Virtual environment evaluation for a safety warning effectiveness study

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Abstract

Warnings inform persons at risk about hazards and promote a safe behavior. For a warning to achieve its purpose it is essential that it is effective. Virtual Reality can be assumed as the most adequate methodology to use in this context as it overcomes the methodological, financial and ethical limitations. A pilot study was conducted to evaluate a Virtual Environment (VE) that will be further used for warnings effectiveness studies. Fourteen master game design students participated in this preliminary study. The main results showed that the developed VE allowed a behavioral assessment of compliance with safety warnings, although some adjustments are required in order to improve their effectiveness and to allow doing experimental studies with improved reliability. Findings in this article contribute with important recommendations for future studies, in the development of virtual environments for the evaluation of safety warnings.

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1. Introduction

In order to prevent hazards, their existence must be warned. Warnings inform persons at risk about hazards and promote a safe behavior [1]. A warning is a tool used when other forms of risk monitoring, such as product or environmental redesign or the use of safeguards is not possible. According to Adams [2], a warning is a safety communication device that should be designed to attract attention to itself, to inform a hazard, the level of seriousness and the possible consequences as well as how these can be avoided.

This work is based on the ANSI Z535.2 and ANSI Z535.4 (2002) standards. These standards provide guidelines to develop warning signs and labels. In 2002, ANSI standards established a single set format for both ANSI Z535.2 and ANSI Z535.4 [3]. Both suggest some components to be contained in a warning. These components can be divided into three parts [4], as shown on Figure 1:

- Signal panel – contains the signal word, the safety alert symbol and the background color. Elements that define the level of severity of the hazard;
- Pictogram – contains the graphic signal which identifies the nature of the hazard;
- Message panel – contains the messages that communicate the nature of the hazard, the consequences if the warning is not obeyed and instructions on how to avoid the hazard.

![Fig. 1. Warning components: 1) Signal Panel; 2) Pictogram; 3) Message Panel. Fonte: [4]](image)

For a warning to achieve its purpose it is essential that it is effective. If the warning is effective, it leads the user to adopt a safe behavior [5].

In order to evaluate the warning effectiveness various elements related to the physical characteristics of the warning and the user’s characteristics must be considered. Extant literature evidence some indications of what a warning should present. Some characteristics are for example, icons and pictograms [6, 7], the use of a specific color or word [8, 9], a static or dynamic style [10, 11]. Despite the fact that the warning is well presented, it is of paramount importance the users react effectively. Some individual characteristics that may interfere with the warning effectiveness are age [12, 13], emotional aspects [14] and high cognitive loads [15].

1.1. Warning effectiveness evaluation

The last component of the warning process is compliance behavior. According to Ayres [16], if the purpose of a warning is to increase individual’s safety through conditioning behavior, the evaluation of warning effectiveness should consider whether the warning leads individuals to change their behavior. Although compliance should be considered the most important test to determine the success of a warning, the literature that considers this component is lacking. Mostly, studies evaluate behavioral intentions [17] or do qualitative (e.g., observational)
studies [18]. This may be due to the methodological, financial and ethical complications associated to evaluating warning compliance in real-time. Consequently, latter studies lack to ability to control specific variables as well as the actual context. Due to these limitations, scholars have encouraged studies in laboratories. However, the external validity of this research is scarce. An economic and effective solution to this dilemma is the use of Virtual Reality (VR), because it allows the development of effective solutions and with a more bearable cost for organizations.

1.2. Virtual Reality (VR)

Virtual Reality (VR) is an advanced computer interface that involves real-time simulation and interactions through multisensory channels. It allows users to examine from different angles, three-dimensional spaces using three unique features of the VR, the so-called three "I’s": Imagination, Interaction and Immersion [19].

- Imagination – is related to involvement, meaning the degree of motivation for the engagement of a person with a certain activity. This involvement can be passive, where there is only the exploitation of the environment; or active, where there is environment interaction.
- Interaction – or manipulation, which is the system’s ability to detect user input and respond to its real time commands.
- Immersion – is the feeling of being inside the virtual environment

In a very broad sense, according to Rebelo et al. [20], “VR is a way of transporting a person to a reality in which they are not physically present but seems like they are there. Of course, any form of simple media (e.g., a text) or pictorial representation (e.g., a painting) can have a similar feeling in which the reader or viewer is abstracted from familiar surroundings to those within the story or painting.”

VR can be assumed as the most adequate methodology to use in this context (i.e. behavioral compliance with warnings evaluation) as it overcomes the limitations presented previously. In fact, extant literature has showed that research regarding warnings has already been done using VR, namely in wayfinding tasks [21–23]. ErgoVR, a unit of the Ergonomics Laboratory at FMH – Lisbon University (http://ergovr.fmh.ulisboa.pt/index.htm) has been working in the modulation of Virtual Environments (VE) and warnings issues [24–27]. However, studies considering the warnings based on the specific norms (i.e., ANSI Z535.2 and ANSI Z535.4) is still scarce.

The present paper will show preliminary results of a larger study that aims to create effective technological-based warnings using the norms mentioned previously. Thus, our current objective is to evaluate a virtual environment that will be further used for the warning effectiveness’ evaluations. The main hypothesis for this preliminary study is that participants will notice, read and comply with the safety warning presented.

2. Method

2.1. Participants

Fourteen university students (5 female and 9 male) from the University of Beira Interior (Game Design and Development master course) participated voluntarily. They were aged between 21 and 38 years old (M = 27.6, SD = 6.1). The participant’s nationalities were Portuguese (64%) and Brazilian (36%).

2.2. Apparatus

Tasks were performed on a Toshiba Qosmio X70-B laptop, with an Intel® Core™ i7 processor, 2.40 GHz, NVIDIA® GeForce® video card, and a 17.3” LCD monitor. The interaction with the VE was performed using computer keyboard, Head Mounted Display (HMD), model DK”, OCULUS (OLED display, resolution 960 X 1080 per eye, 100° field of view) and earphones AKG model K518LE (Figure 2).
2.3. Experimental design

All participants were submitted to that same experimental condition and procedure as our focus was on evaluating the decision making behavior individuals assumed when in front of a safety warning (behavioral compliance with warnings).

2.3.1. Virtual environment

The virtual environment (Figure 3) was planned through systematic meetings with experts in several fields of study, namely, Ergonomics, Design and Psychology. During these meetings, the experts considered the context that would involve the experiment, the type of the building to be designed, the physical characteristics of the space, and the tasks to be performed. A consensus was reached by compromising between the scenario’s quality in producing the desired behavioral responses and the available resources, in order to guarantee the necessary conditions for the study’s purpose. Based on these requirements, it was decided that the VE would assume a factory warehouse, with numbered corridors and cardboard boxes on the shelves. In one corridor there would be a static warning. This static warning was developed in consonance with the ANSI Z535.2 (2002) standards, with respect to signal word, color, use of a pictogram and hazard nature, consequences and actions messages. Additionally, the location of the warning was also taken into consideration. Based on previous studies [25], the warning was placed in an uncluttered site and within the individual’s field of view. In regards to the environmental modeling the 3D 4.3 software Unity was used, taking advantage of the 3D models provided by the virtual Unity assets store that where adapted to the needs of the study. Triggers were inserted in the environment so that when participants crossed the warning, cardboard boxes would fall from the shelves. We also developed scripts that allowed to control the audio (to give instructions to the participants) and animations (related to fall boxes) in the VE, using triggers and an event log, to register all the actions of the first person. The navigation control was made in first person, with an average displacement speed of 3 m/s.
2.3.2. Procedure

The study occurred in a scientific event (ergovr.fmh.ulisboa.pt/ergoux/) and was presented as an activity that was part of a workshop. Participants were given the opportunity to interact with VR equipment. All individuals participated voluntarily and signed an informed consent form before the experiment.

Participants placed the VR equipment (i.e., HMD, earphones) and were then instructed to follow a set of instructions related to the proposed task.

The instructions were played, by a previously recorded male voice, during the virtual interaction using several scripts activated by the researcher at the correct moment of the experiment. The simulation started outside a warehouse, where the participant could see the shelves of the corridor A with boxes, through two entrances. The first instruction asked the participant to go into the corridor B. When the participant reached the corridor B, he/she was asked to count the boxes that were on the shelf B21. Once the participant has done this task, he/she was informed to go to the corridor G and count the boxes on the shelf G61. At this time the participant was confronted with a warning on his/her way to the shelf that said to not move beyond that specific point because it was an area that was in replacement goods and there was a risk of falling objects. If the participant ignored the warning and passed, cardboard boxes began to fall down.

At the end of the experience, an interview was done asking participants if they had seen the warning, if they had read the warning and if they had complied with it. If they had not complied with it they were asked why. Then, an overall impression was asked regarding their navigation in the virtual environment.

Fig.3: The Virtual Environment with the warehouse corridors and the numbered shelves

3. Results and discussion

This study’s objective was to evaluate a virtual environment to study behavioral compliance with safety warnings. First, results concerning data from the interview will be discussed. Data from the behavioral compliance with the ANSI warning are also discussed.
3.1. Participants’ subjective experience

Our participants constituted a special sample, because they are game design master students and they are all experienced gamers. Thereby, they are very tuned to technical aspects of Computer-Generated Imagery and digital games. They are a rich set of users for the purpose of present study.

In regards to participants’ verbalized impressions, it is possible to highlight some positive and negative points. Regarding positive points, no participants reported problems concerning the audio quality and understanding. All proved to be familiar with how to navigate and had no difficulty in controlling the First Person. There were no negative comments about VE illumination.

Regarding negative points, they felt difficulty on navigation flow. They considered a low speed navigation and justified that the number of objects could be the problem. In a detailed analysis, we identified that the high number of textures added on the shelves’ signage could be responsible for this problem. Concerning graphics quality, a participant judged the images as blurred. That means that there was lack of fit with the HMD. In this context, it is recommended care in the setting of the equipment to individual characteristics. Some participants expressed they experienced a weak sense in VR. This problem may be associated with their level of presence, an important aspect of VE experiences. In this context, the use of a challenging narrative is important to enhance a sense of presence in the virtual environment and increase the emotional response of the participant [28]. Moreover, elements such as moving objects and sounds help accentuate the feeling of being present in the virtual world. In this evaluation, we were more interested in assessing the characteristics of the VE, and in absence of a narrative that challenges participants we chose to use sound and boxes’ animations that fell close to the participants as resources.

3.2. Compliance

Although the main objective of this study was not to assess warning effectiveness, it was possible to make some reflections on this parameter. Table 1 shows the compliance results of a warning placed at the entrance of a corridor where there was a risk of objects falling. Contradicting our hypothesis, results show that only 29% of participants had a consonant behavior with the warning, although 71% of respondents claimed in the interview, after the experience, that they had seen the warning, only 50% read the sign (Table 1).

### Table 1. Behavioral Compliance with warnings

<table>
<thead>
<tr>
<th>Noticed</th>
<th>Read</th>
<th>Complied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y* (71%)</td>
<td>Y (50%)</td>
<td>Y (29%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N (21%)</td>
</tr>
<tr>
<td>N (21%)</td>
<td>N (21%)</td>
<td>N (21%)</td>
</tr>
<tr>
<td>N** (29%)</td>
<td>N (29%)</td>
<td>N (29%)</td>
</tr>
</tbody>
</table>

*Yes; **No

Probably, this low rate of behavioral compliance can justify a low hazard perception by part of the participants, perhaps by the absence of a narrative that reinforce hazards existence. On the other hand, it can still be argued that as the participants were experienced gamers, they had a great focus on achieving a task goal and thus adopting a behavior non realistic to danger, disregarding the presence of the warning. These results are in agreement with the extant literature, when the hazards perception is low, the consonance to the warning will be less likely [29]. It is also worth mentioning that all participants were able to reach the goals (find the corridors and counting the boxes). Including, even those who complied with the warning have found strategies of reaching the goal, by counting standing at great distance or bypassing hazardous area.

4. Conclusion

This study’s objective was to evaluate a virtual environment to study behavioral compliance with safety warnings. VR was used as a methodological approach to overcome ethical constrains that can emerge from this type
of study. However, this preliminary study revealed the need to insert some elements to make the simulation closer to the real experience.

Future work should adopt the following recommendations:

- Construction of a narrative that allows participants to find a goal in the VR and be aware of the dangers in order to increase the level of presence and probable warning compliance;
- Use of a training scenario before the experiment to provide participant’s homogenization and habituation to the interaction devices. This experience will verify whether the View and Navigation devices are adjusted to possible limitations of the participants. It will also enable the adaptation of the participants to the devices, also allowing us to see if they are fit for the experimental situation.
- Improve the quality of the virtual environment, in terms of navigation, in particular, optimizing the number of different objects and textures in a UNITY scene, decreased the weight computing.

In summary, despite the fact that the virtual environment allowed the assessment of safety warnings behavioral compliance, it needs some adjustments in order to improve its effectiveness and to start experimental studies with better reliability. Results reported in this paper also contribute with important recommendations for future work, in the development of virtual environments for the evaluation of safety warnings.

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References