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How Does the Visualization Technique Affect the Design Process? Using Sketches, Real Products and Virtual Models to Test the User's Emotional Response

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Abstract

Testing products during the design process can help design teams anticipate user needs and predict a positive emotional response. Emerging technologies, e.g., Virtual Reality (VR), allow designers to test products in a more sophisticated manner alongside traditional approaches like sketches, photographs or physical prototypes. In this paper, we present the results of a study conducted to evaluate the feasibility of seven visualization techniques for product assessment within the framework of emotional design, suggesting that the user's perception depends on the visualization technique used to present the product. This research provides recommendations for product evaluation using physical, virtual, or conceptual prototypes to analyze the user's emotional response throughout 19 parameters. Our results indicate that the use of virtual environments, including VR and VR with Passive Haptics (VRPH), can facilitate user participation in the design process, although these visualization techniques may also exaggerate the emotions perceived by users. In this context, VRPH tends to overstate the tactile perception of the product. Additionally, our results reveal that both virtual and conceptual environments can amplify a user's likelihood to purchase a product. However, the latter setting could also potentially lead to confusion among users in regards to their perception of the product's weight, dimensions, and cost. Based on these findings, the authors encourage industrial designers to develop new methodologies to optimize design process and minimize costs.

Keywords

Design Process, Emotional Design, Product Evaluation, Virtual Reality.

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I. Introduction

The ongoing evolution of technology and society has led to a greater diversity of products on the market [1]. This has resulted in a highly competitive market with numerous products capable of satisfying the user's basic needs [2], [3]. Therefore, different brands are seeking to bring a differentiating value to their products through innovation to make their products preferred by the user over those of competing brands [4]. However, Marquis and Deeb [5] have shown that this is not always enough, as many innovative products fail when they reach the market despite appearing potentially successful. This stems from the fact that it is difficult for users to analyze a product features due to the large number of alternatives and limited time available [6]. Consequently, the user often base their decision on their instantaneous perception of the product. For this reason, the immediate emotional value that the user attaches to a product is being recognized as an effective differentiation tool [7] and some authors even suggest that these emotions need to be positive for the product to be desired [8]. The creation of a "desirable" and "successful" product is a complex task that relies, among other factors, on testing and user involvement in the design process, especially in the early stages of this process [9]. It is evident that industrial designers must guide users towards a positive emotional response. This perception, as Norman [10] suggests, should be assessed through emotional design before, during, and after product use, at three levels: visceral (VL), behavioral (BL), and reflective (RL). This approach continues to be employed in the design process based on the evaluation of users' perceptions of product features, and it is supported by current studies, specifically Zhe [11] and Aftab et al. [12], who were focused on the analysis of only one or two levels, as well as Göremann and Spiekermann [13], Amirkhizi et al. [14], Yoon et al. [15], and Aftab and Rusli [16].

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Others, as Yu Zhe [11] examined the perception that users had of different ceramic pieces through all these levels. Aftab et al. [12], for example, used these three levels to analyze several disposable products and proposed a design methodology that promoted a long-lasting user-product relationship. On the other hand, Görnemann [13] studied user-product conversations and the resulting person-object relationships, while Jourabchi et al. [14] analyzed the emotional response of users from different cultures to objects with different basic geometric shapes at the VL and identified differences between individualistic and collective societies. Additionally, Yoon et al. [15] focused on the same level and proposed new methodologies for designers to intentionally facilitate positive emotional responses in the user. Bustamante et al. [16] evaluated users' perception of wireless headphones during and after use, focusing on the visceral and behavioral levels.

From the evaluation of products qualities, industrial designers can predict how users will respond once they purchase the product, and the level of success or error achieved during the design process [17]. However, these evaluations are complex due to the number of variables involved in the user's perception, which in many cases depend on psychological factors unknown to the consumers themselves [11].

In this regard, it is important to highlight the difference between the VL and RL in comparison with the BL, even though all of them are related to human, cultural, and psychological factors. According to Chapman [18], while the first two evaluate the user's perception of the product, the BL validates the functional aspects . This author states that the VL and RL are affected by an "emotional" perception of the product, related respectively to the user's immediate exposure to the product and to the reflection and memories perceived afterward. However, the BL aims to study the direct user-object interaction objectively and without depending on the feelings that the product evokes in the user.

Despite these differences, BL is also linked to the user's previous experience with other products and cultural factors. In this context, the suitability of a new product's functionality for the user will depend on their previous experience and how its functionality compares to products they have used before [19]. Several authors as Liberman and Bitan [4], Alonso et al. [17], Liu et al. [20] and Boru and Erin [21] have analyzed this relationship using different parameters .

Currently, the most used are ease of learning, effectiveness, efficiency, memorization, and satisfaction. These parameters were established by Nielsen [22] in 1993 and proposed again by Min and Jeong in 2016 [23], who also proposed the same parameters to evaluate the usability of products. In this regards, recent studies have concluded that the results of any evaluation depend on the user's cultural factors and the formal and technological aspects of the product. These challenges (coupled with the need for multiple physical prototypes during the design process), which can be time-consuming and costly, mean that product evaluation is not used by all design teams [24].

To save costs and shorten the design process in product evaluation from a real environment (RE), some design teams use a conceptual environment (CE). This is accomplished using photorealistic images, renders, virtual models, etc. In this context, Ribelles et al. [25] analyzed the playability of a cubic puzzle game by evaluating parameters such as effectiveness and ease of use through simple visual modifications. Furthermore, the emergence of new visualization methods e.g., Virtual Reality (VR) and Augmented Reality (AR), offers the possibility of presenting products in a virtual environment (VE). These visualization techniques have proven to make the design process more economically efficient, but it is important to consider their limitations.

Hannah et al. [26] have shown that the representation method affects user's perception of the product and can result in perceptual differences from the real product . It is generally assumed that our perceptual and emotional response to a product perceived using different visual media is comparable to that of the physical product, but it is not always the case [27]. Specifically, in product design processes, most studies emphasize media that promote the sense of touch, as it offers a direct way to interact with an object and can minimize these differences [28]. In this context, it is important to determine which visualization technique is the most effective for analyzing different product parameters to obtain accurate user evaluations (compared to the real product) that will not lead to errors during the design process.

This paper explores, under the paradigm of emotional design, different product representation methods as well as the differences in the user's perception that each one presents. This research aims to establish which visualization technique (whether developed in a RE, CE or VE) is best suited for product evaluation during the design process, as this information can prevent future retooling and engineering changes, reduce costs, and ensure the process and everyday product quality. This paper presents (1) an introduction section with the goals of the research, (2) a theoretical background that explores the different media used for product evaluation and their possibilities and limitations, (3) the methodology used for the analysis of the selected visualization techniques, (4) the results and discussion obtained from the data analysis, and (5) the conclusions of the contribution, including advice on the use of different mediums for the evaluation of different parameters during the design process.

II. Theoretical Background

Design professionals often require the construction of physical prototypes [19] to test their designs in a RE. These prototypes are used for product validation [29], the creation of evaluation methodology [30], or product optimization [17].

The CEs seek to represent the product in 2D using photographs, drawings, or photorealistic images. An example of this is the FULE methodology [4], which evaluates products based on their photographic image using the criteria of functionality, usability, and look and feel. In a VE, a 3D representation of the model is used, which can be entirely virtual or a combination of virtual and real elements.

In this context, some researchers have studied the application of VR in engineering and product design [31]. This study examines the feasibility of using VR in different phases of the design process with new visualization technologies as a tool for participatory design. Katicic et al. [32] have developed a specific methodology to evaluate the emotional response of potential customers or consumers to future products during early conceptual design phases. To do this, they created a 6-phase methodology that integrates VR with emotion recognition technologies, allowing users to receive reliable emotional feedback on virtual products in the early stages of product development. There are also studies that investigate different tools for analyzing user-product interaction through VR, but they typically focus on interfaces or work situations, as demonstrated by Gorski et al. [33]. These researchers have implemented a digital tool based on VR to aid the decision-making process in configuring the driver's workstation in urban buses by studying human-machine interaction.

It is important to note that there are discrepancies in the use of the VE for product evaluation. While Liu et al. [20] consider virtual media to be a reliable and cost-effective alternative to physical prototypes, Gorski et al. [33] prefer the use of the RE or a CE. Specifically, Laing and Aperly [34] conducted a study on the opinions of industrial designers and concluded that professionals do not consider virtual media to be an efficient tool. This may be due to the limitations of conceptual and virtual environments, which would require validation of the method used or the characteristics to be measured to determine whether one medium is more appropriate than another [35].

Traditional visualization techniques used in CE allow the user to visually appreciate a product but not to touch it. Similarly, this happens in VR. To address this, new techniques have emerged to provide tactile feedback in VEs. VR with Passive Haptics (VRPH) provides a tactile experience in the VE by superimposing a virtual model on a lower quality physical prototype. In this regard, the differences may be minimized, but the perception of the product may still be affected [36].

Higuera et al. [37] have analyzed the differences between AR and other conceptual and virtual media that prevent touch perception, including photographs, 360º panoramas, and VR. These studies highlight the differences between VEs and CEs. For example, 360º panoramas provide results that are closer to what is perceived in AR according to the psychological responses of participants. VR, on the other hand, obtains higher matches according to physiological responses, which may indicate similarities between virtual and physical interaction.

In a study conducted by Palacios-Ibáñez et al. [38], different users evaluated three coffee makers seen through real photographs and virtual media. The study concluded that the use of immersive media favors the purchase decision and provides greater certainty in the user's response. Furthermore, the results showed that Jordan's sociological pleasure category is more susceptible to media switching in aesthetically rich products. This suggests that users may be more interested in a product in a VE than, which can be a disadvantage when evaluating products as some characteristics may be exaggerated. Therefore, it is necessary to establish measurement systems that take this factor into account. Kent et al. [39] also support the differences between virtual and physical prototypes, validating the use of each in five different dimensions.

According to the conclusions of the refd authors, the choice of the visualization technique is crucial not only for validating the product but also for favoring the purchase decision and ensuring a correct and continuous evaluation of the product during the design process. Additionally, when selecting a method, it is important to consider the characteristics of the product to be evaluated. Not all representation media are valid for all measurements, but all may be useful for measuring specific parameters involved in the design process.

In this context, the emotional value or perception of a product is influenced by both objective and subjective factors (regardless of the visual media), and the latter can also influence the former [40]. Schrepp et al. [41] have pointed out that the aesthetics and usability of products are influential factors in their evaluation. This study suggests that aesthetics can influence the usability of products, or at least the user's perception of the product as Wiedmann et al. [42] done. Some authors even claim that the visual appeal and aesthetics of a product are more important than its functionality and usability [4]. Although it is not yet clear which psychological mechanism is responsible for this relationship [43], using non-functional mock-ups for everyday products makes it easier for users to identify problems related to their functioning, physical interaction, and even ergonomics during their evaluation [44]. Additionally, using prototypes or mock-ups that do not match the aesthetic characteristics they were designed with can reduce the perceived quality and ease of use of the technology [45].

Wiedmann et al. [42] have detailed that the appearance of a product is influenced by key aspects such as color. In this sense, these authors consider that color is a factor in perceiving a concept positively or negatively. Other research has related this to visual clarity or the perception of order, alignment, and complexity in arranging of the different visual elements that make up the product. Studies focused on virtual environments, such as web pages, machine interfaces, or mobile products and applications, indicate that visual clarity promotes quick orientation in an interface and creates an impression of simplicity. It can be assumed, therefore, that this visual clarity influences usability dimensions. This is supported by Schrepp et al. [41] who found that products with better visual quality have increased efficiency and ease of learning.

However, Thielsch et al. [45] differentiate between perceived and achieved usability from product aesthetics . To further explore this, Thielsch et al. [46] conducted a study based on the results of 5 other studies. Their analysis found a small but heterogeneous influence on user performance, highlighting possible areas for future research to accurately assess this influence. Given all this, the use of one medium over another could make the cost of marketing and selling a product more profitable. However, to the best of our knowledge, there are no studies that focus on exploring the possibilities that different media can bring to industrial design and design teams for the development of successful products. This study analyzes the perception of 105 young users towards 3 models of an everyday product. The analysis is conducted through seven means of representation corresponding to three different environments (real, virtual, and conceptual). Since the selected everyday product requires a complementary item (umbrella) for its use, the study will also evaluate whether the presence of this item influences the user's perception of the products. The use or non-use of this item is considered a different setting.

III. Methodology

Through this case study, the feasibility of each medium to represent the product is analyzed to elicit an appropriate emotional response from the user. The study uses 19 parameters based on Norman's [10] three levels of emotional design (VL, BL, and RL) .

These parameters will be evaluated using seven means of product representation, which include the use of the RE, VE and CE, with and without the use of complementary items. The visualization techniques used in the study include reality, VR, VRPH, and sketches, coded as R, VR, VRPH, and S, respectively. On the other hand, when the complementary item is used, only the mediums of reality, virtual reality, and sketches are employed, represented as R+, VR+, and S+, respectively.

The results are compared qualitatively and quantitatively to identify differences and similarities between the experimental conditions and recommend the use of different visualization technique for evaluation in various design process stages.

This section has been divided in (A) a description of the case study carried out, as well as (B) the description and origin of the parameters used during the study, and (C) the sample of participating volunteers.

A. Case Study

To provide a clear understanding of the conditions under which the study was conducted, the preparation of the case study is described, including the materials (products, visualization techniques, and scenarios) used during the evaluation and the procedures followed during the user test.

1. Materials

Three different design of umbrella stands were selected as the main stimuli for the experiment. Söderman [47] concluded that prior knowledge about the product can have a negative effect into product evaluation, both in VEs and REs. For this reason, the stimuli selected was not widely consumed by the study subjects (young users). In previous investigations carried out by the some of the authors [27] with these three umbrellas stands models, it was found that the absence of the umbrella (complementary item) prevented users from recognizing the umbrella stand due, according to Galan et al. [48] to their lack of knowledge about this type of product.

As previously mentioned, the presence of the umbrella was found to impact the perception of certain characteristics of the main product, which warrants further study. To more accurately study these characteristics related to the product's usability, the use of the complementary product (the umbrella) was deemed necessary.

Additionally, previous studies [35], [36], [47], [48] have often been limited to evaluating a single product. Therefore, it was decided to conduct this research by evaluating three different models. Acording to Chu and Kao [35] set, using more than three models would have resulted in user fatigue and negatively affected the evaluation due to the extended duration of the study. In this regard, the three selected models are simple and easy to use to avoid user frustration and ensure that hand tracking is not lost during the evaluation in the virtual environment as Slater et al. state [49]. Finally, the geometry of the analyzed alternatives also helps to ensure that hand tracking is not lost during evaluation in the VE, also avoiding user frustration in this environment. On the other hand, the three products evaluated Fig. 1A had a specific cavity or position to hold long umbrellas (feature 1) and short umbrellas (feature 2). The functionalities of the selected products were similar, as well as their representation in neutral colors to avoid major differences in the user's perception. Since these products require a complementary item to fulfill their functions, two umbrellas (one large and one small) were used during experiment Fig. 1B. The umbrella stands were used in each experimental condition described above, while the complementary item was only used in R+, VR+ and S+. Physical umbrella stands were used in the REs (R and R+) and in VRPH to offer tactile feedback, while physical umbrellas were only used in R+.

Fig. 1. Products used in the case study. Main product (A) and complementary item (B).

In the case of media representing concepts in 3D, whether physical (R and R+) or virtual (RV, RV+ and RVHP), the umbrella stand was fixed to the floor. Users could observe and touch the products, but not change their position.

The VR environment was displayed using the Oculus Quest 2 HMD, a standalone immersive VR device with a Single Fast-Switch LCD of 1832×1920 pixels per eye and a refresh rate of 72Hz. The VR environment and 3D was designed using Unity 2019.4.14f1. We used the Oculus Integration asset (version 36.0) and HPTK Posing and Snapping 2.0.0. asset for the hand tracking interaction (as the Oculus Interaction SDK was not available when the experiment was carried out). The Passthrough Capability was enabled for the calibration of the virtual objects before starting the experiment. The scene used a Real-time light with hard shadows enabled, and materials were built using a Standard Shader. The virtual objects were modelled in SolidWorks 2020, and UV mapping was completed in Blender 2.93.0.

Fig. 2A, shows the user experience in the VRPH medium. Although the volunteer perceives the umbrella stands virtually, they are synchronized with their corresponding physical models, bringing touch to the experience. Fig. 2B shows how the user has the same virtual experience, but without perceiving with touch the physical product. Finally, Fig. 2C shows how, in the same environment of the previous case, the user could manipulate the umbrellas and insert them into the different umbrella stands.

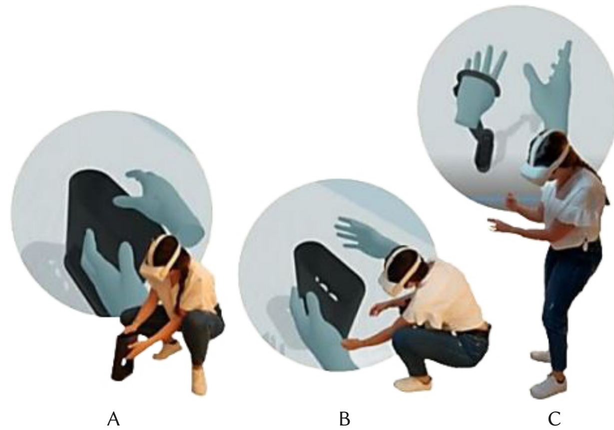

Fig. 2. User-product interaction in virtual media:VRPH(A), VR(B) and VR+(C)

As mentioned above, the user only had direct interaction with the complementary item in the R+ and VR+ media. The S+ medium, however, although it includes the representation of umbrellas, does not allow the user to interact with them. The same applies to the umbrella stands in this and S media. The static image does not allow for any interaction Fig. 3.

Fig. 3. Representation of products in S (left) and S+ (right) media.

In the seven visualization techniques or media described, the products were arranged in the same order and in similar spaces. For this purpose, two similar scenarios (physical rooms) of 6m2 were built, which were replicated virtually. The physical rooms were composed of 8 movable panels fixed to a 6-meter wall and are placed contiguously and symmetrically Fig. 4. The interior of the rooms was perceived by the user in a real or virtual way depending on the experimental condition in which the interaction took place. In any case, scenario 1 (red room) was built to the physical products require was built to carry out all experimental conditions that included physical products: R, R+ and VRPH. Scenario 2 (blue room) includes 3 double-sided A3 printed panels with the main products (S), and with these together with the complementary item (S+). The rest of the room was empty, to accommodate the same products and situations as the red room, but in the VEs (VR y VR+). In front of these scenarios, four seats with a table were reserved for users to comfortably fill in the questionnaires and documents required for data collection.

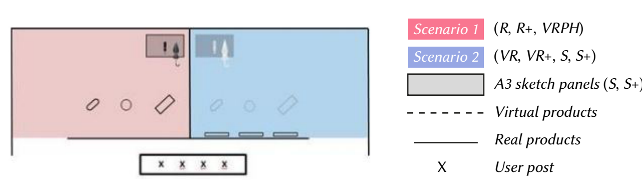

Fig. 4. Scenarios distribution

2. Procedure

After obtaining the participant's consent and addressing any doubts or concerns with the researcher, the procedure outlined in Fig. 5 began in order to analyze 19 parameters.

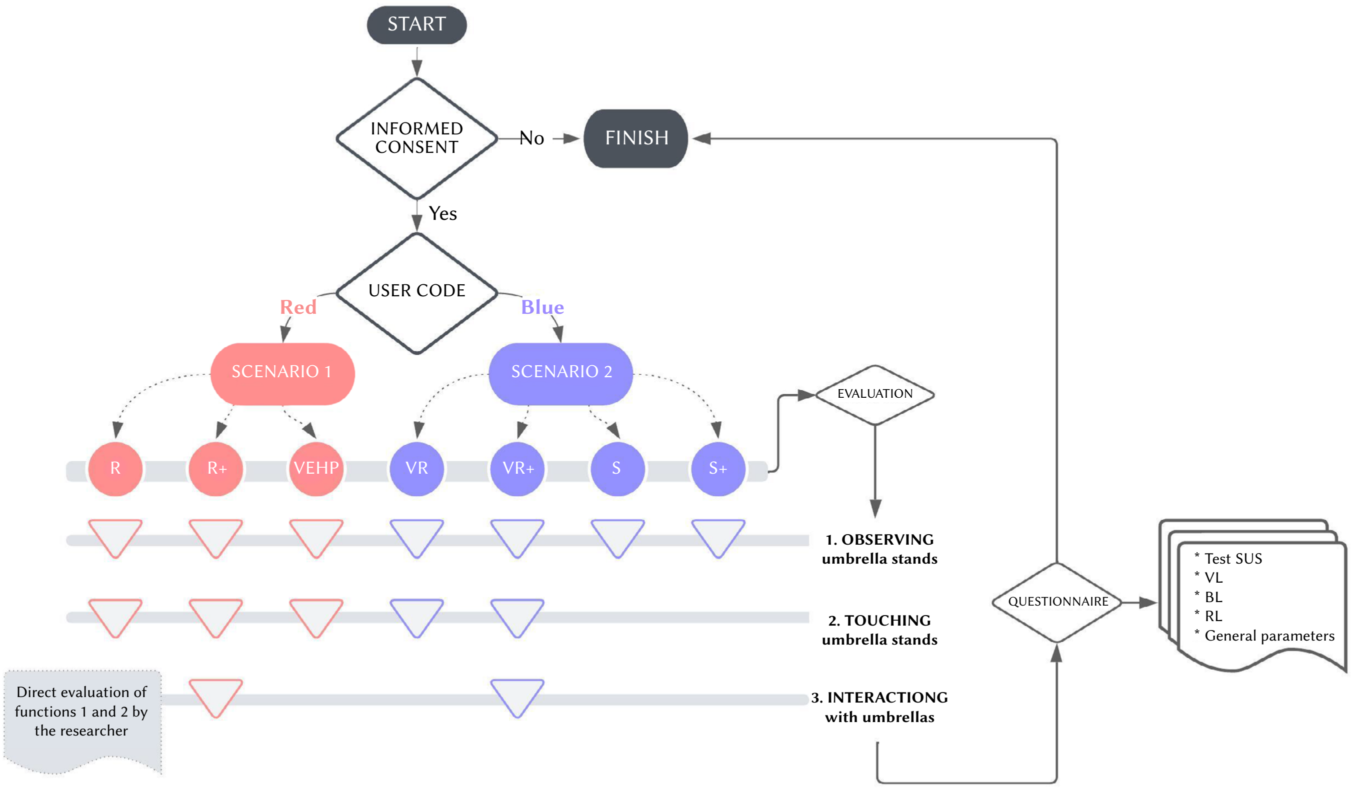

Fig. 5. Complete cycle performed by each user

So, once the consent was signed, each volunteer received an user code with an associated colour and visualization technique. At this time, had to stand in front of the room whose color was indicated. Red corresponded to scenario 1 and blue to scenario 2.

Assisted by the researcher, each volunteer accessed the indicated space and began the evaluation process. Depending on the medium process could consist of 1, 2, or 3 phases.

In this sense, firstly, all participants first observed the three umbrella stand models. Secondly, users who enjoy the experience in the R, R+, VRPH, VR and VR+ visualization techniques proceed to touch the umbrella stands with their hands. Finally, only those who accessed through R+ and VR+ interacted with the umbrellas.

At the end of the experience, each volunteer had to fill out a questionnaire by google form. Additionally, participants who had undergone a virtual evaluation were asked to complete the Slater-Usoh-Steed presence questionnaire (SUS) [50] to quantify and qualify the level of presence in the VE. This questionnaire consisted of six 7-point Likert scale questions, with a higher score indicating a higher level of presence. It had been widely used in similar studies by other authors [27] [35] [36].

B. Evaluation Parameters

The 19 parameters established (Table I) were used for the evaluation of the selected products. These parameters (P1-P19) were used to analyze the different levels of emotional design [10]. In total, 12 parameters were used to evaluate the VL of the products (P1-P12), five for the BL (P13-P17), and two for the RL (P18-P19).

Each of these 19 parameters was evaluated in a minimum of two media (32 participants) and a maximum of seven (105 participants), based on the respective conditions. Table I indicates also the level to which they belonged, the visualization techniques (VT) used for their evaluation, method and scale used for its evaluation and the user responsible for its evaluation (data collector).

As can be seen in (Table I), to gather the users' opinion on these parameters, two different consultation methods were used. Consequently, these methods utilized two distinct scales. Firstly, P1-P14 were evaluated based on a comparison of the three different products analyzed as other researchers had done before [51], [52]. So, each participant had to establish their own "ranking" by placing the products in first, second, or third place. In this way, the results were coded on a scale from (-1) to (+1), where (-1) corresponds to the most negative value, (0) the intermediate one, and (+1) the most positive (similar to a 3 point Likert scale). Secondly, P15-P19 were evaluated individually, on a product-by-product basis. In this way, each product has been evaluated individually using a 7-point Likert scale, from (-3) to (+3), as Galan et al. [36] and Slater et al. [49].

On the other hand, to evaluate the parameters related to the user's first impression of the product (VL), the authors selected 12 bipolar pairs identifying the type of products used. For this purpose, a semantic differential was created [53] according to the procedure established by other authors [54], described in detail in subsection 1. In a comparative manner, as previously mentioned, users independently indicated their ranking positions for each product through a questionnaire. These parameters were evaluated by the users themselves following the completion of the experience, using a questionnaire (P1-P12).

These parameters have been evaluated by the user himself after the end of the experience, through a questionnaire (P1-P12).

In the specific case of the BL (P13-P17), the parameters established by Nielsen [22] and Min et al. [23] were used. These parameters, which will be described in subsections 2 and 3 of this section, were evaluated through the researcher's own observation. The researcher established P13 and P14, once again, through a ranking, the position of the different products analyzed in terms of usability. P15-P17, however, were evaluated by researchers through a 7-point Likert scale, individually.

TABLE I. Parameters Analyzed

		LEVEL	VOLUNTEERS	VT	METHOD	SCALE	DATA COLLECTOR
P1	*Light* / **Heavy**	VL	105	ALL	Ranking	3 Liker	Volunteer
P2	*Small* // Large	VL	105	ALL	Ranking	3 Liker	Volunteer
P3	*Unstable* // stable	VL	105	ALL	Ranking	3 Liker	Volunteer
P4	*Simple* / **Complex**	VL	105	ALL	Ranking	3 Liker	Volunteer
P5	*Impractical* / **practical**	VL	105	ALL	Ranking	3 Liker	Volunteer
P6	*Decorative* / **Functional**	VL	105	ALL	Ranking	3 Liker	Volunteer
P7	*Pretty* / **Ugly**	VL	105	ALL	Ranking	3 Liker	Volunteer
P8	*Modern* / **Traditional**	VL	105	ALL	Ranking	3 Liker	Volunteer
P9	*Minimalist* /**Overloaded**	VL	105	ALL	Ranking	3 Liker	Volunteer
P10	*Inexpensive* / **Expensive**	VL	105	ALL	Ranking	3 Liker	Volunteer
P11	*Vulgar* / **Elegant**	VL	105	ALL	Ranking	3 Liker	Volunteer
P12	*Common* / **Original**	VL	105	ALL	Ranking	3 Liker	Volunteer
P13	*Easy* / **difficult to learn**	BL	32	V+, R+	Ranking	3 Liker	Volunteer
P14	*Effective* / **ineffective**	BL	32	V+, R+	Ranking	3 Liker	Volunteer
P15	*Easy* / **difficult memorization**	BL	32	V+, R+	Individually	7 Liker	Researcher
P16	*Efficient* /**Inefficient**	BL	32	V+, R+	Individually	7 Liker	Researcher
P17	*Satisfactory* / **Unsatisfactory**	BL	32	V+, R+	Individually	7 Liker	Researcher
P18	Shape-assimilation	RL	105	ALL	Individually	7 Liker	Volunteer
P19	Human-assimilation	RL	105	ALL	Individually	7 Liker	Volunteer

Parameters 18 and 19 were designed to assess the recall that each product produced in the user, as well as the level of positively or negativity of the product. These parameters were also evaluated by the user himself through the questionnaire mentioned above, as P1-P12.

1. Visceral Level (P1-P12)

The VL refers to a person's first impression of a product, which is generated at a subconscious level through sensory stimuli. This initial impression cannot be controlled by the person, and the emotions evoked by the product can vary greatly. To understand the VL, three psychological processes are necessary: perception of the external world, cognition of the process of using the product, and understanding of the reflection. To measure this level, parameters are established based on the first impression that users outside of the case study have of the "umbrella stand" concept.

These parameters are based on the 12 bipolar pairs obtained from a semantic differential created using the procedure outlined in reference [54]. This was created using responses from 28 volunteers outside of the case study, including 8 professional designers with at least 5 years of experience, 12 individuals trained in industrial design, and the remaining 8 ordinary users with no design experience. Using a Google form, volunteers were asked to describe the 12 products using 5 representative adjectives. The most representative adjectives for the selected umbrella stand brands were also included, and a keyword analysis was performed. The 12 bipolar pairs are the parameters P1-P12 represented in Table I, representing the first impression that different users have of the product family to be evaluated. For the these parameters, a value closer to (-1) represented a closer correspondence with the adjective in italics, and a value closer to (+1) indicated a closer correspondence with the adjective in bold.

Based on these parameters, the first impression that each user has of the three products selected for the case study is evaluated. The user is responsible for collecting information related to these parameters through product comparison. Each volunteer ranks the three proposed models according to how well they match each parameter. Researchers should code the volunteers' responses as (-1),(0), or (+1) to conduct the data analysis. A value closer to (-1) indicated a higher match to the adjective on the left, a value closer to (+1) indicated a higher match to the adjective on the right, and (0) represents intermediate values.

2. Behavioral Level (P13-P18)

The relationship between the human being and the environment determines human behavior, which can be conscious or unconscious. In fact, in everyday life most human behavior is unconscious [55]. Although there are no specifications for its measurement, recent researchers have used the usability-related parameters [12], [16], already established by Nielsen [22]. These parameters are ease of learning (P13), which shows how easy it is to perform the tasks the first time the product is used; efficiency (P14), which evaluates the time it takes the user to perform the tasks once the product functioning is understood; memorization (P15), aimed at evaluating the errors made when performing the task; effectiveness (P16), able to recognize if after a while the user still remembers how it works; and satisfaction (P17), which seeks to know how pleasant and easy is to use the product. All these parameters are evaluated by the researcher and from the observation of the user-object interaction.

On the other hand, since these products require a complementary item for their operation, it was decided to use the latter for the correct evaluation of the main product. However, as mentioned above, it is only possible in R+ and VR+ media.

While parameters 13 and 14 were evaluated through a ranking by the comparison of the three products, parameters 15-17 were evaluated individually. For this reason, in the first case we find a 3-point liker scale, and in the second a 7-point liker scale.

As before, values with a lower score, i.e., (-1) and (-3) according to the Likert scale, had a closer correspondence with the adjective in italics. Those with a higher score, i.e., closer to (+1) and (+3) according to the Likert scale, indicated a closer correspondence with the adjective in bold.

3. Reflexive Level (P18-P19)

Emotional attachment is determined by the user's disposition to perceive, reflect on, and give meaning to a product, rather than by the product itself. According to Norman [10], this personal satisfaction in the use of a product is produced when the user experience is contrasted with previous memories, evoking an emotional response that creates a link between the user and the product. This level of attachment focuses on the user's emotions, memories, and relationships [18]. Other researchers have argued that this level of attachment can produce long-term effects related to emotions, ownership satisfaction, and the exhibition of a product [56]. To measure this level, users are asked to relate the product to objects and people in their environment based on parameters 18 and 19. Additionally, users are asked to rate the level of interest or relationship they have with these objects and people on a scale from 1 to 7.

As shown in Table I, both parameters were evaluated individually using a 7-point Likert scale. In all cases, the linkage of the product with shapes and humans which generate more negative memories in the participants has been evaluated with the score (-3). However, those products that generate the most positive memories are linked to the highest score (+3).

C. Sample

The sample was composed by engineering students between 18 and 26 years old (average of 19.1). The 64% of the sample was men, and 36% women. This fact may be due to the large glass ceiling that still exists in engineering degrees [35]. The volunteers came, as shown in Fig. 6A and Fig. 6B, from six degrees taught at the School of Industrial Engineering of the University of Málaga: Energy Engineering (EE), Industrial Technologies Engineering (ITE), Electrical Engineering (ELE), Electronic and Robotics Engineering (ERE), Industrial Design and Product Development Engineering (IDPDE) and Mechanical Engineering (ME). The participants were divided equally among the different media and situations used Fig. 6C, with the minimum sample of users participating in each medium being 14 people and the maximum being 16.

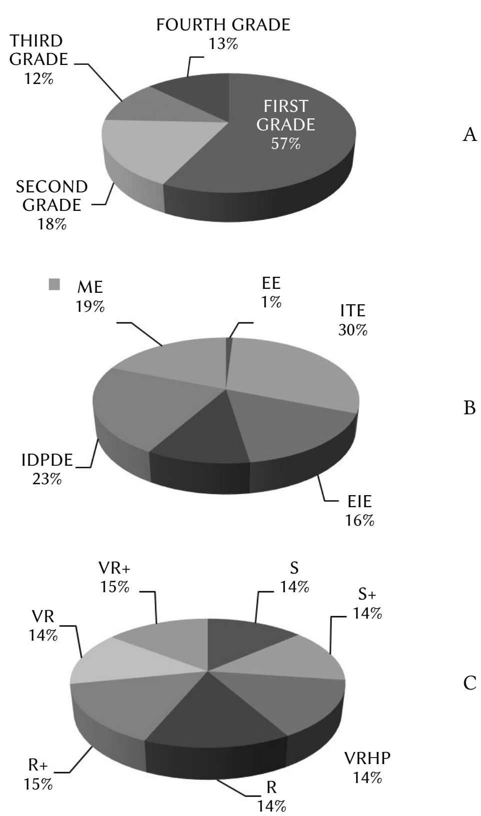

Fig. 6. Distribution of sample by grades (A), degree (B) and means of representation used (C).

The inferential analysis was performed at each level, using the parameters as dependent variables and the number of media (2 or 7) as independent variables. The same significance level (.05) and confidence interval (95%) were applied to each inferential analysis performed.

IV. Results and Discussion

To select the appropriate statistical tests, it was necessary to know the distribution of the data. The Kolmogorov-Smirnov test (for sample sizes ą50) showed that the different data sets did not follow a normal distribution, so the non-parametric Kruskal-Wallis test was used to perform an inferential statistical analysis. As mentioned before, the data has been collected through two different methods. The first consisted of a ranking comparison of the three products. Here, each user had to rank the three-stimulus studied according to the level of affinity with the evaluated parameter, as other researchers have done before [50]. The scores derived from this method were (-1), (0), or (+1) depending on whether the person ranked the product as first, second, or third, respectively, (which would be the equivalent of a 3-point Likert scale). The second was a 7-point Likert scale, where users have individually indicated how they identify the product with the analyzed bipolar pairs. This has also been used in previous studies [48]. The scores derived from this test were from (-3) to (+3).

Certain differences between the analyzed media were detected. This has been also described graphically, based on the descriptive analysis, identifying some problems in the representation of certain attributes of the products. In this context, descriptive statistics were also performed for the level of presence in the VEs. This level, measured on a 7-point Likert scale type from -3 to 3 was quite significant and similar in all the analyzed visualization techniques, although it is important to highlight that the VRPH showed the highest level of presence, being $M_{VR} = 5.18$, $M_{VR+} = 5.11$ and $M_{VRPH} = 5.32$.

A. Visceral Level

Parameters P1-P12 were analyzed through a ranking, obtaining a scale from (-1) to (+1). Fig. 7 shows the different boxplots from the descriptive analysis (one per parameter analyzed). These graphs show the distribution of the responses of the 105 participating volunteers for parameters P1-P12.

The figure suggests that there are differences between the different visualization techniques. However, it is observed that these could be due to the use of different products, and not only to the visualization technique or medium. From this, we evaluate, through an inferential analysis, the differences that may exist, by pair of visualization techniques and product to product. The evaluation difficulties of these parameters were analyzed by product using post-hoc tests with Bonferroni correction. This correction is recommended to avoid the probability of false positives in comparisons greater than 20 (Table II).

In this sense, the inferential analysis corroborates that, indeed, there were no major differences between the visualization techniques, and many of the differences seen in the figure come from the difference that the volunteers found between the products analyzed.

TABLE II. Factor P Value for Each Umbrella Stands (U1, U2, U3) and P1-P12 Parameters

PRODUCT	P1	P2	P3	P4	P5	P6
U1	p=.993	p=.528	p=.723	p=.911	p=.126	p=.495
U2	**p=.009**	**p=.013**	p=.845	p=.705	p=.731	p=.227
U3	**p=.023**	**p=.003**	p=.571	p=.348	**p=.018**	p=.233
PRODUCT	P7	P8	P9	P10	P11	P12
U1	p=.891	p=.103	p=.126	**p=.036**	p=.682	p=.712
U2	p=.479	p=.253	p=.165	p=.496	p=.155	p=.362
U3	p=.314	p=.096	p=.552	p=.170	p=.244	p=.953

Table II, where differences found are shown in bold, it is observed that only P1 (Light/heavy), P2 (Small/large), P5 (Useless/practical) and P10 (Cheap/expensive) showed differences between the visualization techniques (with a p-value < .05). In particular, differences in P1 and

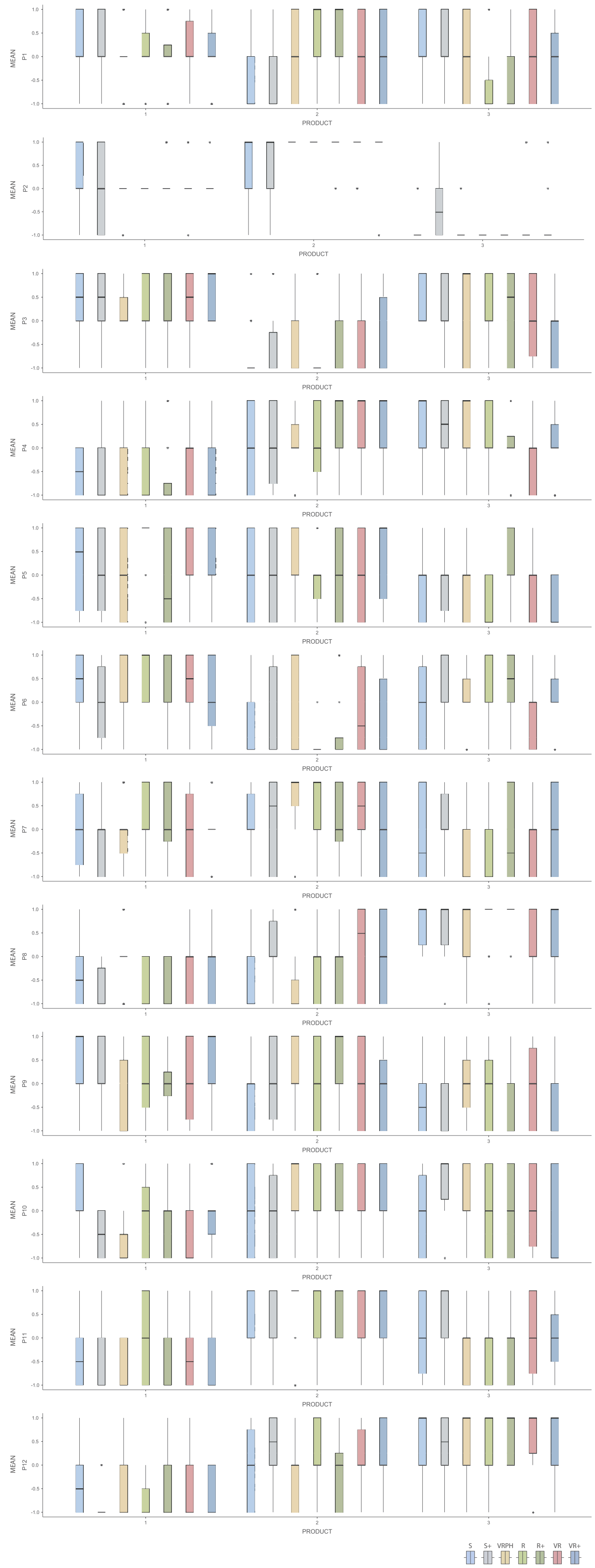

Fig. 7. Boxplot distributions of the seven visualization techniques corresponding to products 1,2 and 3 in P1-P12.

P2 are observed in Umbrella stands 2 (p-values .009 and .013) and 3 (p-values .023 and .003). However, parameters 5 and 10 only show differences in Umbrella stands 3 (p-value .018) and 1 (p-value .036), respectively.

In order to determine the media in which the greatest deviations in user perception are observed, the Post-hoc tests is performed again by visualization techniques pairs. This analysis is carried out only on those parameters that show differences (P1-P2, P5 and P10).

1. Parameters 1 and 2

Table III and Table IV show the inferential analysis for P1 and P2 respectively. In both tables, the values in the upper part correspond to umbrella stand 2, and those in the lower part to umbrella stand 3. Differences between visualization techniques are shown in **bold** by p-values.

TABLE III. Post-Hoc Tests for P1 in Products 2 (up) and 3 (Down)

P1	R	R+	VRPH	VR	RV+	S	S+
R	-	1.000	1.000	1.000	1.000	.077	**.040**
R+	1.000	-	1.000	1.000	1.000	.173	.092
VRPH	1.000	1.000	-	1.000	1.000	1.000	1.000
VR	1.000	1.000	1.000	-	1.000	1.000	1.000
VR+	1.000	1.000	1.000	1.000	-	1.000	1.000
S	.548	.718	1.000	1.000	1.000	-	1.000
S+	**.037**	.102	1.000	1.000	1.000	1.000	-

TABLE IV. Post-Hoc Tests for P2 in Products 2 (up) and 3 (Down)

P2	R	R+	VRPH	VR	RV+	S	S+
R	-	1.00	1.000	1.000	1.000	.328	**.035**
R+	1.00	-	1.000	1.000	1.000	1.000	.962
VRPH	1.000	1.000	-	1.000	1.000	.328	**.035**
VR	1.000	1.000	1.000	-	1.000	1.000	1.000
VR+	1.000	1.000	1.000	1.000	-	1.000	.710
S	1.000	1.000	1.000	1.000	.099	-	1.000
S+	**.003**	**.002**	.102	**.035**	.124	.884	-

According to this results, P1 and P2 showed differences between S+ and R. In this context, different things may be occurring with one of the visualization techniques: first, the CE may not be able to communicate the weight and dimensions of the product to the user, and secondly, the complementary item could be influencing the user's perception of these qualities, probably by confusing the viewer through the apparent resistance that the product exerts on the viewer (P1) and enlarging the volumetric space of the main stimuli through the spatial adhesion of the complementary item (P2).

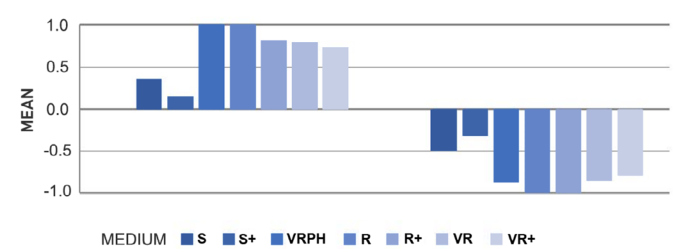

Fig. 8. Visualization techniques of parameters 1 (up) and 2 (down) by descriptive analysis in product 1 (left) and 2 (right).

Upon analyzing the results of the descriptive statistics Fig. 8, it was observed that there were no significant differences between R/R+ and S/S+. Therefore, it can be inferred that the difference detected does not depend solely on the use of the complementary item, but rather on the coordination of its use within the context of the experiment (CE). As such, it is not advisable to use S+ to measure either of the two parameters.

Additionally, even though the inferential analysis does not suggest any significant differences between S and other visual media, we do not recommend its use according to the results obtained in the descriptive analysis. Upon considering both analyses, it is recommended to use real media for P1, while for P2, either virtual or real media can be used interchangeably. This suggests that contrary to previous research [33], VR can be used professionally in the design process. However, it is important to exercise caution in its application and only use it in suitable circumstances.

2. Parameters 5 and 10

Results from P5 (Useless - Practical) and P10 (Cheap -Expensive) are shown in Table V and Table VI.

P5 showed perceptual differences for product 3 between R+/VR+ and R+/R. This seems to be due to the product itself, rather than the medium.

In R+, the product surprised the user with its ability to support the complementary items. Contradicting what may initially seem to be the case, the main product, which appeared to be light and small, could hold both large and small umbrellas. However, this capability was possible by anchoring the product to the ground. As such, all the media that were analyzed are deemed suitable for evaluating these parameters.

TABLE V. Post-Hoc Tests for P5. P Values Showing Perceptual Differences Are Shown in Red

P1	R	R+	VRPH	VR	RV+	S	S+
R	-	**.046**	1.000	1.000	1.000	1.000	.504
R+		-	1.000	1.000	**.046**	1.000	.962
VRPH			-	1.000	1.000	1.000	1.000
VR				-	1.000	1.000	1.000
VR+					-	1.000	.504
S						-	1.000
S+							-

TABLE VI. Post-Hoc Tessts for P10. P Values Showing Perceptual Differences Are Shown in Red

P2	R	R+	VRPH	VR	RV+	S	S+
R		1.000	1.000	1.000	1.000	1.000	1.000
R+		-	1.000	1.000	1.000	1.000	1.000
VRPH			-	1.000	.422	**.026**	**.048**
VR				-	1.000	.716	1.000
VR+					-	1.000	1.000
S						-	.320
S+							-

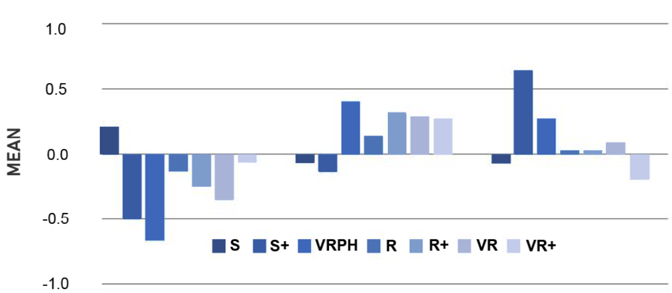

Fig. 9. Means of P10 in products 1, 2 and 3 by descriptive analysis.

The analysis showed differences in P10 for product 1 (yellow), between the S and VRPH. Comparing the results for the evaluation of this parameter between products Fig. 9, the perception of P10 in this medium was opposite between product 1 and the remaining, so that it is not recommended to consult the user about the cost of a product in S. The remaining media (including S+) are recommended as they generally produce similar values.

B. Behavioral Level

Ease of learning, efficiency, memorization, effectiveness and satisfaction (P13-P17) were evaluated based on the researcher's own observation by comparison by ranking, again obtaining a scale of -1 to 1. Additionally, P13, P16 and P17 each offer two values, according to functions 1 and 2 described above. This evaluation has only been conducted on two visual media (R+ and VR+), and the analysis is based on the experience of the 34 selected users. Therefore, the evaluation of these parameters is based on a descriptive analysis. Fig. 10 shows the different boxplots from this analysis (one per parameter analyzed).

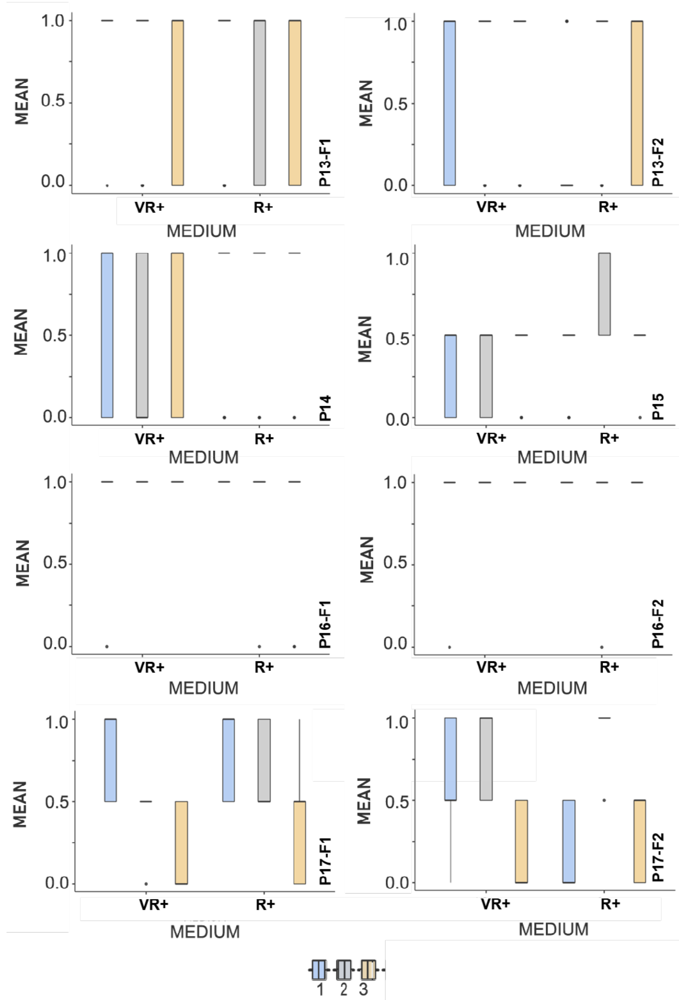

Fig. 10. Boxplot distributions of VR+ and R+ visualization techniques corresponding to products 1,2 and 3 in P3-P17.

According to this analysis, ti is possible to set that, in most of the cases, the user response was positive, except for parameters P15 and P17. Generally, P15 received negative responses in the two media analyzed, with VR+ being worse. The difference in these parameters in these two media was greater in product 2, where the user performed functions 1 and 2 without making errors. This may have been due to the need to place large umbrellas in the umbrella stands at an angle other than 90 degrees, [56] which, although more ergonomic in a real environment (RE), produced a greater number of errors in the virtual environment (VE) due to the limitation of the hand tracking technology used, as other researchers had affirmed previously [49].

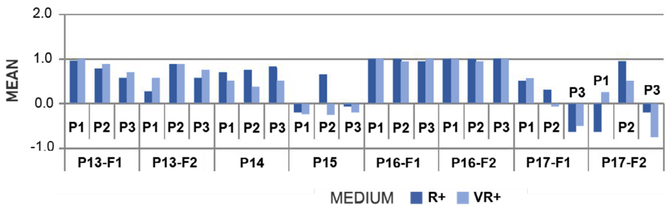

Fig. 11. Means of P13-P17 in products 1, 2 and 3 by descriptive analysis.

In the analysis of functions 1 and 2 of P17, there were significant differences between the two media used. In the case of the large umbrella, users showed greater satisfaction when using the VE, except for umbrella stand 2, which coincided with the difference discussed in P15. In the case of small umbrellas, the opposite was true. Users preferred the RE to the VE, except for umbrella stand 1, probably because the depth of the product prevented the umbrella from being positioned correctly, making it very difficult to extract the complement of the analyzed product. Therefore, in this case, we found that in product 1, the virtual evaluation was positive, while the real one was negative, contrary to what happened with the large umbrella of product 2.

Based on these data, VR+ was not recommended for the evaluation of the degree of satisfaction with the different functions of the product, nor for the detection of anthropometric errors, due to the postural differences that could be found in users who were not accustomed to the technology. However, researchers agreed with Stamps [57] that the use of VR+ could lead to significant cost and time reductions during the new product design process. This visualization technique is recommended for parameters related to functionality and usability as Liberman and Yuba set [4]. Specifically, VR could be useful for assessing ease of learning, efficiency, and effectiveness, showing insignificant differences with the other means analyzed.

C. Reflexive Level

The evaluation of shape assimilation (P18) and human assimilation (P19) was carried out using a 7-point Likert scale from (-3) to (+3). Fig. 12 shows the boxplots related two P18 and P19 parameters from the descriptive analysis. These graphs show the distribution of the responses of the 105 participating volunteers for both parameters.

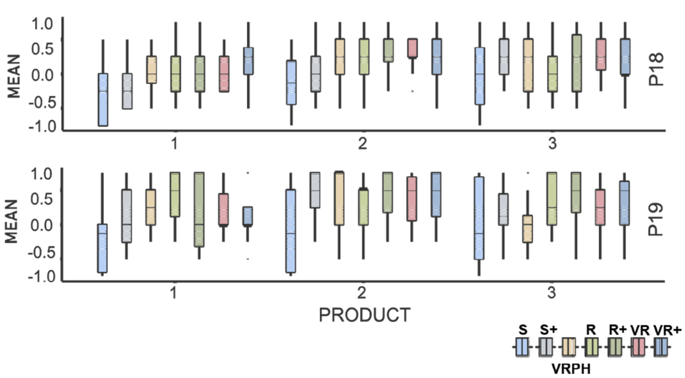

Fig. 12. Boxplot distributions of the seven visualization techniques corresponding to products 1,2 and 3 in P18-P19.

As can be seen in Table VII, no significant differences between visualization techniques were detected for any of the products evaluated, being p-values higher than .005.

TABLE VII. Factor P Value for Each Umbrella Stands (U1, U2, U3) and P19-P19 Parameters

PRODUCT	P18	P19
U1	p=.369	p=.284
U2	p=.920	p=.236
U3	p=.555	p=.274

Specifically p-values are .369, .920, and .555 for the perception of shape assimilation (P18), while .284, .236, and .274 for human assimilation (P19).

However, descriptive analysis showed that while the shape of products 1 and 3 was perceived as unpleasant across most visualization techniques, that of product 2 was perceived as desirable. Fig. 13.

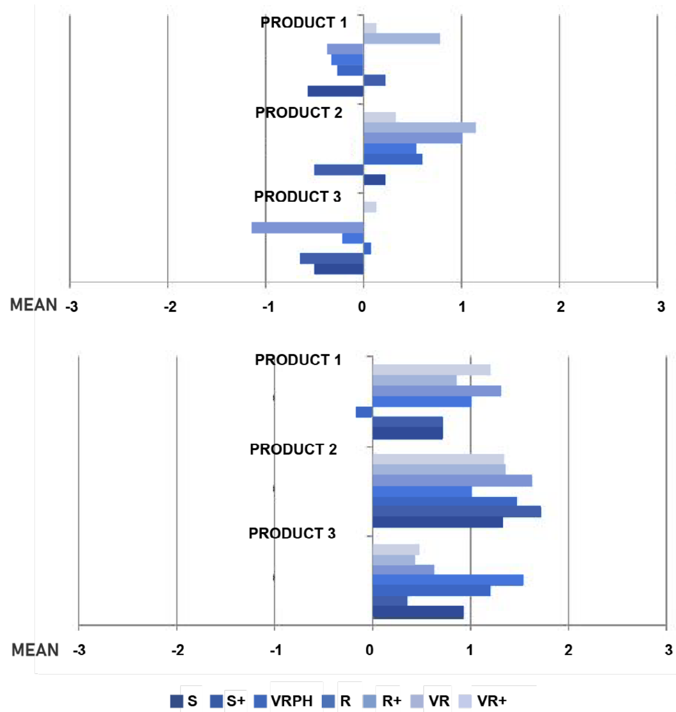

Fig. 13. Means of P18 (up) and P19 (down) in products 1, 2 and 3 by descriptive analysis.

On the other hand, regarding to P19, although users tended to relate the evaluated products with people with whom they had positive relationships, it was observed that product 1 had the lowest values, product 2 had the highest, and product 3 had intermediate values. This fact coincides with the P18 parameter, which could be because product 1 is the most traditional, and products 2 and 3 maintain a differentiating aspect with respect to other commercial umbrella stands.

V. Conclusion

Currently, the number of products on the market has been increased. This situation presents a challenge for industrial designers and practitioners, who must focus their design process on creating successful proposals. To achieve this success, it is necessary to elicit a positive emotional response from the user. To ensure this response, products must be designed and tested by users throughout the design process, from the earliest stages, and at three different levels: VL, BL and RL. However, continuous product testing can be costly in terms of time and money, and not all means of representation are suitable for evaluating user response at different levels.

This study analyzes the possibilities of seven conceptual, real, and virtual media (R, R+, VR, VR+, VRPH, S, and S+) in relation to 19 parameters to recommend to professionals the use of one or another visualization technique in the different phases of the design process.

This research has certain limitations due to the conditions of the study. First, the main products used had to be physically or virtually anchored to the ground because it was not possible to control the synchronization of the main physical product with the virtual one in the case of VRPH. In addition, all products have a drainage system that was not shown for the same reason. This prevents the user from being able to lift the objects evaluated in any of the media, which in turn precludes the perception of the "weight" parameter in the physical environment and the evaluation of the comparison of this real weight with the similar one in the virtual environment after the same action. Similarly, virtual and real environments allow the user to touch the product, while the conceptual environment does not. On the other hand, the type of products used (everyday products) may condition some aspects of the study. In addition, the usability of these everyday products can not be measured in the Virtual Reality with passive haptics visualization technique. Neither at the conceptual environment. Finally, the sample used corresponds to a specific user profile: young engineering students. Therefore, the data may not be applicable to other sectors of the population, due to the high level of familiarity of the user with new technologies.

Our results showed differences in five of them, mainly for the visceral and behavior levels. Specifically, the visualization techniques at conceptual environment (S and S+) presented difficulties for the assessment of some parameters of VL, thus these media is not recommended for the evaluation of weight. On the one hand, if the main product was represented next to the complementary item, there was a risk that the user's attention would be diverted to this item. On the other hand, if it was not applied, the user would not be able to relate the weight of the product to the resistance exerted on it, which would lead to errors in its evaluation. For this case, it is not recommended to evaluate the dimensions of a product with either medium. The sketches did not communicate the correct scale of the product without any reference (S). In the case of using the complementary item as a reference (S+), contrary to what it might seem, the differences were accentuated. The user could be confused and perceive a higher volume, perceiving the volume occupied by the products together. The sketches also indicated serious difficulties in representing the value of a product. Therefore, the use of conceptual media (S and S+) to assess its price is also discouraged.

For measuring the behavior level, R+ and VR+ are generally appropriate. Given the similarity in user response in both media, VR+ is recommended for analyzing parameters to ensure correct intuitiveness of the product, or even for training subjects due to the reduction in cost and time that may result from not making physical prototypes. However, VR+ is not recommended for evaluating the level of satisfaction with different product functions, or for detecting anthropometric errors due to postural differences in users not accustomed to the VE.

These indications are useful for researchers and companies during the design process of new products, which may also lead to the development of new work methodologies where design teams involve the user in the design process of their products.

Moreover, it would be worthwhile to further assess products utilizing the VRPH medium to mitigate the potential overestimation of perception that this medium can present across various parameters. Additionally, an intriguing analysis would be to explore multiple settings with a multifactorial analysis, selected based on the positive effects observed in this study for the most favorable settings. It should be noted that the products examined in this study were either physically or virtually anchored to the ground. In the case of VRPH, the synchronization between the primary physical product and the virtual one could not be controlled. Furthermore, all products in this study possessed a drainage system that was not displayed for the same reason.

This prevents the user from being able to lift the objects evaluated in any of the media, which in turn precludes the perception of the "weight" parameter in the physical environment and the evaluation of the comparison of this real weight with the similar one in the virtual environment after the same action. Similarly, virtual and real environments allow the user to touch the product, while the conceptual environment does not. The sample used in this study corresponds to a specific user profile: young engineering students. Therefore, the data may not be applicable to other sectors of the population, due to the high level of familiarity of the user in question with new technologies.

In addition to these limitations, it may be of interest to further explore the commercial perspective of the products. This could include studying how the presentation medium affects the user's perception of the product in the store, rather than just evaluating the product itself. This could lead to new ways of selling products through the presentation of products using different visualization technologies.

Appendix

Table VIII, Table IX and Table X provide a comprehensive analysis of the perception of three different umbrella stands based on the responses of a total of 105 volunteers. These tables present key statistical measures such as the mean, median, and standard deviation for various parameters related to the evaluation of the umbrella stands.

Table VIII focuses on parameters P1-P12 (VL) and provides insights into the perception of the umbrella stands based on the responses of 105 volunteers. It displays the average values (mean), the middle point of the dataset (median), and the measure of the spread or variability (standard deviation) for each parameter. These statistics allow us to understand the central tendency and dispersion of the responses received for each parameter.

Table IX, on the other hand, delves into parameters P13-P17 (BL), which were evaluated by a smaller subset of 35 volunteers. This table presents the mean, median, and standard deviation values for each parameter, providing a focused analysis of the perception of the umbrella stands in relation to these specific attributes.

Lastly, Table X captures the data for parameters P18-19 (RL) and summarizes the mean, median, and standard deviation values obtained from the responses of 105 participants. This table offers insights into the perception of the umbrella stands based on these parameters and allows for comparisons with the findings from the other tables.

Collectively, these tables serve as valuable tools for understanding the overall perception and variation in responses across different parameters of the umbrella stands. They provide a comprehensive analysis of the data collected, facilitating a deeper understanding of the participants' perception and preferences regarding the evaluated attributes of the umbrella stands.

TABLE VIII. Mean, Median and Standard Deviation Obtained After Descriptive Analysis of Parameters P18-P19

	VT	PRODUCT	P18	P19
Mean	B	1	3.50	4.93
		2	4.21	5.29
		3	4.00	4.71
	S+	1	3.36	4.36
		2	3.79	5.71
		3	5.07	4.71
	VRPH	1	4.07	5.20
		2	4.87	5.47
		3	4.53	3.80
	R	1	4.07	5.53
		2	4.80	5.00
		3	3.93	5.00
	R+	1	3.88	4.63
		2	5.06	5.63
		3	4.63	5.31
	VR	1	4.00	4.43
		2	5.14	5.36
		3	5.07	4.86
	VR+	1	4.67	4.47
		2	4.60	5.33
		3	4.67	5.20
Median	B	1	3.50	4.50
		2	4.50	6.00
		3	4.00	5.50
	S+	1	3.00	4.00
		2	4.00	6.00
		3	5.00	4.50
	VRPH	1	4.00	5.00
		2	5.00	7.00
		3	5.00	4.00
	R	1	4.00	6.00
		2	5.00	6.00
		3	4.00	5.00
	R+	1	4.00	4.00
		2	5.00	6.00
		3	5.00	6.00
	VR	1	4.00	4.00
		2	5.00	6.00
		3	5.00	5.00
	VR+	1	5.00	4.00
		2	5.00	6.00
		3	4.00	6.00
Standard deviation	B	1	1.51	1.44
		2	1.72	2.05
		3	2.18	2.33
	S+	1	1.34	1.60
		2	1.67	1.38
		3	1.38	1.59
	VRPH	1	1.62	1.32
		2	1.30	2.03
		3	2.10	1.70
	R	1	1.53	1.85
		2	1.42	1.81
		3	1.62	1.85
	R+	1	1.78	2.06
		2	1.12	1.59
		3	2.09	2.06
	VR	1	1.47	1.55
		2	0.949	1.69
		3	1.21	1.79
	VR+	1	1.45	1.30
		2	1.68	1.76
		3	1.63	1.70

Acknowledgment

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TABLE IX. Mean, Median and Standard Deviation Obtained After Descriptive Analysis of Parameters P1-P12 From Different Visualization Techniques (VT)

	Product	VT	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Mean	1	S	0.214	0.214	0.286	-0.500	0.214	0.429	0.00	-0.429	0.500	0.214	-0.357	-0.429
	2		-0.357	0.571	-0.714	0.0714	0.00	-0.357	0.0714	-0.429	-0.286	-0.0714	0.214	-0.143
	3		0.143	-0.786	0.429	0.429	-0.214	-0.0714	-0.0714	0.714	-0.357	-0.0714	0.143	0.571
	1	S+	0.143	0.00	0.286	-0.500	0.143	0.00	-0.214	-0.714	0.286	-0.500	-0.571	-0.786
	2		-0.429	0.385	-0.571	0.143	-0.0714	-0.357	0.143	0.0714	0.143	-0.143	0.143	0.357
	3		0.286	-0.357	0.286	0.357	-0.0714	0.357	0.0714	0.643	-0.429	0.643	0.429	0.429
	1	VRPH	0.0667	-0.133	0.267	-0.467	0.0667	0.133	-0.0667	-0.0667	-0.267	-0.667	-0.533	-0.467
	2		0.00	1.00	-0.400	0.133	0.267	-0.200	0.600	-0.533	0.267	0.400	0.667	-0.133
	3		0.00	-0.867	0.133	0.333	-0.333	0.0667	-0.533	0.600	0.00	0.267	-0.133	0.600
	1	R	0.0667	0.00	0.400	-0.400	0.733	0.533	0.133	-0.600	0.133	-0.133	-0.0667	-0.733
	2		0.600	1.00	-0.600	0.200	-0.0667	-0.933	0.400	-0.133	0.00	0.133	0.400	0.267
	3		-0.600	-1.00	0.200	0.200	-0.667	0.400	-0.533	0.733	-0.133	0.00	-0.267	0.467
	1	R+	0.0625	0.188	0.250	-0.563	-0.125	0.188	0.0625	-0.563	0.00	-0.250	-0.500	-0.563
	2		0.500	0.813	-0.438	0.438	0.00	-0.563	0.125	-0.375	0.500	0.313	0.688	-0.125
	3		-0.563	-1.00	0.188	0.125	0.125	0.375	-0.188	0.938	-0.438	0.00	-0.188	0.688
	1	VR	0.143	0.0714	0.429	-0.286	0.214	0.357	-0.0714	-0.357	0.0714	-0.357	-0.286	-0.571
	2		0.00	0.786	-0.571	0.429	0.00	-0.214	0.286	0.0714	0.00	0.286	0.143	0.0714
	3		-0.0714	-0.857	0.143	-0.143	-0.214	-0.143	-0.214	0.286	-0.0714	0.0714	0.143	0.571
	1	VR+	0.0667	0.0667	0.600	-0.467	0.333	0.200	-0.133	-0.400	0.467	-0.0667	-0.333	-0.667
	2		0.133	0.733	-0.333	0.400	0.333	-0.333	0.0667	-0.133	-0.133	0.267	0.400	0.200
	3		-0.200	-0.800	-0.200	0.0667	-0.667	0.133	-0.0667	0.533	-0.333	-0.200	0.00	0.467
Median	1	S	0.00	0.00	0.500	-0.500	0.500	0.500	0.00	-0.500	1.00	0.00	-0.500	-0.500
	2		-1.00	1.00	-1.00	0.00	0.00	-1.00	0.00	-1.00	0.00	0.00	0.00	0.00
	3		0.00	-1.00	0.00	1.00	0.00	0.00	-0.500	1.00	-0.500	0.00	0.00	1.00
	1	S+	0.00	0.00	0.500	-1.00	0.00	0.00	0.00	-1.00	0.00	-0.500	-1.00	-1.00
	2		-1.00	1.00	-1.00	0.00	0.00	-1.00	0.500	0.00	0.00	0.00	0.00	0.500
	3		0.00	-0.500	0.00	0.500	0.00	0.00	0.00	1.00	-1.00	1.00	1.00	0.500
	1	VRPH	0	0.00	0	-1	0	0	0	0	-1	-1	-1	-1
	2		0	1.00	-1	0	0	-1	1	-1	0	1	1	0
	3		0	-1.00	1	1	0	0	-1	1	0	0	0	1
	1	R	0	0.00	0	-1	1	1	0	-1	0	0	0	-1
	2		1	1.00	-1	0	0	-1	1	0	0	0	1	0
	3		-1	-1.00	0	0	-1	0	-1	1	0	0	0	1
	1	R+	0.00	0.00	0.00	-1.00	-0.500	0.00	0.00	-1.00	0.00	0.00	-1.00	-1.00
	2		1.00	1.00	-1.00	1.00	0.00	-1.00	0.00	0.00	1.00	0.00	1.00	0.00
	3		-1.00	-1.00	0.500	0.00	0.00	0.500	-0.500	1.00	-1.00	0.00	0.00	1.00
	1	VR	0.00	0.00	0.500	0.00	0.00	0.500	0.00	0.00	0.00	-1.00	-0.500	-1.00
	2		0.00	1.00	-1.00	1.00	0.00	-0.500	0.500	0.500	0.00	0.00	0.00	0.00
	3		0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	1	VR+	0	0.00	1	-1	0	0	0	0	1	0	-1	-1
	2		0	1.00	-1	1	1	-1	0	0	0	0	1	0
	3		0	-1.00	0	0	-1	0	0	1	-1	-1	0	1
Standard deviation	1	S	0.802	0.699	0.825	0.519	0.893	0.646	0.784	0.646	0.760	0.699	0.745	0.646
	2		0.842	0.646	0.611	0.917	0.877	0.842	0.730	0.756	0.726	0.917	0.802	0.864
	3		0.770	0.426	0.514	0.756	0.699	0.829	0.997	0.469	0.745	0.829	0.864	0.646
	1	S+	0.770	0.877	0.825	0.650	0.864	0.784	0.802	0.469	0.726	0.519	0.646	0.426
	2		0.852	0.768	0.756	0.864	0.917	0.929	0.949	0.730	0.864	0.864	0.770	0.745
	3		0.726	0.745	0.611	0.745	0.730	0.633	0.730	0.633	0.756	0.633	0.756	0.646
	1	VRPH	0.594	0.352	0.458	0.834	0.884	0.743	0.704	0.594	0.884	0.617	0.516	0.743
	2		0.926	0.00	0.828	0.640	0.799	1.01	0.737	0.834	0.799	0.737	0.724	0.743
	3		0.926	0.352	0.990	0.816	0.724	0.704	0.640	0.632	0.756	0.704	0.743	0.632
	1	R	0.704	0.00	0.632	0.828	0.594	0.516	0.743	0.507	0.834	0.834	0.884	0.458
	2		0.632	0.00	0.828	0.862	0.704	0.258	0.737	0.743	0.845	0.743	0.737	0.594
	3		0.737	0.00	0.676	0.676	0.488	0.632	0.743	0.594	0.834	0.926	0.799	0.834
	1	R+	0.680	0.403	0.577	0.814	0.957	0.655	0.772	0.512	0.730	0.775	0.730	0.629
	2		0.730	0.403	0.814	0.727	0.816	0.814	0.806	0.619	0.730	0.704	0.479	0.806
	3		0.727	0.00	0.911	0.619	0.719	0.719	0.911	0.250	0.727	0.894	0.750	0.479
	1	VR	0.663	0.475	0.646	0.726	0.802	0.745	0.829	0.633	0.829	0.842	0.825	0.646
	2		0.877	0.426	0.646	0.852	0.877	0.893	0.825	0.997	0.877	0.726	0.770	0.730
	3		0.917	0.535	0.864	0.770	0.802	0.770	0.802	0.726	0.829	0.829	0.864	0.756
	1	VR+	0.704	0.258	0.507	0.743	0.617	0.862	0.516	0.632	0.640	0.704	0.816	0.488
	2		0.915	0.704	0.900	0.828	0.900	0.900	0.961	0.915	0.834	0.799	0.828	0.775
	3		0.862	0.561	0.775	0.704	0.488	0.640	0.884	0.640	0.816	0.941	0.756	0.743

TABLE X. Mean, Median and Standard Deviation Obtained After Descriptive Analysis of Parameters P13-P17

	PRODUCT	MEDIUM	P13-F1	P13-F2	P14	P15	P16-F1	P16-F2	P17-F1	P17-F2
Media	1	VR+	0.941	0.588	0.647	-0.294	0.941	0.941	0.588	0.294
		R+	0.765	0.235	0.765	-0.176	1.00	1.00	0.529	-0.647
	2	VR+	0.765	0.824	0.412	-0.353	1.00	1.00	-0.0588	0.588
		R+	0.647	0.824	0.824	0.647	0.941	0.941	0.353	0.941
	3	VR+	0.647	0.824	0.647	-0.176	1.00	1.00	-0.588	-0.706
		R+	0.529	0.647	0.882	-0.0588	0.882	1.00	-0.412	-0.294
Mediana	1	VR+	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
		R+	1.00	0.00	1.00	0.00	1.00	1.00	1.00	-1.00
	2	VR+	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
		R+	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00
	3	VR+	1.00	1.00	1.00	0.00	1.00	1.00	-1.00	-1.00
		R+	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00
Deviation standar	1	VR+	0.243	0.507	0.493	0.470	0.243	0.243	0.507	0.588
		R+	0.437	0.437	0.437	0.393	0.00	0.00	0.514	0.493
	2	VR+	0.437	0.393	0.507	0.493	0.00	0.00	0.243	0.507
		R+	0.493	0.393	0.393	0.493	0.243	0.243	0.493	0.243
	3	VR+	0.493	0.393	0.493	0.393	0.00	0.00	0.507	0.470
		R+	0.514	0.493	0.332	0.243	0.332	0.00	0.618	0.470

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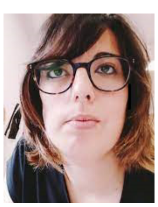

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Almudena Palacios-Ibáñez

Almudena Palacios-Ibáñez is an Industrial Design Engineer who graduated in 2018 from the Universidad de Cádiz (UCA), Puerto Real, Spain. In 2020, she obtained a Master of Science (MSc) degree in Industrial Design from the Universitat Politècnica de València (UPV), Valencia, Spain. During this time, she engaged in early-stage research projects involving Virtual Reality (VR) in the Graphics Engineering Department to investigate its impact on brain plasticity. In the same year, she joined the UPV to pursue her PhD, supported by an FPU fellowship (FPU19/03878) by the Spanish Ministry of Education and Vocational Training. Her research project is titled "Mixed Realities and Product Perception: Experimental Analysis of the Relationship Between Visual Quality, Interaction, and User's Perceptual and Emotional Response." Furthermore, she is currently working as a Research Technician at the IUI Tecnología Centrada en el Ser Humano at UPV. Simultaneously, she is teaching Computer-Aided Design classes for the Industrial Engineering degree at UPV. Almudena's research interests primarily revolve around industrial design and product evaluation, as well as the influence of virtual reality and mixed reality technologies on product assessment.

Óscar David de-Cózar-Macías

Doctor, Industrial Organization Engineer and Industrial Technical Engineer from the University of Malaga. Associate Professor in the Department of Graphic Expression, Design and Projects. He has carried out university management tasks from 2001 to 2023 as Vice-Secretary (7 years) and Secretary (8 years) of the Higher Polytecnic School, as Director of the Secretariat of the Vice President of Smart-Campus (1,5 years) and Secretary of the School of Industrial Engineering (2,5 years), as Vice-Rector for Institutional Organization, COVID Coordinator of the University of Malaga and currently as Director of the Digital Transformation Observatory under the Vice-Rectorate for Business, Territory and Digital Transformation of the University of Malaga and the Andalusia Technology Park (PTA). In his professional role, he worked as an engineer in the company Alcatel-Citesa between 1994 and 1996. Research activity is focused on Image Analysis and Processing within the field of adjustment and recognition of geometric curves, as well as research focused on Industrial Design based on the industrial protection of products and mechanisms and the transfer of results to the business world. Among others, it is worth highlighting applied research that aims to seek transfer in the creation of patents and utility models in reference to mechanisms and industrial products obtained from an in-depth study of market needs, specifying the projects in collaboration agreements with companies. He is the principal investigator of the TEP-189 Research Group on Graphic Engineering and Design of the Junta de Andalucía and participates in Research Projects both at the regional and national level.

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Doctor, Industrial Organization Engineer and Industrial Technical Engineer from the University of Malaga. Associate Professor in the Department of Graphic Expression, Design and Projects. He is a highly skilled engineer and professor with a proven track record of innovation in the medical field. He has led the development of several innovative medical devices, including a goniometer for astigmatism surgery, a mechanical ventilator for COVID-19 patients, and CO2 sensors for air quality monitoring. His work has been published in leading scientific journals and has been recognized with several awards. He is the principal investigator of the TEP-189 Research Group on Graphic Engineering and Design of the Junta de Andalucía and participates in Research Projects both at the regional and national level.