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ASSESSMENT OF HAZARD PERCEPTION FROM PACKAGES SHAPES: A COMPARISON OF VISUALIZATION METHODS

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User safety could be increased by package designs that promote an adequate hazard perception. Different methodologies are available to conduct studies about the influence of package variables on users' perceptions. This paper presents a comparative study of two visualization methods (2D vs 3D) to assess hazard perception from household packages' shape.

1. Introduction

Everyday people come into contact with many different products and, even though many of these products have a high level of safety, some can still cause harm. According to Rausand and Utne (2009), the lack of safety with products could be explained by (i) the products' complexity, (ii) the use of new technology, (iii) designers and/or producers who cut corners to save time or money, (iv) the users' lack of knowledge, (v) products being used in other ways and for other purposes than anticipated.

Norris and Wilson (1997) refer that a product's safety has two components: construction safety and design safety. Construction safety depends on anything related to how the product is constructed (i.e., materials) and design safety is determined by whether the concept and presentation of a product provides a level of safety that might be reasonably expected to any person that comes into contact with it. This safety should extend to users, bystanders and even misusers (e.g., users who drink from a package that is not intended for drinking).

In the case of hazardous products (i.e., household chemicals), product safety is affected by the product's design (i.e., package's variables such as shape, color and on-product warning labels), as well as situational (e.g., time pressure, clutter) and receiver variables, such as the user's background, age, familiarity with the product, among others (Leonard e Wogalter, 2000). In addition, users do not always notice, read, understand or comply with the instructions and/or warnings (e.g., Laughery e Wogalter, 1997; Moskowitz *et al.*, 2009).

The concept of affordances may reveal innovative opportunities for package design (e.g., Ayanoğlu, Duarte, *et al.*, 2013; Fuente *et al.*, 2015), namely to increase users safety. For example, a package's shape can contain implicit information (i.e., affordances) that is important and helps users make certain judgments. The term affordances, originally coined by Gibson (1986), refers to the properties of the world which have significance over actors' behaviors. According to Gibson's ecological perception theory, affordances are a part of nature and they are there even if they are not seen, known, or desirable. Norman (2010), states that when users fail to notice the affordances, designers should add visible signs of their existence, which he calls 'signifiers'. In other words, signifiers make the affordances more salient so that people act upon them and, consequently, behave in a safer manner. By manipulating the signifiers, the users' safety may be enhanced even before they handle a package (Ayanoğlu, 2013).

Each year, many injuries related with household chemicals occur (e.g., Prioleau *et al.*, 2007; Ministry of Health, 2009; Centre for Public Health Research, 2014). Since users come into contact with a product's package before using its content, an effective packaging design can play an important role in safety. Although extensive research on this topic has been done in fields such as marketing, product design and graphic design (e.g., Raghubir e Greenleaf, 2006; Orth e Malkewitz, 2008; Ritnamkam e Sahachaisaeree, 2012; Pentus *et al.*, 2014; Sustainable Packaging Coalition, 2014), in the field of Ergonomics, little attention has been given to the packages' ability to induce safe user behaviors, besides assessing the effectiveness of in-label warnings (e.g., Schneider, 1977; Thrasher *et al.*, 2007; Wilkinson e Room, 2009; Laughery e Wogalter, 2014).

In light of this fact, our main research aims to explore the extent to which a package's shape can be used as a cue to elicit adequate safe behaviors. In order to carry out such an analysis, one of the first methodological decisions to be taken was related to the type of visualization method; i.e., how to display the package to the participants for their assessment.

Different methods are reported in the literature, from different fields (e.g., design, marketing, safety), but the most common options are the use of pictures or drawings as stimuli (e.g., Smets e Overbeeke, 1995; Serig, 2001; Wogalter *et al.*, 2001; Orth e Malkewitz, 2008; Garber *et al.*, 2009), or the real package itself (e.g., Schoormans e Robben, 1997; Van Den Berg-Weitzel e Van De Laar, 2001; Raghubir e Greenleaf, 2006; Clement *et al.*, 2013; Schifferstein *et al.*, 2013). However, pictures and drawings are static representations and, therefore, do not display all of the packages' details, which can subsequently bias the results. On the other hand, the availability of physical prototypes requires either the pre-existence of such packages in the market, which poses some difficulties to researchers such as the total elimination of content traces (e.g., odor), and/or the actual production of physical prototypes. Although physical prototypes are more cost effective in some aspects (e.g., they resemble real-world products), they are less cost effective in what regards availability when compared to the digital prototypes (e.g., Duarte *et al.*, 2010).

One alternative method, which is becoming increasingly popular nowadays to conduct User Experience evaluations in laboratorial-based researches, is Virtual Reality. Among other advantages, this virtual reality-based methodological approach enables researchers to manipulate the target digital prototypes' variables, in a very easy manner, while ensuring the study's internal and ecological validities, plus offering the means to facilitate replication (e.g., Blascovich *et al.*, 2002; Rebelo *et al.*, 2011). Previous exploratory studies suggest that this is an adequate tool to explore the effect of the package's shape on the participants' perceptions (e.g., Ayanoğlu, Rebelo*, et al.*, 2013; Ayanoğlu *et al.*, 2014).

In this context, the objective of the study, reported in this paper, was to compare two visualization methods – static 2D drawings vs. virtual 3D prototypes – to assess hazard perception regarding packages' shapes.

2. Method

2.1. Sample

A total of 60 undergraduate design students (mean age = 20.45 years, *SD* = 1.69) participated in this study. They were equally distributed by number and gender to each experimental condition (Condition 1: mean age = 20.23 years, *SD* = 1.48, Condition 2: mean age = 20.67 years, *SD* = 1.88).

2.2. Stimuli

The study used a total of eight packages, the same ones used in previous studies (Ayanoğlu 2013; Ayanoğlu, et al. 2013; Ayanoğlu et al. 2014). The packages initial selection process was carried out through a focus group session in which experts in Ergonomics made the selection from 264 household packages according to the following criteria: (a) familiarity (familiar or unfamiliar); (b) content hazardousness (hazardous or nonhazardous); and (c) shape (rectilinear and curvilinear). From these, eight packages were selected (see Figure 1).

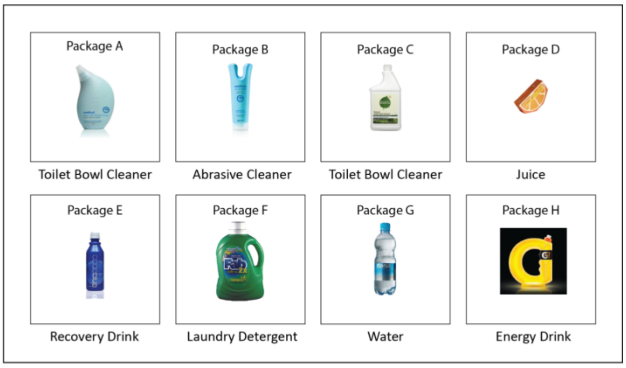

Figure 1. Images of the real product packages used in this study.

For Condition 1, the packages were represented using a black silhouette (see Figure 2) on a white background. Experts whom conducted a Heuristic Evaluation made the selection of this silhouette representation. For Condition 2, the packages were designed in Rhinoceros® and then exported to Unity 3D (see Figure 3). All extra details beyond the packages' shape, such as colors, textures, labels, and brands were removed so as to not influence the participants' judgments.

For both conditions, the eight packages were associated to a letter, from A to H, to facilitate identification.

2.3. Experimental Design

Two experimental conditions were used. In the first condition, the participants were exposed to the packages in 2D (Figure 1) and in the second condition the packages were presented in 3D, in a Virtual Environment (Figure 2).
A mixed design was used, with the experimental conditions (with two levels: 2D, 3D) as the between-subjects factor and the type of package (with four levels: HF - Hazardous Familiar, NHF - Non-hazardous Familiar, HUF - Hazardous Unfamiliar and NHUF - Non-hazardous Unfamiliar) as the within-subjects factor.

The dependent variable was hazard perception. Familiarity was used as a control variable.

Figure 1. Sillouettes stimuli (static 2D images).

Figure 2. Digital prototypes (virtual reality 3D images).

Note. Package A and B are unfamiliar packages with hazardous contents; Package C and F are familiar packages with hazardous contents; Package D and H are unfamiliar packages with non-hazardous contents; and Package E and G are familiar packages with non-hazardous contents.

2.4. Experimental Settings

For Condition 1, the experiment was conducted in a classroom, where all participants performed the task together. Printed stimuli were given to participants for evaluation after a brief explanation. For Condition 2, the participants performed the task individually, in a dark room (in the Virtual Reality Lab) where they interacted with the virtual environment (VE) using a mouse, and visualized the VE projected on a wall-screen by a video projector.

Two VEs, one for training and one for the actual experiment, were used in the experiment. Each consisted of a closed room (with no doors or windows), measuring 6.6 m by 6.6 m, and containing a table (260 cm length, 30 cm depth and 90 cm height) in the middle of the room. The aim of the training environment was to familiarize the participants with navigation inside the VEs.

2.5. Procedure

The same procedure was used for both conditions. Participants were asked to observe the packages and to complete a questionnaire regarding their hazard perception. This questionnaire, with eight questions, was adapted from Wogalter and colleagues (Wogalter et al., 2001; Wogalter, Young, Brelsford, & Barlow, 1999). A 9-point Likert type scale was used, from 0 to 8, where 0 indicated the minimum and 8 indicates the maximum. The eight questions were organized according to two categories: hazard perception and familiarity (see Table 1).

Table 1. Questions and scales of the questionnaire used for both conditions

Questions and Scales
1. Hazardous Contents: Based on this package's shape, how hazardous would you rate its contents? (0) Not at all hazardous (2) slightly hazardous (4) hazardous (6) very hazardous (8) extremely hazardous
2. Hazardous to Children: Based on this package's shape, how hazardous would it be if children came into contact with it? (0) not at all hazardous (2) slightly hazardous (4) hazardous (6) very hazardous (8) extremely hazardous
3. Flammable/Combustible Hazard: Based on this package's shape, how likely is it for it to be containing a flammable / combustible substance? (0) never (2) unlikely (4) likely (6) very likely (8) extremely likely
4. Familiarity: How familiar are you with this package? (0) not at all familiar (2) slightly familiar (4) familiar (6) very familiar (8) extremely familiar
5. Hazardous to Drink: Based on this package's shape, how hazardous would its contents be when/if drunk? (0) never (2) unlikely (4) likely (6) very likely (8) extremely likely
6. Hazardous to Inhale: Based on this package's shape, how hazardous would it be to inhale its contents? (0) not at all hazardous (2) slightly hazardous (4) hazardous (6) very hazardous (8) extremely hazardous
7. Hazardous to Skin Contact: Based on this package's shape, how hazardous would it be if it contacted your skin? (0) not at all hazardous (2) slightly hazardous (4) hazardous (6) very hazardous (8) extremely hazardous
8. Hazardous in Closed Spaces: Based on this package's shape, how hazardous would it be if used in a closed/confined place? (0) Not at all hazardous (2) slightly hazardous (4) hazardous (6) very hazardous (8) extremely hazardous

After participants rated all of the packages, they were asked, in a follow up questionnaire, about the content of each package and demographic data was also collected.

3. Results

3.1. Familiarity

Question 4 asked participants to rate how familiar they were with the packages. For both conditions, half of the packages were rated familiar, and the other half unfamiliar (see Figure 4), which confirmed the previous classification made by the researchers.

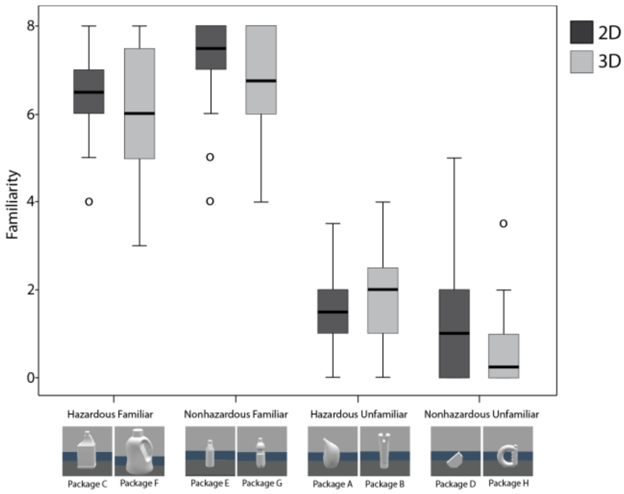

Figure 4. Box-plots of familiarity scores for each package.

3.2. Hazard Perception

The conditions (two levels: 2D and 3D), type of package (four levels: HF, NHF, HUF, and NHUF) and their interaction effects on the hazard perception were analyzed using a two-way mixed-design ANOVA with the type of package as the within-subjects factor and conditions as the between-subjects factor. Regarding the mixed ANOVA's assumptions: (i) no significant deviations from normality and homogeneity of variance were found; (ii) the sphericity assumption was not met, so the Greenhouse-Geisser correction was used for the within-subjects effect.

The mixed ANOVA results revealed that the interaction between type of package and conditions ($F(3,174) = 5.499$, $p = .006$; $\eta_p^2 = .087$, medium effect), type of package ($F(3,174) = 75.145$, $p < .001$; $\eta_p^2 = .564$, high effect), and conditions ($F(1,58) = 8.875$, $p = .004$; $\eta_p^2 = .133$, medium effect) have significant effects on the mean of hazard perception scores. The results are illustrated in Figure 5.

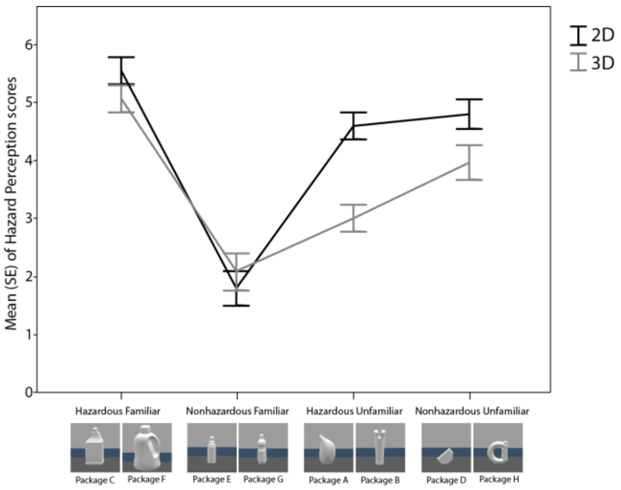

Figure 5. Error bars chart with the mean and standard error (SE) of Hazard Perception scores by experimental condition and type of package.

The effect of conditions was not the same for all types of packages: for the HUF (2D: $M = 4.59$, $SD = 1.24$; 3D: $M = 3.00$, $SD = 1.22$) and NHUF (2D: $M = 4.79$, $SD = 1.37$; 3D: $M = 3.97$, $SD = 1.56$) types of packages, 3D originates a decrease in the hazard perception scores, whereas for the HF (2D: $M = 5.53$, $SD = 1.32$; 3D: $M = 5.04$, $SD = 1.17$) and NHF (2D: $M = 1.80$, $SD = 1.57$; 3D: $M = 2.06$, $SD = 1.63$) types of packages, the means of hazard perception scores are similar.

In what concerns the type of package, and regardless of conditions, post-hoc tests with Bonferroni correction, revealed that the mean of hazard perception was higher for: (i) HF ($M = 5.28$, $SD = 1.26$), when compared to NHUF ($M = 4.38$, $SD = 1.51$; $p = .003$), HUF ($M = 3.80$, $SD = 1.46$; $p < .001$), and NHF ($M = 1.93$, $SD = 1.59$; $p < .001$); (ii) NHUF packages when compared to HUF and NHF packages ($p < .001$ for the two comparisons); and (iii) HUF packages when compared to NHF packages ($p = .001$).

3.3. ***Packages' content classification***

The participants' responses were grouped into 5 categories (i.e., alimentary, household chemicals, car product, personal care and other unrelated replies). The correct classification (i.e., if the participants were able to identify the package original content) of content category was also assessed.
Chi-square tests for homogeneity were performed for each package to verify whether the participants' percentages of correct classification were affected by the conditions (2D vs 3D). Results from chi-square tests, with Bonferroni correction, suggest that the conditions did not significantly affect the percentage of correct classification for all packages (see Table 2).

Table 2. The percentages of correct classification for each package

Familiar Packages					
Package	**Condition**	**% Correct Classif.**	**$\chi^2(1)$**	***p***	**adjust. *p***
C (N = 60)	2D 3D	76.7 60.0	1.926	.267	1.0
F (N = 59)	2D 3D	86.7 89.7	0.126	1.0	1.0
E (N = 59)	2D 3D	73.3 48.3	3.892	.064	.512

Package	Condition	% Correct Classif.	$\chi^2(1)$	*p*	adjust. *p*
G (N = 59)	2D 3D	93.1 86.7	0.669	.671	1.0
Unfamiliar Packages					
Package	**Condition**	**% Correct Classif.**	**$\chi^2(1)$**	***p***	**adjust. *p***
A (N = 57)	2D 3D	66.7 80.0	1.303	.367	1.0
B (N = 46)	2D 3D	30.0 26.9	0.053	1.0	1.0
D (N = 44)	2D 3D	27.3 18.2	0.518	.721	1.0
H (N = 49)	2D 3D	4.0 4.2	0.001	1.0	1.0

Cochran tests (see Figure 6 and 7) revealed that there were:

(i) No significant differences in the percentages of correct classification of familiar packages in 2D ($Q = 5.298$, $df = 3$, $p = .169$), but there were significant differences in 3D ($Q = 18.000$, $df = 3$, $p < .001$). Pairwise comparisons, using Bonferroni correction, showed that in the 3D condition, packages F and G attained a higher percentage of correct classification than packages C ($p = .045$ in both cases) and E ($p = .007$ in both cases).

(ii) There were significant differences in the percentages of correct classification of unfamiliar packages in 2D ($Q = 19.820$, $df = 3$, $p < .001$) and 3D ($Q = 27.295$, $df = 3$, $p < .001$). Pairwise comparisons, using Bonferroni correction, showed that in the 2D condition, package A attained a higher percentage of correct classification than packages D ($p = .029$) and H ($p < .001$); and in the 3D condition, package A attained a higher percentage of correct classification than packages B ($p = .029$), D ($p = .001$) and H ($p < .001$).

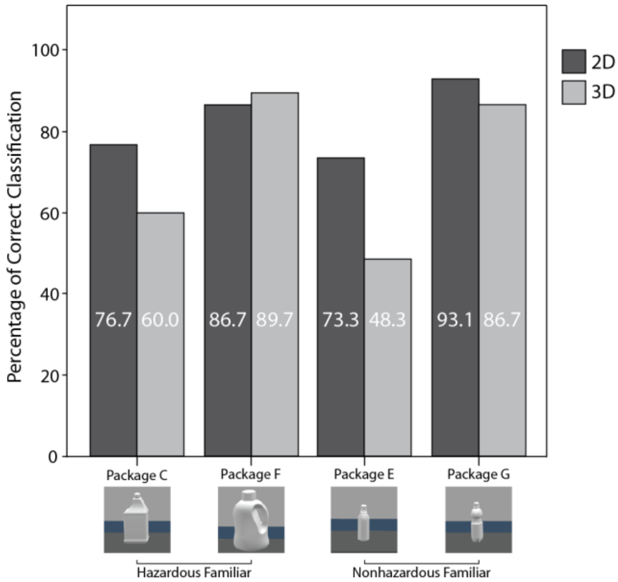

Figure 6. Percentages of correct classification of familiar packages (packages C, F, E and G) regarding package's category of content.

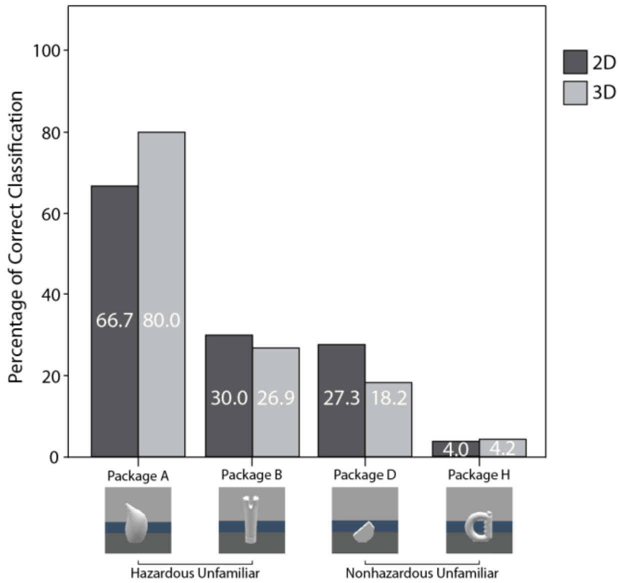

Figure 7. Percentages of correct classification of unfamiliar packages (packages A, B, D, H) regarding package's category of content.

4. Conclusion

The importance of this study can be found in the comparison of two visualization methods for evaluating participants' hazard perception from packages' shape.

Eight packages, categorized as either hazardous or non-hazardous (i.e., with or without hazardous content), and as either familiar or unfamiliar, were rated by the participants. The participants' familiarity with the packages, as well as the correct identification, of each of the package's contents was also analyzed.

The results suggest that the participants were able to perceive diverse levels of hazard with both visualization methods, i.e., they were able to analyze the packages hazard as 2D silhouettes or 3D digital prototypes with minimal details. However, some differences can be seen regarding their hazard perception.

The results show that the visualization methods affect the participants' hazard perception. The virtual reality 3D prototypes result in a significantly lower hazard perception, but only for the case of unfamiliar packages. No significant differences occur for the familiar packages. One possible explanation for this result can be that participants, when confronted with unfamiliar packages, and provided with limited detailed information, as in the case of the 2D silhouettes, they tend to overestimate the hazard's magnitude.

Interestingly, the correct identification of the contents, for each package, is not significantly affected by the visualization method. However, for the familiar packages, in the 3D condition, we found significant differences on the correct association scores; e.g., Packages F = Laundry detergent and G = Water, attained significant higher values than C = Toilet bowl cleaner and E = Recovery drink. Considering that in the 3D condition, the shapes' ambiguity is less apparent, it was hypothesized that, for packages F and G, the association between the shape and its content would be easily established by the participants, that is, such packages have a strong standard format/shape that avoids user confusion. The results found for the unfamiliar packages reinforce this interpretation.

Therefore, from this study, one important question arises: does the type of visualization method affect, somehow, the participants' ability to evaluate a product's level of hazard, by judging its packages' shape? The attained results suggest that, yes; the visualization method does indeed affect hazard perception. However, further investigation is required to better understand this effect.

We are currently exploring other variables beyond shape, such as color and textures, since we believe that these results are important in benefiting the study's' validity.

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