applied sciences

MDPI

Article

Perceiving Design Features in New Interaction Environments: Comparing Rendered Images, 360° Rotation, AR, Immersive and Non-Immersive VR, and Real Product Interaction

Maria-Jesus Agost *, Margarita Vergara and Vicente Bayarri-Porcar *

Department of Mechanical Engineering and Construction, Universitat Jaume I, 12071 Castelló, Spain; vergara@uji.es
* Correspondence: magost@uji.es (M.-J.A.); vbayarri@uji.es (V.B.-P.)

Abstract: The emergence of new display technologies can change the perception of product design features and their assessment. Previous studies are limited to comparisons between a few technologies; the real product is considered only occasionally. This work compares the perceptions of 10 design features in two household products, shown by five display technologies (image rendering, 360° rotation, and augmented, immersive, and non-immersive virtual reality), and also with the real product. Results show that the 360° rotation provides the best perception for the most important features. However, the perception of aesthetic features is better achieved with i_VR. Other global results vary depending on the product. Finally, interaction with the real product shows a quite different perception for many features. The results contribute to the understanding of product perceptions influenced by different displays, comparing them with perceptions generated through real interaction. It is expected that the conclusions will be used to optimize the presentation of product features.

Keywords: display technologies; augmented reality; virtual reality; 360° rotation; product feature perceptions

check for updates

Citation: Agost, M.-J.; Vergara, M.; Bayarri-Porcar, V. Perceiving Design Features in New Interaction Environments: Comparing Rendered Images, 360° Rotation, AR, Immersive and Non-Immersive VR, and Real Product Interaction. *Appl. Sci.* **2024**, *14*, 4470. https://doi.org/10.3390/app14114470

Academic Editor: Laura Cercenelli

Received: 23 April 2024
Revised: 10 May 2024
Accepted: 22 May 2024
Published: 23 May 2024

1. Introduction

The evolution of new display technologies has modified the product–user interaction. In recent years, a radical transformation of consumer goods purchase processes has occurred. The great boom in electronic commerce and the COVID-19 pandemic have caused a change in consumers, who are increasingly searching for and purchasing products through companies' websites and other platform retailing webs [1]. This trend is also observed in other contexts such as the development or assessment of product design making faster and less costly the changes in their design [2]. In other areas, such as entertainment, product perceptions are generated through increasingly varied technologies [3,4].

The use of these new technologies entails that the product interaction is not physical, but rather the information about products is usually shown through other display methods. Some studies have shown that the type of sensory perception and the level of interaction with the product influence user perceptions [5,6], which play an important role [7], since the user final decision will depend on the subjective perceptions generated [8,9]. Therefore, the environment in which the interaction occurs, considered by Crilly et al. [10] as the channel in their framework for design as a process of communication, constitutes a fundamental element for the user's response.

In this regard, new display technologies study the best way to show product information: static images from different angles, zooms, or enlargements to show details are solutions usually adopted to provide potential clients with as much product information as possible. A presentation method that is also common is the 360-degree realistic 3D image system (360° rotation). It offers a 360-degree continuous representation of the product, which can be rotated by the user in any direction to be viewed from any angle. Other newer display systems are achieved through augmented reality (AR) and virtual reality (VR) technologies. It is vital for the information offered by a product to be able to generate the appropriate subjective impressions in order to offer the user the necessary confidence and trust to take assessments or purchase decisions.

Augmented reality is an interactive technology that offers the possibility of superimposing a virtual layer (consisting of elements such as images or texts) on a physical environment, in real time. In this way, from a logo or printed code, AR technology allows virtual images of a product to be displayed in 3D, in the real environment in which it is intended to be located. It can be applied in very diverse fields, including domains such as medicine, manufacturing, military, or education, among others [11]. In the field of marketing, AR has emerged as one of the most relevant interactive technologies, rapidly increasing its fields of application [12–14] and the devices that support it, including smartphones, tablets, projectors, or interactive screens [15]. Therefore, AR is an effective method for influencing human perception, and the assessment of human perception of virtual things in AR should be an interesting and important research domain [11].

In VR technology, the user is immersed in a totally virtual environment with which he/she can interact. Two main categories are considered: immersive and non-immersive systems [16]. Non-immersive virtual reality (ni_VR) consists in a virtual representation of an environment, displayed through a monitor [17]. This representation can usually change in a dynamic way, either automatically or through user instructions introduced by using the keyboard, touching the screen, etc. In immersive virtual reality (i_VR), the virtual representation of the environment is displayed as a realistic experience through head-mounted displays [18], which provide the user the sensation of being inside the scene. The environment visualized by the user changes if he/she changes his or her orientation, providing greater realism to the scene. VR has been applied in many fields, such as medicine [19], psychology [20], industry [21], or teaching [22]. A recent literature review [23] concluded that there is a lack of rigorous studies comparing the VR shop and other shopping contexts, so that VR should be compared with various content display media, such as images or other web-based 3D interfaces. Additionally, there is a lack of studies that compare immersive and non-immersive VR in terms of product perceptions [24].

Therefore, despite the existence of some studies on user interaction with the product in an online context through new display technologies, like the study by Yim and Park [25], which compares AR technologies versus images, or that by Pleyers and Poncin [26], applied to non-immersive VR and static photos, literature is scarce on studies that compare various presentation technologies, with the aim of optimizing the display of the product and the perception of its features. In this sense, the following hypothesis is proposed:

H1. *The perceptions generated about product features may be different, if they come from different display technologies. These differences in features' perception among display technologies, may also depend on the specific product.*

In any case, if these differences are studied with the aim of optimizing the presentation of products, the importance provided to the correct perception of each feature should also be considered, as all features may not be considered equally important, which leads us to the next hypothesis:

H2. *The importance provided to a proper perception may depend on the specific type of feature to be perceived. It may also depend on the specific product.*

The perceptions achieved from these display technologies are occasionally compared in the literature with the actual interaction with the product, such as the study by Arbeláez and Osorio–Gómez [27] on AR, or the review by Berni and Borgianni [28], which is focused on VR applications. A recent study [29] about the presentation of products through VR compared cases in which physical contact with the product is offered (real setting and VR including passive haptics) with other cases in which there is no contact. The study detected differences in some features, depending on the technique used. For example, the product (a chair) was perceived through direct interaction as being significantly lighter than through VR with haptics, larger than through immersive (headset) and non-immersive VR (screen), and nicer than through non-immersive VR (screen).

Some of the existing studies that compare various product display technologies are especially focused on their application as a support tool in early design phases by reviewing different categories of VR applications in design [28], combining and comparing virtual and physical prototypes [30], or evaluating the reliability of product display technologies (such as renderings, AR, and VR) as a tool for product assessment in the early stages of the product-development process to make the design process faster and more profitable [31]. This last study concludes that certain product features can be emphasized in more immersive media (such as AR or VR), which is useful for both product development and point-of-sale presentation.

In any case, a lack of a comparative analysis is detected between the perception achieved through display technologies and that generated with the real interaction with the product. Therefore, the third hypothesis is established.

H3. *The perceptions generated about product features as a consequence of the interaction with display technologies in an online interaction may be different from those generated in the subsequent physical product-user interaction phase.*

In summary, although the great growth of online contexts for sales and other purposes has favored the study of the influence of some new display technologies on product perceptions, these studies usually refer only to one of these technologies, comparing the perceptions with those obtained through images or renders, or with the impressions produced in the interaction with the real product. Studies that compare several types of new display technologies are scarce and often focused on specific aspects, such as assessment in the initial stages of product design, or the comparison of the effects of using haptics on perception. There is still a lack of comparative studies that jointly consider various new display technologies [23,24] in order to generate relevant information that favors the recommendation of the optimal product presentation system. In the same way that the space in a physical storefront is limited, the product information displayed through a web page should be analyzed and selected in each case with the aim of optimizing user perceptions.

Considering this context, the purpose of this paper is to analyze the influence of five different display technologies (including virtual and augmented reality applications and rotation programs) on the perception of a variety of product design features of two different household products and compare these perceptions with the subsequent perceptions generated in the physical interaction with the real product. The study is set in an online context. Some preliminary partial results of the study have been published in [32] and are analyzed in greater breadth and depth in the present manuscript. The results contribute to the understanding of the generation of product perceptions caused by different displays, depending on the technology used and the specific product, and whether or not these perceptions correspond to reality. It is expected that conclusions will be used to optimize the presentation of products.

2. Materials and Methods

To analyze the possible differences in the capacity of each technology to transmit product features, an experiment was designed in which 77 participants were shown a household product through different display technologies. Two products and five display methods were used. Subsequently, they saw the real products. The participants comparatively assessed whether the perception of 10 (general, detail, functional, and aesthetic) product features were influenced by the technologies used.

2.1. Selection of the Subjects

Ninety-six students, aged between 18 and 29 years, in the third year of the Degree in Engineering in Industrial Design and Product Development were invited to participate, although complete, valid data were obtained for only 77 participants (36 females, 41 males). They were selected as they were expected to have experience with the use of new technologies. Also, due to their studies, especially focused on product design, they were expected to be able to easily perceive product design features, such as materials, dimensions, shape, details, etc. All participants signed a written informed consent document. Both the experiment and the informed consent document were approved by the University Ethics Committee. In the characterization of the sample of participants, gender, age range, and experience with online purchases and technologies were included.

2.2. Selection of Products and Features

Two common home appliances were considered: a piece of furniture (a sideboard) and a household accessory (a gooseneck lamp). The objective was to apply the study to products that are widely known and used by the general public, but with very different features, such as size, materials, shapes, mode of use, etc., to gather a better representativeness. Furthermore, the products and their features should be chosen so that they can be shown through the different display technologies. In addition, they had to be available products so that participants could interact with them physically. Ten varied design features were selected for studying their perception: general physical features (dimensions and shape, weight), detailed physical features (materials, color, finishes, details), functional aspects (mode of use, reliability, quality), and also the aesthetic and affective dimension (Appeal) (Table 1).

Table 1. Product design features considered to study their perception, depending on the display technology used.

Design Features	Expression Used in the Form
Dimensions and shape	Perception of dimensions and shape
Weight	Perception of robustness/lightness
Materials	Perception of materials
Color	Color perception
Finishes	Perception of shine and textures
Details	Perception of details and small elements
Mode of use	Perception of the mode of use
Reliability	Perception of resistance and reliability
Quality	Perception of quality
Appeal	Perception of attractiveness

2.3. Product Display Technologies and Development of the Websites

A web page was developed with the premise that it should be accessed from a smartphone (as the most commonly used device). Five technologies were used to display the products: image rendering, 360° rotation display, augmented reality, non-immersive virtual reality, and immersive virtual reality.

Nowadays, image rendering is one of the most commonly used methods to display products. On the website developed for the experiment, a carousel with rendered images (2D) showed the product (the sideboard or the gooseneck lamp) from different perspectives: isolated, integrated into an environment, showing some details in a zoomed image, or showing detailed measures (Figure 1). These images were accompanied by a text offering a description of the product.

Figure 1. Rendered images displayed in a carousel along with a written description (translated from Spanish), on the simulated website. (**Top**): the sideboard, and (**bottom**): the gooseneck lamp.

For the 360° rotation display (360°) technique (Figure 2), the product was displayed on an app (Sketchfab) that allowed simple 3D interaction (rotation, zoom, and opening drawers and doors in the case of the sideboard). The display was shown together with instructions on how to rotate, zoom in on details, and view the three-dimensional models from any angle.

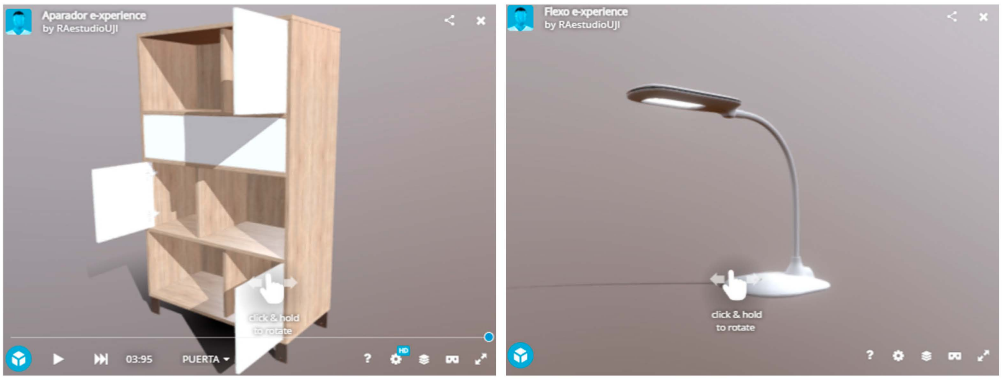

Figure 2. Sketchfab display for the sideboard and the gooseneck lamp.

The same app was used to obtain a virtual representation of the product, this time displayed on a screen over a real location (AR), revealing "how it would look" in the real environment for which the product is intended (Figure 3). The orientation of the product presentation changed (realistically) in accordance with the user's movements.

Figure 3. Virtual representations to download and visualize for non-immersive (via a mobile/tablet screen) or immersive (using support glasses) virtual reality.

VR was included on the website through both types of representations: ni_VR and i_VR. Detailed instructions were provided on how to download an app (VR Media Player) so that a virtual representation of the product located in a virtual room (Figure 4) could be displayed (ni_VR). The orientation of the environment shown on the screen could be modified by the user by sliding his or her fingers across the screen. In addition, for i_VR, instructions were provided on how to visualize the scene on a mobile phone, held by a head-mounted display (glasses) that participants were provided with (Figure 4).

Figure 4. Glasses for i_RV used by the participants.

To avoid the fatigue in the participants that might result from an experiment that was too long, four different versions of the website were generated, depending on the product considered and the use of AR or VR. For each product, two versions of the web page were created: in the first one, the product was shown by means of 2D, 360° and AR. In the other one, the display technologies were 2D, 360°, and ni_VR and i_VR. To simulate a real experience of interaction, the participants used their own devices (smartphone, tablet), and the web pages were developed with the premise that they should be accessible from both types of devices.

2.4. Procedure

The study consisted of two distinct phases (Figure 5). In the first one, after indicating their experience with the use of display technologies, the participants browsed through the randomly assigned web version and interacted with the product through the corresponding technologies. They later assessed the technology's capacity to allow users to perceive product features, and they assessed the importance of each of these perceptions.

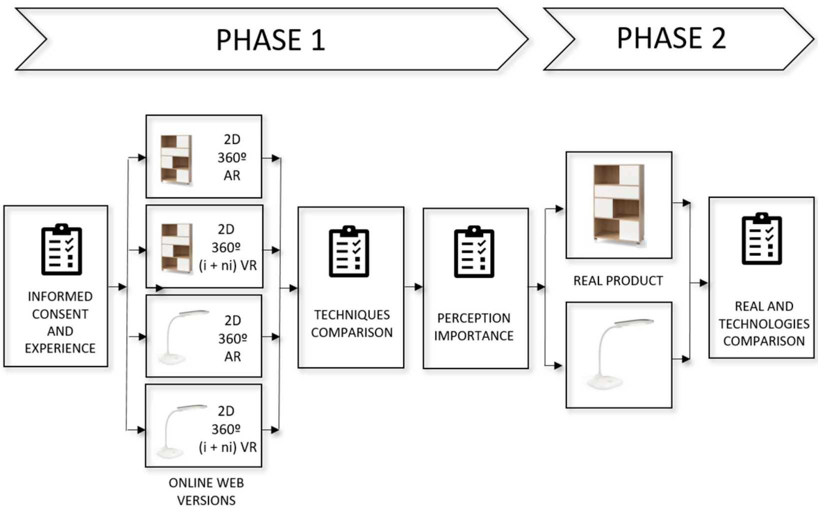

Figure 5. Experiment flowchart.

In the second phase, the participants were called individually to see the real product and then answer a questionnaire comparing the perceptions generated in this real interaction with those they had obtained after Phase 1.

2.4.1. Phase 1: Online Interaction through Display Devices

Through a QR link, the participants accessed the initial form (informed consent and characterization). To optimize the experience with their smartphone, they were recommended to use it horizontally. The expected amount of time required to complete the task was approximately 20 min. Once the study conditions had been accepted, the participants indicated their level of experience with the use of the display technologies by means of a scale with the following levels: 0 Never; 1 Once or twice; 2 Sometimes; 3 Often; 4 Very often.

Next, the participants were distributed in a random and balanced manner among the four versions of the simulated website so that they could interact with the products through the display technologies. The order in which they interacted with the technologies was not controlled. Participants could have used the technologies in a different order, although this was not recorded. They were provided instructions on how to interact with the product using all of them. As already mentioned, 77 individuals participated in the study after discarding the records of five participants who could not use the AR or the VR technologies due to technical problems with their mobiles. The distribution of participants among technologies and products is summarized in Table 2.

Table 2. Distribution of the number of participants in the study, according to the product and the technologies used.

		Technologies	
		2D + 360° + AR	**2D + 360° + VR**
Product	Sideboard	19	19
	Gooseneck lamp	20	19
	TOTAL	39	38

The participants who were assigned immersive virtual reality as a visualization technology previously received glasses for their smartphone to be able to carry out the experience, and the rest were provided a backpack as an alternative gift.

After using all the assigned display technologies, the participants were asked to assess the perception of each product design feature (Table 1) on a comparative basis for each technology assigned by means of a questionnaire with a five-point scale (“1. Very bad”; “2. Bad”; “3. Neutral”; “4. Good”; “5. Very good”). They were then asked about the importance given to correctly perceiving each of the product design features, also using a five-point scale, from “1 Not important at all” to “5 Very important”.

2.4.2. Phase 2: Face-to-Face Interaction with the Product

In the second phase, the interaction occurred with the actual product (Figure 6). Each participant individually entered a room where he/she could physically interact with the same product (without touching it) answered in Phase 1. Next, they answered a questionnaire to compare the same design features of the real product with respect to their previous perception (Table 3). Specifically, for each feature, they were asked to assess whether their perception was the same or different. If they found a different perception, they were asked to indicate what the difference consisted of. For a more detailed comparison, the original features, dimensions, shapes, and finishes were divided. The reason is that, in the comparison between display technologies, the participants rated three or four different techniques for each perception, so excessive detailing of the perceptions was avoided. So the overall volume was considered, joining “Dimensions” and “Shape” into a single feature. Likewise, finishes included the features “Shine” and “Texture,” which were considered separately in this second phase.

Figure 6. Photographs of the actual products.

Table 3. Product design features and comparative options after seeing the real product, with respect to the perceptions generated from display technologies while browsing the website.

Design Features	Comparison Options: The Real Version, Regarding the Perceptions Obtained through the Display Technologies, Seems to Me:		
	Above	**Below**	**The Same**
Dimensions	Bigger	Smaller	The same
Weight	Heavier	Lighter	The same
Color	Darker	Lighter	The same
Shine	Brighter	More matte	The same
Texture	Rougher	Smoother	The same
Reliability	More reliable	Less reliable	The same
Quality	Higher quality	Lower quality	The same
Appeal	More attractive	Less attractive	The same
	The same	**Different**	
Shape	The same	Different	
Materials	The same	Different	
Details	The same	Different	
Mode of use	The same	Different	

2.5. Analysis of Results

The statistical analyses were performed with IBM SPSS statistical software (v23 for Windows). Descriptive statistics were analyzed, which allowed conclusions to be drawn about the best- and worst-valued technologies in the perception of different design features and about the importance provided to each of these perceptions.

The data from the questionnaires could not be considered to follow a normal distribution, based on the Kolmogorov–Smirnov test. Therefore, to check whether there are any statistically significant differences between technologies, non-parametric Friedman tests (non-parametric repeated measures) were applied. The ratings on the perception achieved for each product feature were considered as dependent variables. The display technology was considered as the independent variable. As half of the participants used AR and the other half used VR, the analysis compared 2D, 360°, and AR technologies for half of the sample, and for the other half the technologies compared were 2D, 360°, ni_VR, and i_VR (note that ni_VR and i_VR have been treated as two different technologies). Pairwise comparisons for the technologies were performed within each group, and significance values were adjusted using the Bonferroni correction for multiple tests. An a priori power analysis was performed (Wilcoxon signed-rank test for matched pairs), considering a power of 80%, error probability α of 0.05, and an effect size of 0.5 (mean difference of 0.5 and SD of difference = 1) as input parameters. The analysis, established for two tails, showed a total sample size of 35 participants.

Moreover, as the participants that used AR and VR were different, the independent-samples Mann–Whitney U test was applied to identify possible differences between perceptions for AR and ni_VR, and for AR and i_VR.

To verify possible differences in perception importance and ratings, depending on the product type, independent-sample Mann–Whitney U tests were also applied, considering the perception importance or the perception rating for each technology as dependent variables, and the type of product as the independent one.

Results from the comparison between the perceptions generated by the real product features and those produced through the interaction with the display technologies (Table 3) were described and represented by means of bar charts. To study differences between them, crosstabs (Chi-square coefficient) were applied for the perceptions, depending on the technologies used.

3. Results

3.1. Importance and Perception of Product Design Features

Regarding participants' experience with the use of display techniques, the most used was 360° rotation. Only 15.6% of participants said they had never used it. Most of them (36.4%) had used it "Sometimes", and 26% had used it "Often" or "Very often". AR and i_VR were the least-used technologies. Regarding AR, 42.9% said they had never used it, and only 3.9% said they used it often. In relation to i_VR, 67.5% had never used it, and no participant declared they used it often. In contrast, ni_VR was often used by 15.6%, and 57.4% said they had used it once, twice, or had never used it.

Table 4 (shaded columns) shows descriptive statistics (mean and standard deviation) of the importance ratings on the perception of product features. The following columns show the statistics for the assessment achieved by each technique in the perception of each design feature. The last row contains the mean values achieved by each technique in the perception of all the features.

Table 4. Statistics about the importance of perceiving product features and the level of perception achieved with each technology. The largest mean value in each row is shown in bold and in a green box, while the smallest one is in italics and in a red box.

			Ratings									
	Importance		2D		360°		AR		ni_VR		i_VR	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Dimensions and shape	4.62	0.54	3.81	0.74	**3.92**	0.84	3.78	1.17	*3.63*	0.75	3.67	1.12
Weight	3.66	0.86	*3.25*	0.85	3.48	0.84	3.56	1.00	3.47	0.65	**3.61**	0.77
Materials	3.96	0.83	3.79	0.91	**3.84**	0.78	3.56	1.00	*3.55*	0.72	3.69	0.89
Color	3.77	1.02	**4.16**	0.81	4.04	0.70	*3.83*	0.88	3.84	0.75	3.86	0.68
Finishes	3.95	0.79	3.75	0.96	**3.79**	0.88	3.78	0.87	*3.45*	0.76	3.50	1.06
Details	3.75	0.83	3.73	0.93	**4.04**	0.85	3.67	0.93	*3.08*	1.19	3.22	1.31
Mode of use	4.06	0.93	3.81	1.04	3.82	0.96	**3.94**	0.92	*3.61*	0.92	3.86	1.20
Reliability	3.92	0.91	*3.23*	0.89	3.49	0.75	3.47	0.88	3.34	0.71	**3.61**	0.87
Quality	4.42	0.65	3.68	0.98	**3.71**	0.79	*3.47*	0.84	3.50	0.80	3.69	0.95
Appeal	4.27	0.82	4.09	0.99	*3.88*	0.95	4.03	0.84	4.11	0.69	**4.33**	0.76
MEAN			3.73		**3.80**		3.71		*3.56*		3.71	

According to the participants' assessment, the most important feature to be perceived is the dimensions and general shape of the product, with a high consensus (small SD value), followed by its quality, appeal, and mode of use (all of them with an average importance rating above 4). However, in these features, the diversity in the opinions increases since the SD value does the same.

Analyzing the importance provided to perceptions depending on the type of product used in the study, the results of the Mann–Whitney U test show that a significant difference

(U = 916.0, $p = 0.047$) is only seen for the importance of the perception "Quality", which is considered more important by the participants who interacted with the gooseneck lamp (Figure 7).

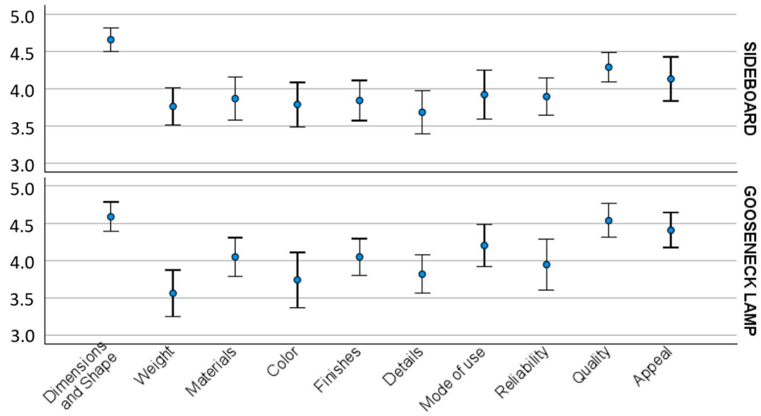

Figure 7. Importance ratings for perception of product features, by type of product.

Regarding the ratings of the technologies on each feature, the mean rating values range between 3.08 and 4.33; that is, perceptions are mostly rated between "Neutral" and "Good". For some features, the perceptions provided by all the technologies are quite similar (i.e., "Quality", for which the ratings move a total of 0.24 points, around 3.60), while in other cases, there are more differences between technologies (as in the perception of "Details", with a range of almost one point, between ratings slightly above "Neutral" in ni_VR and i_VR, up to others above "Good" for 360°). The technology with the best overall perception of the selected product features is the 360° rotation, while ni_VR is the technology with the worst general assessment, although the difference is not very high. The rest of the technologies have reached very similar mean ratings.

The Friedman test for related samples indicated that there are significant differences in the perception of weight (Chi-square (3) = 13.939, $p = 0.003$) and in the perception of details (Chi-square (3) = 10.588, $p = 0.014$). The post-hoc analysis showed that the weight was better perceived using i_VR than using 2D ($p = 0.021$), while details were better perceived using 360° rotation than with the use of ni_VR ($p = 0.032$).

On applying the Mann–Whitney U test, a significant difference in the perception of details was detected between AR and ni_VR (U = 505.0, $p = 0.044$), while no differences were detected between AR and i_VR.

Figure 8 shows the mean rating for each feature and technology against mean importance. Each vertical line represents a design feature, and the technologies are represented by the colored lines.

Figure 9 shows the mean ratings for each perception and technology, differentiating by type of product. Significant differences were found between the type of product (Mann–Whitney U tests) in the perception achieved by the following technologies: for 2D, differences were found between both products in the perception of colors (U = 936.5, $p = 0.031$), Details (U = 946.5, $p = 0.028$) and Quality (U = 937.0, $p = 0.037$). In all three cases, the perception in the gooseneck lamp is considered better. For 360°, the mode of use of the sideboard is perceived significantly better than that of the gooseneck lamp (U = 402.0, $p < 0.001$). In the case of ni_VR, the materials (U = 111.0, $p = 0.043$), finishes (U = 96.5, $p = 0.013$), and details (U = 111.5, $p = 0.043$) are perceived significantly better for the sideboard. In i_VR, in addition, the materials (U = 80.5, $p = 0.009$), finishes (U = 74.0, $p = 0.005$), details (U = 60.0, $p = 0.001$), reliability (U = 94.5, $p = 0.031$), and appeal (U = 96.0, $p = 0.037$) are better perceived for the sideboard. No significant difference was detected between the two products in the perception of features using AR.

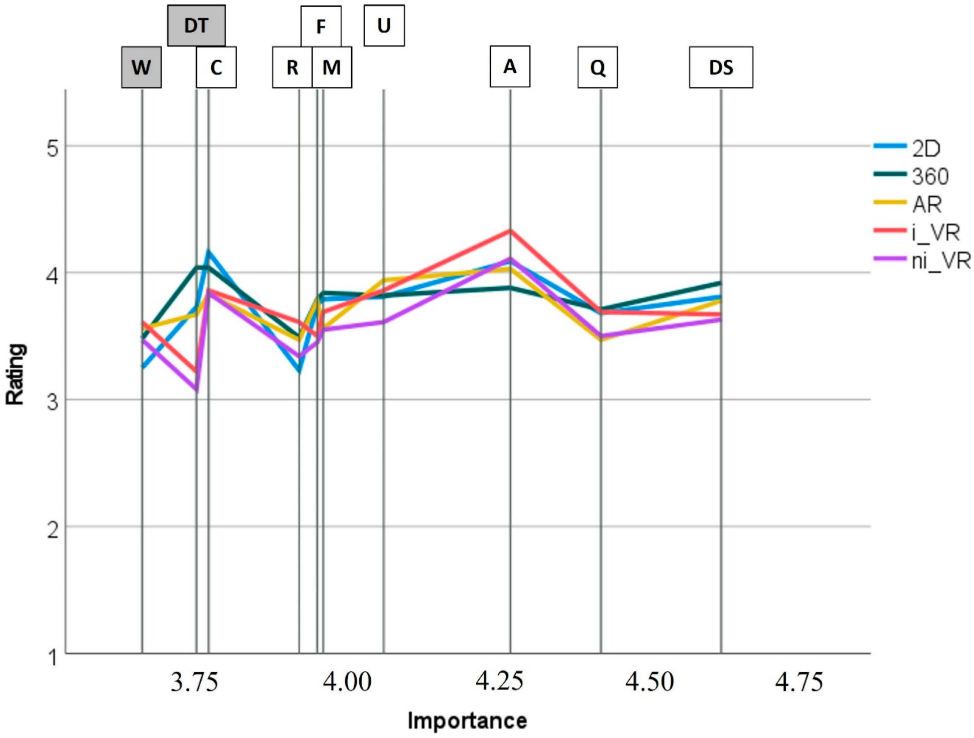

Figure 8. Mean ratings for the perception of each feature with each technology against mean importance of their perception. The level of importance of each feature perception is represented on the X axis. For each feature, the ratings of the technologies are arranged on the Y axis. The initials of the technologies with a gray background indicate significant differences detected between technologies, according to the Friedman test for related samples. W: Weight; DT: Details; C: Color; R: Reliability; F: Finishes; M: Materials; U: Mode of use; A: Appeal; Q: Quality; DS: Dimensions and shape.

It should be noted that, when distinguishing between products, the smaller sample size is expected to prevent the identification of more significant differences, especially in the case of technologies that have not been used by all the participants (AR, i_VR, ni_VR), but differences were still observed.

3.2. Comparison with the Actual Product

Most features are perceived differently in the real product (Figure 10) than with the technologies used. Only "Shape" and "Mode of Use" present a low percentage (<25%) with no difference in perception. Differences in features such as dimensions, weight, shine, texture, reliability, or quality should be highlighted, with more than 50% of cases with a different perception, while in one case it was over 80% (dimensions with VR). On the contrary, "Shape" and "Mode of Use" are the features with the least differences detected between the real product and the technologies.

For some features, differences between AR and VR are observed. For example, the perception of "Materials" and "Appeal" seems more similar to the real one through VR than through AR technology. In contrast, in the case of the perception of quality, the proportion of VR users who indicate a different perception is higher than for AR users. In any case, it should be noted that the difference with AR users seems to be mainly due to those VR users who believe that the quality of the real product is below that of the previous perception. Significant differences were detected using crosstabs in the perception of the real product quality, with respect to that previously perceived through the display technologies, depending on whether AR or VR had been used (Pearson Chi-Square χ^2 (2, N = 77) = 6.596; p = 0.037). In the case of color, VR users also appreciate more differences, this time mostly in the sense that the actual product has a darker color.

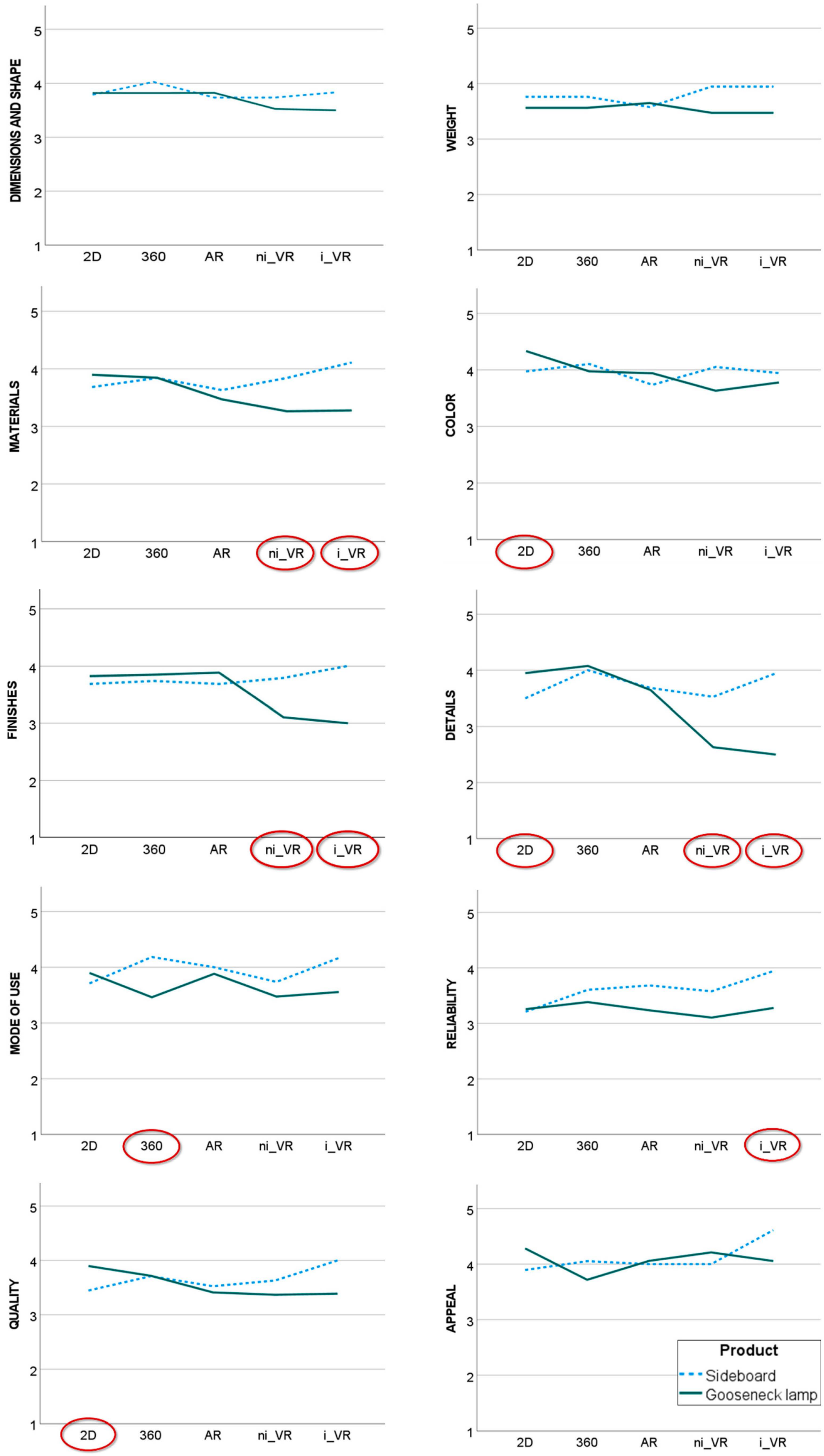

Figure 9. Mean ratings for each perception and technology by type of product. Significant differences are marked with a red ellipse.

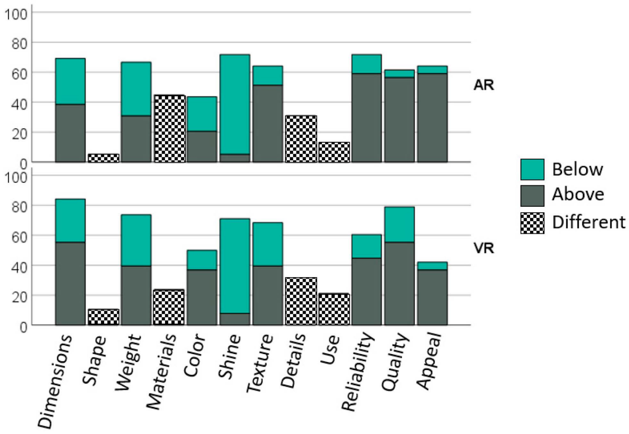

Figure 10. Percentage of participants that perceived the real product differently than through technologies. See Table 3, for the meaning of "Above" and "Below" for each feature.

On analyzing the results by product (Figure 11), it is remarkable that, in the case of the sideboard, no difference was detected in the perception of shape between the real product and that perceived through the technologies. The most notable difference between the two types of technology is the perception of "Shine" for the gooseneck lamp; while VR users detect a very high percentage of differences, AR users barely identify them. Regarding differences between the products, the perception of the materials stands out, with more differences detected, by both AR and VR users, for the gooseneck lamp, while, in contrast, many more differences were found in the case of the sideboard for "Color". Furthermore, in this case, the VR users mostly perceive the real product as darker, while the AR users perceive it as darker and lighter.

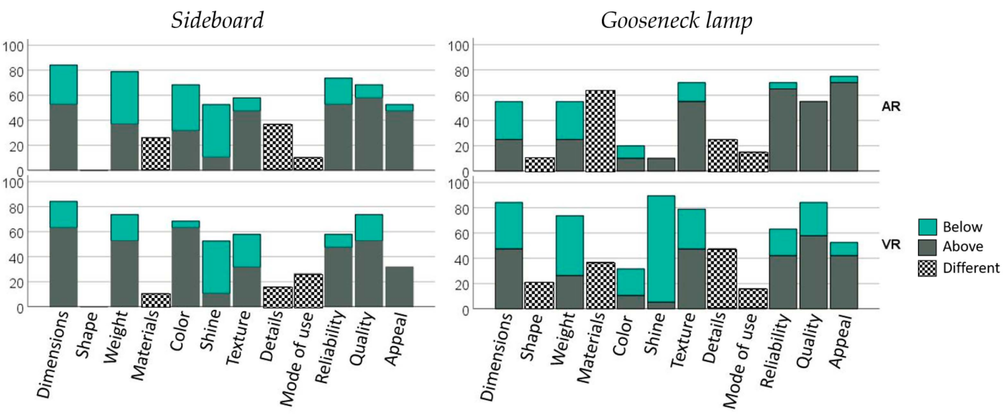

Figure 11. Percentage of participants who perceived the real product differently than through the technologies, separating by product. See Table 3 for the meaning of "Above" and "Below" for each feature.

4. Discussion

This study aims to contribute to the understanding of product perceptions generated by different display methods (including AR and VR technology) and compare them with those produced in real interaction. Some results presented in [32] are now expanded to consider ten product features instead of five, including i_VR as a new technology, and studying aspects not considered there, such as the importance of the perception of each design feature or the comparison with perceptions in interaction with the real product. Two everyday products with different design features were chosen. This breadth in the study has allowed us to obtain new results, which are discussed in the following.

The technologies with which the participants indicate they have less experience are AR and i_VR. The perception of the product design features, globally, is scored in a similar way for all the technologies, with ratings between 3.56 and 3.80. Although there is not a big difference, the 360° rotation technology stands out with the highest rating, while the ni_VR technology is the worst valued. Rendered images AR and i_VR have scored similarly overall. Considering that a rating scale of 1 to 5 was used, the mean ratings obtained are only slightly above the central neutral value. Therefore, the general assessment of the perception is not rated very well. Moreover, it does not seem to be related to the current degree of development of the technologies, since display methods with different levels of development (such as 360° rotation or VR) were rated in a similar way. Although at a global level, the statement "The perceptions generated about product features may be different, if they come from different display technologies" from hypothesis H1 does not seem to be verified. Breaking down by features, some more differences can be observed in the ratings, although not in all of them; it depends on the specific perception considered.

Additionally, the assessment of the importance of the perception of the features allows for a more complete analysis of the results. In general, all feature perceptions are considered important, since the importance ratings are close to 4 or higher (especially for "Appeal", "Quality", and Dimensions and Shape). The features related to general physical aspects (Dimensions and Shape and Weight) have the most extreme importance scores, with the first considered as the most important, and the second the least. Detail features do not reach scores higher than 4, so they are generally considered less important than those related to functionality, which are more distributed, with "Quality" being the most notable. Finally, the feature on attractiveness, "Appeal", also stands out as the third-most important.

Although, as it has been said, the features have been valued in general as important, these perceptions do not seem to be properly displayed by technologies, since ratings sometimes have values that barely exceed the average value, as in the case of "Weight" or "Reliability" (with ratings close to 3.5). Even so, significant differences were detected for two perceptions considered least important. For the "Weight" perception, a difference was detected between i_VR (considered the best perception) and rendered images (rated as the worst one). The biggest differences between technologies occur in the perception of "Details", where a significant difference was detected between the 360° rotation, which was the best value for perceiving details, and ni_VR, which was the worst one.

The perception of "Appeal" also shows varied ratings based on the technologies, although for this specific case, the 360° rotation becomes the worst-valued one, while i_VR is the best considered. However, if we focus on the two perceptions best valued in terms of importance, "Quality and "Dimensions and Shape", the best-rated display technology is 360° in both cases.

It should be noted that the study sample was chosen considering that the answers are matched pairs. Therefore, the power is lower in the case of comparisons between AR and (ni_ and i_)VR technologies, since only half of the sample assessed them. However, the perception of Mode of Use (Table 4) is the only case for which the maximum and minimum values correspond to AR and VR, with a difference between means of 0.33 points; that is, it is less than our effect size of 0.5. Therefore, even with the analysis by matched pairs, significant differences still might not have been found. It is therefore concluded that, although there is not enough power for comparisons between AR and VR technologies, they would not have been detected with the general power of the study. In the case of "Appeal", where the difference between the ratings of the technologies stands out, no significant difference was detected between the extreme ratings (i_VR and 360°), and it had the maximum power of the study.

Thus, overall, the 360° rotation technology stands out among the technologies studied, as it is well accepted as allowing the best perception of some of the most important features considered. Among these, there are general physical features of the product ("Dimensions and Shape"), detailed physical features ("Materials", "Finishes", and "Details"), and functional features ("Quality"). Therefore, it is an appropriate technique to achieve an adequate general perception of the product displayed. However, users already have some experience with this technology, which should be considered because it could have influenced the results. In addition, it must be noted that it is not very suitable for the perception of aesthetic features (Appeal), so if this perception has a special relevance in the product–user interaction, the use of i_VR is recommended, instead of the 360° rotation.

However, these overall results suffer some variations if the assessments are analyzed according to the type of product. In the case of the sideboard features, it can be seen that the perceptions obtained through i_VR achieve the highest rating in 7 of the 10 features considered, including two of the three most important perceptions: appeal, as in the general case, and also the perception of quality, which in the global case was better valued through a 360° rotation. The most important perception, “Dimensions and Shape”, continues to obtain a higher rating in 360° rotation, as well as “Color”, “Details”, and “Mode of Use” (although in this perception, the rating of the i_VR is very similar). Seven out of the 10 features analyzed, including “Quality”, “Reliability”, and “Appeal”, are the worst perceived through rendered images for the sideboard. AR obtained the lowest rating in the perceptions of four features, including the most important, “Dimensions and Shape”. In the case of the gooseneck lamp, the opposite occurs, and many of the highest ratings are obtained by rendered images. This occurs in six features, including the three most important (“Dimensions and Shape”, “Quality”, and “Appeal”), while VR (mainly ni_VR) often has the lowest ratings. This does not happen in the perception of “Appeal”. Following the previous results, this perception is well valued. For the perception of the details, a greater difference between ratings of the technologies is observed for the gooseneck lamp than in the case of the sideboard, probably because it is a smaller product with a greater number of small elements. AR scores the best on perception for four features, including “Dimensions and Shape” (tied with rendered images) and “Finishes”, features for which AR scores lowest on the sideboard.

Significant differences between products were detected for both types of VR in the ratings of “Materials”, “Finishes”, and “Details”, and for i_VR in “Reliability” and “Appeal”. Moreover, significant differences for renderings were also detected in “Color”, “Details”, and “Quality”, and for 360° for “Mode of Use”. These differences, which corroborate the second statement of the Hypothesis H1, were observed despite the low power (since only half of the sample was answered for each product), so it can be presumed that many more differences would appear between products with a complete sample.

Despite the differences found in the perception of features depending on the display technology, it is notable that the relative importance of these perceptions hardly varies based on the type of product shown; only “Quality” was rated as slightly more important for the gooseneck lamp than for the sideboard. Consequently, the second statement of Hypothesis H2 cannot be verified.

These results show the importance of choosing the display technology based on the features to be highlighted, and that the suitability of the technologies when it comes to perceiving particular product features also depends on the type of product displayed. While for a large product, such as a sideboard, the i_VR is the one that obtains the highest ratings and rendered images often come last, in the case of a smaller product, such as a gooseneck lamp, perception through renders is better assessed. This is a remarkable result, as many of the studies carried out to date about the influence of display technology on perceptions have only considered one type of product, and from the results of this study, they cannot be generalized to all products.

The interaction with the real product shows that perceptions of features are often different from those achieved through display technologies, both by AR and VR users. This relevant result corroborates H3 and should be considered when analyzing the subjective opinions of the participants about displays’ performance comparison. These differences are appreciated in a variety of features, relative to general aspects (such as “Dimensions” and “Weight”), detailed aspects (as in the case of “Shine” and “Texture”) features relative to product functionality and use (“Reliability” and “Quality”), and also features relative to aesthetics (“Appeal”).

The perception considered the most important, “Dimensions and Shape”, is here separated into two features. Dimensions are perceived differently when interacting with the real product by most of the participants: more than 60% of AR users, and more than 80% of VR users. In both cases, the proportion is greater among those who perceive the product to be bigger in reality. However, “Shape” is perceived in a similar way in reality.

In the case of the second-most important perception, “Quality”, something similar to the case of “Dimensions” happens; most participants detect differences in their perception. VR users again detect more differences between the real product and the perceptions coming from the technologies (nearly 80%) than AR users (more than 60%). In addition, this greater number of differences is mostly in the sense that the quality of the real product is above the quality perceived through the technologies. The fact that differences in perceptions between reality and display technologies have been found in a greater proportion for VR users than for AR users does not agree with the ratings provided to each technology. On reviewing the comparative ratings of the users between technologies (Table 4), it can be seen how the perception is better rated through (i_ and ni_)VR than for AR. Therefore, in this case, it could be deduced that the participants rated VR better in terms of quality transmission, which does not agree with the results after the second phase of the study.

However, in the case considered as the third-most-important perception, “Appeal”, it is observed that more than half of VR users find no difference between the perception in real interaction and that it is achieved through display technologies. On the contrary, AR users indicate a higher percentage of differences. This result is in accordance with the high ratings for the perception of “Appeal” through i_VR (and ni_VR, to a lesser extent), with respect to AR (Table 4, Figure 8). Something similar, although with less strength, occurs with the perception of “Materials”, for which VR users find fewer differences than AR users.

It should be highlighted that the most subjective perceptions, “Reliability”, “Quality”, and “Appeal”, were valued mainly with “Above” (especially for AR), which means that they are perceived to a greater extent in the real product than through technologies. These results show the need to study whether the technologies can transmit not only the physical features of the product design but also those aspects that are more subjective, although they are probably more related to an attachment to the product.

In short, the differences obtained in the perceptions of the real product, with respect to those generated from the technologies, indicate that the technologies analyzed in the study do not seem capable of offering an accuracy comparable to the interaction with the real product. This accuracy depends on the type of feature, the specific technology and display model, and the quality of the virtual representations (shape or details should be correctly replicated by the technologies, while shine or texture could be more dependent on the quality of the rendering), and it is expected to increase progressively over time. However, this comparison of the perceptions obtained from the technologies with those coming directly from the product is essential to be able to contrast the ratings about the technologies’ capacity to transmit the features of the product.

Moreover, it can be seen that the perceptions obtained by AR and VR users could vary depending on the type of product. For example, “Dimensions” and “Weight” seem to be better appreciated (more similarly to reality) by AR users than by VR users in the case of the gooseneck lamp, while this difference is not as noticeable for the sideboard. The same goes for the perception of “Shine”, which is much better among AR users than VR users for the gooseneck lamp, while this difference is not appreciated in the case of the sideboard. Regarding “Details”, while VR users detected fewer differences than AR users for the sideboard, the opposite occurs for the gooseneck lamp. AR users indicated that the real product presents fewer differences with the perception from the technologies. In any case, to obtain conclusive results, a larger sample size should be adopted.

In conclusion, some results vary depending on the type of product and the feature considered. Therefore, it is not always possible to establish general guidelines on the best technologies to transmit certain perceptions. In contrast, some similar results have been identified for different cases. Thus, 360° is the display technology that has obtained the best ratings in most of the perceptions studied, so it seems appropriate when looking for general, not specific use. On the other hand, if the desired perception is specifically "Appeal", the results of this study indicate that i_VR is an appropriate technique for its transmission.

Some of the results obtained in this study partially agree with other previous results in the literature, although some differences in the studies should be considered. For example, Galán et al. [29] stated that the attractiveness of the product was greater in real interaction than through ni_VR. In this paper, we have shown that most users did not find differences in "Appeal" between real and display technologies interactions, although those who did find them also indicated that the appeal was higher in the real product. In any case, it should be noted that in this study the perception came not only from ni_VR but from a set of varied display technologies.

Some other results obtained agree with Galán et al. [29]. In their study, the product (a chair) was perceived to be larger in a room (real product) than through i_VR and ni_VR. Similarly, in our study, it was seen that most of the VR users perceived both products (sideboard and gooseneck lamp) to be bigger in reality than through display technologies. However, in other cases, the perception depends on the type of product. Thus, while Galán et al. [29] identified that the chair was perceived as being lighter in a room than by the use of VR with haptics, the results of this work show that the perception of lightness among VR users depends on the product.

These results corroborate the fact that the study of perceptions achieved through display technologies should consider the specific features of the product displayed. In this sense, this work represents an interesting contribution since previous studies usually compared perceptions between different models of only one type of product, but not between different products [29,33–35]. In this research, two well-known products with really different features were studied, and further research should continue to extend the comparison of perceptions obtained through display technologies for other types of products.

Moreover, it is not usual in the literature to use such a wide variety of technologies in the comparison of product perceptions, including rendered images, 360° rotation, AR, i_VR, and ni_VR. In this regard, it is worth highlighting the work of Palacios Ibañez et al. [34], which considers photographs or renders, AR, and VR, although it is focused on a single type of product and is based on an approach that assesses the reliability of these XR tools for the early stages of product development and assessment.

Another notable contribution of this work is the comparison of the perceptions generated by the real product with those obtained by means of the technologies. Unlike other studies in which the perception of the real product is compared with specific technologies, in this work, the comparison is with the general perception generated by a set of these technologies. Therefore, it is not possible to distinguish which of the technologies has caused the previous perceptions about the product or if these were produced as a result of the use of all of them. However, this fact is not seen as a limitation, but on the contrary, it tries to reproduce a probably more realistic situation since it is usual for interactions, such as an online sales environment, to include different display technologies, and for products to be shown through a combination of images (real or rendered), 360° rotation, and at least one of the XR technologies (AR or VR). Note that the study could reproduce, for instance, the real context of a purchase: Phase 1 (perceptions through technologies) is conducted from the smartphone and location chosen by the user, and a few days later, the real product is shown (Phase 2), which is compared to the idea held by the user.

As a limitation of the study, the results have been obtained for the types of products considered. Moreover, it should be noted that, by dividing the sample between AR and VR users, in the comparison between these technologies, only half of the data was available, while for the analysis of the 2D or 360° technologies, it was possible to use the data for the entire sample. This could have had an influence when finding significant differences in some perceptions between these AR and VR technologies. However, it has been argued that differences between AR and VR ratings would not have met with the power of matched pairs, since the largest difference found between the mean AR and VR ratings is smaller than the effect size. Considering two different products also supposes a limitation in the power when it comes to obtaining results. Lastly, the results obtained may have been influenced by the degree of development of each technology, as well as the user experience with each one of them.

5. Conclusions

The use of new product display technologies has changed the environment of user–product interactions, which can also modify the generated perceptions about design features. This study goes further than previous work by analyzing the perception of different design features of two household products through five different technologies, plus comparing them with the real product.

As a strength of the methodology applied, it is worth highlighting the application of a wide variety of technologies (image rendering, 360° rotation display, augmented reality, and non-immersive, and immersive virtual reality) for the comparison of the perception achieved in 10 different design features, related to physical and detailed aspects, functionality, and aesthetics. Furthermore, two usual but very different products have been used in the study, which is not common in previous studies in the literature. Another relevant point is the comparison of the perceptions generated by the real product with those obtained through the set of technologies used while trying to ensure the context was as real as possible by reproducing the conditions of an online sale for example.

Results from this study have shown that some technologies, especially a 360° rotation, are generally well valued for the perception of different types of features, and, therefore, seem suitable for use in a wide variety of contexts, while others were rated with a special focus on certain perceptions. This is the case of immersive virtual reality, which is especially valued for the perception of product appeal. Furthermore, the perceptions of these features have also been assessed in terms of importance, which is useful when deciding which technologies to use in a specific case. "Dimensions and Shape" and "Quality" are considered the most important perceptions, and in both cases, 360° rotation is the technology that is best valued to achieve them, while non-immersive VR is the worst.

The use of products with well-differentiated features has revealed that results depend, to a great extent, on the specific product. Thus, for the sideboard, immersive VR stands out as the best-valued technology in many features, while renders seem to be the worst valued. In contrast, in the case of the gooseneck lamp, the opposite occurs. Therefore, additional studies are necessary as future work to continue studying the influence of the product type on these perceptions.

Finally, it is expected that the development of technologies may vary some results due to the notable differences detected between some perceptions coming from the real product and those generated in the context of the website.

Author Contributions: Conceptualization, methodology, writing and original draft preparation, funding acquisition, M.-J.A.; Conceptualization, methodology, supervision, M.V.; Visualization, writing review and editing, V.B.-P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Universitat Jaume I, grant number 18I372.

Institutional Review Board Statement: This study was approved by the Deontological Committee of the Universitat Jaume I (reference number CD/32/2019). Authenticity confirmation on http://www.uji.es/documents entering the security verification code: 0D067F3542D1C766B6D2. Date of approval 6 June 2019.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Lyu, R.; Zhang, C.; Li, Z. Optimal Strategies of Green Express Packaging Recycling and Sales Mode in an Online Platform. *J. Clean. Prod.* **2023**, *390*, 136090. [CrossRef]
2. Galán, J.; García-García, C.; Felip, F.; Contero, M. Does a Presentation Media Influence the Evaluation of Consumer Products? A Comparative Study to Evaluate Virtual Reality, Virtual Reality with Passive Haptics and a Real Setting. *Int. J. Interact. Multimed. Artif. Intell.* **2021**, *6*, 196–207. [CrossRef]
3. Li, H. The Research of Virtual Reality Technology on Application and Competition. *Highlights Bus. Econ. Manag.* **2024**, *24*, 1868–1872. [CrossRef]
4. Pranith, R.; Maruthi, K.; Saheb, S.H. Real-Time Applications of Virtual Reality. In *Metaverse and Immersive Technologies: An Introduction to Industrial, Business and Social Applications*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2023; pp. 349–378, ISBN 9781394177165.
5. Kuo, J.Y.; Chen, C.H.; Roberts, J.R.; Chang, D. Evaluation of the User Emotional Experience on Bicycle Saddle Designs via a Multi-Sensory Approach. *Int. J. Ind. Ergon.* **2020**, *80*, 103039. [CrossRef]
6. Vergara, M.; Mondragón, S.; Sancho-Bru, J.L.; Company, P.; Agost, M.J. Perception of Products by Progressive Multisensory Integration. A Study on Hammers. *Appl. Ergon.* **2011**, *42*, 652–664. [CrossRef]
7. Yoo, J.; Kim, M. The Effects of Online Product Presentation on Consumer Responses: A Mental Imagery Perspective. *J. Bus. Res.* **2014**, *67*, 2464–2472. [CrossRef]
8. Agost, M.J.; Vergara, M. Relationship between Meanings, Emotions, Product Preferences and personal Values. Application to Ceramic Tile Floorings. *Appl. Ergon.* **2014**, *45*, 1076–1086. [CrossRef]
9. Desmet, P.; Hekkert, P. Framework of Product Experience Human-Product Interaction. *Int. J. Des.* **2007**, *1*, 57–66.
10. Crilly, N.; Moultrie, J.; Clarkson, P.J. Seeing Things: Consumer Response to the Visual Domain in Product Design. *Des. Stud.* **2004**, *25*, 547–577. [CrossRef]
11. Kim, K.; Billinghurst, M.; Bruder, G.; Duh, H.B.L.; Welch, G.F. Revisiting Trends in Augmented Reality Research: A Review of the 2nd Decade of ISMAR (2008-2017). *IEEE Trans. Vis. Comput. Graph.* **2018**, *24*, 2947–2962. [CrossRef]
12. Javornik, A. Augmented Reality: Research Agenda for Studying the Impact of Its Media Characteristics on Consumer Behaviour. *J. Retail. Consum. Serv.* **2016**, *30*, 252–261. [CrossRef]
13. Scholz, J.; Duffy, K. We ARe at Home: How Augmented Reality Reshapes Mobile Marketing and Consumer-Brand Relationships. *J. Retail. Consum. Serv.* **2018**, *44*, 11–23. [CrossRef]
14. Liao, Y.-C.; Wang, T.-H.; Koong Lin, H.-C.; Lin, K.-Y. Innovative Technologies and Learning. In *Proceedings of the Augmented Reality Applied to Smartphones and Wearable Devices—Virtual Furniture Simulation System*; Springer: Berlin/Heidelberg, Germany, 2018.
15. Carmigniani, J.; Furht, B.; Anisetti, M.; Ceravolo, P.; Damiani, E.; Ivkovic, M. Augmented Reality Technologies, Systems and Applications. *Multimed. Tools Appl.* **2011**, *51*, 341–377. [CrossRef]
16. Bin Kim, W.; Jung Choo, H. How Virtual Reality Shopping Experience Enhances Consumer Creativity: The Mediating Role of Perceptual Curiosity. *J. Bus. Res.* **2023**, *154*, 113378. [CrossRef]
17. Zhu, T. The Impact of Non-Immersive Virtual Reality Technologies on Consumers' Behaviors in Real Estate: A Website's Perspective. In Proceedings of the 2022 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), Singapore, 17–21 October 2022; pp. 13–20. [CrossRef]
18. Park, M.; Im, H.; Kim, D.Y. Feasibility and User Experience of Virtual Reality Fashion Stores. *Fash. Text.* **2018**, *5*, 32. [CrossRef]
19. Dubin, A.K.; Julian, D.; Tanaka, A.; Mattingly, P.; Smith, R. A Model for Predicting the GEARS Score from Virtual Reality Surgical Simulator Metrics. *Surg. Endosc.* **2018**, *32*, 3576–3581. [CrossRef]
20. Formosa, N.J.; Morrison, B.W.; Hill, G.; Stone, D. Testing the Efficacy of a Virtual Reality-Based Simulation in Enhancing Users' Knowledge, Attitudes, and Empathy Relating to Psychosis. *Aust. J. Psychol.* **2018**, *70*, 57–65. [CrossRef]
21. Segura, Á.; Barandiaran, J.; Moreno, A.; Barandiaran, I.; Flórez, J. Improved Virtual Reality Perception with Calibrated Stereo and Variable Focus for Industrial Use. *Int. J. Interact. Des. Manuf.* **2018**, *12*, 95–103. [CrossRef]
22. Figueiredo, M.; Mafalda, R.; Kamensky, A. Virtual Reality as an Educational Tool for Elementary School. *Smart Innov. Syst. Technol.* **2021**, *198*, 261–267. [CrossRef]
23. Xi, N.; Hamari, J. Shopping in Virtual Reality: A Literature Review and Future Agenda. *J. Bus. Res.* **2021**, *134*, 37–58. [CrossRef]
24. Lombart, C.; Millan, E.; Normand, J.M.; Verhulst, A.; Labbé-Pinlon, B.; Moreau, G. Effects of Physical, Non-Immersive Virtual, and Immersive Virtual Store Environments on Consumers' Perceptions and Purchase Behavior. *Comput. Human Behav.* **2020**, *110*, 106374. [CrossRef]
25. Yim, M.Y.C.; Park, S.Y. "I Am Not Satisfied with My Body, so I like Augmented Reality (AR)": Consumer Responses to AR-Based Product Presentations. *J. Bus. Res.* **2019**, *100*, 581–589. [CrossRef]
26. Pleyers, G.; Poncin, I. Non-Immersive Virtual Reality Technologies in Real Estate: How Customer Experience Drives Attitudes toward Properties and the Service Provider. *J. Retail. Consum. Serv.* **2020**, *57*, 102175. [CrossRef]
27. Arbeláez, J.C.; Osorio-Gómez, G. Crowdsourcing Augmented Reality Environment (CARE) for Aesthetic Evaluation of Products in Conceptual Stage. *Comput. Ind.* **2018**, *99*, 241–252. [CrossRef]

28. Berni, A.; Borgianni, Y. Applications of Virtual Reality in Engineering and Product Design: Why, What, How, When and Where. *Electron.* **2020**, *9*, 1064. [CrossRef]
29. Galán, J.; Felip, F.; Garciá-Garciá, C.; Contero, M. The Influence of Haptics When Assessing Household Products Presented in Different Means: A Comparative Study in Real Setting, Flat Display, and Virtual Reality Environments with and without Passive Haptics. *J. Comput. Des. Eng.* **2021**, *8*, 330–342. [CrossRef]
30. Zhou, X.; Rau, P.L.P. Determining Fidelity of Mixed Prototypes: Effect of Media and Physical Interaction. *Appl. Ergon.* **2019**, *80*, 111–118. [CrossRef]
31. Palacios-Ibáñez, A.; Alonso-García, M.; Contero, M.; Camba, J.D. The Influence of Hand Tracking and Haptic Feedback for Virtual Prototype Evaluation in the Product Design Process. *J. Mech. Des. Trans. ASME* **2023**, *145*, 041403. [CrossRef]
32. Agost, M.J.; Vergara, M.; Bayarri, V. The Use of New Presentation Technologies in Electronic Sales Environments and Their Influence on Product Perception. In *Proceedings of the International Conference on Human-Computer Interaction*; Springer Science and Business Media: Berlin/Heidelberg, Germany, 2021; Volume 12765, pp. 3–15.
33. Palacios-Ibáñez, A.; Felip-Miralles, F.; Galán, J.; García-García, C.; Contero, M. Consumer Subjective Impressions in Virtual Reality Environments: The Role of the Visualization Technique in Product Evaluation. *Electronics* **2023**, *12*, 3051. [CrossRef]
34. Palacios-Ibáñez, A.; Navarro-Martínez, R.; Blasco-Esteban, J.; Contero, M.; Camba, J.D. On the Application of Extended Reality Technologies for the Evaluation of Product Characteristics during the Initial Stages of the Product Development Process. *Comput. Ind.* **2023**, *144*, 103780. [CrossRef]
35. Felip, F.; Galán, J.; Contero, M.; García-García, C. Touch Matters: The Impact of Physical Contact on Haptic Product Perception in Virtual Reality. *Appl. Sci.* **2023**, *13*, 2649. [CrossRef]