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An Examination of the Relationship between Visualization Media and Consumer Product Evaluation

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Abstract—Virtual product presentations that rely on static images and text are often insufficient to communicate all the information that is necessary to accurately evaluate a product. Technologies such as Virtual Reality (VR) or Augmented Reality (AR) have enabled more sophisticated representation methods, but certain product characteristics are difficult to assess and may result in perceptual differences when a product is evaluated in different visual media. In this paper, we report two case studies in which a group of participants evaluated three designs of two product typologies (i.e., a desktop telephone and a coffee maker) as presented in three different visual media (i.e., photorealistic renderings, AR, and VR for the first case study; and photographs, a non-immersive virtual environment, and AR for the second case study) using eight semantic scales. An inferential statistical method using Aligned Rank Transform (ART) proceedings was applied to determine perceptual differences between groups. Our results show that in both cases product attributes in Jordan's physio-pleasure category are the most affected by the presentation media. The socio-pleasure category was also affected for the case of the coffee makers. The level of immersion afforded by the medium significantly affects product evaluation.

Index Terms— Artificial, augmented, and virtual realities, Virtual reality, Consumer products, Perception and psychophysics

1 INTRODUCTION

Manufactured products play a substantial role in our daily lives [1]. People buy, collect, and surround themselves with different objects, sometimes to express different aspects of their personalities [2]. Current markets are highly competitive [3] and people are often faced with a variety of options that can satisfy their basic needs in terms of quality, price, and function [4]. As a result, affective values [5], which have been extensively examined by researchers in the field of emotional design, are now becoming a product differentiation tool [6].

Product evaluation is an essential activity in the early stages of the development [7]. Obtaining feedback from potential customers is essential to identify the design issues that must be resolved before validating design concepts [8][9]. These processes require continuous product evaluations which are usually conducted with physical models and prototypes whose level of fidelity may vary widely depending on the design phase and testing purpose [10][11].

The cost of design changes increases dramatically as a product moves through its lifecycle [12]. In this regard, effective evaluations can help identify potential issues early in the design process. Additionally, prototyping may involve considerable financial and time investments with limited flexibility to modifications [13]. In large scale production environments, for example, prototypes can take months to produce, and even cease to be valid representations of the product at the time of evaluation [14].

Virtual prototyping is an affordable and versatile alternative to physical prototyping [15]. High-fidelity virtual prototypes, which have been shown to positively influence user's confidence and accuracy in product evaluation [16], can be produced faster and more cost-effectively than traditional methods.

In increasingly competitive markets where e-commerce is becoming more prevalent [17], the manner in which a product is portrayed and presented to the user can be a key differentiating factor. Static images, text, and other common means of representation are often insufficient to convey all the information related to a product, especially in terms of the experience that the product can afford [18]. Furthermore, product displays in physical stores are gradually being replaced by digital media in online platforms through which the different characteristics of the product must be conveyed [19].

Emerging visualization technologies such as Virtual Reality (VR) are changing the manner in which products are presented to the user and helping consumers form a clearer understanding of complex products [20]. These technologies are rapidly evolving in terms of hardware, software,

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usability, ergonomics, quality, and efficiency. They are establishing themselves as effective mechanisms to represent virtual models in various design applications [21][22][23]. Augmented Reality (AR) [24], for example, is being widely adopted in industry [25] to enhance consumer experiences by combining virtual assets with real content [26] to elicit specific emotions [27].

The availability and affordability of extended reality technologies, both in terms of hardware (e.g. Quest 2, Pico 4) and software (e.g. the "Metaverse") have fueled their adoption in product development settings [28][29] and are shaping the way we work and collaborate. Likewise, continuous advances in smartphone technology have favored access to mixed reality environments. Indeed, many companies have implemented AR in their online catalogs as an effective product representation tool (e.g., Ikea, Sephora, or L'Oreal) [30].

From an impact standpoint, it is important to understand how these technologies influence the subjective impressions of users about a particular product, i.e. the manner in which a product is perceived, interpreted, and internalized by the consumer, as they may vary significantly depending on the presentation platform [31][32]. Extended reality can be an effective tool to optimize the product development process [33] as well as a means to provide additional information to potential customers during purchasing, particularly in online environments [34]. However, its value is predicated on the assumption that our subjective impressions and emotional responses to a virtual prototype are similar to those elicited by the real product, which is not necessarily the case [32][35]. Therefore, in order to obtain the most accurate evaluation, it is critical to consider how the representation medium can influence the user's emotional response.

The present study contributes to advance our understanding of how visual media influences the various dimensions of the perceptual space linked to a product and whether consumer-grade extended reality technologies can be an effective tool for product evaluation both (1) during the NPD process (an environment in which the experimental conditions and the context in which the product is displayed are controlled), and (2) at the point of sale (where there is limited control over the user's physical environment and devices). In this paper, we discuss two experimental studies in which a group of participants used the Semantic Differential method to evaluate designs of two product typologies presented in different media (photorealistic renders, AR, and VR for the first case study; and real photographs, a non-immersive virtual environment, and AR, for the second case study).

2 Related Work

The role of emotion is critical for providing a meaningful user experience and influencing consumer choices [36][37]. Different approaches have been proposed to characterize product emotion [38]. Most notably, Jordan suggested four pleasure categories [39]: physiological-pleasure (deriving from sensory organs), sociological-pleasure (deriving from relationships with others), psychological-pleasure (related to people's cognitive and emotional reactions), and ideological-pleasure (related to people's values). Alternatively, Desmet [40] applied cognitive appraisal theory to explain the process of product emotion, while Norman described product emotion by distinguishing three levels of information processing: visceral, behavioral, and reflective [1].

For over two decades, various studies have examined how different media can influence the user's emotional response in product evaluation, ranging from simple 2D images and interactive 3D models displayed on computer screens, to AR and VR devices with different levels of immersion and realism. For example, Söderman [13] examined the perceptual differences elicited by viewing a car in non-immersive VR and as a set of sketches, versus reality. The author found no significant differences among the interaction methods and attributed this finding to the prior knowledge that the participants may have had about the product, as they were potential consumers interested in it. Karlsson et al. [41] concluded that experience and prior knowledge of the product (or a similar product) plays a critical role in product evaluation, and Schoormans et al. [42] suggested that prior knowledge of the product enables users to unconsciously fill in missing information. Similarly, Reid et al., [43] stated that prior knowledge about the product's dimensions could influence the user's decisions, a factor that was considered in other studies to minimize deviations [10][31].

Artacho-Ramírez et al. [31] made further advances by presenting two models of loudspeakers in five different media (photographs, static infographic imagery, an interactive 3D model, and stereoscopic images) and comparing user evaluations with the corresponding real products. The authors concluded that the type of representation significantly influences the user's subjective impressions of the product.

It is important to note that different representation methods do not afford the same possibilities for interaction with a product. More sophisticated media usually provide higher levels of interaction, so it can be expected that these perceptual differences stem from the inherent differences between media, as demonstrated by Ozok and Komlodi [34]. In their study, the authors found significant differences with respect to the information provided by 2D images and non-interactive and interactive CAD objects.

Various researchers have begun to incorporate immersive virtual reality headsets (e.g., Oculus Rift, HTC Vive) in their experimental studies, such as Forbes et al. [44], who evaluated the perception of three armchairs using prints of a rendered CAD model, a 3D interactive CAD model, AR, VR, as well as real settings with and without tactile interaction. The authors concluded that, although virtual prototyping cannot completely replace physical prototypes, it can provide sufficient information to filter out poor design concepts before producing physical prototypes. In product evaluation scenarios, immersive VR technology can also highlight aspects of the product that would go unnoticed in a real setting. Furthermore, different levels of immersion can affect how certain characteristics of the product such as size are perceived [45][46]. We highlight the study by Felip et al. [35], who observed that product evaluation in

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VR differed significantly from physical evaluations when using passive haptics. In their study, evaluation scores were generally higher when performed in the virtual environment, which could be explained by the novelty effect (all the participants in the study had limited to no experience with product presentations in VR). The previous work was expanded by Galán et al. [32] who observed that although some product features were affected by the change of medium, the overall product evaluation remained unaffected by this factor. Additionally, the authors noted that the introduction of touch during the virtual experience could positively influence the user's opinion of the product.

However, comparatively few studies have investigated the perceptual differences that may be elicited by AR [47]. In this regard, Ray and Choi [48] investigated how AR representations differ from other kinds of concept representations. The authors identified user interface challenges but also emphasized the opportunity for studies to explore the role of AR in the design lifecycle. Other studies have suggested that younger participants tend to consider AR more helpful during the purchasing decision process than 2D renderings [49]. Agost et al. [50] studied how the presentation media (2D renderings, a 360-degree display technique, AR, and VR) influenced product evaluation in online shopping environments. The researchers reported that some users had difficulty using AR and VR in their experiment, but highlighted the value of AR for evaluating certain products such as large appliances. According to a recent study [51], AR can increase the user's level of confidence in the response during product evaluation, as long as users do not experience technology-related anxiety [52], and the change of medium does not generally affect the purchasing decision. Experiments, however, are often limited to a single type of product or design option.

Little is known about how gender may affect product evaluations [53][54]. Studies have shown that women generally have a more positive attitude toward conventional shopping than they do toward online shopping [55], which may be explained by the lower cognitive attitude toward this modality [56]. The literature discussed in this section illustrates the need for further research on the influence of the medium, particularly AR, on the evaluation of different product typologies.

3 Research Goal and Hypotheses

The goal of our study was to analyze the influence of the presentation mechanism in product evaluation to determine whether differences in subjective impressions exist when a product is presented in different media. In addition to the presentation medium, we also considered gender as a factor in perceptual variations as well as how product design within the same typology can affect the evaluation of certain bipolar pairs of the Semantic Differential. In our studies, a group of consumers was asked to view and evaluate a product in three different settings.

One main hypothesis was postulated: the medium used to present a product influences how the user evaluates the semantic scales regardless of their classification in Jordan's categories (H1). Two complementary hypotheses were also postulated: a particular design within the same product typology influences the user's subjective impressions of the product (H2); and gender differences exist in the evaluation of a product and how it is perceived (H3).

4 Materials and Methods

Two case studies were conducted to test the hypotheses. For each case study, three designs of a particular product typology with clear morphological differences were used: desktop telephones for the first case study and coffee makers for the second. Both case studies consisted of a within-subject study where participants were allowed to view the product in three different visual media, and asked to evaluate it using semantic scales and rate it using a 5-point Likert scale.

For the first case study (desktop telephones), our goal was to examine the influence of the representation technique on product evaluation *in the design process*. The product was displayed using photorealistic renderings, AR, and VR. The physical room was identical for all users to eliminate the potential influence of external factors on the evaluation. An attempt was made to minimize the differences in the product placement context between experimental conditions.

For the second case study (coffee makers), the goal was to examine the influence of the medium during the evaluation of the product *in an online assessment scenario*. Due to COVID-19 restrictions, some interviews were conducted online. Furthermore, a certain level of control over the product placement context was lost (i.e., environmental noise, the complementary objects within the evaluation scene, and the exact device used for evaluation), which is common in online shopping scenarios.

4.1 Case Study I: Desktop Telephones

Three representative designs of a desktop telephone were selected for this experiment: Swissvoice Epure 2 (Fig. 1.a), Daewoo DTD-1400 W (Fig. 1.b), and Philips M110w (Fig. 1.c). To test the hypotheses, three studies were designed. For each case, a particular design of a desktop telephone was used. Each product was presented in three different media:

1. Photorealistic images (Fig. 2.a), which display multiple points of view of the product. Images were displayed on a computer screen.
2. AR, where the virtual product was presented in a real environment. The product can be viewed from any angle (Fig. 2.b) but no interaction was allowed. The product was displayed on a smartphone.
3. VR, where the virtual product was presented in a virtual room with neutral colors and dimensions of 4 x 3.5 x 2.5 m. The product was placed on a table in the center of the room (Fig. 2.c). Interaction was not allowed.

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Fig. 1. Swissvoice Epure 2 (a), Daewoo DTD-1400W (b), and Philips M110w (c) desktop telephones. Images of the actual phones from vendors' websites.

Fig. 2. Siwssvoice displayed in different media: photorealistic render (a), AR environment (b), and VR environment (c).

4.2 Case Study II: Coffee Makers

Three different designs of coffee makers were selected: Nespresso Essenza (Fig. 3.a), Moka Pot (Fig. 3.b), and Nespresso Inissia (Fig. 3.c). Each product was presented in three different media:

1. Photographs of the product (Fig. 3), which displayed multiple points of view of the product. Images were displayed on a computer screen.
2. A non-immersive virtual environment (N-IVE), which displayed a 3D model of the product on a table in a virtual environment. User interaction with the product was not allowed but the user was allowed to navigate the environment using the computer mouse and keyboard (Fig. 4.a).
3. AR, where the VP was presented in a physical environment. The product could be viewed from any angle (Fig. 4.b), but no interaction was allowed. The product was displayed on a smartphone (Fig. 5).

Fig. 3. Nespresso Essenza (a), moka pot (b), and Nespresso Inissia (c) coffee makers. Images of the physical coffee makers from vendors' websites.

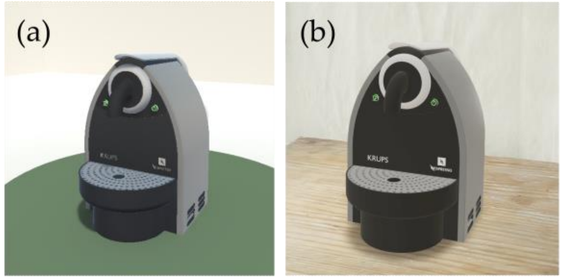

Fig. 4. Nespresso Essenza displayed in different media: N-IVE (a), and AR environment (b).

4.3 Semantic Differential for Product Evaluation

The Semantic Differential is a common method of product evaluation [40] that uses a 5- or 7-point Likert-type scale and typically includes various bipolar pairs of adjectives to describe the product that is being evaluated. For the first case study, we adopted the semantic space from the work by Hsu et al. [41] since the product typology used to define the semantic space was also desktop telephones. We classified the 24 bipolar pairs collected by the authors according to the four categories defined by Jordan: physio, socio, psycho, and ideo [42]. For each of them, two pairs were selected, resulting in a total of eight bipolar pairs of adjectives.

For the second case study, we generated a semantic differential based on adjectives collected from three different sources: users, vendors, and manufacturers. As in the previous case, eight semantic scales were generated and classified according to Jordan's pleasure categories. The adjectives are listed in Table 1.

TABLE 1
LIST OF THE SELECTED BIPOLAR PAIRS OF ADJECTIVES

PHYSIO	PSYCHO	SOCIO	IDEO
Desktop telephones			
Heavy/ Handy	Decorative/ Practical	Traditional/ Modern	Childish/ Mature
Large/ Compact	Simple/ Complex	Nostalgic/ Futuristic	Handmade/ High-tech
Coffee makers			
Minimalist/ Overelaborated	Practical/ Impractical	Traditional/ Modern	Unsustainable/ Sustainable
Large/ Compact	Difficult/ Easy to use	Unappealing/ Appealing	Expensive/ Inexpensive

4.4 Materials

The 3D models of the phones used as stimuli were created from scratch using Blender 2.93.0, a free and open-source 3D creation suite. Coffee maker models were downloaded from free online repositories and optimized with Blender 2.93.0. Photorealistic renders were generated using Blender's Cycles engine and displayed on a Fujitsu Lifebook E Serie laptop with a 15.6 inche screen size.

Virtual environments (VR and N-IVE) were designed using Unity 2019.4.14f1. For the VR setting, the Oculus Integration package (version 29.0) was used, which is freely

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available at the Unity asset store. The environment used baked lights and a standard shader was utilized for product materials. The VR environment was experienced on a Meta Quest 2 headset, a standalone immersive virtual reality device with a Single Fast-Switch LCD of 1832×1920 pixels per eye and a refresh rate of 72Hz. The N-IVE setting was displayed in a wide range of computer screens since the experiment was conducted online due to COVID-19 restrictions. The user was able to navigate the environment using their mouse and keyboard.

The AR environment was displayed in a Huawei P20 smartphone with a screen size of 5.8 in and a resolution of 1080x2240 pixels for desktop telephones. In the case of coffee makers, a wide range of smartphones were used since the experiment was conducted online due to COVID restrictions. To visualize the 3D model in the real environment, we used Clon Digital (https://clondigital.es), an online resource for integrating 3D products in a real space without the need to develop a specific application (Fig. 5). A texturized 3D model in a compatible format (.glTF, in our case) is required. The tool positions the 3D model on a flat surface at the pressing a button. For the AR viewer, ARCore (for Android devices) and ARKit (for iOS devices) light estimation were used. Geometry cannot exceed 100,000 polygons, and textures are compressed to 512 pixels.

4.5 Sample

We conducted an a priori power analysis with G*Power [57] assuming an ANOVA with repeated measures with the following input parameters: effect size: 0.25, α=0.05, (1-β)=0.80 and 1 group. Our results estimated a total sample size of 28. To guarantee a power of 0.80, a total of 36 volunteers participated in the first experiment (19 women and 17 men ages between 19 and 35 years old, with a mean age of 25.25 years old). 55.56% of the volunteers were from France, 25% from Spain, and the remaining 19.44% were from Belgium, England, Germany, New Caledonia, South Africa, Sweden, and Switzerland. A total of 39 participants from Spain participated in the second experiment (15 women and 24 men, with a mean age of 31.46 years old).

Prior to the experiment, users were asked to rate their previous experience with AR (for both cases) and VR (for the first case study) using a four-point Likert scale from 0 to 3 (0 = no experience with the technology, and 3 = significant experience). In the first case study, 52.8% had no previous experience with AR, and 50% had no experience with VR. 30.6% of the participants rated their experience with AR as limited and 44.4% did so with VR. 13.9% stated that they had significant experience with AR and 5.6% with VR. Only 2.8% of the participants claimed they had extensive experience with AR, but no participant claimed to have extensive experience in VR. In the second case study, 64.1% reported to have no previous experience with AR, 28.2% had some experience with AR, and 7,7% had significant experience with this technology.

Participants were recruited via web advertising in the university website. No target population was defined. Any individual was eligible to participate. Participants were required to have a computer and a smartphone for the second case study. People interested in participating signed up using an online questionnaire. The online form provided detailed information about the experiment. Participants were then contacted by a member of the research team to schedule an appointment. Participants who expressed interest in receiving the results after the experiment were contacted a second time for debriefing.

All participants provided verbal informed consent to participate in our studies. Our study was deemed exempt from IRB at our institution, since the information obtained is the result of straight-forward consumer acceptance testing which does not employ an intervention. Also, all information obtained was recorded in such a manner that the privacy of subjects is protected and the confidentiality of data is maintained. For the online part of our study, participants provided verbal consent during a virtual meeting with one of the members of the research team prior to the study.

4.6 Methodology

Participants were not paid to participate in our study. Also, due to COVID-19 restrictions at the time of performing our second case study, some interviews were conducted online. Instructions were given to participants prior to starting the session. As part of the study, we also collected data on the user experience in AR and VR.

Each participant went through each experimental condition of the assigned case study. To minimize the possibility of the order of presentation of the stimuli affecting the results, the presentation sequence for each participant was randomized. The physical evaluation room was the same for all experimental conditions in the first case study (desktop telephones), so the potential influence of the external environment on the evaluation was the same for each medium. Since some interviews were conducted online for the second case study, the physical room was the same between each of the experimental conditions but not between participants.

Fig. 5. Using Clon Digital with the Nespresso Essenza coffee maker (second case study).

Participants were informed that interaction with the product was not allowed on any medium. In the VR and AR environments, participants were allowed to move

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around and perform any actions that did not involve direct interaction with the product. 2D images of the product were displayed on a computer screen. Participant could switch between images using their keyboards. Six views were provided for each product for desktop telephones (a front view, two side views, a zenithal view, and two isometric views), whereas four views were provided for each product in the case of coffee makers (a front view, a side view, a zenithal view, and an isometric view). Users pressed the left and right arrow keys to scroll through the images. In the AR environment, users were asked to hold the smartphone to examine the object until they considered they had enough information to complete the evaluation. Likewise, in the VR environment, users were allowed to adjust the headset beforehand to ensure that the image quality was acceptable.

In both case studies, the evaluation was performed during the viewing of the product to avoid assessments based on recalled information. Each condition took approximately ten minutes to complete. Participants were asked to rate the product according to the eight semantic pairs using a 7-point semantic scale. In addition, they used a 5-point scale to rate how much they liked/disliked the product being displayed, as well as their intended purchasing decision.

5 Analysis and Results

5.1 Case Study I: Desktop Telephones

Descriptive statistics for each data set in our study are shown in Tables 2 and 3. The stacked bar charts for the semantic scales are shown in Fig. 6. The semantic scale data collection uses a 7-point Likert scale with a neutral value of 0 and two extreme values of 3 (-3 and 3). A higher value indicates better correspondence with the adjective represented on this end. For the “Like/Dislike” data set, a 5-point Likert scale was used with 1 as the lowest value and 5 as the highest.

TABLE 2
Descriptive Statistics for the Semantic Scales (Case I)

Scales		Daewoo			Swissvoice			Philips		
		VR	AR	2D	VR	AR	2D	VR	AR	2D
Heavy/ **Handy**	M	**2.22**	2.08	*1.31*	**1.08**	.31	*.14*	**.94**	-.06	*-.17*
	Md	2.00	2.00	2.00	2.00	1.00	-.50	2.00	.50	.00
	SD	1.17	.99	1.72	1.78	1.88	2.11	1.72	1.72	1.61
Large/ **Compact**	M	**2.03**	1.94	*1.36*	**.28**	-.31	*-1.00*	**-.36**	-1.00	*-1.06*
	Md	2.00	2.00	2.00	.50	-1.00	-1.50	*-1.00*	-2.00	-2.00
	SD	1.21	.92	1.55	2.07	1.96	1.77	1.85	1.55	1.61
Decorative/ **Practical**	M	1.33	*1.28*	**1.50**	-1.72	*-1.78*	**-1.56**	1.14	**1.33**	*.67*
	Md	2.00	2.00	2.00	-2.00	-2.00	-2.00	1.00	2.00	*1.00*
	SD	1.33	1.34	1.06	1.45	1.61	1.42	1.39	1.43	1.57
Simple/ *Complex*	M	**-1.75**	-1.61	*-1.56*	**-1.53**	*-1.36*	-1.39	-1.36	*-1.00*	**-1.72**
	Md	-2.00	-2.00	-2.00	-2.00	-2.00	-2.00	-2.00	-2.00	-2.00
	SD	1.52	1.42	1.40	1.72	1.64	1.59	1.42	1.76	1.21
Traditional/ **Modern**	M	.17	**.19**	*-.19*	**1.58**	1.22	*1.14*	-.39	*-.44*	**-.28**
	Md	.50	1.00	-.50	2.00	2.00	2.00	-.50	-1.00	.00
	SD	1.84	1.58	1.68	1.72	1.79	1.93	1.71	1.69	1.91
Nostalgic/ **Futuristic**	M	**.19**	.16	*.11*	**.42**	.25	*.00*	*-.67*	-.53	**.19**
	Md	.00	.50	.00	.50	.00	.00	-1.00	.00	.00
	SD	1.34	1.34	1.47	1.99	1.90	2.11	1.39	1.38	1.53
Childish/ **Mature**	M	**1.47**	*1.06*	**1.47**	*-.25*	-.47	**-.75**	**1.83**	*1.47*	1.56
	Md	2.00	1.00	2.00	.00	-1.00	-1.00	2.00	*2.00*	2.00
	SD	1.16	1.26	1.21	1.86	1.75	1.81	1.13	1.18	1.36
Handmade/ **Hi-tech**	M	**1.03**	.94	*.78*	**1.08**	.31	*.14*	*.69*	.72	**.83**
	Md	1.00	1.00	1.00	1.00	.00	.50	1.00	1.00	1.00
	SD	1.42	1.29	1.31	1.78	1.88	2.11	1.23	1.37	1.50

Highest values and corresponding adjective are shown in bold, lowest values and corresponding adjective in italics.

TABLE 3
Descriptive Statistics for the Overall Evaluation (Case I)

		Daewoo			Swissvoice			Philips		
		VR	AR	2D	VR	AR	2D	VR	AR	2D
Like/ Dislike	M	**2.72**	2.44	*2.38*	**4.06**	*3.75*	3.89	*2.41*	2.44	**2.69**
	Md	3.00	2.50	2.00	4.00	4.00	4.00	2.00	2.00	2.50
	SD	.91	.99	1.10	.86	1.08	.95	1.23	1.05	1.17

Highest values are shown in bold, lowest values in italics

An inferential statistical method was applied to test the hypotheses described in Section 3 and a normality test was performed on each data set to select the appropriate statistical test. As the sample size was less than 50 participants, we used a Shapiro-Wilks’s normality test (significance level of .05). Results showed that the data did not follow a normal distribution, so parametric tests proved unsuitable.

Since classic nonparametric statistical tests only allow for the analysis of a single factor, we applied the Aligned Rank Transform (ART) procedure [58] in order to analyze multiple factors. ART is known to provide a powerful and robust nonparametric alternative to traditional techniques [59]. It relies on a preprocessing step that “aligns” data before applying averaged ranks. After this step, common ANOVA procedures can be applied [60].

In our study, we performed a series of Repeated Measures ANOVAs after the ART procedures as well as post-hoc tests (Bonferroni correction was applied) when perceptual differences were found between media to determine the exact groups involved.

Our Repeated Measures ANOVA (Tables 4) showed that Jordan’s physio-pleasure category was the most influenced by the medium, as “Heavy – Handy” showed significant differences for each telephone, while “Large – Compact” showed differences phones. On the other hand, gender differences were found on “Simple – Complex” for the Daewoo DTD-1400w, and for "Large - Compact" for the Swissvoice Epure 2. The latter phone also showed a combined effect of the medium and the gender for “Handmade – Hi-tech”.

Post-hoc tests for the semantic scales are shown in Table 6. It is important to note that, although the p-value of the bipolar pair "Childish – Mature" was .048 in the Daewoo DTD-1400W, post-hoc tests did not reveal any significant differences in the pairwise comparison.

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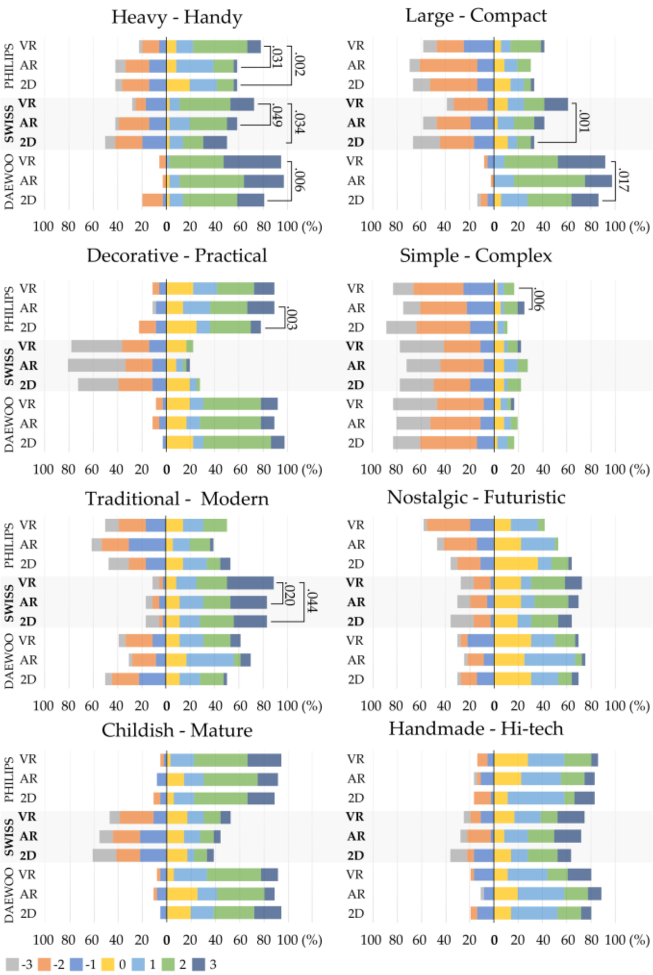

Fig. 6. Stacked bar charts for semantic scales (desktop telephones).

TABLE 4
TWO-FACTORS REPEATED MEASURES ANOVA FOR SEMANTIC SCALES (CASE I)

			Daewoo		Swissvoice		Philips	
Scales		df	F	Sig.	F	Sig.	F	Sig.
Heavy/ Handy	Media	2	6.590	**.002**	3.962	**.024**	7.855	**<.001**
	Gender	1	.182	.673	.299	.588	2.880	.099
	Mixed	2	.054	.948	1.352	.265	.711	.495
Large/ Compact	Media	2	4.560	**.014**	7.601	**.001**	2.624	.080
	Gender	1	1.110	.299	7.520	**.010**	.791	.380
	Mixed	2	.691	.505	1.723	.186	1.054	.354
Decorative/ Practical	Media	2	.197	.822	.945	.394	4.826	**.011**
	Gender	1	.262	.612	.239	.628	2.310	.138
	Mixed	2	.004	.996	.413	.663	2.631	.079
Simple/ Complex	Media	2	.111	.895	.264	.768	6.200	**.003**
	Gender	1	5.600	**.024**	.459	.503	.000	.998
	Mixed	2	0.597	.942	.456	.636	2.858	.064
Traditional/ Modern	Media	2	.738	.482	5.232	**.008**	.142	.868
	Gender	1	.546	.465	.220	.642	.194	.662
	Mixed	2	.073	.929	2.561	.085	.306	.737
Nostalgic/ Futuristic	Media	2	.151	.860	1.611	.207	1.429	.247
	Gender	1	.156	.695	.688	.413	.151	.700
	Mixed	2	.078	.925	.180	.835	.108	.898

			Daewoo		Swissvoice		Philips	
Scales		df	F	Sig.	F	Sig.	F	Sig.
Childish/ Mature	Media	2	3.180	.048*	1.875	.161	1.910	.156
	Gender	1	.001	.982	1.220	.276	1.840	.184
	Mixed	2	.411	.664	.345	.710	.455	.636
Handmade/ Hi-tech	Media	2	.978	.381	2.203	.118	.278	.758
	Gender	1	.096	.758	.315	.578	.004	.952
	Mixed	2	1.820	.170	3.378	**.040**	1.260	.291

Factor value in which perceptual differences were found are shown in bold.
** No significant differences were found in the pairwise comparisons.*

TABLE 5
TWO-FACTORS REPEATED MEASURES ANOVA FOR OVERALL EVALUATION (CASE I)

			Daewoo		Swissvoice		Philips	
		df	F	Sig.	F	Sig.	F	Sig.
Like/Dislike (1 – 5)	Media	2	3.21	.046	3.63	**.032**	2.06	.135
	Gender	1	.0491	.826	.181	.673	.0195	.890
	Mixed	2	.255	.776	1.72	.186	.663	.519

Factor value in which perceptual differences were found are shown in bold.

TABLE 6
POST-HOC TEST FOR SEMANTIC SCALES (CASE I)

Scales	Condition	Daewoo	Swissvoice	Philips
		Sig.	Sig.	Sig.
Heavy/ Handy	2D - AR	.150	.970	1.000
	2D – VR	**.006**	**.034**	**.002**
	VR - AR	.263	**.049**	**.031**
Large/ Compact	2D - AR	.278	.060	
	2D – VR	**.017**	**.001**	
	VR - AR	.656	.302	
Decorative/ Practical	2D - AR			**.003**
	2D – VR			.218
	VR - AR			1.000
Simple/ Complex	2D - AR			**.006**
	2D – VR			.107
	VR - AR			.337
Traditional/ Modern	2D - AR		1.000	
	2D – VR		**.044**	
	VR - AR		**.020**	
Childish/ Mature	2D - AR	.233		
	2D – VR	1.000		
	VR - AR	.085		

Conditions and p-values in which perceptual differences were found are shown in bold.

The p-value for the overall evaluation was .046 (Table 5), but post-hoc tests did not reveal any significant differences in the pairwise comparison. Post-hoc tests showed that differences were found between 2D–VR (p=.028).

Finally, a repeated measures ANOVA with two within-subjects factors (product and medium) was performed to test whether the product's appearance and design could affect the perceptual variation of the semantic scales and thus explain our previous results. Our results (shown in

Table 7) revealed a significant influence of the phone's design for the paired adjectives "Heavy - Handy", "Large - Compact", "Decorative - Practical", "Traditional - Modern" and "Childish - Mature". The adjectives "Decorative - Practical" and "Handmade - Hi-tech" showed a combined effect between the two factors. The adjectives in the physical pleasure category ("Heavy - Handy", "Large - Compact") as well as "Childish - Mature" were the most affected by the medium.

TABLE 7
TWO-FACTORS REPEATED MEASURES ANOVA FOR SEMANTIC DIFFERENTIAL (CASE I)

	Product	Media	Mixed
Scales	Sig.	Sig.	Sig.
Heavy/Handy	**<.001**	**<.001**	.118
Large/Compact	**<.001**	**<.001**	.233
Decorative/Practical	**<.001**	.192	**.005**
Simple/Complex	.238	.082	.064
Traditional/Modern	**<.001**	.521	.659
Nostalgic/Futuristic	.092	.396	.233
Childish/Mature	**<.001**	**.045**	.215
Handmade/Hi-tech	.501	.227	**.031**

Factor value and bipolar pairs of adjectives in which perceptual differences were found are shown in bold.

5.2 Case Study II: Coffee Makers

The descriptive statistics for each data set for this case study are shown in Tables 8 and 9. The same criteria were used for data collection as in the previous case. The stacked bar charts are shown in Fig. 7.

To test our hyoptheses, we applied an inferential statistical method. In this case, a Shapiro-Wilk's normality test showed that the data did not follow a normal distribution, so the ART procedure was applied.

TABLE 8
DESCRIPTIVE STATISTICS FOR THE SEMANTIC SCALES (CASE II)

		Moka			Inissia			Essenza		
Scales		2D	3D	AR	2D	3D	AR	2D	3D	AR
Minimalist/ *Overelaborated*	M	*.72*	1.64	**1.72**	*0.46*	1.00	**1.13**	*-.15*	.59	**.77**
	Md	.00	2.00	2.00	.00	1.00	1.00	.00	.00	.00
	SD	.32	1.27	1.08	1.34	1.19	1.36	.23	1.37	2.49
Large/ *Compact*	M	.15	**-.51**	*.33*	-.33	**-.56**	*.51*	*-.13*	**-.72**	-.38
	Md	.00	-1.00	.00	-1.00	.00	0.00	.00	-1.00	.00
	SD	.71	1.52	1.13	1.38	1.21	1.91	1.59	1.28	1.18
Practical/ *Impractical*	M	**1.72**	*1.54*	**1.72**	2.13	*2.05*	**2.36**	**2.03**	*1.69*	**2.03**
	Md	2.00	2.00	3.00	2.00	2.00	3.00	2,00	2.00	3.00
	SD	1.56	1.70	1.81	1.08	1.32	.87	1.20	1.78	1.44
Difficult/ *Ease to use*	M	**1.79**	1.87	*1.97*	2.23	**2.13**	*2.33*	2.03	*2.26*	**1.71**
	Md	2.00	2.00	3.00	2.00	3.00	3.00	2.00	3.00	3.00
	SD	1.79	1.61	1.46	.96	1.20	.87	1.14	1.33	1.37
Traditional/ **Modern**	M	-2.31	*-2.56*	**-1.05**	*.74*	.95	**1.49**	*.00*	.05	**1.05**
	Md	-2.00	-3.00	-1.00	1.00	1.00	2.00	.00	.00	1.00
	SD	0.77	1.10	1.92	.91	.86	1.02	1.43	1.49	1.30
Unappealing/ **Appealing**	M	.28	*-.28*	**1.79**	1.49	*1.38*	**2.13**	*.15*	1.08	**1.49**
	Md	.00	.00	2.00	1.00	1.00	2.00	0.00	1.00	2.00
	SD	1.19	1.61	1.17	.91	1.09	.98	1.71	1.42	1.49
Unsusainable/ **Sustainable**	M	**1.72**	**1.72**	*1.46*	*-2.13*	-2.08	**-2.03**	**-.19**	*-1.92*	-1.82
	Md	2.00	2.00	1.00	-3.00	-2.00	-2.00	-.00	-2.00	-2.00
	SD	1.40	1.28	1.14	1.17	1.11	1.20	1.35	1.18	1.34
Expensive/ **Inexpensive**	M	**2.36**	2.28	*1.05*	-.18	*-.37*	**.05**	*-.08*	**.15**	.00
	Md	3.00	3.00	1.00	.00	.00	.00	.00	.00	.00
	SD	.84	1.00	1.70	1.30	.22	1.34	.38	1.33	1.10

Highest values and corresponding adjective are shown in bold, lowest values and corresponding adjective in italics.

TABLE 9
DESCRIPTIVE STATISTICS FOR THE OVERALL EVALUATION (CASE II)

		Moka			Inissia			Essenza		
Scales		2D	3D	AR	2D	3D	AR	2D	3D	AR
Like/ *Dislike*	M	3.23	*2.82*	**4.51**	*3.72*	3.79	**4.46**	*3.10*	3.49	**4.21**
	Md	3.00	3.00	5.00	4.00	4.00	5.00	3.00	4.00	4.00
	SD	.93	1.28	.56	.86	.89	.68	.85	.82	.83

Highest values are shown in bold, lowest values in italics

Once again, we performed a series of Two-factor Repeated Measures ANOVAs after the ART procedures for the semantic differential (Tables 10) and the Overall evaluation (Table 11). Post-hoc tests (with Bonferroni correction) were also performed when perceptual differences were found between media to determine the exact groups involved (Table 12).

TABLE 10
Two-Factors Repeated Measures ANOVA for Semantic Scales (Case II)

			Moka		Inissia		Essenza	
Scales		df	F	Sig.	F	Sig.	F	Sig.
Minimalist/ Overelaborated	Media	2	.556	.576	7.029	**.002**	8.661	**<.001**
	Gender	1	9.349	**.004**	1.440	.238	5.050	**.031**
	Mixed	2	.611	.545	.467	.629	1.654	.198
Large/ Compact	Media	2	3.189	**.047**	8.623	**<.001**	1.992	.144
	Gender	1	.028	.869	7.548	**.009**	.855	.361
	Mixed	2	.552	.578	2.408	.097	.941	.395
Practical/ Impractical	Media	2	1.233	.297	1.407	.251	5.985	**.004**
	Gender	1	16.841	**<.001**	.236	.630	.502	.483
	Mixed	2	3.176	**.048**	.277	.759	8.421	**.001**
Difficult/ Ease to use	Media	2	14.079	**<.001**	.469	.627	8.115	**.001**
	Gender	1	12.607	**<.001**	2.506	.122	.521	.475
	Mixed	2	4.170	**.019**	1.004	.371	.713	.494
Traditional/ Modern	Media	2	14.838	**<.001**	8.149	**.001**	10.245	**<.001**
	Gender	1	5.722	**.022**	7.773	**.008**	3.537	.068
	Mixed	2	1.336	.269	1.396	.254	1.269	.287
Unappeal/ Appealing	Media	2	35.657	**<.001**	10.702	**<.001**	13.070	**<.001**
	Gender	1	1.490	.230	.245	.623	.475	.495
	Mixed	2	1.584	.212	2.866	.063	5.655	**.005**
Unsustainable/ Sustainable	Media	2	1.398	.255	.681	.509	1.661	.197
	Gender	1	2.559	.118	1.060	.310	.696	.409
	Mixed	2	1.296	.280	.452	.638	1.877	.160

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Expensive/ Inexpensive	Media	2	13.066	**<.001**	.496	.611	1.214	.303
	Gender	1	2.219	.145	.034	.855	.664	.420
	Mixed	2	1.481	.234	.650	.525	2.116	.128

Factor value in which perceptual differences were found are shown in bold.

TABLE 11
TWO-FACTORS REPEATED MEASURES ANOVA FOR OVERALL EVALUATION (CASE II)

			Moka		Inissia		Essenza	
		df	F	Sig.	F	Sig.	F	Sig.
Like/ Dislike	Media	2	45.231	**<.001**	15.263	**<.001**	27.558	**<.001**
	Gender	1	.481	.492	2.437	.127	1.098	.301
	Mixed	2	.800	.453	.680	.510	5.498	**.006**

Factor value in which perceptual differences were found are shown in bold.

TABLE 12
POST-HOC TEST FOR SEMANTIC SCALES (CASE II)

Semantic scales	Condition	Moka	Inissia	Essenza
		Sig.	Sig.	Sig.
Minimalist/ Overelaborated	2D – 3D		-158	**.004**
	2D – AR		**.001**	**.036**
	3D - AR		.297	.278
Large/ Compact	2D – 3D	.252	.725	
	2D – AR	1.000	**.037**	
	3D - AR	**.022**	**<.001**	
Difficult/ Ease to use	2D – 3D	**.001**		**.004**
	2D – AR	**.001**		**.028**
	3D - AR	**.010**		.632
Traditional/ Modern	2D – 3D	**.011**	.868	1.000
	2D – AR	**.043**	**.001**	**<.001**
	3D - AR	**<.001**	**.027**	**.003**
Unappealing/ Appealing	2D – 3D	.853	1.000	**.002**
	2D – AR	**<.001**	**.004**	**<.001**
	3D - AR	**<.001**	**<.001**	.323
Expensive/ Inexpensive	2D – 3D	1.000		
	2D – AR	**<.001**		
	3D - AR	**.001**		

Conditions and p-values in which perceptual differences were found are shown in bold.

Our results show that the Overall Evaluation was influenced by the medium for each coffee maker. Pairwise comparisons showed that these differences were statistically significant between 2D – 3D and 2D – AR (p<.001) for each case. The Repeated Measures ANOVA for the semantic differential showed that, although some scales were influenced by the medium in certain products, the adjectives related to Jordan's sociological pleasure category were the most affected by the visual media. Post-hoc tests showed that these differences were mostly found between 2D – AR and 3D – AR.

Finally, a Repeated Measures ANOVA with two within-subjects factors (product and medium) was performed to test whether the product's appearance and design could affect the perceptual variation of the semantic scales. Results are shown in Table 13.

TABLE 13
TWO-FACTORS REPEATED MEASURES ANOVA FOR SEMANTIC SCALES (CASE II)

Semantic scales	Product	Media	Mixed
	Sig.	Sig.	Sig.
Minimalist – Overelaborated	**<.001**	**<.001**	**.004**
Large – Compact	.076	**.003**	.212
Practical – Impractical	.455	**.031**	.456
Difficult to use – Ease to use	.192	**<.001**	**<.001**
Traditional – Modern	**<.001**	**<.001**	**.009**
Unappealing – Appealing	**<.001**	**<.001**	**<.001**
Unsustainable – Sustainable	**<.001**	**.031**	**.001**
Expensive – Inexpensive	**<.001**	**<.001**	**<.001**

Factor value and bipolar pairs of adjectives in which perceptual differences were found are shown in bold.

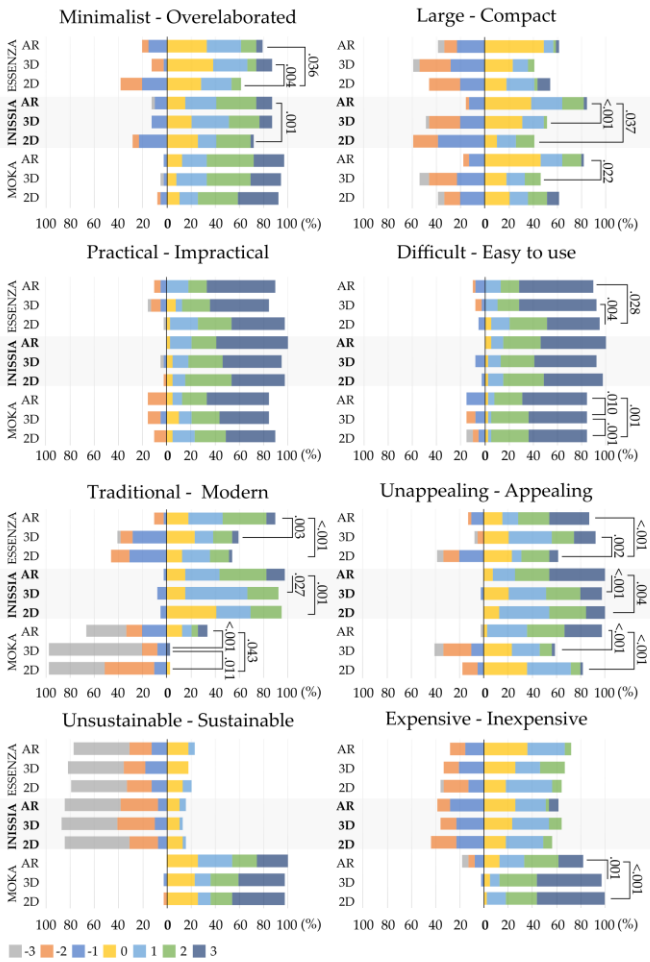

Fig 7. Stacked bar charts for the semantic scals (coffee makers).

6 DISCUSSION

In this paper, we presented the results of two case studies where a group of participants evaluated three different designs of a product typology using the Semantic Differential method in different visual media.

In our main hypothesis H1, we questioned whether the medium used to present a product influences how the user evaluates the semantic scales regardless of their classification in Jordan's categories. The classification of the bipolar pairs according to the pleasure categories defined by Jordan [61] helped us determine which type of adjectives are most affected by the display medium.

Results of our two-factor repeated measures ANOVA for the semantic scales for desktop telephones (Table 4) showed that visual media can influence the user's subjective impression of a product, which agree with similar studies [31][62]. Although several bipolar pairs of adjectives were influenced by the medium, not all categories were affected in the same manner, as confirmed by Galán et al. [32]. These results align with those from similar studies such as [46] in which the differences are justifed by the absence of touch. Although the absence of touch may be highly relevant to the physical category [63] (which may also explain our results), our evaluation relied entirely on the sense of sight, so visual differences between media may have caused these variances.

In the case of "Large - Compact", the stimulus was displayed in various sizes, which could be interpreted as a limitation when presenting a product. For example, the descriptive statistics for this data set (Table 2) show that the product was perceived as larger when displayed through 2D images. Reasons could be attributed to the size of the computer screen, which may have made the object appear oversized, or to color saturation (some authors have suggested that the higher the color saturation, the greater the perception of size [64]). Brightness may have also affected size perception, as brighter objects often appear larger and closer [65] to the user. Although an attempt was made to maintain consistent levels of saturation and brightness for each medium, slight differences may have influenced the results (e.g., slightly higher color saturation or brightness may be present in the 2D images). Additionally, scale/size/distance judgements in VR are difficult [66] and the fact that the product was viewed with no references to other objects may also have hindered the assessment in 2D images (in both AR and VR, a virtual table was present which could have served as a reference) [67]. The pair "Heavy - Handy" could be directly related to the perception of size (the larger the heavier). It is important to note that differences were found mainly between 2D and VR.

The fact that no differences were found in the bipolar pair "Large - Compact" for the Philips M110w phone could be explained by the possible influence of certain aspects of the product (e.g., geometric elements) on the adjectives, as reflected in Table 7. Indeed, shape can influence the user's subjective impressions [68], but this is further discussed in H2. For this phone, perceptual differences were also found for "Decorative - Practical" (in this category, the effect of the product and the combined effect between medium and product were also significant) and “Simple–Complex”, which are part of Jordan's psycho-pleasure category. Our results suggest that the psycho-pleasure category can be affected by the presentation medium, not for a specific product typology (desktop telephones) but for a specific product design within a typology. To draw more generalizable conclusions, additional studies with different types of products are needed.

Finally, it is important to note that in the overall evaluation for this case study (Table 5), significant differences were found only for one of the phones (Swissvoice), which means that the results cannot be generalized to any medium. Additionally, the aesthetics of this particular design stand out from the others, which may have influenced this result. Furthermore, the highest scores for this dataset (Table 3) were generally found in the VR medium, suggesting that presenting a product in an immersive virtual medium may favor the overall evaluation of the product.

Similar results were obtained for the case of coffee makers. Several bipolar pairs of adjectives were affected, mostly within Jordan's physiological and sociological pleasure categories. Some authors have suggested that the physical pleasure category may not be the only one affected by the display method. Galán et al. [32], for example, showed that the ideological pleasure category could also be highly influenced by the medium.

Regarding physical pleasure, the results are analogous to the case of telephones, i.e., the presence of touch could have naturally affected this category [63] but the visual differences between the media are likely at the source of these variances. For example, for the bipolar pair "Minimalist – Overelaborated," we speculate that the photographs could have shown the product in greater detail, which could have distorted the user's subjective impression of the product compared to 3D or AR media. Alternatively, the 3D medium could have made users perceive the product as larger compared to AR, where objects generally appear smaller and are conditioned by the size of the smartphone screen. Similarly, saturation, brightness, and product context may have also affected the results [64][65][67]. The socio-pleasure category (adjectives linked to the aesthetics of the product) may have been affected by the combination of the product appearance and the medium (Table 13). Finally, bipolar pairs where significant differences were found for the medium for only one of the designs could have been affected by the product geometry [68].

The overall evaluation was also affected by the change of medium for all three products. In addition, the descriptive statistics (Table 9) for this dataset showed much higher values for the AR medium, suggesting that the presentation of a product in a physical context or using visualization techniques with higher levels of interaction may favor product evaluation.

In general, although the overall evaluation cannot be generalized to all the products, results related to product features (those that comprise the semantic differential) agree with previous studies in that adjectives that require sensory interaction such as touch are more sensitive to the change of display medium [24][28][46]. Therefore, the visualization medium may have an impact on the user's subjective impressions of the product, particularly those in the physical pleasure category, which derives, to a great extent, from senses such as touch. Because of this, the absence of physical interaction with the product may have influenced the evaluation, which confirms H1.

In H2, we postulated that a particular design within the same product typology may influence the user's subjective impressions (H2). Many authors have examined the relationship between a product's shape and the emotions

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elicited by it. Aesthetics is one of the first channels through which designers communicate with consumers [70][71].

The results of our study (Table 7 and 13) are consistent with those obtained by other authors which suggest that the geometric features of the product (i.e. product aesthetics) may influence the user's subjective impressions [4][68]. Additionally, for the case of desktop telephones (Table 7), the bipolar pair "Decorative – Practical" (Jordan's psychological-pleasure category) and "Handmade – Hi-tech" (ideo-pleasure category) revealed a combined effect between factors. For the case of coffee makers (Table 13), "Large – Compact" (physio-pleasure category) and "Practical – Impractical" (psychological-pleasure category) were the only pairs that did not show a combined effect. It is important to note that although the medium is not the only factor that may influence the user's subjective impressions, a combination of factors may cause perceptual differences. Based on the above discussion, H2 is confirmed.

In our third hypothesis (H3), we questioned the existence of gender differences in the user's subjective impression of the product. In the case of desktop telephones, although the overall evaluation did not show an influence of gender in any case (Table 5), the Essenza coffee maker did show a combined effect between gender and medium for the overall evaluation (Table 11).

Regarding the semantic scales (Table 4 and 10), different adjectives revealed an influence of gender in some of the products, but no pattern was observed to draw general conclusions. In other words, there may be an influence of gender on the evaluation of some characteristics, but only for certain designs within the same product category. For example, the Daewoo DTD-1400w, gender differences were found in "Simple-Complex", while for the Swissvoice Epure 2, they were found in "Traditional – Modern." A combined effect of Media*Gender in "Handmade–Hi-tech" was also found for this phone. The mean scores obtained for "Simple – Complex" by gender are M_{IMG}=-1.12, M_{AR}=-1.35, M_{VR}=-1,12 for males, and M_{IMG}=-1.95, M_{AR}=-1.84, M_{VR}=-2,32 for females. On the other hand, the mean scores obtained for "Traditional – Modern" are M_{IMG}=1.47, M_{AR}=1,12, M_{VR}= 2.00 for males, and M_{IMG}=.84, M_{AR}=1.32, M_{VR}=1.21 for females. In general, females scored the adjectives "Simple" and "Traditional" higher than males in all media. In this context, some authors have suggested that women generally favor the evaluation of physical products more than men [55][72], so preferring a traditional shopping method may have had an effect on some evaluations. Our results suggest that gender differences may exist in product evaluation, not for a specific type of product but for some characteristics within a specific product design, so H3 is rejected. Further research is needed for testing this hypothesy.

Our study shows that the visual medium used to present a product may significantly affect how the product is perceived. However, other factors such as geometry can also influence the user's subjective impressions of a product. Therefore, not all products will yield the exact same response when the presentation medium is changed. For certain product features (e.g., those in Jordan's ideo pleasure category) and specific evaluation purposes, technologies such as VR or AR can be effective tools, but it is important to recognize how a particular medium relates to a specific product typology.

7 Conclusions

Understanding how a product is perceived and how users evaluate it are important aspects to ensure a design is presented and communicated effectively.

This study demonstrates that the medium used to view a product can influence how it is perceived, as certain characteristics (such as weight and size) are particularly significant, as the perceptual differences elicited by the different media are more pronounced. By furher dividing the bipolar pairs that make up the semantic differential used for the evaluation of the product typologies used, we observed that not all of Jordan's pleasure categories are affected equally by the presentation medium.

TABLE 14
SUMMARY OF RESULTS FOR THE TWO CASE STUDIES

Hypotheses	Result	Desktop telephones (case study I)	Coffee makers (case study II)
H1	Confirmed	1 – Jordan physio-pleasure category was the most affected. 2 – Psycho-pleasure category can be affected by the presentation medium, not for a specific product typology but for a specific product design within the typology. 3 – Although the overall evaluation may not be influenced by visual medium, the VR setting can positively influence user's subjective impressions.	1 – Although the physiological pleasure category was influenced by visual medium, the physiological and sociological pleasure categories were the most affected by the medium. 2 – The overall evaluation was also affected by the change of medium, whereas the AR setting can positively influence user's subjective impressions.
H2	Confirmed	"Decorative – Practical" (psychological-pleasure category) and "Handmade – Hi-tech" (ideo-pleasure category) presented a combined effect.	"Large – Compact" (physio-pleasure category) and "Practical – Impractical" (psychological-pleasure category) did not present a combined effect.

Hypotheses	Result	Desktop telephones (case study I)	Coffee makers (case study II)
		1 – The medium is not the only factor that may influence the user's subjective impressions. 2 – A combination between factors may cause perceptual differences.	
H3	Rejected	1 – Gender differences may exist in product evaluation, not for a specific type of product but for certain characteristics within a specific product design. 2 – Further research is needed for more generalizable conclusions.	

Other aspects may be affected by design factors, and not just by the change of medium. The presentation media can also be a powerful mechanism for highlighting certain attributes of the product, especially those that require physical interactions with the product.

Our findings are useful from a product development standpoint and identify important communication aspects that should be considerd for presentation at the point of sale. Product features in Jordan's physical pleasure category are the most difficult to evaluate with virtual prototypes. In these cases, physical prototypes can help minimize these differences [73][46].

VR and AR technologies can facilitate both product development processes and product presentation at physical points of sale where there is a high level of control of the evaluation context. Multiple design alternatives can be evaluated virtually without the need for physical prototypes, which can save time and costs. In online sales channels, the use of physical prototypes is not possible, but AR and VR technologies can help enhance the user's perception of the product as well as provide richer information, especially when compared to simple 2D images. Because the use context is important during product evaluation, VR can also increase the level of control over the evaluation process.

Although our study can be extrapolated to similar products of the same typology (i.e., telephones and coffee makers), additional tests with other types of products are necessary to draw more generalized conclusions. In future studies, we plan to use physiological measures such as eye-tracking technologies to analyze user behavior more accurately and objectively during product evaluation.

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