Using Virtual Reality to Examine Hazard Perception in Package Design

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Abstract. Informing users about the correct hazard level associated with products can be one of the most important measures to help promote user safety while they handle hazardous household chemicals. The aim of this paper is to present pilot study's results about the effectiveness of using a VR-based methodology to examine the influence of a container's features (e.g., shapes) on the users' perception of hazardousness. Previous works have mostly used 2D drawings for this type of study. Issues which may compromise the quality of future experiments: e.g., adequacy of VR devices, interaction quality, simulator-sickness, procedure and quality of the instruments (i.e., questionnaires) are discussed. Despite the fact that the key experiment has not yet been completed, very promising results have been obtained, suggesting that the VR simulator and the methodology adopted may provide a successful evaluation of the packages' hazardousness.

Keywords: Package Design, Virtual Reality, Virtual Prototyping, Hazard perception.

1 Introduction

Although extensive research on packaging has been conducted in the fields of marketing [1–4], product and graphic design [5–8], little attention has been given, in the field of Ergonomics [9–11], to the packages' power to induce safe human behaviors (e.g., to read a warning before handling an object).

This study is concerned with packages for household hazardous liquids. If packages of household products are poorly designed, users may make wrong assumptions about their contents, and therefore, may not perceive the real level of hazard while interacting with it. Furthermore, it is not realistic to assume that it is possible to design-out all hazards from all the packages.

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According to a User-Centered Design approach, in order to ensure that the users' abilities and needs are considered in the design process since the earlier stages of development, the potential users must be actively engaged in the design process [12, 13]. Prototyping offers the potential user the opportunity to observe and examine different product alternatives, with diverse levels of detail, and then compare them with the defined requirements. There are two forms of prototyping that are commonly used [14]: physical and virtual prototyping. With physical prototypes, users can feel the products' weight, as well as differentiate textures and temperatures, among other properties. However, physical prototypes may take a long time to be produced, the materials used might not be the same as in the final product and a new prototype must be built for each modification, which makes it an expensive procedure. This does not happen with virtual prototyping, since most changes (e.g., shape, color, texture) are easily achievable in a virtual object. Conversely, due to technological limitations, virtual prototypes do not yet allow users' to sense the products' physical properties in a realistic manner.

Most of the previous studies about packages used 2D drawings or pictures to express the shape of a package's taste (e.g., [15]), to express a visual form's scent or sound (e.g., [16]) or to analyze if shapes and colors influence hazard perception (e.g., [11, 17]). However, since 2D drawings cannot show all the objects' details, users may get a wrong impression. A Virtual Reality (VR) simulation can be an effective way to present scenarios that facilitate effective interaction between users and products [18]. In this manner, the observation of 3D virtual prototypes may be more effective than 2D drawings, and also increase a study's validity.

As such, VR could be used to visualize the 3D prototypes. For that, some criteria need to be followed to ensure the best simulation quality. In this study, the first criterion considered was the easiness to discern the details of the 3D prototypes. Other criteria were that participants should be able to easily observe the packages, as well as freely navigate in the Virtual Environment (VE). The VE should be presented in stereoscopy in order to provide the participant with depth information. The participant needs to be in control of what they want to observe (possibility to navigate and change their point of view in the VE). The task that participants need to fulfill inside the VE should not be so complex that it prevents them from replying verbally to questions while they are interacting with the VE.

Considering all these criteria, the purpose of this study was to examine the feasibility and adequacy of a VR-based methodology to study the influence of packages' features (i.e., shape) on the users' perception of hazardousness when exposed to diverse household packages with chemical substances.

2 Method

2.1 Design of the Study

This study used a within-subjects design. The measure of interest was the VR-based methodology's feasibility and adequacy according to the criteria that were defined.

Additionally, measures regarding the simulation (i.e., if participants can observe the packages from different viewpoints, walk freely in the VE), the interaction with the equipment (e.g., 3D glasses, mouse), instruments (i.e., verbal questionnaire) as well as simulator sickness, were collected through a follow-up questionnaire.

2.2 Sample

The sample consisted of 10 undergraduate students (5 males and 5 females), ranging in age from 18 to 24 years old (mean age = 21.6, SD = 1.5 years) from the Technical University of Lisbon, Portugal.

2.3 Experimental Settings and Virtual Environment

A Lightspeed DepthQ 3D Video Projector presented the VE with the 3D prototypes. The virtual prototypes were designed using Rhinoceros and then exported to Unity. MacNaughton Inc's APG6000 shutter glasses were used to see the VE in stereoscopy. Participants were free to visually explore the prototypes by navigating in the VE using a mouse. Pressing the left button of the mouse allowed the participants to move forward and the right button to move backwards. By completely moving the mouse, the participants were able to control their point of view.

The projected image size was 1.72m (horizontal) by 0.95m (vertical) with an aspect ratio of 16:9. The observation distance between the screen and the participant was 1.50 m, resulting in a 35.2° of a vertical field-of-view (FOV) and 59.7° of a horizontal FOV. Participants remained standing during the experiment. The researcher stood with the participant inside the room, which was darkened to prevent any external light interference. There was no sound in the VE.

The VE was a closed room, measuring 6.6m by 6.6m, containing a table (260 cm length, 30 cm depth and 90 cm height) in the middle. The packages were placed on the table standing 20 cm away from each other. When the simulation began, the participant's view was as if they were standing 1m away from the table. Each package was associated to a letter, from A to H, so that their identification was easier and accurate.

2.4 Procedure

Participants were asked to sign an informed consent form before starting the experiment. Subsequently, the researcher explained how the equipment and the experiment worked.

Before the test, participants became familiarized with the VR devices and the task by practicing in a training VE, which was similar to the one to be used for the experiment, but with 3D geometrical objects being displayed instead of packages. After they declared they felt able to do the test, the experimental session began. At this point the researcher stressed that they could stop the experiment at any time without any prejudice. After the experimental session, the participants were given a follow-up questionnaire. More detailed information about the training and the experiment are as follows:

Training. Participants were placed in a training VE so that they could familiarize themselves with the equipment and the task. The training VE was a closed room where different 3D objects (e.g., sphere, cylinder, cone, cube) were located on a table. The researcher asked the participants to observe the 3D objects, and then informed them that they could walk around the table. While observing the 3D objects, the participants were asked to verbally reply to the researcher's questions. If they were able to accomplish the task (examine the 3D objects and reply to the questions without showing any signs of simulator sickness) they were considered able to do the experiment.

Experiment. In the experimental stage, participants were given a scenario and a task before the simulation started. As such, the cover story used and the task, were as follows:

Cover Story.
Imagine that your friend is moving to a new house and he/she asks you to help unpack and to organize liquid household products' packages according to their level of hazard (e.g., how poisonous can the content be when drunk, how toxic can it be when inhaled, or how irritant/harmful can it be if it comes into contact with skin).

Task.
Observe the packages and reply to the questions.

When the simulation started, eight containers were presented on a table, as depicted in Figure 1. Participants were asked to observe the packages and to reply orally to the researcher's questions (the researcher took notes of the answers).

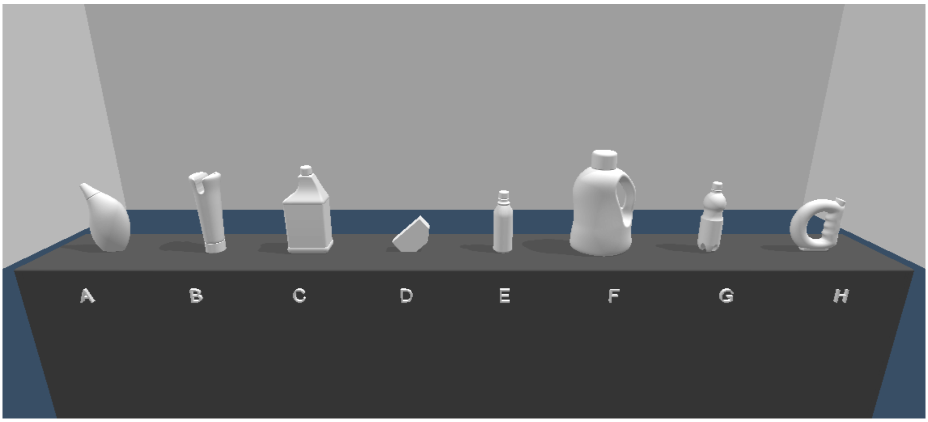

Fig. 1. Screen shot of the VE

2.5 Measures

In the present study, a two parts questionnaire was used. The first part, which was to be responded immediately after observing the prototypes, intended to evaluate the influence of the packages' features on the perception of hazard. The questions were adapted from the questionnaire that was developed by Wogalter and colleagues [11, 19]. There were 6 questions as shown in Table 1, divided equally into two sets: package selection and package rating. There were two different kinds of questions to check if the participants were able to verbally reply to them. On the package selection set, participants had to select one package out of the eight packages. On the package

Table 1. Questionnaire Part I

	Selection Questions
1.	Based on the shape of the package, which one do you think has the most hazardous contents?
2.	Based on the shape of the package, which one do you think is the most hazardous package?
3.	Based on the shape of the package, which one do you think has the most hazardous content when children enter in contact with it?
	Rating Questions
4.	Based on the shape of the package, how familiar are you with this package?
5.	Based on the shape of the package, how hazardous would it be to drink its contents?
6.	Based on the shape of the package, how cautious would you be when handling this package?

Table 2. Questionnaire Part II

	Questions	Category
1.	How easy could you control the point of view in the virtual environment?	Usability
2.	How easy could you control the navigation in the virtual environment?	Usability
3.	How easy could you explore/visually search the details of 3d packages?	Physical Fidelity
4.	How easy could you associate the letters with the 3D packages?	Usability
5.	How much did the 3d glasses cause distraction?	Presence
6.	How conscious were you of the mouse presence during the simulation?	Usability
7.	How much did the mouse cause distraction?	Presence
8.	How much did the shadows of the packages cause difficulty on observing details of the packages?	Physical Fidelity
9.	Were you able to concentrate in the questions asked instead of being concentrated on the interaction devices?	Performance
10.	How easy was to reply the questions asked verbally during the test?	Performance
11.	How much did you feel claustrophobic inside the room?	Usability

rating set, participants were requested to rate the 8 packages, according to the three questions, using a 9-point Likert type scale [20], with 0 indicating the minimum quantity and 8 indicating the maximum of the dimension.

The second part consisted of a written questionnaire, shown in Table 2, asking to rate issues related to the quality of the participants' interaction with the equipment (e.g., 3D glasses, mouse), instruments (i.e., verbal questionnaire) as well as simulator-sickness in a Likert type scale. The first eleven questions used a 7-point Likert type scale: (1) very easy/low/little to (7) very hard/high/much; whereas questions about simulator-sickness had a 4-point scale: (1) absent, (2) slight, (3) moderate and (4) severe.

The questions were created according to these categories: physical fidelity (how well the VE emulates the real world), usability of VE and interaction devices, performance of the participant (accomplishment of the task), presence (whether the participant was distracted with the equipment) and simulator-sickness [21].

3 Results

3.1 Questionnaire Part I – Package Evaluation

According to the results, it can be seen that all the participants were able to reply orally to all of the questions, while they were interacting with the VE.

Selection Questions. The frequency distribution for each package that was chosen, across the three selection questions, is depicted in Table 3.

Packages that were most often perceived as having the most hazardous content (Question 1) were packages F, C and H. In what regards the most hazardous package itself (Question 2), the three most chosen packages were F, D and E. Surprisingly, package F was not perceived as containing a hazardous substance for children (Question 3). In this context, the packages most chosen were C, B and E, while packages A and G were never chosen as being the most hazardous.

Table 3. Frequency distribution of packages selection across questions

	Packages							
	A	B	C	D	E	F	G	H
Question 1	0 (0%)	0 (0%)	3 (30%)	0 (0%)	1 (10%)	4 (40%)	0 (0%)	2 (20%)
Question 2	0 (0%)	0 (0%)	1 (10%)	2 (20%)	2 (20%)	3 (30%)	0 (0%)	1 (10%)
Question 3	0 (0%)	2 (20%)	3 (30%)	1 (10%)	2 (20%)	0 (0%)	0 (0%)	1 (10%)

Rating Questions. The mean ratings and standard deviation, for the rating questions, are shown in Table 4.

The data show that the three most familiar packages (Question 4) were G, F and E, while the less familiar were A, H and D. Regarding ingestion hazard (Question 5) packages C, F and B elicited high hazard ratings, while packages D, E and G elicited

Table 4. Mean ratings and standard deviation (SD) for the three questions across packages

	Packages							
	A	B	C	D	E	F	G	H
Question 4	2.50 (2.16)	2.60 (2.87)	5.60 (2.01)	0.30 (0.64)	6.80 (1.60)	7.30 (1.19)	7.40 (1.50)	0.80 (0.75)
Question 5	5.00 (2.24)	5.40 (1.80)	7.00 (1.55)	4.20 (2.18)	3.10 (2.88)	6.10 (2.81)	2.30 (3.52)	5.00 (2.57)
Question 6	5.30 (2.61)	4.10 (2.07)	5.90 (2.21)	4.70 (1.55)	2.70 (2.24)	5.40 (2.94)	1.70 (2.28)	5.30 (2.28)

low hazard ratings. The packages perceived as having high level of hazard when handled were C, F and A, while packages B, E and G had a lower relation with handling packages

3.2 Questionnaire Part II – Simulation Evaluation

The results of the second part of the questionnaire, according to the categories defined, are shown in Table 5 and Table 6.

Table 5. Mean ratings and standart deviation for the subjective questions regarding simulation

Question	1	2	3	4	5	6	7	8	9	10	11
Mean	2.20	2.70	2.70	1.40	1.70	3.00	1.50	1.40	5.50	3.10	1.30
(SD)	(1.08)	(1.00)	(1.35)	(0.92)	(0.64)	(1.18)	(0.50)	(0.66)	(1.75)	(1.22)	(0.64)

Note 1. The response format was a 7-point Likert type scale, from 1 to 7. Lower means are better except for the question 9.

Table 6. Mean ratings and standart deviation for simulator-sickness conditions

Conditions					
	Mean	(SD)		Mean	(SD)
Generalized Indisposition	1.1	(0.3)	Difficulty in concentrating	0.5	(0.5)
Tiredness	0.2	(0.4)	"Heavy head"	0.4	(0.9)
Headache	0.2	(0.4)	Blurry vision	0.4	(0.49)
Eyestrain	0.7	(0.64)	Open eyes dizziness	0.1	(0.3)
Difficulty maintaining focus	0.3	(0.46)	Closed eyes dizziness	0.2	(0.4)
Increase in salivation	0.1	(0.3)	Vertigo	0.0	(0.0)
Sweat	0.0	(0.0)	Abdominal discomfort	0.0	(0.0)
Nausea	0.2	(0.4)	Burp	0.0	(0.0)

Note. The response format was a 4-point Likert type scale, from 1 to 4.

By analyzing the data according to category it is possible to see that for physical fidelity, participants felt that it was easy to distinguish the packages' features (Question 3), and that the presence of shadows did not cause difficulty in distinguishing such features (Question 8).

For the usability category, the point of view (Question 1) and navigation (Question 2) were found easy to control. Participants were also able to easily match the letters with the packages (Question 4) and they did not feel claustrophobic inside the VE (Question 11). An almost average number of participants claimed that they were aware of mouse presence (Question 6).

Considering the data gathered for performance questions, participants were able to concentrate on the questions that were asked while they interacted with the devices (Question 9). At the same time, participants considered that they could verbally reply to the questions that were asked during the simulation (Question 10).

According to the presence category, the distraction caused by the mouse (Question 5) and 3D glasses (Question 6) were low during the simulation.

Finally, regarding simulator-sickness (see Table 6), participants reported a minimal level of sickness symptoms. Possible explanations for this could be because the experiment made use of a large screen projection instead of head-mounted display, the reduced dimensions of the VE, as well as its low level of visual complexity, reduced motion of users and objects, the simple task to be performed, and the short amount of time spent inside the VE [22].

4 Conclusion

Measurement of users' perceptions of packages' hazardousness can be limited by methodological constraints, such as the extent to which the experimental scenario mimics real-world situations. Virtual Environments (VE) can be used as research tools to avoid such limitations. In this context, this paper presents a pilot study concerning Virtual Reality (VR) adequacy/feasibility to examine the influence of packages' shape on the users' perception of hazardousness.

It is important to note that, unlike previous studies, which used 2D drawings, the data presented here was gathered from 3D virtual prototypes observed in a VE. Due to the details that cannot be seen in 2D drawings, users may get a wrong impression about the packages' correct shape. Thus the use of 3D prototypes in VR could enhance the packages' perception due to several factors such as: details, stereoscopic view, perspective actualization, navigation in the environment and presence.

The results attained in this pilot study, indicate that participants were able to make a perceptual judgment of the 3D packages' hazardousness, as well as to evaluate their level of familiarity. Considering a specific example, Package G (a water bottle) was rated as the most familiar package from the set and, at the same time, the one with the less hazardous content.

Responses to the simulation quality assessment questionnaires indicate that the VR-devices and the VE used in the experiment did not negatively affect task performance. Participants did not report they were distracted by the presence of the interaction devices, nor an increased difficulty in using them to perform the task. The visual inspection of the packages was easy and accurate enough to the required level of detail. Also, results revealed that participants did not report many symptoms of simulator-sickness, or any light symptoms. Apparently, the option of having the participants replying orally to the questions, posed by the researcher, was adequate and did not increase task difficulty.

Though generalizing results from a pilot study is risky at best, our results suggest that VR can be successfully used to assess users' perceptions about packages' hazardousness. Clearly, further investigations are required. In terms of future work, since this pilot study provided promising results, a larger sample and a more detailed questionnaire, related with hazard perception, shall be used. Furthermore, the next step shall examine other features of the packages beyond shape (e.g., color, texture, material).

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