

Product visualization in configurators: laying the foundations for a comparative description

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Abstract

Visualization plays a critical role in the purchasing process, particularly for customized products, as it improves customer engagement and decision-making. Despite the importance of product configurators in presenting customized products, there is limited research on the characteristics of visualization modes that configurators employ. This study aims to address this gap by developing an evaluation framework consisting of 11 descriptive variables: embodiment, presence, interactivity, authenticity, realism, media richness, avatar similarity, functional control, visual control, interaction richness, and vividness. Each variable of the framework is defined and exemplified by practical examples. These variables, derived from the literature on e-commerce and customer experience, offer a structured framework to describe and compare product visualization modes in configurators.

Keywords

configurator, product visualization, virtual reality, augmented reality

1. Introduction

Visualization is a crucial element in the purchasing process, especially for customized products. The configuration process demands effort from the customer but ultimately strengthens their bond with the product. According to Di et al. [1: 550], images enhance attention, trust, and conversion rates in the purchasing process. More images provide a more complete visual representation of the product, which is effective in boosting sales. Interactive and visually appealing configurators help customers make informed decisions aligned with their expectations. Thus, visualization may reduce choice complexity and improve consumer benefits from customization.

Effective visualization is a powerful tool for knowledge transfer and assimilation, having been used since ancient times [2, 3, 4]. The transfer and assimilation of visual knowledge is simpler and faster than that of textual knowledge [3, 4]. The textual representation of a system of relationships through, for example, a table may also be extremely accurate, but the absence of visualization makes the passage of

information hermetic and tedious. This is an example of why highly valuable work without visualization can be difficult to understand, even for experts in the same field, not to mention professionals from other scientific areas [3]. In the case of customized products, the variant may be novel and difficult to understand to the customer, thus the use of visualization may reduce the cognitive complexity borne by the customer at the stage of selecting the most suitable configuration to satisfy his/her needs.

Visualization technologies are undergoing significant advancements. For example, Apple's Vision Pro revolutionizes visual representation by projecting high-resolution output directly into the eyes, controlled by eye tracking and gestures, eliminating traditional peripherals such as mouse and keyboards [5]. Advanced visualization methods such as augmented reality (AR), virtual reality (VR), and mixed reality (MR) are becoming more and more widespread. The AR, VR, and MR market was valued at approximately \$26 billion in 2021 and is expected to reach \$242 billion by 2028 [6]. Consumer trends indicate that 71% would shop more frequently using AR, 61% prefer AR-equipped stores,

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and 55% find that AR makes shopping more enjoyable [7].

An important tool for presenting and selling customized products is the configurator. However, research on the visualization of configurable products is limited and a comprehensive and comparative description of the various product visualization modes in configurators is lacking [8].

This research starts to fill this gap by proposing an evaluation framework composed of 11 descriptive variables. These 11 variables, derived from customer experience and e-commerce literature, enable a systematic description of the product visualization modes that a configurator can adopt. The framework defines the 11 descriptive variables according to the literature and presents examples of their modality. The proposed framework is designed to evaluate all visualization modes used in product configurators, encompassing both traditional (e.g., 2D and 3D images) and new modes (e.g., VR, AR, and MR), serving as a consistent tool for describing and comparing different visualization modes in configurators.

2. Theoretical background

There is a need for comparative descriptions of product visualization modes in configurators. To be able to describe and compare in a structured way these product visualization modes, a framework that includes a set of description variables that allow to describe in a structured way the visualization modes is needed. With the goal of finding the dimensions of the framework along which to describe and evaluate visualization modes in configurators, the relevant literature was searched, although it did not refer to product configurators. Three sources [9, 10, 11] and their references are taken as a starting point for our research.

Zeng and Richardson [9] conducted a review of the literature on product presentation characteristics in e-commerce. This literature review synthesizes existing research findings, explores key theoretical foundations, and highlights the predominant research theories and methodologies employed in the field. It also categorizes the constructs used to describe the characteristics of presentation formats, consumer reactions and performance, as well as marketing effects, such as attitudes towards the product and purchase intention.

Flavián et al. [10] discussed the impact of VR, AR, and MR on the integration of physical and virtual objects, leading to new hybrid customer experiences. They highlighted the lack of clear boundaries between these technologies and experiences, proposing a new taxonomy, the 'EPI Cube,' to classify current and potential technologies that enhance customer experiences. The 'EPI Cube' is based on three dimensions

of description: (technological) embodiment, (psychological) presence, and (behavioral) interactivity.

Recently, Hsu et al. [11] empirically investigated how key variables (interactivity, authenticity, vividness, product presence, and instant gratification) affect impulsive purchasing intentions using AR.

3. Framework for visualization description

The framework variables are taken from the work of Zeng and Richardson [9], Flavián et al. [10], and Hsu et al. [11] and the references cited in these papers. Furthermore, focused searches of literature on specific variables and real applications were performed to clearly define or to exemplify the variables considered in the present framework. Through this process, 11 key variables have been identified:

1. Embodiment
2. Presence
3. Interactivity
4. Authenticity
5. Realism
6. Media richness
7. Avatar similarity
8. Functional control
9. Visual control
10. Interaction richness
11. Vividness

Each variable in the framework is defined and exemplified by practical examples. By integrating and extending previous works, this framework provides a more comprehensive set of variables, scientifically justified by its potential to offer a more complete and nuanced understanding of diverse aspects of product visualization modes for evaluating configurators.

3.1. Embodiment

3.1.1. Definitions

"Ihde [12] regarded embodiment as situations in which technological devices mediate the user's experience and, as a consequence, the technology becomes an extension of the human body and helps to interpret, perceive and interact with one's immediate surroundings" [10: 550].

Technological embodiment involves two important factors: sensory stimulation [10, 13, 14], i.e., the process of activating and responding to the body's senses through received stimuli [13, 14]; and immersion [10, 13, 15], i.e., the ability of the technology to allow users to better focus on what is in front of them and to extend their perception of time; it can have positive effects on experience satisfaction [10, 16].

3.1.2. Examples

Intraocular lenses, which belong to the category of devices implanted in the human body, guarantee a maximum level of embodiment. They are small contact lenses that are permanently implanted in the eye in order to restore the visual capacity that has been impaired as a result of operations or pathologies affecting this apparatus [17]. Embodiment is maximized because the user is unaware that he or she is wearing a device, but benefits from countless advantages in daily life; in this case, the technology is in complete symbiosis with the human body and acts as an extension of it.



Figure 1: Intraocular lens. Photograph: Frank C. Müller [Public domain], via Wikimedia Commons. ([https://commons.wikimedia.org/wiki/File:Hinterkammerlinse_01_\(fcm\).jpg](https://commons.wikimedia.org/wiki/File:Hinterkammerlinse_01_(fcm).jpg)).

3.2. Presence

3.2.1. Definitions

Vonkeman et al. [18: 1039] define presence as "the degree to which an online product experience appears to be unmediated, rather than mediated". They build upon the definition of Waterworth et al. [19], which describe "presence as a concept that provides the user with the illusion of nonmediation, is driven by external technological sensory cues, and is subjective in nature by focusing on the experience of the user" [18: 1039].

Flavián et al. [10: 551] regard presence "as a psychological stage (not related to a specific technology) and the medium is simply the way to arrive at that stage [20]". They define presence as "the user's sensation of being transported to a distinct environment outside the real human body [13]" [10: 551].

3.2.2. Examples

Presence is a highly subjective sensation and can therefore be evoked in different ways depending on the user in question. This perception can be evoked by reading a book, listening to a song, and interacting with

video games [10, 21]. Books and video games allow one to identify with the story: in a detective story, one can identify with the investigator, while in an adventure game, one plays the role of the protagonist directly. Music allows us to abstract from the real world through lyrics or specific sounds, such as the rhythm in South American music, which can make us imagine being in those faraway places.

Presence can be provoked in a virtual environment when there is a sense of 'illusion of place' [10, 22]. Virtual reality systems, such as visors, can facilitate this factor by providing deep sensory stimulation that is so immersive that they can cause a nausea-like disturbance related to perceived movement within the device [23].

3.3. Interactivity

3.3.1. Definitions

Interactivity is defined as "the extent to which users can participate in modifying the form and content of a mediated environment in real time" [24: 84]. It regards "the users' capacity to modify and receive feedback to their actions in the reality where the experience is taking place [25, 26]. [...] Interactivity is a behavioral factor in that users have the ability to control and manipulate the environment that is in front of them [27]" [10: 552].

The mechanistic or structuralist approach [28] "considers interactivity as the response to the attributes of the technology and proposes that it can be enhanced through the development of these technologies" [10: 552].

Interactivity is not a yes/no property: it is a matter of degree. "Degree to which users of a medium can manipulate the form or content of the mediated environment" [9: 5] [e.g., 18, 29]. In the case of AR, Hsu et al. [11: 5] define interactivity as the "degree to which users can choose, browse, and look up product information and provide feedback through an AR app [24, 30]".

3.3.2. Examples

The characteristic of interactivity is easily found in the everyday life of each individual; just think of the use of a computer or a smartphone, where a multitude of interactions take place, consisting of making changes to the system and receiving feedback on them.

In virtual reality devices, it turns out that the control of navigation is the basic level of interactivity present; think of the first prototype 'Sensorama,' which played short films and multimedia content with the involvement of multiple senses [31].

An internal tool such as the viewer can present both levels of interactivity: while watching a film, the device allows viewing in a controlled navigation mode; on the other hand, while playing a video game, using the

joystick and tactile devices (such as suits and gloves), one can modify and monitor the state of the objects presented [10, 22]. The same is true for an external tool such as a computer. When buying a product on Amazon, the process is controlled and the consumer simply follows the predetermined steps. In contrast, when using a product configurator such as Nike's, the customer is able to manipulate and configure the product as he or she wishes.

3.4. Authenticity

3.4.1. Definitions

Authenticity is the “degree to which users understand a product based on their prior consumption experience, knowledge, or time and space in an AR app environment” [11: 5]. The concept of authenticity by Grayson and Martinec [32] is examined in relation to consumers' evaluation of market offerings. This approach distinguishes the two types of authenticity:

- Indexical authenticity gives the term 'authentic' the meaning of describing “something that is thought not to be a copy or an imitation [33: 400, 34: 157]” [32: 297].
- Iconic authenticity gives the term 'authentic' the meaning of describing “something whose physical manifestation resembles something that is indexically authentic. Authors sometimes distinguish this sense of authenticity from indexical authenticity by using phrases such as ‘authentic reproduction’ or ‘authentic recreation’ [33: 399, 35: 421-422, 36: 208]” [32: 297].

Algharabat and Dennis [37: 6] propose the following definition of “perceived authenticity in a computer-mediated environment: Authenticity is a psychological state in which virtual objects presented in 3D in a computer-mediated environment are perceived as actual objects in a sensory way” [37: 6].

3.4.2. Examples

According to the definition of indexical authenticity, Jimmy Stewart's handprints in the concrete of Grauman's Chinese Theatre in Los Angeles are considered authentic if they are perceived to be the actor's original and genuine handprints [32, 38]. According to the description of iconic authenticity, silver pieces available in a museum gift shop are considered authentic because they are believed to bear remarkable similarities to coins produced by Spanish colonies in the 16th century [32, 39]. Furthermore, to judge the authenticity of a Victorian-era chair, a

consumer must have some basic or more detailed idea of how it looks and how it is used [32].

In general, a product image that can be considered authentic is a photograph of it, as it allows the user to see the actual condition and characteristics of the item. The product configurator of the company Design Italian Shoes [40], thanks to its 3D model animation, allows the buyer to perceive the displayed article as tangible. Due to this function, the visual sense processes a concrete image of the item to be purchased.

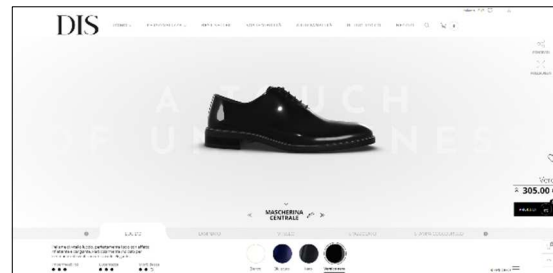


Figure 2: Shoe configurator [40]. Screenshot from https://www.designitalianshoes.com/apps/zakeke/c/verdi-custom?sku=120A00020106XX_353535, with permission from DIS - Design Italian Shoes.

3.5. Realism

3.5.1. Definitions

“Realism refers to the extent to which one believes the virtual environment is real [41] – the degree to which one feels the virtual space represents the actual physical space” [29: 1055]. It also “refers to the perceived correspondence between a technology-mediated experience and a similar experience not mediated by technology [42]” [43: 3].

3.5.2. Examples

When designing a building, architects take advantage of 3D virtual environments, software with a high degree of realism, in which physical spaces that do not yet exist can be created and experienced [29].

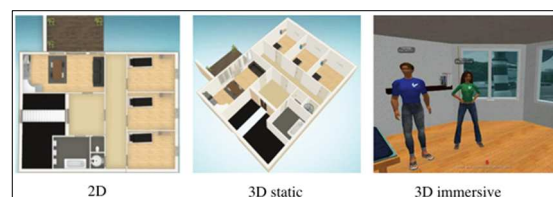


Figure 3: Three visual presentations of an apartment [29: 1058]. Reprinted from Computers in Human Behavior, 29, S. van der Land, A. P. Schouten, F. Feldberg, B. van den Hooff, M. Huysman, Lost in space? Cognitive fit and cognitive load in 3D virtual environments, 1054-1064, Copyright (2013), with permission from Elsevier.

Van der Land et al. [29] state that when the degree of realism of a virtual environment reaches the affinity of the real world, the user is assisted by the technology in the process of making decisions and understanding their concrete problem.

The 'Street View' feature of Google Maps provides a realistic visualization of the route or location that the individual is searching for. Thanks to this feature, the user can get an idea of what he or she will be facing in the real future, helping to increase safety. Manufacturers of in-car navigation assistance devices offer reality visualization features that help drivers. For example, they provide high-quality images when approaching a motorway exit or give advice on which lane to take in situations with complex arterial roads [44].

3.6. Media richness

3.6.1. Definitions

Media richness regards the “extent to which interface facilitates communication [45]” [9: 5]. “Media can be characterized as high or low in 'richness' based on their capacity to facilitate shared meaning” [46: 358]. According to Daft et al. [46], this factor is based on a combination of four criteria.

1. Feedback: instant feedback that allows for specific questions and corrections during the interaction;
2. Multiple cues: a range of cues from which a message can be composed, including physical presence, body gestures, graphic symbols, numbers, and words;
3. Language variety: the range of meanings that can be conveyed by language symbols. For example: numbers convey greater precision than natural language, while the latter helps to convey understanding of a wider range of ideas and concepts [46, 47];
4. Personal focus: a message is conveyed more fully when its communication evokes personal feelings and emotions.

3.6.2. Examples

The following four media channels (unaddressed documents, addressed documents, telephone, and face-to-face) are based on the hierarchy proposed by Daft et al. [46] and are presented in ascending order of media richness, from low to high.

Examples of unaddressed documents are fliers, bulletins, and standard quantitative reports. They mainly use messages consisting of three signals: graphic symbols, words, and numbers. They are useful for communicating quantifiable information, but they lack the ability to convey articulated ideas and concepts.

They also lack personalization because they are delivered to a large audience and it is impossible to get feedback.

Addressed documents, such as letters, express written information. They are suitable for presenting personalized content tailored to the individual, thus creating a psychological connection with the reader. Despite this positive criterion, the feedback is still slow.

The telephone call has the ability to provide feedback quickly. Interlocutors rely on their own voice, tone, and language skills to convey messages. This type of channel, which uses natural language communication in real time, is quite rich. A rich communication tool facilitates intuition and allows for rapid understanding of the content presented.

The 'face-to-face' conversation is considered to be the form of interaction with the highest level of this factor. It allows for a rapid exchange of feedback and the creation of a direct connection with the interlocutor. The sender sends multiple signals, making the message comprehensive; the receiver develops empathy more quickly and the content may evoke emotions in him/her.

3.7. Avatar similarity

3.7.1. Definitions

The avatar is everyone's technological alter ego and the digital representation that each user chooses to identify themselves in an online community.

Avatar similarity is defined “as the perceived similarity between the avatar's physical appearance and the user's physical appearance; the extent of an avatar's similarity is regarded as the degree of reflection of self-concept” [48: 715]. The construction of this virtual element involves the creation of a bond with it, as it is seen as a representation of oneself within the simulated environment [48, 49, 50].

3.7.2. Examples

Suh et al. [48] highlight methods that allow the generation of an avatar in its likeness. We begin with the production of an avatar that incorporates the feature of facial similarity. Two production methods are presented: a three-dimensional facial scan and the selection of a generic face among those proposed, with modifications of the features considered significant. A 3D scanner makes it possible to obtain the precise shape of the face; during the scan, several high-resolution digital photographs are taken, resulting in a virtual face. The subject will undoubtedly perceive a closer resemblance to the first process described. In a very similar way, body similarity has been achieved using three-dimensional body scanning and the use of the body mass index. Although it is clear that the first technique gives a better result, it has a number of

limitations, such as the cost of the machine and a difficult detection procedure. The second method requires the subject to enter values such as height, weight, and age, and to select the body shape that most resembles their own from those presented. One hundred body shapes are included in the database, and the system processes the most suitable according to the data received; the user can then model the features that he or she considers most important.

3.8. Functional control

3.8.1. Definitions

“Functional control enables consumers to explore and experience different features and functions of products” [51: 111]. Functional control regards the “manipulation of product functionality to understand how a product works [51]” [9: 5].

3.8.2. Examples

The functional control enabled by software such as Shockwave allows consumers to test different attributes of products on their computers [51].

An obvious demonstration is online interaction with some product configurators, such as those for electronic watches [51]. As the user adds new features, such as buttons to the item, the cyber product is updated, and its virtual operation mirrors real behavior. Reactions, such as the sound produced by pressing a button, can be reproduced by the sound emitted by clicking on the virtual representation of that particular item.

It is worth mentioning PhET's website for creating simulated electrical circuits, as it clearly implements this factor. By simply clicking on the various objects presented in the interface, it is possible to create an electrical circuit and simulate it so that the user can understand how it works in order to implement it in practice.

3.9. Visual control

3.9.1. Definitions

“Visual control enables consumers to manipulate Web product images, to view products from various angles and distances” [51: 111]. It regards the “manipulation of product images to understand product looks by moving, rotating and zooming [51]” [9: 5].

3.9.2. Examples

Functionalities such as panning, rotating and zooming a virtual product image allow the user to enjoy visual control. The latter, implemented in software such as QuickTime and Flash, allows consumers to manage visual operations using the mouse and keyboard [51].

This factor is particularly noticeable when interacting with the graphical representations in online configurators. Ikea's virtual environment allows for an extremely detailed visual experience for the consumer [52]. Once the room has been configured, it is possible to move around the room using the mouse to view any details.

3.10. Interaction richness

3.10.1. Definitions

Interaction richness is the “possibility of interaction with products and seller [53]” [9: 5]. It is also useful to quote the definition of ComputerLanguage.com [54], where ‘rich interaction’ is described as a beneficial and pleasant user experience when using an electronic device. It is worth pointing out that the concept of ‘rich’ is constantly evolving according to the technologies available; in fact, today it means software with a very intuitive and easy-to-use interface, while in the future it will be through tools such as automatic assistance and voice recognition.

3.10.2. Examples

The experiment by Jahng et al. [53] provides two examples with different levels of interaction richness for each of the dimensions mentioned above. The richness of interaction with the salesperson can be achieved through two means of communication: email and an interface implementing real-time two-way audio and one-way video. It is clear that the second interaction is richer because it makes the product presentation more effective and the communication support to the customer more direct.

On the other hand, the richness of the interaction with the product can take the form of a simple static image associated with a textual description of the specifications, or an interactive three-dimensional test of the product features accompanied by an explanation.

The effectiveness of the latter is obvious, as it allows better manipulation to understand the features and overall functioning of the product. Banking service sites such as Fineco offer a feature such as ‘live chat’. Live chat is a type of customer service software that allows visitors to interact with operators in real time and through a chat window [55]. It is clear that effective customer service is provided through interactive interfaces that allow the user to engage in profitable communication before and after purchase.

3.11. Vividness

3.11.1. Definitions

“Vividness means the representational richness of a mediated environment as defined by its formal features,

that is, the way in which an environment presents information to the senses” [24: 75]. “Vividness refers to the abundance of information that an external environment (e.g., AR app) gives to the human senses, of which perceptual breadth and perceptual depth are the two primary variables [24]” [11: 4]. “Perceptual breadth refers to the extent to which an individual utilizes multiple sensory modalities to perceive information simultaneously” [11: 4]. “Perceptual depth is defined as the measure of both the quantity and quality of information received by the senses” [11: 4].

3.11.2. Examples

“The quality of the media directly impacts perceptual depth, and more advanced technology (e.g., AR) generally has better perceptual depth performance” [11: 4]. Vonkeman et al. [18] present interesting examples of vividness while investigating the effect of different product (in the specific case sunglasses) display formats, namely: static images, 360-degree rotation tool and virtual mirror.



Figure 4: Virtual mirror [18: 1046]. Reprinted from *Information & Management*, 54, C. Vonkeman, T. Verhagen, W. van Dolen, Role of local presence in online impulse buying, 1038-1048, Copyright (2017), with permission from Elsevier.

The static images are captured by a simple camera and are noninteractive, whereas the 360-degree rotation tool allows the displays to be rotated by clicking and dragging the mouse. A webcam captures the participants' faces and transfers them to the screen via a 'virtual mirror' application by placing the product on it. The three presentation modes differ in terms of vividness, particularly in terms of depth, i.e., the quality of sensory stimulation provided. Static images provide fixed visual input and elicit the lowest level, while the 360-degree rotation tool and the 'virtual mirror' provide higher levels through real-time manipulation. The latter, in particular, through the captured image of the face, provides a higher quality of representation, and thus a higher level of vividness.

4. Discussion and conclusion

This paper continues the line of research regarding visualization in configurators [e.g., 8, 56]. In particular, it contributes to that line by distinguishing dimensions for describing and evaluating product visualization modes by drawing on literature from e-commerce and customer experience. Based on literature on e-commerce and customer experience we identified a list of 11 variables that can be used as a framework for describing and evaluating all product visualization modes in configurators. Each variable of the framework is defined and exemplified by practical examples.

While this study provides a starting point for evaluating product visualization modes in configurators, it predominantly draws from the e-commerce domain. Consequently, certain aspects specifically related to the VR/AR/MR domain may not be fully captured. For example, in immersive environments, flow, motion sickness, dizziness due to avatar similarity, and the uncanny valley effect may arise. Future research could integrate insights from related disciplines, particularly those focusing on immersive technologies, to enrich the framework or to identify relationships among the framework's variables and other relevant outcome variables.

Additionally, we acknowledge that some of the proposed 11 variables may be correlated. However, at this stage, there is no empirical or theoretical basis to reduce them to a smaller set. We believe it is beneficial to present all variables and address potential consolidation in future research.

Regarding the practical contributions of this study, the identified dimensions can serve as valuable tools for managers who need to select visualization alternatives and for designers responsible for developing product visualization interfaces in configurators. The proposed framework, when applied to describe and compare different visualization modes, allows the presentation and comparison of the unique features, advantages, and disadvantages of the modes. This detailed description is effective for managers and designers who are choosing the most suitable product visualization mode for their specific context, providing crucial support during the evaluation process. Additionally, this framework allows one to systematically compare these visualization modes, simplifying the decision-making process.

However, the study did not apply these evaluation dimensions to the various visualization modes in configurators, which would further benefit both managers and designers. Therefore, the next step involves characterizing these visualization modes on the basis of the 11 dimensions that comprise the proposed framework. To achieve this, it is necessary to develop appropriate measurement metrics. While some metrics have already been proposed in the literature, others will

need to be developed. In any case, it is crucial to adapt these metrics and test their effectiveness within the context of configurators.

Finally, new technologies come with limitations in costs and benefits. High development and implementation costs, including hardware and software, can be significant barriers. User accessibility and the need for specialized equipment could also limit adoption. For products not requiring spatial interaction or immersive experiences, traditional visualizations can still provide a satisfactory configuration experience at a lower cost. Future research should explore cost-benefit analyses to identify scenarios where advanced visualization modes offer distinct advantages over conventional approaches.

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