Exploring Interaction Mechanisms and Perceived Realism in Different Virtual Reality Shopping Setups

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Abstract: Within the e-commerce field, disruptive technologies such as Virtual Reality (VR) are beginning to be used more frequently to explore new forms of human-computer interaction in the field and enhance the shopping experience for users. Key to this are the increasingly accurate hands-free interaction mechanisms that the user can employ to interact with virtual products and the environment. This study presents an experiment with a set of participants that will address: (1) users' evaluation of a set of pre-formalised interaction mechanisms, (2) preference for a large-scale or small-scale shopping environment and how the degree of usability while navigating the large-scale one, and (3) the usefulness of monitoring user activity to infer user preferences. The results provided show that i) interaction mechanisms made with users' hands are fluid and natural, ii) high usability in small and large shopping spaces and the second ones being preferred by the users and iii) the recorded interactions can be employed for user profiling that improves future shopping experience.

1 INTRODUCTION

Virtual Reality (VR) is emerging as one of the key technologies in retail innovation and in enhancing the shopping experience for users in the coming years (Grewal et al., 2017). In fact, studies suggest that VR, along with Augmented Reality (AR) and other technologies, are part of the competitive strategy of many retailers (Kim et al., 2023). Since the COVID-19 pandemic, the use of e-commerce services has increased dramatically, not only among younger people but also among individuals of all ages, including older adults who were initially more reluctant.

One way to enhance this competitiveness is by improving the shopping experience, making it more realistic and closer to that of a physical store. Generally, the shopping experience can be described as what arises from the interactions between a consumer and a product in a specific shopping situation or environment over a certain period of time. This definition is directly applicable to a shopping experience in a virtual space. In recent years, thanks to advances in hardware for VR devices, it has become easier to foster greater immersion in a virtual shopping environment with the use of VR headsets (Xi and Hamari, 2021), which provide a much more comprehensive field of view (FOV).

The mechanisms of interaction between the user and virtual elements play a crucial role in the shopping experience and have a direct influence on the sense of realism. However, until recently, interaction mechanisms in these virtual environments were quite limited, focusing on classic input devices like the mouse and keyboard, or head movements in devices using a smartphone (Speicher et al., 2017). These methods, in a way, represented a somewhat unnatural and restricted way of exploring displayed products.

Recent advances in hand, body, and even eye tracking in the latest VR headsets, such as the Oculus Meta Quest 2, 3, and PRO models, open new avenues for research and design of more complex interaction mechanisms. Previous studies have shown that the shopping experience in an immersive virtual shopping environment provides greater immersion and more natural interactions compared to desktop-based solutions (Schnack et al., 2019).

Thus, we aim to achieve several objectives in this study. The first is to investigate the sensations, fluidity, and comfort that the interaction mechanisms provided by Meta's SDK and others defined by us, such as the shopping cart, produce in users in immersive shopping environments. In terms of how these products should be displayed in a virtual shopping environment, we aim to determine the user's preference for a large, store-like environment, or a smaller, sim-

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pler one with minimal distractions. This will allow us to ascertain how motivated they are to interact in each environment, as well as the usability and navigability of the environment. Lastly, monitoring user activity on current e-commerce websites is very useful in understanding their tastes and preferences. Similarly, we want to investigate the utility of such monitoring in a VR Shopping environment so that the generated data can be used by AI algorithms.

To achieve the proposed objectives, we have designed and conducted an experiment with a group of volunteers. Following the study, participants answered a 26-question survey. The results of this survey have helped us determine the preferred layout for virtual shopping environments, their feelings about the presented interaction mechanisms, their preference compared to other forms of shopping, and their tastes based on the products they interacted with.

The remainder of this paper is structured as follows. Section 2 introduces previous work related to interaction mechanisms used in virtual shopping environments and experiments conducted in this context. Then, Section 3 outlines the methodology followed for conducting the experiment, as well as the resources used and other considerations. Subsequently, Section 4 presents the results obtained from the experimentation, and Section 5 discusses the conclusions of our work.

2 RELATED WORK

In their investigation into gesture-based controls within VR shopping environments (Wu et al., 2019) conducted a pair of studies that led to the development of a novel approach for formulating dependable user-defined gestures. The research included an experimental setup where 32 participants engaged with a series of VR shopping tasks, ranging from object selection to color changes and size adjustments—using an HTC Vive headset. Nevertheless, the study's description lacks specific details on the recording and subsequent analysis of the gesture data.

(Peukert et al., 2019) explored the impact of immersive experiences in VR shopping settings on the likelihood of users adopting the technology for future use. To this end, the researchers designed an experimental study utilizing two distinct environments: one with a high level of immersion facilitated by the HTC Vive, and a less immersive version presented on a standard desktop display. In the more immersive setting, the study monitored and captured data on the movements of the participants' hands and head, including their interactions with products such as grabbing, dropping, or transferring items between hands. Eye-tracking data was also gathered. The findings of Peukert et al. suggest that the immersive quality of the VR environment could shape a user's decision to reuse the system via two distinct avenues: one being hedonic, driven by enjoyment, and the other utilitarian, driven by practicality.

(Speicher et al., 2017) explored a VR shopping platform to analyze the effects of user interface modalities on shopping efficiency, user preferences, and behaviours. Initial investigations involved a survey to capture the highs and lows of online shopping, leading to the creation of VR prototypes for both desktop and smartphones, focusing exclusively on voice and head-pointing controls. This work culminated in the proposal of design principles for VR shopping ecosystems. Building upon this, they further innovated with a new VR shopping prototype, the "Apartment" metaphor (Speicher et al., 2018), to probe into product selection and manipulation strategies, alongside different shopping cart designs. Their study revealed that immersion and a seamless user experience are paramount for users, prompting recommendations to mitigate motion sickness and advising on product assortments that are most amenable to VR shopping interfaces.

(Ricci et al., 2023) compared immersive virtual reality (IVR) and desktop virtual reality (DVR) in the context of virtual fashion stores to assess their influence on the shopping experience. A within-subject experiment with 60 participants was conducted to explore the use of an HTC Vive head-mounted display against a desktop setup. The results revealed that IVR provides a more engaging, pleasurable, and efficient shopping experience, with participants showing a higher intention to use IVR setups in the future due to enhanced hedonic and utilitarian values. The authors underscored the significant potential of IVR in enriching the shopping experience in the fashion industry.

In this section, we have presented works related to VR Shopping and experiments conducted with prototypes in this context. However, none focused on exploring the importance of realism in purchase intention, complex interaction mechanisms with products and environment, or the utility of monitoring user activity in the shopping environment.

3 EXPERIMENT METHODOLOGY AND SETUP

In this section, we will describe both the resources used and the methodology followed to execute the experiment. The experiment carried out focused on the following aspects: 1) usability and preference of a large and/or small shopping environment, 2) evaluation of the proposed interaction mechanisms, including interaction with the shopping cart, and 3) the utility of monitoring user activity for profiling and purchase intention. Due to space limitations, the conceptualisation and mathematical formalisation in 3D space of the interaction mechanisms used in the experiment (grabbing, translating, rotating, scaling, teleporting, adding to shopping cart and looking with the eyes) as well as the elements with which to carry out these interactions can be found in the following GitHub repository: https://github.com/AIR-Research-Group-UCLM/VR-IM-Experiment.

3.1 Setup and Resources

The application, run on the Meta Quest Pro HMD, was developed using the Unity graphics engine, version 2022 LTS, to ensure compatibility with the latest update of the Meta XR All-in-one SDK. The developed application consists of 3 scenes, each corresponding to the steps of the experiment. The equipment used for development and execution of the experiment was an MSI Vector GP66, featuring an i7-12700H, 32GB RAM, and an Nvidia GeForce RTX 3060 6GB VRAM GPU. During the experiment, the laptop was connected to the Meta Quest Pro using a 5-meter Oculus Link cable, in order to provide the smoothest experience possible and minimize any performance degradation during the experiment. It should be noted that in all samples taken, the frame rate of the application was maintained at 60 FPS.

A 2 m $\times$ 2 m space was defined to allow the user some freedom of movement, especially in the small environment, as the large environment required the use of teleportation to move around due to the lack of physical space.

3.2 Participants

For the experiment, we involved 10 participants (8 male, 2 female) from the university campus, with ages ranging between 22 and 28 years (8 participants) and 58 years (2 participants). The experimental session was conducted the same day, with each participant taking a mean (M) = 28.50 minutes to complete the experiment and answer the subsequent questionnaire. The questionnaire also included questions about age, gender, and experience with VR, as well as online shopping and related aspects (see Fig. 1). According to the mean and standard deviation results shown in Fig. 1, most volunteers had little experience with VR and the HMD used for the experiment (Meta Quest Pro).

3.3 Scenes Developed for the Experiment

For the execution of the experiment, three scenes were developed in Unity to cover the previously described objectives. Each of these was executed successively, and each participant was notified beforehand of what each scene entailed, what they would encounter, and what they were expected to do.

3.3.1 Second Scene: Small Virtual Shopping Environment

The second scene consists of a single counter that displays the five scanned products, along with a label that provides basic product information: name, short description, and price. Fig. 2a shows the aforementioned scene. In this part of the experiment, participants were expected to interact freely with the displayed products for 2 to 3 minutes. Here, they could move, rotate, and scale the objects. After the interaction time, they were to include in the shopping cart the three products they preferred or would buy.

The purpose of this step is to explore the usability of such environments and the sensations they evoke in users within a simple, distraction-free setting. In addition to the questionnaire, interaction data with the products and the shopping cart were monitored to determine which products were added, along with eye-tracking data to gather results on their focus of attention. In this way, we aim to deduce a correlation between the number or duration of interactions and the frequency or length of time a product is viewed, with the final decision to add it to the shopping cart.

Analyzing the recorded data, our intention is to discern whether a simple environment fosters greater user interaction with objects and whether this leads to an increase in the participant's purchase intention for the interacted products. While possible layouts for virtual shopping environments have been investigated, some using uncommon metaphors like an apartment (Speicher et al., 2018), most prototypes resort to the concept of a supermarket (Chandak et al., 2022; van Herpen et al., 2016). There exists a gap in the exploration of simplified shopping environments. Furthermore, the authors of (Ricci et al., 2023) proposed using small-sized virtual shopping environments to help avoid cybersickness, so we will also include questions on this topic in the post-experiment questionnaire.

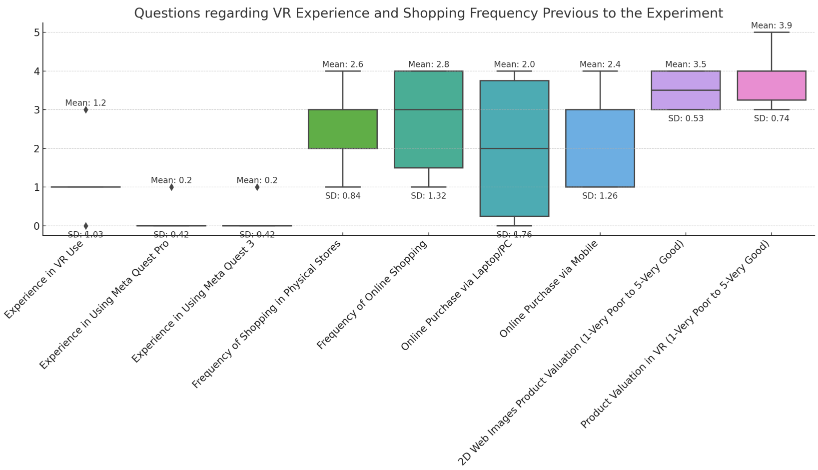
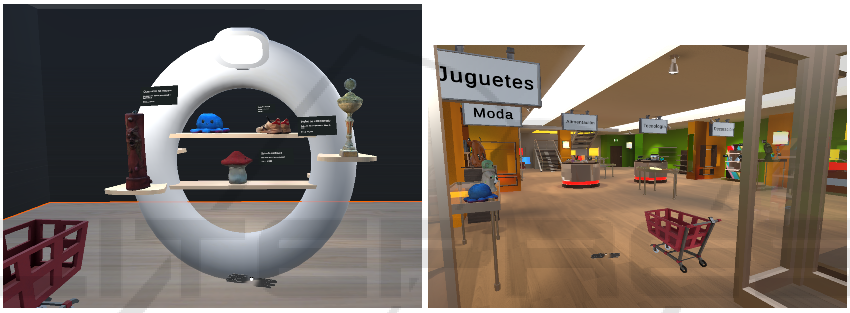


Figure 1: Box plot of responses to questions from pre-experiment questionnaire. All questions followed a Likert scale from 1 to 5. The first six questions ranged from 1- No experience to 5- Very frequently.



(a) Small environment with a single exhibitor of products and the shopping cart.

(b) Screenshot of the large environment, consisting of 24 products and 7 counters.

Figure 2: Screenshots of the environments developed for the experiment.

3.3.2 Third Scene: Large Virtual Shopping Environment

The third and final phase of our experiment consisted of a shopping experience in a large environment that recreates a floor of a shopping center, as shown in Fig. 2b. In this last environment, our main objectives were to address the usability and comfort of interactions in a large setting, with a special focus on teleportation, and to gather data to observe the effect of a large environment on the time spent interacting with products. Finally, through a post-experiment questionnaire and the data obtained from interactions, we aim to discern whether monitoring user activity in an immersive shopping environment provides useful data for inferring their tastes and preferences.

All participants began the experiment in the same position. This time, the experience was based on tasks of searching for a product in a specific section. This allowed us to collect data on navigation through the environment and interaction in the sections.

Thus, the first task for each participant was to navigate to the back of the environment, to get accustomed to the teleportation interaction. From there, participants were instructed to visit 3 product sections and then a section of their choice, with the option to revisit one of the first three. The user had to add to the cart the product they would buy from the respective section at each point.

Each participant took between 3 and 4 minutes to complete all the steps, having the freedom to interact with the products once they reached the requested section. Following this, they proceeded to complete the questionnaire (see Section 4.4), which took them an average of 10 minutes.

3.4 Data Collected

A series of Unity scripts were developed to save a range of data into a .csv file during the execution of the second and third scenes. The generated .csv files contain data on interactions with products, the shopping cart (products saved in each scene and when), eye tracking, and teleportation. Detailed information about the headers of the .csv files, as well as the files generated during the experiment, can be found in the README file of the following repository, located in the "csv-Files" directory of the repository: https://github.com/AIR-Research-Group-UCLM/VR-IM-Experiment.

4 RESULTS

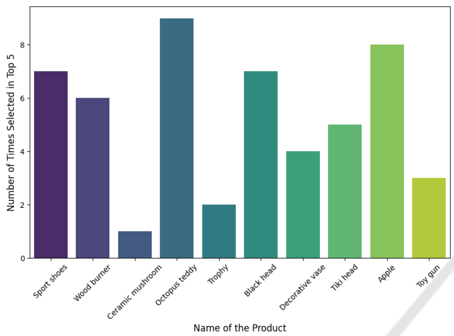


Figure 3: Frequencies of each product as being selected in top 5 more realistic products.

4.1 Products Selected as Most Realistic

Fig. 3 shows the frequency with which each product was selected as one of the top 5 most realistic by the 10 participants. Out of a total of 50 responses (5 products selected by each participant), 50% were products scanned with Luma AI. Therefore, on average, 2.5 scanned products were selected by each participant. Notably, the most popular products, as observed, were the octopus teddy, followed by the sport shoes and the burner, which are the visually most attractive objects and were chosen by more than 60% of the participants in their top 5. Although we were aware that these scans had lower visual quality due to being mostly composed of materials that cause reflections, like metal (the application's own best practices guide[1] advises against scanning such objects), we included them to cover a wider range of materials.

4.2 Participants Behaviour in the Small Environment

The top graph in Fig. 4 compiles the data from the ten .csv files of eye tracking. The left graph displays the total amount of time, in seconds, each object was viewed (i.e., the rays emitted from the eyes collided with the object's collider), with an annotation on each bar indicating the number of times it was added to the shopping cart. Conversely, the right graph shows the number of times each product was looked at (counted by the number of collisions), with the same annotations as the left graph.

Notably, the products most frequently added to the cart were the sport shoes, the octopus teddy, and the wood burner, followed by the trophy and the mushroom. However, in terms of collision time, the burner registered the least amount of time. This could be due to the object's characteristics and the use of capsule colliders, resulting in a narrower collider compared to, for example, the shoes, affecting the data recording. This situation is similar for the trophy. As observed, the burner was the third most viewed product, which might support this assumption. Regarding the spatial information gathered from the eyes (position and rotation), it's noteworthy that the standard deviation (SD) on the Y-axis is 0.61 for both eyes, while SD = 0.11 and 0.28 for the X and Z axes, respectively. This indicates that designs with less vertical or high counters might be more comfortable for users.

The bottom graph in Fig. 4 shows a barplot of the total time that each object was interacted with by hands (left Y axis) and the total number of interactions (right Y axis). This graph shows a similar trend to those of the top barplots in Fig. 4, as we can see that the three objects with the most interactions were the sport shoes, the octopus teddy, and the wood burner, followed by the trophy and the mushroom. An interaction was considered from the moment the user interacted with the object (in this case, grabbing it for inspection) until releasing it. These data seem to support the assumption about the low viewing time of the burner, as it's observed that users interacted with the burner more than 20 times in total for over 200 seconds. Analyzing the time to the first interaction, the mean (M) = 9.86 and SD = 4.19, suggesting that users take about 10 seconds to visually scan the scene before deciding to interact with a product. Additionally, M = 9.0 and SD = 1.45 for the number of interactions performed by each user, indicating that the users interacted more times than necessary for the experiment on average. Finally, each participant interacted with the octopus for M = 33.45 seconds (s), with the sport shoes for M = 26.36 s, with the trophy for M = 20.36 s, with the burner for M = 14.85 s, and with the mushroom for M = 9.91 s.

[1] https://docs.lumalabs.ai/MCrGAEukR4orR9

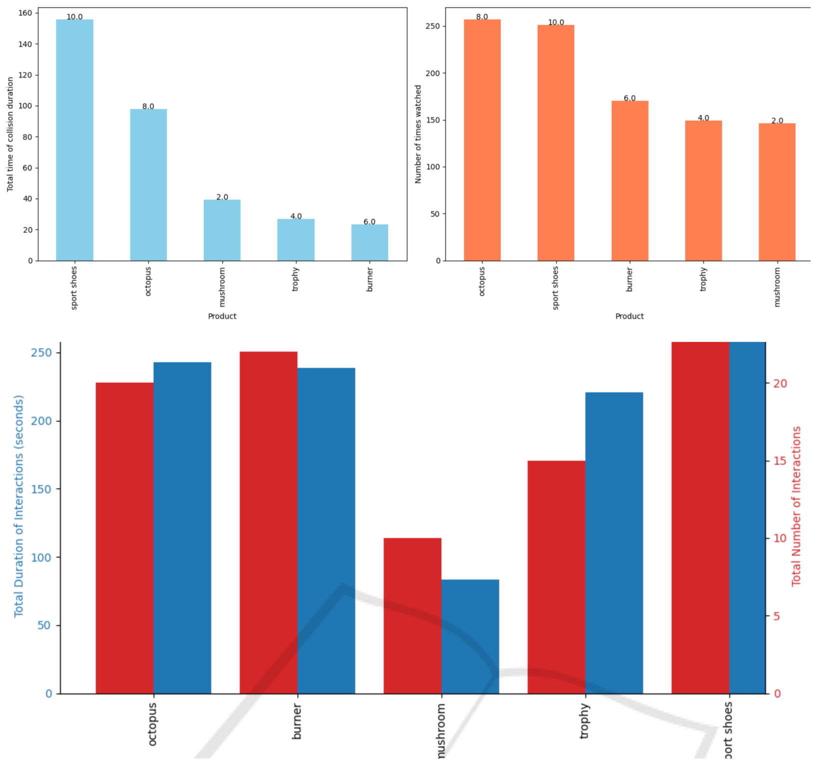


Figure 4: At the top, barplots showing total time (in seconds) and number of times every item was watched. At the bottom, barplot showing total duration of interaction and total number of interactions for each product.

Table 1: Statistics of metrics extracted from teleportation files.

	Mean (M)	Standard Deviation (SD)
First teleportation	14.76 seconds	6.10 seconds
Number of teleportations	17.60	4.36
Attempts before teleportation	2.25	0.40
Time for teleporting	8.47 seconds	2.16 seconds
Teleportation distance	3.74 meters	1.70 meters

4.3 Participants Behaviour in the Large Environment

In this section, we will address the analysis of the recorded data with the same approach as in Section 4.2. First, we will present statistics of some metrics related to teleportation within the virtual environment, which was the main novelty compared to the previous environment. Table 1 shows the results obtained for the metrics we will discuss. To successfully perform the first teleportation, participants required an average of M = 14.76 seconds, with an SD = 6.01. This means they needed about 15 seconds on average until they correctly formed the gesture with their hand, pointed to a valid location to teleport, and joined their thumb and index finger. Furthermore, the time to successfully complete a teleportation took users an average of M = 8.47 seconds, SD = 2.16. Although there may be false negatives in the data (for example, the HMD's hand tracking system detecting the pointing gesture for teleportation when the user's intention is different) or the dimensions of the teleportation zones being a factor, we consider the average teleportation time to be moderately high. While it's true that the teleportation distance is slightly high (M = 3.74 meters, SD = 1.70 meters), which may also have influenced a longer teleportation time as it requires more time to aim, it suggests that participants opted to move a greater distance with each teleportation. Lastly, we observe that the number of teleportation attempts before successfully completing one has an average of M = 2.25 attempts, SD = 0.4 attempts.

In terms of eye tracking data, Fig. 5 displays the number of times products in a section were viewed. It also includes the times information signs of the sections, which guided the user (approximately 15% of

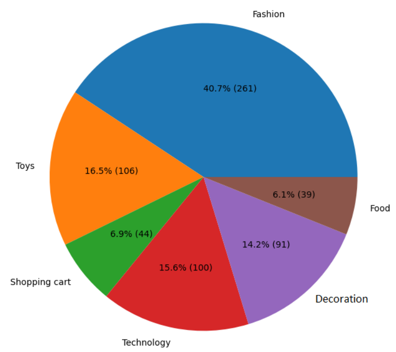


Figure 5: Number of times that each section drew the attention of participants.

the total), and the products added to the shopping cart were viewed. As expected, the three most viewed sections were those of the initial searches; however, the fashion section stood out. Moreover, the technology section was also one of the most popular during the last step of free exploration of the environment, with 60% of users choosing a product from this section. This environment also included many computer-designed 3D models. Nevertheless, among the scanned objects, both the sport shoes and the octopus teddy were added to the shopping cart 4 times each, and the trophy 2 times, maintaining moderate interest among the participants. The rest of the scanned objects, except for the trophy, were not included in the environment.

Regarding product interactions, participants interacted with 18 of the 24 products included, with the least interaction in the food section. It's notable that the average number of interactions in this environment was M = 5.2, SD = 1.23, which is about half of that in the small environment. On the other hand, the average time spent interacting with products per participant was M = 71.06 seconds, SD = 19.0. Compared to the small environment, where the average time was M = 117.16 seconds, SD = 16.02, there was a 39% decrease in interaction time. These data suggest that interaction was primarily limited to the first product chosen by the user in each product search.

4.4 Questionnaire Answers

The post-experiment questionnaire completed by the users can be consulted in the README of the repository referenced in Section 3.4. We used questions from questionnaires present in the literature on User Experience (UEQ), Immersion (SUS) and Motion Sickness (MSAQ). Most of the questions were formulated following a Likert scale from 1 to 5.

4.4.1 VR Shopping Usage

The participants significantly preferred inspecting products as 3D models rather than 2D images (M = 4.0, SD = 0.63), positively influencing their purchase intention (M = 3.9, SD = 0.83). Thanks to the inspection in VR using 3D models, participants indicated that their purchase intention would change after examining an object in VR as opposed to just seeing it in 2D images (M = 4.1, SD = 0.54), noting the majority of imperfections present in the sport shoes that could be hidden with 2D images. Despite the data collected, the majority preferred shopping in an environment similar to the large environment (M = 1.7, SD = 0.46).Despite the data collected, the majority preferred shopping in an environment similar to the large environment (M = 1.7, SD = 0.46). Regarding the usefulness of monitoring user activity to infer their preferences and tastes, 8 out of 10 participants added the product they wanted from the same section they responded to in question Q24.

4.4.2 Immersion and Motion Sickness

Participants indicated very low levels of general malaise (M = 1.6, SD = 0.66), fatigue (M = 1.9, SD = 0.94), and dizziness (M = 1.5, SD = 0.67), suggesting that the color palette of the environments and other graphic aspects are comfortable for users in not very long shopping sessions. Regarding immersion, participants felt quite immersed in the shopping environments (M = 4.1, SD = 0.54), and time passed quickly during the experiment (M = 4.1, SD = 0.54). However, they were neutral in feeling like they were in a physical store (M = 3.0, SD = 0.45).

4.4.3 User Experience and Usability

Participants found the environment moderately easy to understand and use (M = 3.7, SD = 0.9), and thought it would be so for most of the public (M = 3.6, SD = 0.92). Regarding the shopping cart, participants equally valued adding products themselves (M = 3.6, SD = 0.92) or through the user interface button (M = 3.6, SD = 0.8), while opinions regarding the use of gravity in the large environment varied (M = 3.0, SD = 1.18). Additionally, users moderately positively rated the ease of moving through the large environment using teleportation (M = 3.7, SD = 0.64) as well as the fluidity and naturalness of interactions (M = 3.5, SD = 0.92), where the variety of responses was slightly higher. Finally, participants preferred interacting using hands freely (M = 3.5, SD = 0.81) over the use of controllers (M = 2.6, SD = 0.49).

5 CONCLUSIONS

Based on the presented results, we can conclude that realistic products appear to influence both purchase intention and the time and frequency with which a user interacts and inspects them. The data shown in Section 4.2 indicates that the most viewed products and those with which there was more extended interaction were the ones most added to the shopping cart. We also identified aspects to improve in future shopping environments, such as the use of colliders that allow for more consistent data recording, as seen in the case of the wood burner.

We also observed differences between a large and a small shopping environment. Although participants generally preferred the large environment, possibly influenced by its novelty and the use of teleportation, we found that a small environment encourages interaction. While only 10 seconds were needed in the small environment to visually scan the scene and start interacting, it took users in the large environment on average four times more seconds to begin interacting due to needing to become accustomed to teleportation. However, user preference for a large environment indicates flexibility in configuring a virtual shopping environment, focusing more on product interaction or a thematic store that gamifies the shopping experience and makes it more enjoyable for the user.

Additionally, participants positively rated the interaction mechanisms included in the environment in the post-experiment questionnaire responses, resulting in averages close to 4 on the presented Likert scales. Also, the monitored data showed that about 85% of the time spent by each participant in the experiment steps was used to interact with objects, indicating that the interactions were pleasant and natural for them to continue repeating. Moreover, environment navigability was perceived as simple, although the data shown in Table 1 indicate somewhat elevated times, as participants needed more time to aim at a greater distance. Lastly, the utility of monitoring user activity in these virtual environments has been demonstrated, corroborating that the objects in which the user shows the most interest are those added to the cart, corresponding to the section answered in question 24 of the questionnaire.

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