Title

Influence of presentation means on industrial product evaluations with potential users: a first study by comparing Tangible Virtual Reality and presenting a product in a real setting.

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Abstract

Nowadays Virtual Reality allows products to be presented to potential users, but as they cannot feel them physically, their perception of some product attributes can be distorted. Conversely, the mixture of visual and touch feelings that Tangible Virtual Reality (TVR) offers could act as a similar approach to knowing products in real settings.

This is a first study to compare the evaluation of product attributes presented in a real setting and by Tangible Virtual Reality to verify the possible equivalence of both means. The Semantic Differential Method was used to evaluate product attributes by creating a semantic scale with 16 bipolar pairs. Seventy-seven people (mean age of 21.7) evaluated one product by both means in an alternate viewing order.

The results revealed that the product that was chosen was rated with more positive attributes in some bipolar pairs when experienced via TVR, while it was better rated in others when experienced in a real environment. The Wilcoxon test ($\alpha=0.05$) corroborated that the presentation means used to evaluate the product influenced the evaluation of 15 of 16 attributes.

Keywords

Tangible Virtual Reality, product presentation, attributes evaluation, industrial design.

Aknowledgements

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1. Introduction

Nowadays, an image has become an important vehicle to take a product to consumers, which often acts as a presenter and informer of product characteristics. Recent studies have looked in-depth at how products presented using images are perceived by consumers. Some focus on a product's formal aspects by examining the influence of shape on one's perception of objects (Chang and Wu 2007); e.g., how a product's visual geometry influences its perceived quality (Forslund, Karlsson and Söderberg 2013), or how the feeling of novelty transmitted by a product's shape influences consumer preference for it (Hung and Chen 2012). Other studies have identified the attributes that a consumer values as positive in a product's appearance (Blijlevens, Creusen and Schoormans 2009), which must be distinguishable even though a product is presented with an image instead of being physically presenting. This makes the image particularly relevant in e-retailing (Jiang and Benbasat 2007; Jeong et al. 2009; Yoo and Kim 2014) as it helps improve product knowledge or reinforces users' understanding of its main attributes when users cannot come into contact with a physical product sample. All these studies indicate the real importance that an image acquires during the product presentation process, and that is necessary to prepare them properly so they are effectively perceived.

Virtual reality (VR) involves a new way to visually present and experience objects and settings. Lanier (1992) defined VR as users' immersing and interactive experience with a completely artificial setting created by a computer without them being in visual contact with their real surroundings. Today's VR technology allows very similar textures, details and lighting conditions to real ones to be reproduced visually, while also creating settings in which an object can be placed to be viewed as the constituent part of a scenario. The fact that VR-related devices have recently come down in price has allowed the implementation of this technology to speed up, and new industrial and domestic applications have appeared. Today computers' high calculating power allows scenarios to be shown using viewing devices with users quite fluently and naturally, which correspond to their head movements and their moving around a space.

All this extends the use of VR to new domains, which include product presentations in visualized settings in VR stores (Chittaro and Ranon 2000; De Troyer et al. 2007; Speicher et al. 2017; Rojas et al. 2015; Pizzi et al. 2019). Martínez-Navarro et al. (2019) showed that product presentation through VR encourages higher levels of presence compared to other means, which renders virtual stores more effective in generating cognitive and conative responses than physical stores. It can be concluded that VR increases purchase intentions compared to traditional stores. These settings offer an advantage to present products over conventional images as they allow users greater interactivity. However, the main advantage that conventional stores have over VR is that products can be physically felt or touched.

Having taken this concept one step forward, recently research has been conducted about integrating physical objects into VR experiences to more closely link virtual and real worlds with several applications (Harley et al. 2017; Shen-Kuen Chang et al. 2017; Zielinski et al. 2017). It is also possible to create a virtual immersive setting and place a real product in it so that users can visually experience the setting and the product, while interacting with the product physically and by touch, which brings the virtual experience closer to the real physical one (Hoffman et al. 1998).

The Tangible Virtual Reality (TVR) concept belongs to Mixed Reality in the Reality-Virtuality Continuum (Milgram and Kishino 1994) (Figure 1). In this continuum, the real environment corresponds to the reality perceived both physically and visually with no device. In contrast, VR offers a visual environment generated entirely by computer, and perceived via a device. Between these two concepts lies Mixed Reality (MR), which presents objects from both real and virtual worlds at the same time via a device. Within MR, Augmented Reality (AR) (Caudell et al. 1995; Azuma 1997) presents virtual objects that are visually integrated into a real environment, while real world objects are introduced into a virtual environment in Augmented Virtuality (AV). In Tangible Virtuality (Horváth 2007; Horváth et al. 2009), a symbiosis between physical and virtual realities is achieved by a multitude of perceptive, cognitive and physical links between real objects and virtual ones (Horváth et al. 2008) to emulate physical properties and the behavior of synthetic objects, and by increasing the manipulative experience of these objects. We can understand TVR as a similar concept, an experience that immerses users in a virtual setting through VR headsets, where all visual information is computer-generated, but whose objects and surfaces allow a physical and touch interaction because they match the shape, size and position of similar objects in a real setting.

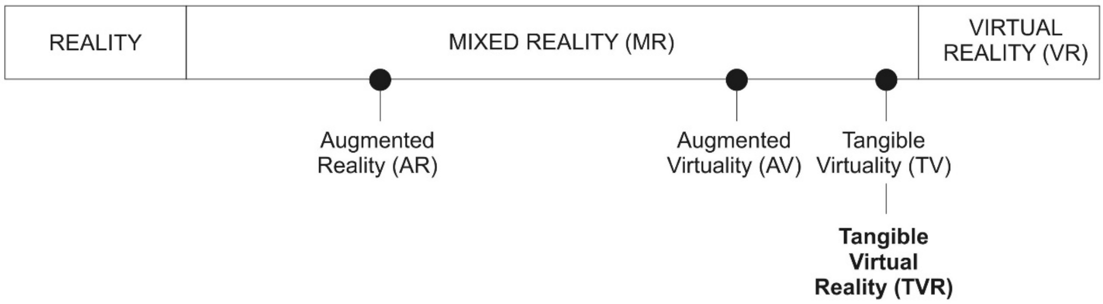

Figure 1. The TVR concept in the Milgram and Kishino's Reality-Virtuality Continuum.

Although TVR may be a new way of presenting products, it is worth wondering how users perceive the attributes of the products viewed by this means as they may be perceived and viewed differently depending on the product presentation means employed, which could change users' opinions about the product or any of its attributes.

Some works have studied how the attributes of some products have been perceived using photographs (Hsiao and Chen 2006), VR (Katicic, Häfner and Ovtcharova 2015; Abidi et al. 2016; Söderman, 2001) or with a real physical product sample (Karana and Hekkert 2010; Rahman 2012). Nonetheless, very few studies have investigated product attributes being evaluated when presented via TVR, and whether these evaluations differ from those made about the product when presented in a real setting.

Therefore, conducting a first study to measure the evaluation of one same product to be presented by two different means (experiencing a real product in a real setting and via TVR) would enable us to see to what extent this technology can influence how product attributes are perceived and would, at the same time, help us to consider the feasibility of this presentation means as a substitute for other more conventional product presentations.

2. Research aim and hypothesis

This first study aims to investigate whether the values scored given by users for a product's attributes vary according to the means of presentation: in the real environment or via TVR. The mixture of visual and haptic sensations of TVR can help users to perceive the product similarly to the real one, while offering some advantages compared to other means of presentation. For example, using TVR in a controlled setting (e.g., a showroom) allows users to visually experience and touch a product that has been integrated into the natural place it is used in (recreated virtually), and is perceived by users more naturally than by in two-dimensional images. At the same time, using this technology enables real-time changes to be made in a setting or to a product's visual features, such as color or surface visual texture (physical texture, perceivable through touch, would be that of the real product). This would enable companies to show their complete catalog of visual colors and textures in only one physical product sample in their shops.

Using TVR can also offer advantages in industry. In the early stages of conceptual design, interacting with various physical prototypes visualized through VR devices could provide valuable information from consumers and potential users, who could provide an opinion on the tactile sensations produced by different volumes or surface finishes, in relation to their appearance. Seeing and experiencing the prototype tactilely through TVR could allow users to communicate an opinion very similar to the one they would have using the real finished product, so it could help designers to better adjust the final product to the requirements of users. While this way of working may be costly in the early stages of product creation due to the cost of building several prototypes, it may offer advantages in later stages, when an advanced prototype is already available. In this regard, TVR would help designers in the process followed to choose finishing touches before they are produced, and could help companies to enable users to personalize their products.

For this study, an armchair was chosen because it is a type of industrial product whose qualities allow users a broad physical interaction by them being able to sit down and experience its tactile qualities in both means of presentation (real and TVR). To conduct this research work, the following hypothesis was put forward: "The means to present an armchair impacts the evaluation made of its different attributes".

3. Methods

3.1 General description

To verify if the hypothesis would be met, an experiment was designed and consisted in showing observers the same industrial product in two different ways: viewing it in a real setting and using a VR headset. For the present study, an armchair was selected because it is an industrial product that users are familiar with, to offer attributes that allow good physical interaction as users can sit on it and experience its attributes by touch in both product presentation means.

To make both viewing experiences similar, in both cases the product was located in a scenario, which was real for the former and was simulated for the latter. In both cases, users were able to touch, sit on and physically experience the product while viewing it, but not move it from where it stood. To make a clear comparison between both viewing forms, users had to evaluate the product on the same semantic scale.

3.2 Product evaluation: selecting semantic descriptors or adjectives to create a semantic scale.

To evaluate a product, one suitable way of doing this is to examine the different formal aspects and characteristics that define it. The Semantic Differential Method (Osgood, Suci and Tannenbaum 1957) determines a list of attributes of one product or of a product family to allow users to evaluate them on a qualitative scale that separates the pairs of antonymous adjectives that define each attribute. This method has been widely used in quite different product design-related fields, such as evaluating perception of shape (Perez Mata et al. 2017), attributes of tools (Mondragon, Company and Vergara 2005) or attributes of color combinations (Hsiao, Chiu and Shian Chen 2008). The scale that is normally used is the 7-point Likert scale because assessing an attribute on a scale with more levels can become more difficult and tedious for users, who could encounter difficulties when making such exact evaluations (Al-Hindawe 1996).

For our research, creating a semantic scale to help evaluate an armchair according to its different attributes was necessary. This was done by selecting a list of adjectives with which any armchair could be defined as completely as possible in accordance with its different characteristics. To create the semantic scale, the methodology followed by Achiche, Maier, Milanova and Vadean (2014) was adapted: collecting semantic descriptors from various sources, selecting images of the product from different websites, and classifying descriptors according to the Pleasure Model and filtering them.

For our particular case, we consulted three different sources to ascertain which adjectives were most commonly used to define an armchair, and to obtain a sample of the most varied adjectives: websites that sell habitat products, habitual users of this product and professional designers. The intention was to obtain a representation of all the people involved in the product, designers, distributors and users, by thus minimizing the authors' possible subjective decisions when selecting adjectives.

Twelve websites that habitually sell this type of product were selected from among the most prestigious European websites. Eleven specialized in domestic furnishings, and one was more generalist (Amazon.com). We made a note of the adjectives that they used to describe armchairs.

To draw up a list of the most usual adjectives that designers and users employ to describe armchairs, it was necessary to show them the product and ask them to describe it. The first step was to choose the images that represented different kinds of armchairs because the more varied the typology was, the more different adjectives we would obtain. Fifty images of different armchairs were obtained from several websites that sell furniture and habitat products, of which 15 that represented armchairs with bigger formal differences from one another were selected. So that observers could pay attention to formal armchair characteristics, a decision was made to remove the background and color by changing the images to grayscale (Figure 2)

Figure 2. Images of the 15 selected armchairs.

The images of the 15 armchairs were shown to a group of 70 habitual users of this product and to 10 professional designers. With an anonymous survey, they were asked to write down the five adjectives that best defined each armchair.

This enabled us to obtain three samples of adjectives: that provided by the product descriptions on websites (211 adjectives), that of the users (5,250 adjectives) and that of the professional designers (750 adjectives).

As the analyzed sample was not the same in each case (12 websites, 70 users and 10 designers), and by assuming that the adjectives obtained in all three samples were equally significant, we decided to multiply the quantity of adjectives obtained in each sample by a corrector factor so that the number of adjectives obtained in the three samples was comparable to one another.

To find out which were the most habitual adjectives in each sample, synonyms and antonyms were grouped as the same concept; i.e., repetitions of adjectives like “nice”, “beautiful” or “ugly” were related to a single concept (“beauty”), and were added and recorded as a single adjective: “nice”. To consider only the more habitual adjectives, the 25 most repeated adjectives in each sample were selected.

Next we classified these 25 adjectives, or semantic descriptors, from each sample using the four Pleasure Model categories: Physio, Psycho, Ideo and Socio (Tiger 1992; Jordan 2000). This model can be employed to broadly evaluate how pleasurable a product can be perceived. Here we intended that the list of semantic pairs would be formed by a representation of each category to acquire the most global information about a user's perceptions of the product in different fields. This classification of the adjectives in all four Pleasure Model categories was made after a consensus was reached by two teachers of the Bachelor's Degree in Industrial Design and Product Development at the Universitat Jaume I (Spain).

For all four categories, the adjectives obtained through the users, websites and designers were added. Repeated adjectives, synonyms and antonyms were added, and 12 different adjectives in the Physio category, 12 different ones in the Psycho category, 9 in the Socio category and 7 in the Ideo category were recorded. Only the four adjectives that appeared as the most frequent ones in each category were selected to prepare the semantic pairs. This provided a total number that was not excessively big to avoid making answers tedious for the participants.

Category	Adjectives			Total	Selected adjectives
	Users	Websites	Designers		
PHYSIO	11	6	9	12 (different)	Comfortable Light Large-sized Organic
PSYCO	5	6	7	12 (different)	Simple Practical Well-proportioned Minimalist
SOCIO	8	8	6	9 (different)	Classic Nice Original Discreet
IDEO	1	5	3	7 (different)	Fun Timeless Formal Tasteful
Total	25	25	25		

Table 1. Number of adjectives classified in all four Pleasure Model categories and the adjectives selected to prepare the semantic pairs.

Finally, a table was created with 16 semantic pairs using the antonyms of each selected adjective. So that the adjectives with positive or negative connotations did not always appear on the same side of the table, half the semantic pairs were inverted. A 7-point scale was used between one adjective and its antonym (Figure 3).

	+3	+2	+1	0	-1	-2	-3	
Cómodo / Comfortable								Incómodo / Uncomfortable
Pesado / Heavy								Ligero / Light
Voluminoso / Large-sized								Pequeño / Small-sized
Geométrico / Geometric								Orgánico / Organic
Sencillo / Simple								Complejo / Complex
Inútil / Useless								Práctico / Practical

Desproporcionado / Disproportionate								Proporcionado / Well-proportioned
Minimalista / Minimalist								Recargado / Overelaborate
Clásico / Classic								Moderno / Modern
Feo / Ugly								Bonito / Nice
Original / Original								Vulgar / Common
Llamativo / Loud								Discreto / Discreet
Elegante / Tasteful								Exagerado / Tasteless
Aburrido / Boring								Divertido / Fun
Intemporal / Timeless								Pasajero / Temporary
Informal / Informal								Formal / Formal

Figure 3. List of the semantic pairs used to assess the armchair (in the original Spanish worded and translated into English)

3.3 Preparing the VR scene

The armchair selected for the experiment was chosen from among the 15 models shown to the users and designers during the process followed to obtain the adjectives to form semantic pairs. In this process, apart from asking the participants to define each armchair with five different adjectives, they were requested to globally evaluate how much they liked them on a 5-point Likert scale, where 1 was the lowest score ("I do not like it at all") and 5 the highest ("I like it very much"). The fact that an armchair model was liked very much or very little could affect the way the user assessed other features on the semantic scale. For this reason, a decision was made to choose armchair no. 10, characterized by obtaining a mean evaluation score by the surveyed participants of 3.12 points out of 5, which is an intermediate value between 1 and 5.

When presenting a product, it is known that the setting it is placed in and the elements surrounding it can somewhat influence the way it is perceived (Baker, Grewal and Parasuraman 1994; Yoo and Kim 2014). Therefore, in order to make a valid comparison between the two different viewing systems, the setting in both cases would be perceived as similarly as possible to obtain a neutral factor for the comparison. For this purpose, to present an armchair in a real setting and virtually, we decided to place it in a scenario that was physically prepared in one setting, with 3D modeling in the other by making the visual sensation as similar as possible in both settings. In this way, the only independent variable of the experiment was the presentation format (VR and real), while the only dependent variable was the participants' evaluation of the armchair's attributes. All the other variables were annulled so they would not affect the experiment (shape, size, texture, lighting, color and distance among the different elements).

Therefore, the only independent variable of the experiment is the presentation format (VR and real), and the only dependent variable is the participants' assessment of the armchair attributes. All other variables have been annulled so that they have no effect on the experiment.

To help the participants to pay attention to the element that we wished to evaluate (an armchair), we opted to select products with neutral colors (i.e., colors with low saturation and medium brightness) that were more simply shaped than the armchair to be placed in the scenario. The following models were chosen: Adum (rug), Lack (table), Papaja (plant pot) and Ribba (pictures), which are all featured in Ikea's current catalog. Likewise, we selected a neutral color for the room's walls (mid gray), ceiling (light gray) and floor (mid gray texture) to not distract the observers.

The armchair and the other elements included in the scenario (rug, plant pot, table, pictures), and the walls, ceiling and floor, were modeled using Autodesk 3DS MAX 2017, based on the elements and lighting conditions of the real setting to be used.

The final setting was prepared with Unity, version 2017.2.0f3, and was viewed using the Rift VR Headset by Oculus. The sensors used to position the users at all time also came from the same company.

Figure 4. Comparison: photos of the real room (left) and the modeled room as seen via VR (right).

Figure 5. The modeling details viewed via the Oculus Rift VR headset.

3.4 Sample (participants)

To run the experiment, 77 volunteers were recruited, 41 men and 36 women, aged between 19 and 53 years, with a mean age of 21.73 years, with a standard deviation of 4.12. So even though one participant was 53 years old, the participants' demographic profile was young people. All the participants were students of the Bachelor's Degree in Industrial Design and Product Development, of whom 55 declared never having previously used a VR device (71.43%), 21 stated having had previous experience with such a device (27.27%), and only one person indicated being very used to VR technology (1.3%).

3.5 The experiment's protocol

The experiment was carried out on the mornings of 3 days in the same week. Twenty-three people came on day 1, 40 on day 2 and 17 on day 3.

Two rooms were prepared, which were similar in size and characteristics terms. In one room, the devices involved in the TVR experiment (computer, cameras and goggles) were set up, along with the chair to be viewed. It was placed on a rug, and the other elements were placed at a suitable distance to ensure the system worked properly and the user's experience would be obstacle-free. A screen prevented the participants from seeing what had been set up when they entered the room and throughout the experiment. The various elements that shaped the physical space used for the experiment were placed (armchair, rug, table, plant pot and pictures) in the other room, and were arranged in the same way as in the image viewed with VR goggles.

All the participants viewed the armchair twice: in the real setting and via VR. To avoid the influence that viewing order could have on their responses, roughly half the participants firstly entered one room and then the next. This allowed 38 people to view the scenario first by TVR and 39 did so later. The research personnel took photographs and videos to document the experiment.

The following protocol was applied to the participants who entered the room to experience the product via TVR. Once the participants entered the experiment room, the research personnel put on and adjusted the VR headset, and told the participants that they were going to see a scenario with an armchair, and they would finish by filling in a questionnaire to evaluate, as users, the armchair's different attributes (e.g., comfort, aesthetics, shape, style, etc.); the light in the room was switched off to avoid it filtering through the goggles; someone remained with them behind the screen where the viewing commenced. They were informed that they should carefully view the armchair for 1 minute by moving around it and crouching; next they were told they had 2 minutes to touch it and sit in it, but could not move the armchair from where it stood; finally, they were accompanied when they left the room, the headset was removed and they were thanked for their collaboration. The research personnel went with them to another room, where they sat down to complete the questionnaire and to sign a document that authorized the possibility of disseminating the photographs that had been taken.

A similar protocol was followed for the participants who entered the other room. They were told that they would see a scenario with an armchair and would then have to fill in a questionnaire to evaluate this product. They performed the same actions during the same time, and were told they could not move the armchair, but could move around, touch it and sit down.


Figure 6. Rooms for the experiment run with the product via TVR (left) and in a real setting (right).

Figure 7. The participants during the experiment in the TVR setting (left) and in a real setting (right).

The survey asked each participant about their gender, age, if they had any eyesight problems (myopia or astigmatism) and, if they did, whether they normally used glasses or contact lenses. First each participant had to rate the armchair in accordance with all 16 semantic pairs in Table 3, and had to use a 7-point semantic differential scale for this purpose. Next they had to indicate how much they liked the armchair globally by scoring their answer on a 5-point Likert scale that went from 1, the lowest value ("I do not like it at all") to 5, the highest score ("I like it very much"). This question was intended for the participants, as users, to rate their general opinion of the armchair. Although this rating is general and does not provide as detailed data as the rating made on through the 16 semantic pairs, here the intention was to acquire some more information with which to compare both means of presentation. Finally, they had the option of writing some personal comment about the experiment

3.6. Data analysis

To make comparisons easier, it was necessary to organize the scores given to the different armchair attributes according to the viewing mode. To determine whether using TVR influenced a user's product evaluation, it was necessary to apply a statistical inference method and check the tested hypothesis. The Kolmogorov-Smirnov test (Lilliefors, 1967) helped to verify if data followed a normal distribution. The Wilcoxon test (Zimmerman and Zumbo, 1993) allowed a comparison to be made of the medians of the differences in scores that each participant gave the armchair when interacting with it by either TVR or not.

4. Results

With the data obtained with the questionnaire, we checked if the armchair evaluations differed when a user viewed and experienced the product via TVR *versus* doing so in a real setting with no viewing technology support. Table 2 provides the means obtained for the different armchair attributes in accordance with whether TVR was used or not. Figure 7 graphically depicts the means for the pairs of opposite adjectives by distinguishing the results according to viewing type: with TVR and without TVR (in a real setting viewing).

Semantic pair	TVR viewing		In a real setting viewing, without TVR	
	Mean	Standard deviation (σ)	Mean	Standard deviation (σ)
comfortable / uncomfortable	+2.08	0.96	+1.64	1.40
heavy / light	+0.04	1.44	+0.16	1.67

large-sized / small-sized	+0.87	1.02	+1.06	1.15
geometric / organic	-0.62	1.25	-0.53	1.30
simple / complex	+1.16	1.15	+1.05	1.17
useless / practical	-1.57	0.86	-1.29	1.13
disproportionate / well-proportioned	-1.27	1.30	-0.94	1.50
minimalist / overelaborate	+1.27	1.20	+1.26	1.17
classic / modern	-1.00	1.36	-0.99	1.40
ugly / nice	-1.83	0.88	-1.77	1.07
original / common	+0.82	1.08	+0.61	1.05
loud / discreet	-0.35	1.52	-0.43	1.56
tasteful / tasteless	+1.45	1.07	+1.31	1.31
boring / fun	-0.38	1.04	-0.25	0.95
timeless / temporary	+0.65	1.30	+0.66	1.20
informal / formal	-0.97	1.22	-1.00	1.31

Table 2. The mean values for each semantic pair (from -3 to +3)

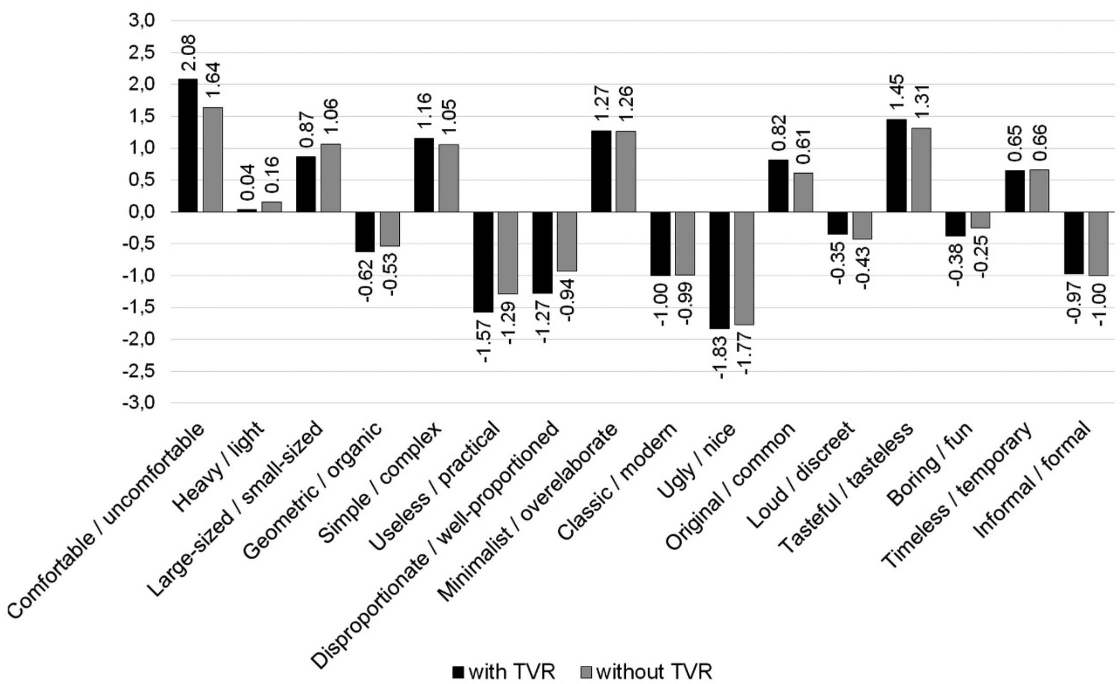

Figure 8. The mean values for each semantic pair.

We can see that TVR positively affected the evaluation of many attributes. When comparing the mean values obtained by each adjective, the same armchair was evaluated as being more comfortable, simple, minimalist, original, loud, tasteful and informal when viewed by and interacted with using TVR. Similarly, the armchair was evaluated as being less heavy, large-sized, geometric, useless, disproportionate, classic, ugly and boring than when viewed and interacted in a real setting (Table 2 and Figure 8).

For the question "How much do you like the armchair on a 5-point Likert scale", the armchair obtained a mean score of 3.87 points when viewed via TVR (σ=0.61), and one of 3.79 when TVR was not used (σ=0.80). In both cases, a score of 4 points was the most frequently chosen. Figure 9 provides the distribution of the responses of the scores that users gave.

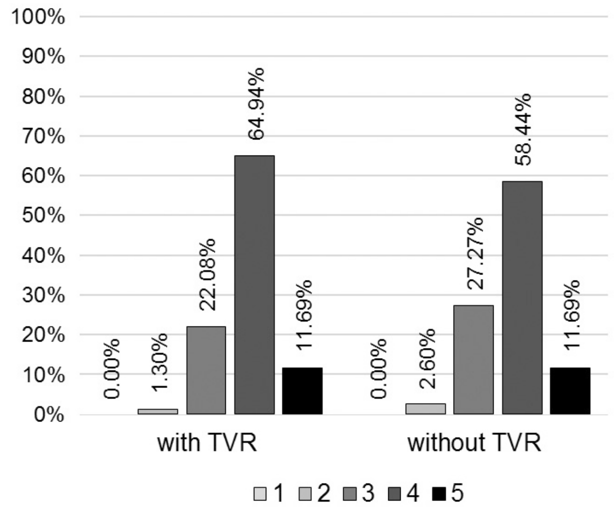

Figure 9. Distribution of the responses to the question "How much do you like the armchair?" (score from 1 to 5: 1="I do not like it at all", 5="I like it very much").

The Kolmogorov-Smirnov test indicated that data were not normal. In this case, and as the data to be compared were related because the same user scored the armchair in all the ways it was interacted with, the Wilcoxon test was run with a sample size n=77 (154 data collected) and with a 5% estimation error (α=0.05) for all the questionnaire's dependent variables. Although the mean values of all the scores were similar, if using TVR had no influence, the medians of the differences among the scores given by the users would have to be zero or come very close to zero. When this occurred, the p significance level would be higher than the estimation error (0.05).

The tables below show the results obtained for the following null hypothesis (H_0) for all the variables in the table: "the score that the user gives to the adjective does not depend on if the armchair was viewed and interacted with via TVR". The alternative hypothesis (H_A) is that score a user gives to adjectives depending on whether the armchair was viewed and interacted with via TVR. The null hypothesis is the equivalent to checking if the differences in the armchair evaluations viewed in both ways can be considered null, i.e., if the p-value is higher than 0.05. As it can be seen in Table 3, although the mean values are quite similar in some of the pairs, many of the medians of the differences between the scores obtained with and without TVR are important. For instance, for the 'comfortable' score, the negative ranks are higher than the positive ones. Table 4 shows the result of the statistical test.

Semantic pairs	Ranks	N	Mean rank	Sum of ranks
comfortable / uncomfortable	Negative Positive Ties	131 13 10	72.89 68.54	9549.00 891.00
heavy / light	Negative Positive Ties	53 73 28	52.88 71.21	2802.50 5198.50
large-sized / small-sized	Negative Positive Ties	81 30 43	54.99 58.73	4454.00 1762.00
geometric / organic	Negative Positive Ties	23 105 26	43.48 69.10	1000.00 7256.00
simple / complex	Negative Positive Ties	92 29 33	62.30 56.86	5732.00 1649.00
useless / practical	Negative	4	48.13	192.50

	Positive Ties	136 14	71.16	9677.50
disproportionate / well-proportioned	Negative Positive Ties	19 113 22	26.61 73.21	505.50 8272.50
minimalist / overelaborate	Negative Positive Ties	100 22 32	60.90 64.25	6089.50 1413.50
classic / modern	Negative Positive Ties	20 123 11	42.15 76.85	843.00 9453.00
ugly / nice	Negative Positive Ties	4 143 7	10.50 75.78	42.00 10836.00
original / common	Negative Positive Ties	63 37 54	51.41 48.95	3239.00 1811.00
loud / discreet	Negative Positive Ties	0 153 1	0.00 77.00	0.00 11784.00
tasteful / tasteless	Negative Positive Ties	108 19 27	63.77 65.32	6887.00 1241.00
boring / fun	Negative Positive Ties	18 90 46	35.72 58.26	643.00 5243.00
timeless / temporary	Negative Positive Ties	63 46 45	56.03 53.59	3530.00 2465.00
informal / formal	Negative Positive Ties	15 119 20	34.07 71.71	511.00 8534.00
How much do they like the armchair	Negative Positive Ties	153 0 1	77.00 0.00	11781.00 0.00

Table 3. Wilcoxon signed ranks for interaction with TVR and without TVR. N= number of cases.

Adjectives of null hypothesis H_0	Wilcoxon signed-rank test	Conclusion	Effect size (N=154)
comfortable / uncomfortable	Z=-8.807 p<0.000	H_0 is rejected. It depends on the interaction type	0.71
heavy / light	Z=-2.976 p=0.003	H_0 is rejected. It depends on the interaction type	0.24
large-sized / small-sized	Z=-4.096 p<0.000	H_0 is rejected. It depends on the interaction type	0.33
geometric / organic	Z=-7.574 p<0.000	H_0 is rejected. It depends on the interaction type	0.61
simple / complex	Z=-5.471 p<0.000	H_0 is rejected. It depends on the interaction type	0.45
useless / practical	Z=-10.003 p<0.000	H_0 is rejected. It depends on the interaction type	0.81
disproportionate / well-proportioned	Z=-8.921 p<0.000	H_0 is rejected. It depends on the interaction type	0.72
minimalist / overelaborate	Z=-6.137 p<0.000	H_0 is rejected. It depends on the interaction type	0.49
classic / modern	Z=-8.791	H_0 is rejected. It depends on the	0.71

	p<0.000	interaction type	
ugly / nice	Z=-10.577 p<0.000	H_0 is rejected. It depends on the interaction type	0.85
original / common	Z=-2.591 p=0.010	H_0 is rejected. It depends on the interaction type	0.21
loud / discreet	Z=-6.275 p<0.000	H_0 is rejected. It depends on the interaction type	0.51
tasteful / tasteless	Z=-6.974 p<0.000	H_0 is rejected. It depends on the interaction type	0.56
boring / fun	Z=-7.275 p<0.000	H_0 is rejected. It depends on the interaction type	0.59
timeless / temporary	Z=-1.672 p=0.095	H_0 is not rejected. Data show no dependence on interaction type	0.13
informal / formal	Z=-9.037 p<0.000	H_0 is rejected. It depends on the interaction type	0.73
How much do they like the armchair	Z=-10.960 p<0.000	H_0 is rejected. It depends on the interaction type	0.88

Table 4. The Wilcoxon test results for $H_{0.}$ p= significance level; Z= standard score (z-score); effect size=

A Wilcoxon test was also applied to check if gender influenced the obtained scores. The results showed that gender had a influence. Sample size was not enough to test the null hypothesis only with one gender.

5. Discussion

From the obtained data we found that the evaluations made of the armchair attributes differed depending on viewing type. Basically, we can state that viewing and interacting via TVR influenced the perception of most evaluated product characteristics. The results also revealed that the selected armchair was liked slightly more overall when viewed and experienced via TVR.

Providing an explanation as to why the selected product was liked slightly more if viewed by TVR goes somewhat beyond the scope of this study, but we can consider two possibilities: one is that our sample was formed mainly by young people who generally tend to be highly receptive to new technologies. The other is that the evaluations might have been influenced by the novel effect as most participants had limited experience with product presentations performed with VR, and had no experience with TVR.

Thus one of the limitations of this experiment was the sample of participants who, albeit large enough, had very specific characteristics. On the one hand, it was composed of young people (mean age of 21.73 years), so the results should only be considered for this age group. On the other hand, their experience with TVR technology was nonexistent, so we did not know if the results would have been the same for more experienced people in this visualization technology. Moreover, the statistical test showed that gender influenced the scores, but the sample should be bigger to state exactly how this occurred.

Another limitation was the setting used to present the armchair. This was prepared to set the product in an environment that would be coherent for users, and it was accompanied by other usual furniture elements, presented in simple shapes and discrete colors. The scenario that the user saw in the TVR experience reproduced the real scenario in detail after taking into account lighting conditions, colors, textures, room size, and distance between elements. The possible effect that the elements of the scene could have had on their evaluation of the armchair was annulled as they were the same in both settings (real and TVR). However to verify if the results were stable, the experiment had to be carried out with several different settings, and with other furniture elements or other lighting conditions.

It is important to note that although the study compared two presentation means (a real environment and a TVR environment), both used the same armchair, so participants in both means shared the tactile experience of the same product. Therefore, a limitation of this study is that it does not compare two completely different presentation formats, since in this case both share common features (the use of the same physical armchair).

In order to collect data, the participants had to complete a questionnaire, as in other studies in which a product had to be evaluated using semantic pairs (Khalaj and Pedgley 2014; Yoo and Kim 2014). However, as each questionnaire had to be filled in after the end of the test (real scene and TVR scene), there was the possibility that the assessment made of each semantic pair did not derive from the first impression of seeing and experiencing the product, which is usually instantaneous. Applying other procedures, such as Think-aloud (Wright and Monk 1991), would help to check whether assessments were affected by the data collection method.

This first study helps to consider TVR as a technology capable of presenting a product to potential users and helping them to form an opinion of it by being able to see it at the same time as they touch it or test it. The study also shows that there is a wide variation in the ratings given by this means to lots of the product's attributes, compared to those given when the product is presented in a real setting. Although the results are interesting, the limitations in this first study mean that their scope should not be generalized or extended to other user groups or other product families.

6. Conclusions

The data in Table 2 reveal that 15 of the 16 attributes evaluated by users deny that the evaluations are equal when interacting with TVR and without TVR. Therefore, the hypothesis that we put forward in this study was met. This means that the presentation means apparently influences the way this product's attributes are evaluated, except for the timeless attribute, which we could not demonstrate.

Through this first study using TVR, we confirm that users' understanding of the product differs depending on the representation means, just as previous studies have indicated when comparing different means. In line with this, Artacho-Ramírez et al. (2008) showed that the representation mode has a significant influence when transmitting the concepts that compose the product semantic space. Reid et al. (2013) proved that people form different opinions of products when viewing distinct product representation modes. Söderman (2005) made comparisons between different presentation forms, like sketches, VR and a real product sample, to conclude that the understanding of the product depends on the means that represents it and is related with previous product knowledge that users have. Rojas et al. (2015) compared the presentation of a bottle with pictures and computer-generated images that were visualized via VR headsets. These authors concluded that the presentation means influenced how the product was perceived and evaluated, possibly in part because of small details in stimuli, such as the quality of the image rendering seen through VR.

Presenting products in a real setting offers first-hand experience with a product which can be observed and experienced physically. TVR also gives users a first-hand experience to a real experience, by providing them the chance to observe, touch and physically interact with a product in a simulated setting. The data analyzed in this first study allowed us to corroborate that both presentation means in the same setting with the selected armchair allowed many of its attributes to be experienced and understood, which helps users to understand its features and outlines a very complete product evaluation. Nonetheless, although this study is limited to using only one product, the fact that a difference exists in the evaluations made between both presentation means evidences a distorted perception of some product attributes. Therefore, when presenting products via TVR, it should be borne in mind that, although they may be slightly more appealing overall, their features could be misinterpreted.

As a first study, the present work has focused on presenting a given piece of domestic furniture. It would be interesting to study what effect these two presentation means may have by analyzing a sample with older users. It would also be interesting for future work lines to check what effects TVR would have with more similar products or evaluating attributes from other different industrial product categories to find out if this viewing means would suitably inform about the product or, conversely, if it would seriously affect the perception of its attributes as opposed to presentations held in real settings. Another interesting possibility would be to compare the use of TVR and VR to present products in order to investigate the influence of physical interaction and the feeling of touch on the evaluation users make of different product attributes when observing them by both immersive technologies. This would help to determine the importance of physically interacting and touching the product when forming a valid and complete view about a product.

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