findings regarding to the participants’ sense of presence into simulation suggest that, while interacting with the simulation, participants are able to transport themselves into the virtual world, acting as they were in the real-world. However, some limitations related to the used equipment may have limited the users’ sense of presence, mainly the HMD which have a reduced field of view and no stereoscopic view. The use of a joystick as motion controller can also have reduced the immersion and the performance.

The study confirms the ErgoVR’s system efficacy in the collection of objective measures to investigate the human wayfinding performance before or after the guidance system implementation.

The findings suggest that the existence of a guidance system increase the wayfinding performance in VE. The task execution time was similar for both groups (horizontal and vertical conditions). However the participants in vertical condition presented a higher distance travelled into the simulation than the participants in horizontal condition, with a high average speed. It can suggest a higher confidence grade while using a guidance system that is the most usual for buildings.

A potential drawback of this study may be the reduced size of sample and the use of rating scales to evaluate sense of presence and performance since it requires non-parametric data analysis.

Improved wayfinding has particular importance for airports, colleges, hospitals, office buildings, museums, libraries, shopping malls, entertainment parks, transport stations, resorts and convention centres. Thus, it is important to gain a better understanding of the effects of guidance systems for indoor wayfinding on users’ behaviour.

REFERENCES


Differences in Indoor Wayfinding. Environment and Behavior, 28(2), 204-219.


