Improved perception of ceramic molds through augmented reality

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Abstract

Augmented Reality techniques allow the user to visualize part of the real world through a display device by incorporating graphical information into the existing physical information. In this sense, it is important to know how the physical presence of the user in the augmented reality experience can affect the perception and evaluation of the product. To this end, this work presents a theoretical framework that explains how users perceive and evaluate the benefits and quality of augmentation with augmented reality through their physical presence, compared to visualizing the same experience through a video. The application was developed for the exhibition and sale of ceramic molds. Users viewed graphical information about the mold, placed between them and the screen while seeing themselves in the television as if it was a mirror. The experiments showed that the integration of the product into the environment and the spatial presence of the users had a positive effect on the perceived value in terms of usefulness and enjoyment, improved comfort in the purchase decision, and reinforced the overall opinion of the product.

Keywords Augmented reality · Product demonstration · Spatial presence · Decision comfort · Ceramic molds

1 Introduction

Augmented reality (AR) is a visualization technology that allows enriching real-world images by inserting synthetic elements that are integrated into them [3]. Since the first research on the field back in the 1960s [50] to its extension to the general public in the

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2010s [8], this technology has been applied in fields as diverse as education [34], medicine [57] and engineering [19], among others.

AR has been and is used to improve the representation of content, either through its static arrangement in the world or dynamically with animations. One of the fields where its potential has been most exploited is product sales and promotion, where it has been detected to have a positive effect on decision comfort, purchase satisfaction, and brand positioning [10]. This not only has a short-term effect on a specific product but by its contribution to consumer satisfaction, purchase loyalty upgrade, buyer retention and word-of-mouth effect [29].

This work presents a study of a user experience with an AR audiovisual application for the exhibition and promotion of molds in the ceramic industry. In this AR experience, an avatar shows up explaining the most outstanding elements of the mold through an animated scene and with sound effects, while performing the procedures for which they have been designed. The purpose of the application is focused on visually demonstrating how the mold technology works and attracting the attention of the visitors. This is done through the virtual arrangement of a scripted sequence on the projection of the mold.

From an analytical standpoint, the goal of this work is focused on technically determining what benefits, and to what extent an AR experience helps to improve product awareness and marketing. In addition, it is analyzed to what extent the spatial presence of users during the AR experience influences a more positive evaluation of the product, along with the utility and hedonic benefits, increasing the quality feeling about the product and the decision capacity.

The paper presents a comparison of feedback from users who participated in the AR experience versus those who only viewed the experience through a video. All this is analyzed with a Structural Equation Modeling (SEM) that takes into account different aspects that influence users' expectations. This model straightforwardly explains user behavior, although there are alternative models with more variables and feature clustering techniques that could be employed [7, 33, 45–47].

The context for which the application was designed consists of a ceramic mold placed in the center of a trade fair stand next to a large television monitor and a high-resolution camera. Figure 1 shows an image of the application context inside the stand of the company, which was located at the International Fair for Ceramics (CEVISAMA) [12].

As a summary, this paper is organized as follows. Section 2 presents a brief state of the art on AR within the field of engineering and marketing, which is the associated context to this paper. In Section 3, the hypotheses and general objectives of the study carried out on the experience are presented. Section 4 describes the ceramic mold, the main aspects of the application, and the elements that have contributed to its design and development. Section 5 shows the different parts that were developed to implement the AR application. The protocol used to evaluate the effectiveness of the application by performing user tests and studying their results is described in Section 6. A brief discussion of the implementation and its impact on users is included in Section 7. Finally, conclusions and possible future lines are presented in Section 8.

2 State of the art

A widely accepted definition of AR is given by Azuma [3] as a system that enables the user to see the real world, with virtual objects overlapped or composited. To this end, the author
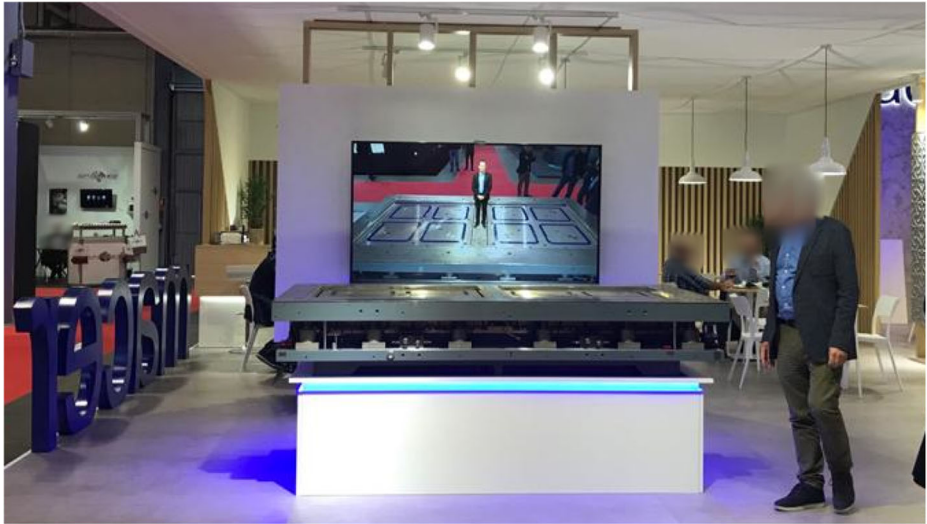
Fig. 1 Application and ceramic mold at the advertising company's stand

defines three aspects: the combination of real and synthetic elements, real-time interaction, and the alignment of all elements in a 3D world. Accordingly, AR complements reality rather than replacing it so that virtual and real objects coexist in the same space. In this sense, Carmigniani et al. [11] emphasizes that AR does not create an artificial reality that replaces the real environment, but rather overlaps additional information on real environments or objects.

Currently, AR technology is under development and there are still challenges to be solved in different aspects of its implementation and applications [52]. Simultaneously, AR plays an important role in visualizing information about training and manufacturing processes [20], education [1, 13], cultural heritage [2] and product presentation [37].

From an engineering and industrial processes standpoint, technologies such as AR are applied in multiple fields [36]. Their applications range from learning how to use industrial tools, the analysis of protocols within factories, to process training simulators [14, 41]. Additionally, there are concrete examples such as a training tool for the maintenance of high voltage lines [24], an industrial assistant within the processes of a shipyard [21], a tool for use in the automotive field [30], a solution for the inspection and analysis of architectural elements [55], and a marketing element in the sales process of products [17].

Within the field of marketing and product visualization, it is easy to find multiple uses: as an advanced product visualization tool in a physical store via smartphone [39], as a method of previewing the arrangement of furniture [27, 44], or to establish settings in the presentation of products during their online retailing [18]. However, at present, AR is not yet a widespread element in physical store shopping processes, and its effectiveness on the shopping process is still under evaluation [16, 56]. Some studies try to validate whether their inclusion improves brand reputation and user experience, and thus increases consumer conversion rates [44]. By adding these functionalities to the user experience, retailers expose themselves to a paradigm shift in the way their potential customers interact with their products and with the decisions they have to make before and after agreeing to purchase the product [29, 49].

3 Hypotheses

At a practical level, the incorporation of AR seeks to add value to the product to be marketed, trying to highlight its characteristics and provide a visual concept in its promotion and sales process, something new in the ceramic machinery industry. However, despite their inherent relationship, two aspects can also be distinguished in the objectives of this work. The first one is focused on a commercial and promotional perspective of the company, and the second one is focused on a technical analysis of the performance provided on the potential consumers of a product. This paper focuses on the analysis and discussion of the second one, following previous works done about user experiences and customers' interaction with products, and decision-making processes.

Thus, inspired by the proposal of Hilken et al. [29], this model raises four factors that determine the attitude of users towards product quality: *Hedonic*, *Usefulness*, *Spatial Presence* and *Purchase Intentions*. In addition, two latent variables are included in the model that act as intermediaries: the *Perceived Value of Experience* and the *Product Decision-Making*, that act on the final opinion of the product (see Figs. 6 and 7).

3.1 Aspects related to the perceived value of experience

The study is based on feedback from participants of the experience created for the trade fair where the mold was exhibited. After experiencing the AR application, data was collected to estimate their degree of satisfaction with the product. This information was compared with another group of independent users who experienced the same sequence about the ceramic mold through a video.

In this sense, the first level of experiential knowledge about service products arises in terms of *Usefulness* and *Hedonic* values [4, 5], where a first impression about the functionality and performance of the product and experiential enjoyment provided by the service experience is collected. Accordingly, in the work developed by Childers et al. [15] it is shown that users value utility and enjoyment when purchasing a product. Recent works following this approach suggest that the use of AR improves the perception of these two terms when purchasing a product [43]. All this is supported by the impression generated in the user about the functionality and performance of the product and the experiential enjoyment provided. In this sense, the following hypotheses can be formulated:

H1.   *Hedonic* enjoyment has a positive reaction on the perceived value of the AR experience.
H2.   *Usefulness* has a positive reaction on the perceived value of the AR experience.

Besides that, AR makes it possible to generate applications with environmental embedding, in the sense of displaying virtual content in the person's real environment and adding a control through physical simulation, so that users can interact with the synthetic elements of the AR experience. In this work, the user only acts passively observing the features of the product that is explained through an avatar, so in the experience, there is only environmental integration of the users who observe the virtual content that shows up over the ceramic mold.

Another aspect to consider is the correspondence between the synthetic elements and the real world through *Spatial Presence*. It implies that people perceive and experience inputs as if they were real even though some of them are not. If this sense of *Spatial Presence* is achieved, users feel located in the real world, even though the virtual elements displayed

are no more than an illusion [28]. In the work by Klein et al., [32] it is shown that the feeling of *Spatial Presence* increases customers' beliefs and attitudes about product attributes. Focusing the analysis on the sense of *Spatial Presence* perceived in a real environment and the effects that this experience causes over the visitors, this third hypothesis is proposed:

H3. The *Spatial Presence* of users in the display of synthetic elements increases the perceived value of the AR experience.

In this work, an avatar carries out an understanding of the ceramic mold features while visually showing, through synthetic elements, the different parts of the mold. In this sense, a comparison could have been made about whether the visual information was more relevant than the verbal one. This could affect users in their way of processing the information. However, it was decided not to incorporate this aspect in the work since the language shown was quite technical and some users did not have this level of expertise.

3.2 Aspects related to the product decision-making

One aspect to validate is the degree of satisfaction reported by the customer after deciding to purchase the product. Parker et al. [42] define this concept as "decision comfort" or the degree to which the consumer feels pleased with the decision made. Decision comfort constitutes a soft-positive affective response that explains customers' changes of opinion in their decision making, beyond generic affect and decision confidence. The latter reflects the level of certainty about making the best decision, based on a cognitive evaluation of the pros and cons around the decision. As the same authors state [42], decision comfort is an affect-based sense of ease related to the process of making the decision.

These possible changes in decision-making are influenced by the way of presentation and the initial satisfaction of the user with the product and ultimately influence the *Purchase Intentions*. For example, Li et al. [35] showed that a 3D presentation of products significantly and positively impacts online *Purchase Intentions*. In other works, the authors apply AR techniques to enrich user experience when shopping for a product in a physical store [17].

Furthermore, AR enhances the feeling of *Spatial Presence* in an environment and the virtual objects rendered in the experience [48]. It is felt that in the case of AR on a ceramic mold, the fact that users can see themselves on the screen influences the processes of unconscious spatial cognition, making presented virtual objects look real and it can affect the *Product Decision-Making*. This allows the following two new hypotheses to be established:

H4. The *Spatial Presence* of the user has a positive effect in the *Product Decision-Making*.
H5. The *Purchase Intentions* have a positive effect in the *Product Decision-Making*.

3.3 Result of combining perceived value of experience and product decision-making

In the proposed model, it is given by the combined action between the perceived value of the AR experience and the *Product Decision-Making* process, which determines its final satisfaction. Both concepts are defined by latent variables that try to collect different factors taken into account by users and whose combination is compared to the last question of the questionnaire that collects user satisfaction about ceramic mold. With all this, the context

in which the experience was developed is presented below. Furthermore, an attempt will be made to check the validity of the hypotheses raised in this section.

4 Description of the exposed product

A ceramic mold is an industrial engineering component that allows shaping tiles during the pressing stage. The appearance and quality of the finished product depend directly on the functioning of the mold. For its design, the features of the ceramic pieces to be produced (material, dimensions, relief, and decorations) and the pressing operations to be performed on it must be taken into account. Ceramic molds can be classified into five types according to their structural and functional characteristics: penetrating molds, penetrating mirror molds, MSF/SFS double mirror molds, quick-change molds (CRS), and 380/440V molds. Although there are multiple types of molds, most of them share components although there are important differences between them, both in structure and operation [23].

The product on display at the fair and described in this paper is a MSF/SFS double mirror mold, which features a penetrating-type top arrangement. This double die system allows the formation of tiles with a spacer and with the thin side of the spacer facing up. The upper part is used with presses of 10,000 tons of pressure through an incorporated isostatic system and supported by a guiding system working along with a compensation system that allows maintaining a balanced pressure between the different cavities. Additionally, this mold incorporates state-of-the-art elements that improve its reliability in the event of accidental maneuvers: quick electrical connections, internal cleaning system, anti-wear plate, and isostatic punch holder. The advantage of the MSF/SFS double mirror mold is its application to any type of special molding and in any technology.

The physical environment of the presentation is in the context of a commercial stand of approximately 20 square meters hosted at CEVISAMA [12]. At the center of the location is the ceramic mold measuring 212 by 110 centimeters, resting on a stand 105 centimeters high. Visitors can approach and interact with the mold at will. About 120 centimeters inward from the location, and placed on a wooden panel, rests a high-resolution television covering a space of 191 by 110 centimeters, with its top 215 centimeters above the floor. At this upper point is located a high-resolution camera oriented towards the mold and the outside of the stand, giving a perspective of the scene that produces a mirror effect on visitors. Figure 2 shows a diagram in dihedral perspective of the layout of the physical environment of the experience.

The description of the features of the ceramic mold is based on a script provided by the advertising company where the technical characteristics of its ceramic mold are exposed.
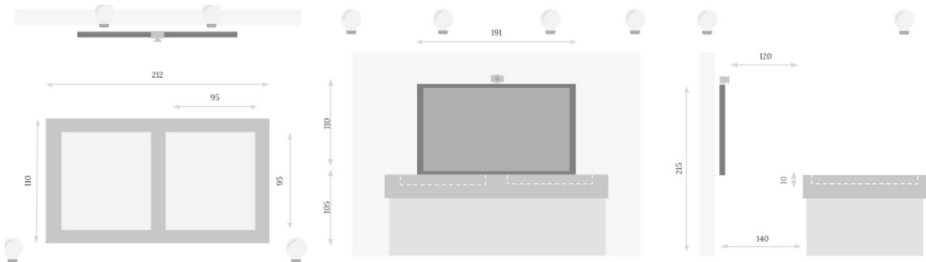

Fig. 2 Dihedral representation of the application environment

The storyline of the presentation is led by an avatar that presents each element of the mold in its augmented reality representation of the real mold. As a whole, the application consists of a 10-minute cyclic sequence.

The mold elements that are highlighted are:

– **Removable blades**: Elements integrated into the edges of the raw material containers. They are in charge of preserving the integrity of the edges of the container and the ceramic pieces.
– **Anti-wear plate**: Device located in the contact areas between the upper and lower elements of the mold, to protect the components during pressing operations.
– **Internal cleaning system**: System based on air pulses to eliminate the rest of the material retained in the mold after each operation.
– **Quick electrical connectors**: Mold electrical outlet connection rack to provide safety and failure protection.
– **Sliding system**: Device in charge of extracting the ceramic piece from the mold with a system of guides and pistons that lift the part out of the punch and the mold.
– **Isostatic system**: System that manages the force compensation applied by the press on the mold to operate more uniformly on the final part.

5 Implementation of the AR application

The application's purpose is to transform a script about the commercial demonstration of the operation and characteristics of a ceramic mold into an AR system. For this purpose, three phases are defined within the development of the application: the transformation of the script into a 3D sequence, the calibration of the AR system, and its integration in a single execution. Figure 3 shows a diagram with the elements that compose these three phases.
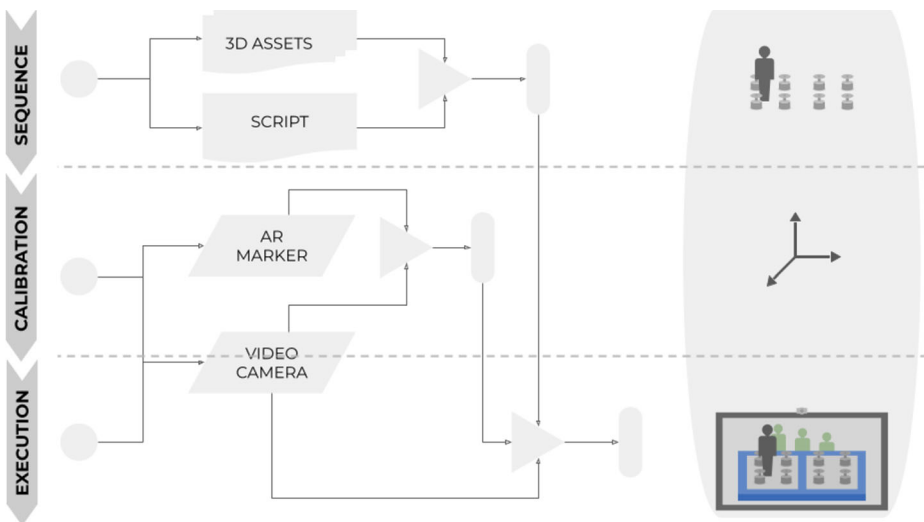

Fig. 3 Flowchart describing the composition and integration of the three phases that compose the design and real-time execution of the AR application

At the technical level, the application generated for this experience was developed on the Unity game engine [51] along with the OpenCV computer vision API in its plugin version for Unity based on markers (OpenCV for Unity v2.3.7). And at the hardware level, the kit available for the implementation and execution of the application consists of a mid-high-end computer (HP Z420 - CPU Intel Xeon E5-1660, 3.70GHz, 32GB, NVIDIA Quadro K5000), a high-resolution USB camera (Logitech Brio 4K Stream Edition) and a high-resolution television (Sony KD85XG8596 85" Ultra HD 4K Android TV).

5.1 Scripted sequence and synthetic elements

The script developed by the marketing company is composed of a cyclical sequence of stages to promote key features of the product, all linked by the presence of a narrator. Each of the stages of the sequence is composed of 3D elements generated from different sources.

The narrator is integrated into the action in video format. The production of the videos took place in a recording studio with an actor placed on a chroma key. The post-processing of the chroma key to remove the green background is done using a shader implemented for this application.

The assets used in the application to represent the mold components were modeled based on the manufacturer's technical specifications using 3DS Max. Similarly, the animations designed for their integration into the sequence were planned to take into account the actual arrangement of the elements in the mold, their operation, and range of motion, trying to generate fluid and visually appealing movements. The materials used for the synthetic elements of the mold were parameterized so that they resemble as closely as possible the real elements of the mold in the lighting conditions of the scene at the fair. That is, the materials with metallic properties and in dark tones try to simulate the visual perception of elements such as steel or tungsten that are part of the real mold materials. As examples, Figure 4, the 3D models of three parts of the mold are arranged from left to right: the sliding system, the quick electrical connectors, and the anti-wear plate.

To technically implement the script provided by the advertising company, a sequence of actions was generated within a Unity scene. These actions are controlled sub-sequences for the input and output of the elements that are intended to be highlighted in the script. Each sub-sequence is stored inside a Unity game object, with its elements and animations, and is managed by a general sequence controller that activates or deactivates it accordingly.

As can be seen in the first phase of Fig. 3, the outcome of this phase is a 3D sequence generated in Unity.

5.2 Vision module and system calibration

A key element in any AR system is the correspondence between the real and synthetic worlds. In the literature, multiple libraries provide the necessary tools to establish this correspondence, such as ARCore [26], Vuforia [54], and OpenCV [9]. For this experiment, one aspect to take into consideration is that the relative position between the camera and the mold remains constant once the system is calibrated. Since the camera is anchored to the television set placed on wall support, the mold is a static element of large tonnage.

Given these conditions, and taking into account the dimensions and geometry of the mold and the particularities of the experience, it is impossible to have a continuous mark that determines the reference system for positioning the virtual objects. However, given the static situation of the system, it is possible to use a previous calibration to obtain the reference system that allows establishing a correspondence between the 3D points of the

Fig. 4 Examples of some of the 3D models representing the mold components

physical mold plane in different positions and its projection in the image integrating the synthetic world and the real world. This information, captured by the real-world camera, is captured in a plane on which the video texture is applied from the USB camera input.

For this process, the ArUco module implemented in OpenCV was used to calibrate the camera by obtaining the intrinsic and extrinsic parameters as well as their distortion coefficients. For this purpose, a correspondence is established between the points belonging to the environment and their projection on the camera image. With this module, calibration can be performed from the corners of a marker or the corners of the ChArUco [25]. This calibration method is more versatile than traditional methods based on checkerboard patterns and allows for occlusions or partial views. In this way, it is possible to detect the mark, to know its position and rotation, and to be able to project on the mark 3D objects accurately. In this way, it is possible to determine a reference plane on which to position the synthetic world.

5.3 Integration and execution in unity

Finally, with the sequence of actions generated and the reference system obtained, it only remains to integrate these elements in a final application that executes a continuous loop and integrates the elements in the real environment of the fair.

From the reference system, the projection is arranged between the video input coming from the camera and the synthetic elements that make up the sequence. As can be seen in the last phase of the diagram of Fig. 3, the result intends the video with the sequence.

As a technical note, to achieve the effect of occlusion of the synthetic elements when they "emerge" from the mold, an occlusion shader was implemented from the synthetic geometries of the elements present in the scene. An example of this case can be seen in Fig. 5, with the pistons that lift the ceramic pieces coming out of the mold.

6 Experimentation and analysis of results

6.1 Experiments protocol

One of the goals of this work was to test if the use of AR improves the perception of product features. For this purpose, two experiments were carried out. The first experiment was planned to collect data to estimate the degree of satisfaction that the user perceived about the product after visualizing the AR experience. During the experience, participants had freedom of movement around the ceramic mold, being able to contemplate the physical model and visualize the synthetic elements integrated with the camera video image observed through the television screen. Additionally, a second experiment was arranged to measure the reality-enhancing effect of an AR experience and analyze how it affects *Spatial Presence*. This second experience was conducted with another group of users, different and

Fig. 5 Example of integration of elements in the AR application and with the environment and visitors to the stand

independent from AR ones. For this case, participants watched the playback of the sequence through a video on a screen.

In both groups, users enjoyed the experience for 10 minutes. In the end, they were asked to fill out a questionnaire. The questionnaire consisted of 10 questions to express their impressions, rating each on a five-point Likert scale ("very unfavorable" = 1 to "very favorable" = 5).

The test was carried out on a population of 50 people for the AR experience and 50 people for the video experience. In the first group, 32 were men and 18 were women with ages ranging from 19 to 55 years old, among the visitors who came to the stand and voluntarily took the survey. In the second group, 34 were male and 16 were female, and respondents ranged from 20 to 51 years old.

The test questions were intended to test the validity of the experience and the hypotheses stated above. The questions were designed to express impressions of the AR experience at four levels: *Hedonic*, *Utility*, *Spatial Presence* and *Purchase Intentions*. The definition of the questions was based on the analysis of questions on different aspects raised in the literature on users' perception of an AR experience [6, 15, 29, 44, 53] (see Table 1). Moreover, a final question was included to measure the user's overall satisfaction with the product.

In Table 1, the description of the questions is shown in Column 1. Columns 2 and 3 show the mean score and standard deviation for users who watched the video experience (Video), and for users who watched the AR experience (AR). The grouping of the test questions into latent constructs is also shown.

Overall, the results presented in Table 1 reveal that users' ratings of the different questions were better for the AR experience than the experience through video. These differences are clearly seen at the *Hedonic* and *Spatial Presence* levels. In the case of the questions related to *Utility* and *Purchase Intentions*, these improvements are not as significant as users take into account other factors such as product features. In the case of final *Product Satisfaction*, there is also a clear improvement from $Avg_{video} = 3.1$ to $Avg_{AR} = 4.4$.

Table 1 Questionnaire and overview of constructs

Questions	Video	AR
Hedonic adapted from [29]		
Q1. I found the viewing experience entertaining.	3.0 ± 1.1	4.2 ± 0.7
Q2. The sequence has been funny.	2.8 ± 1.2	3.8 ± 1.1
Usefulness adapted from [15, 29, 44]		
Q3. The sequence provides information on its operation in a short time.	3.9 ± 0.8	4.4 ± 1.0
Q4. The sequence allows me to more clearly appreciate the characteristics of the mold.	3.7 ± 1.0	4.4 ± 0.7
Spatial Presence adapted from [29, 53]		
Q5. I felt that the experience could fit into the real world.	2.8 ± 1.2	4.1 ± 0.9
Q6. I have perceived that the elements of the mold were integrated in a realistic way.	3.1 ± 1.0	4.1 ± 0.7
Q7. I felt the action seemed real.	2.2 ± 0.9	4.1 ± 0.8
Purchase Intentions adapted from [6, 29]		
Q8. If I had to buy the mold, the visual experience has helped me make a decision.	3.2 ± 1.1	3.9 ± 0.9
Q9. The characteristics of the product are interesting as a purchase option in the ceramic industry.	3.6 ± 0.7	4.1 ± 0.8
Product satisfaction		
Q10. My general opinion on the ceramic mold has improved.	3.1 ± 1.0	4.4 ± 0.8

It is shown the average score and the standard deviation for users for video and AR experiences

6.2 Hypothesis testing

To evaluate the hypotheses proposed in Section 3, a SEM was run with the program LISREL 10.20. A maximum likelihood model was applied to generate the model using robust estimation, considering that the data do not necessarily follow a normal distribution [31]. Using this methodology, the different constructs represented by the independent latent variables KSI (*Hedonic*, *Usefulness*, *Spatial Presence* and *Purchase Intentions*) associated with the questions in Table 1, could be grouped into the dependent latent variables ETA (*Perceived Value of Experience* and *Product Decision-Making*). These dependent latent variables act as intermediaries collecting different constructs that are combined to establish a relationship with the final satisfaction of the product (question Q10). The grouping mechanism is determined by a model that obtains a better fit. The proposed model was inspired in [29] and [44] although the AR experience proposed in both articles are not the same as the present work. From these latent variables, Tables 2 and 3 show the relationships between the different constructs on Q10. In these tables, it can be seen how for instance the *Hedonic* component affects the scores on Q10 in a different way in the AR experience (0.91) than in the video experience (0.55).

Figures 6 and 7 show the model for the case of the experience with video and AR, respectively. The same model was applied to the test data obtained from both groups of users, those who saw the features of the ceramic mold from a video and those who saw them in AR. The goal was to evaluate the differences that arise in the model based on the feedback received by both groups of users.

The results on the proposed model in Figs. 6 and 7, show that the *Perceived Value of Experience* is influenced by both constructs *Hedonic* ($\beta = 0.83$; p $= 0.001$) and *Usefulness* ($\beta = 0.86$; p $= 0.001$) for the video experience, and *Hedonic* ($\beta = 1.00$; p < 0.001) and *Usefulness* ($\beta = 0.30$; p < 0.001) for the AR experience. In this sense, hypothesis H1 and H2 were validated. Additionally, by looking at the model in the AR experience, it can be seen that *Hedonic* expectations reinforce the *Perceived Value of Experience* more than viewing through video. However, the *Usefulness* has given higher values in video than AR for this construct.

Hypothesis H3 states that the *Spatial Presence* of users in the display of synthetic elements increases the *Perceived Value of Experience*. In the case of video, the model indicates a value of ($\beta = 0.11$; p $= 0.540$) for the *Spatial Presence*. In this case the *Spatial Presence* was not significantly linked to *Perceived Value of Experience*, rejecting H3 for video. For the case of AR, the value obtained is ($\beta = 0.37$; p < 0.001) complying with H3.

Table 2 Relation between independent latent variables KSI and dependent latent variables ETA for the video experience

	1	2	3	4	5	6	7
1. Hedonic	1.00						
2. Usefulness	0.72	1.00					
3. Spatial Presence	0.43	0.45	1.00				
4. Purchase Intentions	0.48	0.50	0.77	1.00			
5. Perceived Value of Experience	0.83	0.86	0.52	0.58	1.00		
6. Product Decision-Making	0.48	0.50	0.77	1.00	0.58	1.00	
7. Q10	0.55	0.57	0.69	0.88	0.66	0.88	1.00

Table 3 Relation between independent latent variables KSI and dependent latent variables ETA for the AR experience

	1	2	3	4	5	6	7
1. Hedonic	1.00						
2. Usefulness	0.30	1.00					
3. Spatial Presence	0.66	0.20	1.00				
4. Purchase Intentions	0.73	0.22	0.53	1.00			
5. Perceived Value of Experience	1.00	0.30	0.66	0.73	1.00		
6. Product Decision-Making	0.89	0.27	0.65	0.81	0.89	1.00	
7. Q10	0.91	0.27	0.65	0.80	0.91	0.98	1.00

It should be noted that the *Spatial Presence* also intervenes in the *Product Decision-Making* (hypothesis H4). When observing the models in Figs. 6 and 7, the data indicate values of ($\beta = 0.70$; p < 0.001) and ($\beta = 0.33$; p < 0.001) from video and AR respectively. In this case, both experiences verify hypothesis H4, obtaining a higher value of the *Spatial Presence* influence for the video viewing. It is possible that the lack of spatial presence in video has a negative effect on purchase intentions and that it would be related to the low values given to the questions for the case of video viewing in Table 1.

In the case of *Purchase Intentions*, this construct provides direct information in the *Product Decision-Making* process. In the case of video, this variable is decisive ($\beta = 1.00$; p < 0.001) while in AR its value decreases ($\beta = 0.81$; p < 0.001). In both experiments, it can be stated that hypothesis H5 is confirmed.

Finally, both in the case of video and in the case of AR, the dependent latent variables *Perceived Value of Experience* and *Product Decision-Making* have a similar importance in predicting product satisfaction (question Q10). This is a delicate aspect to assess and the importance of both variables could vary depending on the context in which the experience was carried out, although it seems that both aspects significantly affect product satisfaction.

Table 4 shows the latent variables including the question Q10, that were used for the case of video and AR experiences. Also included in the Average Variance Extracted (AVE) and the Composite Reliability (CR) for each variable. This allows measuring the internal consistency between the constructs within the questionnaire and their relationship by generating dependent latent variables.

Table 5 shows the model fit results for the test data generated from users who saw the experience in video and AR, respectively. The reference values that indicate whether the model has achieved a good fit are shown in the last column of the table [38]. In the case
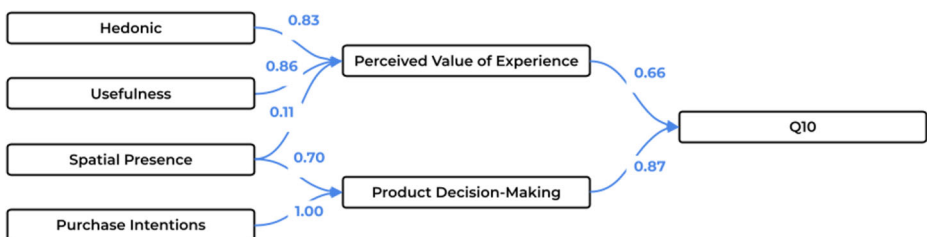

Fig. 6 Model to explain the degree of satisfaction with the product through the video experience
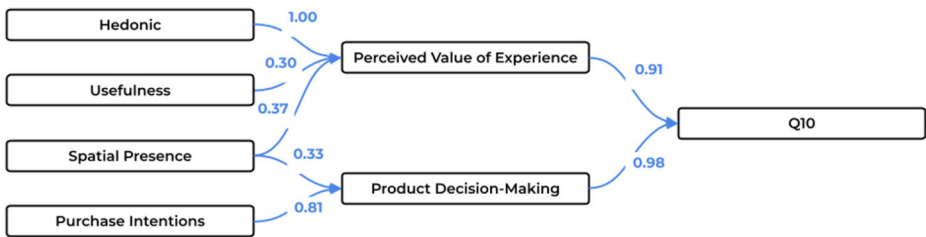
Fig. 7 Model to explain the degree of satisfaction with the product in AR experience

of the parameter χ^2/df (Chi-squared divided by the degrees of freedom), its value is rela-tively low in both experiences. This parameter is sensitive to sample size and the number of degrees of freedom of the model.

In the case of the descriptors Root Mean Square Error of Approximation (RMSEA) and Root Mean Square Residual (RMSR), the AR experience got a reasonable fit, RMSEA = 0.09 and RMSR = 0.08. For the parameters Goodness of Fit Index (GFI) and Adjusted Goodness of Fit Index (AGFI) parameters, in AR relatively high values are achieved, espe-cially for the Goodness of Fit Index, GFI = 0.90 in the range of values for a good fit. This decreases for the case of AGFI that is adjusted by the degrees of freedom of the model.

For the group of users who viewed the experience via video, the data collected for the model through the user test fit similarly to the AR case. In this sense, it can be indicated that the relationships between the latent variables in the model for the video experience are produced differently, although they do not significantly affect the fit of the model.

7 Discussion

One of the marketing company's goals in promoting and developing this AR experience was to present to its customers an image of a technologically advanced company. In this sense, regardless of the results analyzed, it can be stated that the objective was fully met and, in general, all customers enjoyed the experience to some extent, so the impact on users was very positive.

Table 4 Average Variance Extracted (AVE); Composite Reliability (CR) for the case of video and AR experiences

	Video		AR	
	AVE	CR	AVE	CR
Hedonic	0.59	0.62	0.35	0.27
Usefulness	0.40	0.34	0.26	0.16
Spatial Presence	0.51	0.61	0.74	0.86
Purchase Intentions	0.35	0.27	0.58	0.61
Perceived Value of Experience	0.48	0.57	0.41	0.46
Product Decision-Making	0.75	0.81	0.38	0.32
Q10	0.61	0.65	0.89	0.94

Table 5 Indicators of structural fit model in the case of users for the video and AR experiences

Indicator	Video	AR	Reference Value
χ^2/df	46.94 / 31 = 1.51	35.56 / 31 = 1.15	Between 1 and 3, good fit
RMSEA	0.10	0.09	< 0.08 reasonable fit
RMSR	0.10	0.08	<= 0.05 reflects a good fit
GFI	0.87	0.90	>= 0.90 reflects a good fit
AGFI	0.76	0.83	>= 0.90 reflects a good fit

As a differentiating aspect to other works [22, 30, 40, 41] that focus on displaying interactive 3D information looking for task efficiency, training, maintenance, or decision making, this AR experience seeks to catch the attention on the technological features of the product in potential customers or fair visitors who approached the company's stand. The simulation through AR techniques of complex mechanisms of industrial devices explains in a very didactic way how they operate. This can be done thanks to the animation of the parts that compose them, their scaling in case they are very small, and their visualization on the device in case they are hidden. This kind of simulation is essential for the demonstration of industrial products and has a great impact on the users.

From the data collected in the experiments and the SEM model proposed in this work, it can be observed that *Spatial Presence* of users has an important influence on increasing customer satisfaction with the displayed product. This is seen in the comparison of responses to the test carried out for users who could only visualize the experience through a video (see Table 1). Moreover, unlike other works in AR such as [29, 44] that seek to improve the service experience on the user individually, the AR setup proposed is a collective experience where users see themselves on the television screen and exchange opinions, being able to verify that this interaction between the users stimulated that satisfaction.

As for the hypotheses related to *Perceived Value of Experience* in terms of utility and enjoyment, it was found that, although AR technology is still far from being able to integrate virtual elements into the real world with a high degree of fidelity, participants considered the attributes of virtual objects as if they were real improving both their understanding of product functionality and their impression of product quality.

Finally, it is shown that in AR applications such as this one, there is a positive relationship between *Spatial Presence* and *Product Decision-Making*. Therefore, it is considered of great importance the development of this type of experiences to understand the operation of complex systems in an attractive way in which users are involved as final consumers of the product.

8 Conclusions and future work

This paper presents an AR application for the display and sale of ceramic molds. For this purpose, the physical element of the ceramic mold is visualized combined with virtual components of the interior of the ceramic mold in real time. All the action is developed by an avatar that is incorporated during the visualization in AR explaining the functioning of the mold. Users visualize the graphic information about the mold, placed between them and a large-format television screen. In this way, users see themselves on the television as if it was a mirror.

In order to analyze the impact of the AR experience on users, two experiments were conducted with user tests. The first one on the AR experience and the second one on the same experience but in video format. For this purpose, this paper presents a theoretical framework that explains how users perceive and evaluate the benefits and quality of AR augmentation through their physical presence, compared to viewing the same experience through a video.

The results confirm that the use of AR played a positive role on users by enhancing their understanding of the product technology displayed by the company. The *Perceived Value of the Experience* in terms of usefulness and enjoyment was found to enhance comfort in the decision on *Purchase Intentions*. Furthermore, this stimulus was reinforced by the *Spatial Presence* of the users during the AR experience.

In this context, it can be deduced that content creation that has a clear and persuasive use is an important aspect for companies when promoting their products. Improvements in AR visualization with more realistic content and user feedback lead to an exploration of visual technology and digital design, leading to the development of new applications in other fields such as entertainment, sports and gaming.

In the future, it will be necessary to explore adjacent vias to the one exploited in this work by adding protocols for interaction with users of this type of experience, even testing its reliability in other contexts such as virtual reality (VR). Examples of these lines would be a comparison between different immersion levels such as a first-person VR experience and a screen display, or the usage of prop elements to enhance the interaction with AR experiences like the one presented for this work.

Declarations

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