Immersive VR for Real Estate: Evaluation of Different Levels of Interaction and Visual Fidelity

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***Abstract* - This work presents a study on how an immersive virtual environment's level of interaction and fidelity can affect the quality of experience (QOE) in a real estate context. Four versions of the virtual space were created with the level of interaction and the level of fidelity varying between them. The QoE dimensions considered in this work are user satisfaction, lighting quality, interior space quality, and interaction features. The sample comprises 28 participants, of which 21 are men and 7 are women, aged between 18 and 29 years. Results show that, overall, the level of fidelity is more relevant when the level of interaction is low, assuming the movement around the apartment is statistically higher in high-fidelity experiences.**

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1. Introduction

VR is one of the top technologies that has the potential to bring innovation and leverage to the real state sector [33].

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In fact, several factors can make it difficult to visit the real estate in person, from possible limited mobility, the characteristics of the space, or other external factors such as the fact that the space is still under construction or even unexpected events such as the CoViD-19 pandemic. The nature of Virtual Reality (VR) technologies can play a critical role in this application field due to the possibility of recreating real environments in a virtual format and allowing users to experience them from a first-person perspective.

In addition to other possibilities, a Virtual Reality (VR) environment allows the user to move freely and observe its details or modify any space element. Such will enable users not to be conditioned by inherent limitations that an actual visit to a property brings (e.g., availability of the real estate agent or the physical space or transportation constraints such as international travels just to see a space). Thus, the interested party may prefer to visit the space virtually in some cases.

Although it is already possible to visit a space through different devices and formats, most digital media cannot provide a faithful interaction with the real estate space as if it was an actual visit. Most of the existing solutions are based on websites or mobile applications where the potential client only has access to pictures and small videos, which often do not represent the space's full potential. These limitations can leave potential clients with uncertainties regarding different property elements, such as building materials or space dimensions.

Using an immersive VR setup to represent a virtual space, the visitor can, from any location, explore the property freely and analyse its characteristics in a more natural way than when viewing pictures. Although many commercial entities, like EyeSpy360 [9] or Matterport [20], have developed a marketing strategy using VR technologies mostly based on 360º pictures to represent a real estate space, this format still presents limitations regarding visitors' interactions and the visual fidelity of the real place. Moreover, to the best of our knowledge, the literature on evaluating the impact of immersive VR factors, such as the level of interaction and visual fidelity, in real state VR applications is scarce and the lack of this understanding might compromise the effectiveness of the VR applications (to be) developed.

To tackle the above-mentioned gap, this work developed a VR application focused on a real state case study on how a virtual visit's level of interaction and level of fidelity (visual fidelity) can influence the user's quality of experience regarding user satisfaction, quality of lighting, notion of quality of the interior space, and interaction features. Such will contribute to the body of knowledge by determining how interaction and fidelity can influence a virtual visit and how both complement each other, putting forward guidelines on how one can take full advantage of VR technologies when applied to the real state.

2. Related Work

VR allows its users to interact with the Virtual Environment (VE) where they are, freely modifying and manipulating the elements of that same space. The ability to replicate multisensory stimuli, higher capability for interactions in multiple stages of product development and usage and the contextualisation of product experiences make VR the type of media to have the most impact when compared to others [29], [31], [35]. Applied to the real state sector, a study [14] within the scope of understanding the impact of VR on marketing communication exposed 150 random participants (75 men and 75 women) to three different presentations (photo, video, and VR) and the results have revealed that the VR scenario experiment outperformed the other two technologies, suggesting the potential to offer a better experience than other technologies.

2.1. Real Estate VR Apps

There are several VR solutions based on 360 videos, such as 360 VR Real Estate by Case3D [5], iStaging [17], Roundme – Virtual Tour Online [28], EyeSpy360 - Virtual Tour Software [9], Kuula [19], and Immoviewer [16], which are described below:

- 360 VR Real Estate by Case3D [5] allows the user to take a virtual tour by visualising 360-degree photographs around a property using any mobile VR headset (Samsung VR Gear, Google Cardboard, or their custom branded VR glasses). Although intuitive and straightforward, it does not allow any type of interaction with the property other than movement via teleportation.
- iStaging [17] is a company focused on creating, building, editing, and sharing virtual experiences through different platforms and templates to turn any real-life environment into a virtual space that customers can visit through the iStaging website, using both immersive and non-immersive VR technology. Besides making any space virtual, it is also possible to add 3D elements to it.
- Roundme – Virtual Tour Online [28] allows you to capture and publish panoramic tours. This application can turn panoramic photos into 360-degree tours of any property. The software creates footage compatible with various devices, such as tablets, smartphones, and computers. Furthermore, it allows the creation of an online VR portfolio by embedding multiple photos on a website.
- EyeSpy360 - Virtual Tour Software [9] allows you to create 360º virtual tours by uploading panoramic photos taken with a 360º camera to the software. The resulting interactive images are compatible with smartphones, tablets, VR headsets, and computers. Publishing the tours online and simultaneously sharing the virtual tour among multiple viewers is a possibility that allows real estate agents to display property to multiple interested clients.
- Kuula [19] is aimed at real estate professionals looking for affordable and straightforward software. Kuula uses WebXR as a VR resource and can be used with most of the most popular HMDs, such as Oculus and Google Cardboard. Through it, it is possible to share links to posts and tours with friends, colleagues, or clients without installing any application [19], using a simple Google Cardboard or an HMD such as Oculus Rift. Virtual Tour Pro from 3DVista allows the creation of virtual tours in which an interaction between the guide and guests is made. The host can communicate with guests during this guided tour through a video call. It is still possible to provide information about furniture and other decorative elements [2].
- *Immoviewer* [16] allows the creation of 360º virtual tours and floor plans and automated real estate video content. Although it is not possible to customise the space, several ways to view the property are available. While in "3D blueprints" mode, there is an interface that makes it possible to hide parts of space that we do not want to see or look for by specific division.

Nevertheless, there are also VR real state-oriented applications such as Matterport [20] Softweb Solutions Inc’s VR application for real state [1], the IKEA solutions [24], [30], and Idealista [26]

As for Matterport [20], it facilitates the creation, customisation, and publication of a 3D digital environment from any physical space. Matterport stands out for its "dollhouse" viewing feature and floor plan view, ideal for gaining insight into real estate space before moving around inside the property.

The Softweb Solutions Inc VR application for real estate business [1] is compatible with the Oculus Rift headset, where the potential customer can move freely around the house. Besides the application being immersive, it offers an interface in which it is possible to interact using the controller, changing the distinct elements of the house (furniture, colour, wall, and floor texture).

The VR Store – IKEA [30], a company specialising in selling home furniture and has been developing ways for its customers to choose and combine different furniture before buying. IKEA started using augmented reality (AR) to present its products to achieve this. Using the AR mobile app and the smartphone camera, users can see how the furniture they want to buy fits into their own home, allowing users to move, rotate and change the furniture and its colours. Furthermore, the application allows a VR headset to interact with the virtual space. Its interface allows users to choose furniture, decorations, and utensils from a catalogue and bring them to the VR environment, thus creating a personalised space with these elements without buying them. Also by IKEA, the IKEA VR Kitchen Experience, created in 2016 by IKEA [24], makes it possible to change kitchen elements and simulate domestic activities using different cooking utensils available on the IKEA online store. While the VR Store – IKEA [30] is not an application designed for the sale of real estate, the clients can experiment with the furniture with real-life proportions in a virtual space. The user can choose the living room shape and decorate it with IKEA products. The application's interface allows the selection of furniture, decorations, and utensils (the price is indicated) to fill the virtual space. Unlike the Softweb Solutions prototype, it is compatible with two distinct HMDs (HTC Vive and Oculus Rift). Applications using VEs create more complex environments than those developed by 360º images. However, developing these types of applications usually requires much more work and time.

Idealista [26] allows the user to have a virtual tour in some advertisements. In technological terms, the visit can be done in two different ways, 3D models and 360-degree photographs, where it is possible to combine both. In the fully immersive 3D model, the user can move freely through the property's rooms. To achieve this, the Idealista team combines high-quality photography and laser measurements. Another way to explore a property is through 360-degree photographs of points of interest of the said property, in which the user can teleport from one point of interest to another. Finally, these two possibilities can be merged, where the user can move freely and interact with 360-degree photographs. Using any mobile VR headset, the results can be presented in non-immersive VR or immersive VR.

When comparing the 360-based VR applications to those based on 3D VEs, these applications are pretty limited in space customisation and movement around the property. However, its implementation is much cheaper, simpler, and faster. Considering these factors, the application that stands out is EyeSpy360 - Virtual Tour Software [9]. Although there is no space customisation, unlike applications like Virtual Home Staging, this application is compatible with most mobile devices and allows for the use of HMD. Although teleport is not part of the features, the user can move to pre-defined locations in the VE. The notion of virtual space becomes clear from the beginning of the experiment when using the mini-map and the 3D model. These features are only available by Immoviewer and Matterport. Virtual Tour Pro is the only one that makes it possible to schedule guided tours of the real estate space and interact with guests via video calling integrated into the application. Additionally, some examples of how VR can be implemented in the Real Estate sector will be presented and which conditions are used in their respective case study.

2.2. VR Factors that Affect the Virtual Experience

There are some factors that can affect the VR experience. This work focuses on the interaction level, the fidelity of the VE, and the Quality of Experience (QoE) dimensions of user satisfaction, lighting quality, VE quality, and interaction experience.

The interaction level of one VE can be defined as the assortment and quality of the user's interactions during the virtual experience. This includes moving around the scene, identifying an object, moving it from one place to another, or modifying that same object [11]. Since a VR system reproduces sensor-motor contingencies presented in our interaction with the real world and our movements [12], these interactions can make the experience more similar to a real-life estate visit. Therefore, a VR system with these characteristics can turn a virtual experience into a more credible one when the objective of the VE is to represent and simulate an authentic experience.

Fidelity is another parameter that can be used to evaluate VR experiences and measures objectively how well the simulation represents the real world [13], [22]. Environments that offer higher levels of fidelity are more likely to provoke a higher sense of "being there" in the scene [6]. In addition, visual stimuli can trigger different user responses. Therefore, fidelity can also affect how users interact in the virtual environment [21].

QoE can be influenced by different factors related to the user's perception of the equipment used during the experiment. The resolution, rendering device, participant gender, familiarity with the VR content, and interest in VR videos are factors used to measure the QoE [4]. Measuring the response of a human in any environment. User satisfaction is a QoE dimension that can be influenced by factors such as immersion and social interactions [15]. It is utilised to evaluate VR simulation/training systems and user experience, specifically user interactive learning and operation efficiency [7]. The user satisfaction during VR experience can be related to the realism and interaction level of the experience and promotes the development of cognitive capacities [34]. These factors are significant when the objective is to build a simulation or a specific representation of an environment. Also, the illumination quality of the VE and its influence on the user experience were studied decades ago [3]. The implementation of real-time illumination and the addition of reflections and shadows represented realistically already proved the improvement of the user experience [32]. The illumination quality level can modify how the VE elements are presented and make them more realistic. For example, one of the real-time illumination potentials allows the VR system to generate shadows and reflections of the user body [23].

3. Methods

The adopted methodology consists of a quasi-experimental design, cross-sectional study with a quantitative approach. The sampling technique used was the non-probabilistic convenience sampling procedure.

3.1. Sample and Experimental Design

The sample consisted of 28 volunteer participants, of which 21 were men and 7 were women. They had ages between 18 and 30 years ($M = 22$, $SD = 3.448$). The participants were mostly students, and none had previous knowledge about the study. At the beginning of the experiment, participants were presented with a document to express their willingness to participate in the study. The sample was divided into two groups of 14 participants, one group focused on the environment with a high-fidelity level (Fig. 1 - top), and the other focused on the environment with a low-fidelity level (Fig. 1 - bottom), and each experiencing both low and high interaction environment. A between-subjects experimental design was used between the two groups to understand the impact of the interaction level under different fidelity levels. A within-subjects experimental design was used to understand the impact of the fidelity level under different interaction levels. Both types of experiences took place in the same real space, and the order of experiences relative to different levels of interaction was counterbalanced.

3.2. Variables

The study's independent variables were the interaction level and the fidelity level. Regarding the interaction level, there are two levels: low and high. The low-interaction level environment only allows the visitor to use the teleport function to move around the apartment and open/close its doors. The high-interaction level environment allows the visitor to customise and change the position of the different furniture elements. As for the fidelity level, there are also two levels: low and high. While the low-fidelity level environment only benefits from outdoor lighting with flat shading, the high-fidelity level environment also features lighting probes that allow high-quality lighting effects that allow baked lights to interact with moving objects. A post-process layer was also used to make the apartment visually appealing.

Figure 1. Comparison between the high-fidelity level (top) and low-fidelity level (bottom)

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The dependent variable of the study was QoE, composed of the following subscales:

- User Satisfaction (general impression about the apartment);
- Lighting (of the elements of the property);
- Quality (of the interior space: notion of location and layout of spaces, notion of dimensions, realism, and details of the apartment);
- Interaction (movement around the property/ apartment customisation).

These variables allow understanding if changing the interaction or fidelity levels impacts the users' experience.

3.4. Materials

Considering state of the art, it was considered necessary to create a VR application that facilitates the analysis and evaluation of this technology as a confirmation of its relevance in this context. Therefore, a representative VE of a T1 apartment with a bedroom, a kitchen, a living room, a bathroom, and a balcony was created. In addition to the development of the empty property, a furnished version was also created to have a better sense of space and acknowledge the impact of moving elements on the apartment's visualisation and its user's movement. Since the users may not be familiar with the technology, developing an interface accessible to any user was considered pertinent. Therefore, an interface was created based on a single menu (Fig. 2 -top), activated by a single controller, accessible from anywhere in the apartment. One controller opens so-called customisation menu, while the other controller allows the user to teleport around the apartment floor (Fig. 2 - bottom).

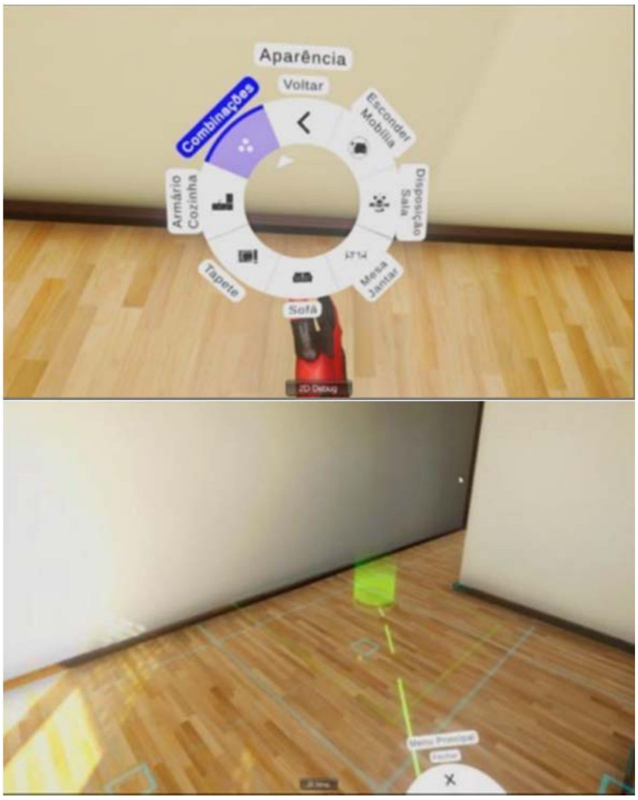

Figure 2. Controllers Interface: customisation menu (top) and teleport (bottom)

Concerning the levels of interaction, two versions of the VE were created, one without any customisation and the other with several ways to interact and customise the space. The low-interaction level version has no furniture and only allows the user to move through the apartment and open and close the doors from different divisions. In addition to the movement through the space, the high-interaction level version allows to furnish the flat and modify the materials of the property itself and its elements, both in terms of their position within the property and the materials that constitute them. The developed application was adapted for experimental purposes. Four versions were created for the VR environment to be prepared for different conditions, which differed by their level of interaction and fidelity.

The hardware, software, and peripheral resources used to carry out the study were a Desktop PC (CPU Intel Core i7-8700K, RAM 16 GB, NVIDIA GeForce GTX 1080), the Unity game engine, and an HTC Vive setup.

3.5. Instruments

In addition to the sociodemographic questionnaire, a questionnaire with a 5-point Likert scale was used. This questionnaire was based on the study mentioned above [27], in which a non-immersive VR real estate environment was developed for a similar purpose. This questionnaire has categories that allow measuring the user experience with the lighting of the elements of the property, quality of the interior space (notion of location and layout of spaces, notion of dimensions, realism, and details of the apartment), interaction (movement around the property) and satisfaction (general impression about the apartment). Since the environment with a low-interaction level does not allow the customisation of the environment, only the high-interaction level questionnaire has questions related to this functionality. Thus, the questionnaire is divided into three parts: Part A, aimed at experiences that took place in an environment with a low-interaction level, Part B, aimed at experiences that took place in an environment with a high-interaction level; and Part C, gathered the user preference about the variables between the two levels of interaction.

3.6. Procedures

Several mandatory procedures were established to ensure a proper evaluation, ensuring the users go through all the application features. In addition, a guide with different steps was created to assist the user in this context.

To understand the number of participants who felt comfortable with the equipment, they were asked if they knew how to use the VR equipment and how it worked, using a scale from 1 to 7, in which 1 corresponds to "I totally disagree" and 7 "I totally agree.

All experiments were performed in a laboratory environment where the illumination, sound isolation, temperature and smells were controlled. The experiment consisted of two similar trials, each using a different level of interaction environment, respectively low and high. The 28 participants were received at the experiment site and began filling out a consent form and a sociodemographic questionnaire. Initially, participants were instructed on how to equip and adjust the HMD, use the controllers, move through the VE, and access the menu. Then, the participants were equipped with the HMD and the respective controllers. After finishing the VR experience, in both environments with different interaction levels, the participants completed Questionnaire C. All experiments took place within 17 to 30 minutes, and none took place simultaneously.

Some users may not be familiar with VR equipment or how to interact with the environment. This situation can compromise the project evaluation and make the experience negative. Therefore, to ensure that the user feels comfortable using the VR equipment and takes advantage of all the application's features correctly, a tutorial was developed so users could learn how to use all the features before visiting the virtual property. The tutorial was developed by dividing it into two parts. In the first phase, users will learn to move around the virtual space using teleport and manually interaction with two different objects: a grabbable sphere and a door. In the second phase, it was also possible to customise the different objects in terms of their colour, texture and arrangement in space using the UI.

3.7. Statistical Procedures

All statistical tests were performed in IBM® SPSS® Statistics 27 software, and the significance level was maintained at 95% (alpha level of 0.05) for all statistical tests. Non-parametric tests were used to compare the different conditions since the values did not follow a normal distribution (Shapiro-Wilk test, $p < 0.05$). The shape of the distribution of differences was not symmetrical. As such, Sign Tests were used to compare values within subjects and Mann-Whitney U Tests for comparing values between subjects.

4. Results

Tables 1 and 2 present the mean and median results for all experimental scenarios, showing both levels of fidelity and interaction by the dependent variable.

Table 1. Descriptive statistics results for the Low-Fidelity level environment and both levels of interaction by the dependent variable

Dependent Variable	Low-Interaction Level				High-Interaction Level			
	M	***SD***	***Mdn***	***IQR***	***M***	***SD***	***Mdn***	***IQR***
User Satisfaction	4.514	0.420	4.600	0.650	4.629	0.322	4.700	0.700
Illumination	4.839	0.348	5.000	0.188	4.857	0.213	5.000	0.250
Space Arrangement	4.514	0.420	4.600	0.650	4.629	0.322	4.700	0.700
Dimensions	4.586	0.277	4.600	0.400	4.743	0.253	4.800	0.300
Realism	4.524	0.448	4.500	0.670	4.691	0.357	4.670	0.330
Details	4.482	0.373	4.500	0.438	4.529	0.320	4.500	0.550
Navigation	4.811	0.215	4.835	0.330	4.787	0.211	4.670	0.330
Customisation	—	—	—	—	4.666	0.453	5.000	0.670

Table 2. Descriptive statistics results for the High-Fidelity Level environment and both levels of interaction by the dependent variable

Dependent Variable	Low-Interaction Level				High-Interaction Level			
	M	***SD***	***Mdn***	***IQR***	***M***	***SD***	***Mdn***	***IQR***
User Satisfaction	4.629	0.383	4.700	1.188	4.714	0.357	4.800	0.950
Illumination	4.929	0.117	5.000	0.188	4.929	0.153	5.000	0.000
Space Arrangement	4.629	0.383	4.700	1.188	4.714	0.357	4.800	0.950
Dimensions	4.714	0.455	5.000	0.550	4.714	0.398	4.900	0.400
Realism	4.429	0.605	4.500	0.918	4.501	0.581	4.670	0.918
Details	4.196	0.614	4.250	0.875	4.314	0.548	4.400	0.938
Navigation	4.976	0.088	5.000	0.000	4.714	0.450	5.000	0.585
Customisation	—	—	—	—	4.453	0.608	4.670	1.000

Table 3. Results of the Sign Test regarding the impact of changing the interaction level on the dependent variables for each of the fidelity levels. Means and medians of the difference between the interaction levels

Dependent Variable	Low-Fidelity Level			High-Fidelity Level		
	M	***Mdn***	***p***	***M***	***Mdn***	***p***
User Satisfaction	0.114	0.200	0.549	0.086	0.000	0.453
Illumination	0.018	0.000	1.000	0.000	0.000	1.000
Space Arrangement	0.043	0.000	0.289	-0.086	0.000	1.000
Dimensions	0.157	0.100	0.180	0.000	0.000	0.727
Realism	0.168	0.165	0.070	0.072	0.000	1.000
Details	0.046	0.050	1.000	0.118	0.050	0.581
Navigation	-0.024	0.000	1.000	-0.262	0.000	0.063

Table 4. Results of the Mann-Whitney U test regarding the impact of changing the fidelity level on the dependent variables for each of the interaction levels. (significant difference)*

Dependent Variable	Low-Interaction Level			High-Interaction Level		
	U	***z***	***p***	***U***	***z***	***p***
User Satisfaction	113.000	0.706	0.480	115.000	0.806	0.420
Illumination	102.000	0.232	0.816	118.000	1.120	0.263
Space Arrangement	129.500	1.590	0.112	113.500	0.810	0.418
Dimensions	133.500	1.682	0.093	105.500	0.359	0.719
Realism	93.000	-0.238	0.812	82.500	-0.750	0.453
Details	69.500	-1.330	0.184	77.000	-0.977	0.328
Navigation	140.500	2.479	0.013*	104.500	0.329	0.742
Customisation	—	—	—	78.500	-0.961	0.337

Table 5. Results of user preference (questionnaire C) where a higher value indicates a preference for the high-interaction condition

Dependent Variable	Low-Fidelity Level				High-Fidelity Level				Mann–Whitney U		
	M	***SD***	***Mdn***	***IQR***	***M***	***SD***	***Mdn***	***IQR***	***U***	***z***	***p***
Environment	4.310	0.929	4.667	1.167	4.262	1.126	4.667	0.917	95.000	-0.145	0.884
Illumination	2.381	0.885	2.333	0.583	2.667	1.513	2.500	2.333	89.000	-0.417	0.676
Realism	3.357	1.066	3.500	1.250	3.119	1.167	3.000	1.500	83.000	-0.691	0.489
Interaction	4.548	0.517	4.667	0.667	4.524	0.713	4.833	0.583	93.500	-0.216	0.829
Overall	3.649	0.469	3.833	0.792	3.643	0.822	3.667	0.542	97.500	-0.023	0.982

The results regarding the impact of changing the interaction level on the dependent variables for both high-fidelity level and low-fidelity level can be seen in Table 3. Analysing the results of the Sign Tests, there was no statistically significant median increase in any of the dependent variables when subjects experienced low-interaction levels compared to high-interaction levels for both fidelity levels.

A Mann-Whitney U test was performed to determine if there were differences in the dependent variables when changing the fidelity levels for each level of interaction (Table 4). In the Low-Interaction level environment, distributions of the navigation scores for low-fidelity and high-fidelity levels were not similar. The scores for the navigation experience under a low-fidelity level (Mdn = 4.835) were statistically significantly lower than for high-fidelity level (Mdn = 5.000), U = 140.500, z = 2.479, p =0.013. The score of the remaining dependent variables was not statistically significantly different. In the High-Interaction level environment, the score of the dependent variables was also not statistically significantly different.

Table 5 shows the results of questionnaire C, which indicate the preference for the level of interaction where a higher score means the user preferred a higher level of interaction in the respective dependent variable. This is for both low and high-fidelity levels of experiences. A Mann-Whitney U test was performed to determine if there were differences in the score of the dependent variables between low-fidelity level and high-fidelity level, i.e., if the user preference for an interaction level changed depending on the fidelity level. Distributions of the low and high-fidelity levels scores were similar, as assessed by visual inspection. The scores were not significantly different.

5. Discussion

This paper aimed to evaluate the impact of different levels of interaction and visual fidelity on QoE dimensions of user satisfaction, lighting quality, the quality of the interior space and interaction features. For this purpose, a VR application was developed to support the experimental study. There are four versions of it: high fidelity with low and high levels of interaction and low fidelity with both low and high levels of interaction.

Regarding user satisfaction, changing the level of interaction or the level of fidelity showed no significant impact on the QoE scores. This may indicate that there is no need to create highly well-represented environments or interactions to ensure participant satisfaction. In a Marketing context, if the commercial entity wants to adopt a more economical strategy and not develop environments with a high-interaction or high-fidelity level, there are no indicators that the customer will be dissatisfied.

The illumination obtained the highest rating in all four scenarios but was not significantly affected by the level of interaction or fidelity of the experience. The lowest result (*M*= 4.84) was verified in a low-fidelity level environment with a low-interaction level. It was expected that because low-fidelity environments did not have lighting probes or post-processing camera filter, their scores would be lower than high-fidelity experiences. This is because additional lighting has been processed to match the interactions of light rays with objects in the scene, creating a more faithful environment. However, this difference was not found, and there were no statistically different scores.

None of the interior space sub-scales quality showed statistically significant differences in either comparison. This may reveal that even if the VE is not very visually appealing in the low fidelity condition, the client can consider it realistic and credible if this environment provides a sufficiently satisfactory range of interactions. This result may also indicate that the level of the interactions does not compromise the perception of interior quality perception.

The Interaction variability showed no statistically significant differences regarding the impact of changing the interaction level is neither the low-fidelity environment nor the high-fidelity environment.

On the other hand, the results of the fidelity study demonstrate that when the level of interaction is low, navigation is statistically higher in high-fidelity experiences, with a median increase of $p = 0.013$.

The other interaction subscale, customisation of the real estate space and its elements, did not significantly differ. The results indicate that even in environments with low-fidelity levels, the customisation of the property and its elements provides a very positive experience.

Regarding questionnaire C, except illumination, all the other dependent variables have scores showing that the users preferred a higher level of interaction, both in low-fidelity and high-fidelity environments. However, in the case of preference for the level of interaction concerning illumination, the scores show that there was no preference for either low or high interaction. Bearing in mind that illumination was the QoE variable that obtained the highest rating in all four scenarios above, this could imply that users were equally satisfied with the environment illumination regardless of the level of interaction.

This study indicates that VR technology can be implemented in the real estate industry and be part of a marketing strategy, even if the VE does not have a high-fidelity and/or high-interaction level. Furthermore, depending on the promotional strategy adopted, it is possible to shape the way elements of the VE are presented to match the objectives of the promotional strategy.

Regarding the promotional strategy used, as this type of experience is accessed from a digital medium, it will not make sense to promote it through print media. As the internet is a new marketing channel [25], horizontal marketing can be used in the real estate sector to promote a property digitally.

Implementing ways for the customer to share both their experience and respective evaluation with other customers allows for the creation of an economical and credible advertising strategy by the ideals of Marketing 3.0 [18].

By implementing the application on the internet, there are advertising benefits and the possibility of using the participant's behaviour to improve further the experience offered. For example, it is possible to save and later compare the behaviour during a customer visit with other customers to create a segmentation strategy [10] dedicated to different types of customers, using Inbound Marketing strategies [8] without the need to invade the client's private space or run the risk of being intrusive (outbound marketing). Analysing the results of this study, it appears that the level of interaction in a high-fidelity environment does not significantly influence the quality of the interior space. Therefore, if one develops a high-fidelity virtual real estate environment, there is no need to spend time and resources developing a high-interaction level to improve interior space quality or customer satisfaction. So, if the available budget is not enough to guarantee a VE rich in interactions and ways to personalise it, the results of this study indicate that it is valid to choose a high-fidelity environment without a high-interactions level to guarantee the quality of the experience.

Comparing the results of this study with results of a previous study in which a visit to the real property was compared with a virtual visit, from a non-immersive VR system and in which a Likert's scale was used for the , it is possible to verify that the use of VR increases the quality of the real estate experience when compared to experiences made through non-immersive VR systems. The quality of the interior space, the movement around the apartment, and the general impression about the apartment showed higher averages in the VR visit in all analysed results, even using environments with low-fidelity and low-interaction levels. It is important to note that in this comparison, the non-immersive VR study [27] does not provide a way to customise the property and its elements, unlike the application developed for this paper, which can influence the result of this comparison when the results of high-interaction level experiences are used to personalise the space visited.

6. Conclusion

This study evaluated how the level of interaction and fidelity of a VR environment can influence the virtual visit to an apartment, namely, the quality of its lighting, interior space, interaction, and the level of satisfaction between the types of experiences. Four virtual versions of a real estate environment were used, with different fidelity levels and interaction. Comparing the four versions of the experience, the level of fidelity is more relevant when the level of interaction is low.

When compared with another study [29] in which a non-immersive VR system was used, both movements around the apartment, the notion of location and arrangement of the elements of the property, notion of dimensions, apartment details, and general impression of the apartment obtained higher ratings in this study. This indicates that using immersive VR technology in the promotional strategy of a real estate environment can bring an advantage compared to non-immersive reality systems. Although, compared to some of them, there may be economic or resource disadvantages, as demonstrated by the results of this study, it is possible to optimise the application used to reduce these costs.

The characteristics of a property that an individual looks for during a real estate visit vary depending on their needs. These needs can be met by tailoring the experience to them, whether these needs are revealed before the visitor or through the customer's choices during a visit. Therefore, it is recommended that to ensure that the customer's needs are met without spending an excessive number of resources, document preferences and selections that the participants create during the experience, namely which elements of the property were more modified or which of the customisation elements they used to decorate the apartment and use that information to optimise later visits.

Since the external environment of the property can often influence the customer's choice, it would be interesting to measure how the factors that constitute the property's external space, such as noise or visual pollution, can influence the experience. Furthermore, regarding the economic factor, it would be interesting to develop a way to inform the participant about the monetary costs of both the property visited and the different furniture that are presented to understand what impact these factors would have on the participant's choices.

Some barriers limited the development of the study. One of them was that it occurred during the COVID-19 pandemic and, as such, precautions and safety measures were required. In addition to having to sanitise their hands, HMDs, and controllers when entering and leaving the experiment site, they had to wear a mask during their stay at the site, which may, in some way, have influenced the study.

Initially, the aim of the study included experimenting in a real-life estate environment using potential clients and comparing the real visit to the property with the virtual visit. Due to the pandemic, this was not possible. Future work intends to broaden the study to a larger sample with real potential clients and study the real-life visit versus the virtual visit mentioned above.

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