Usability and Sense of Presence in Virtual Worlds for Distance Education: A Case Study with Virtual Reality Experts

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Abstract: This case study presents a virtual reality experts' evaluation of a desktop-based virtual world developed towards distance education, under the perspectives of usability and sense of presence, which are considered factors that can potentially influence learning outcomes. Among the results, data from usability and sense of presence were positively correlated. The sense of presence was achieved, with participants losing track of time while performing the activity. Experts agreed that the virtual world is easy to use and can prepare students for the real-world task. The findings outline positive and negative points that must be addressed in order to optimize the experience of distance education students.

1 INTRODUCTION

Virtual Reality (VR) technology allows the creation of interactive Virtual Environments (VE) in 3D graphics. Applied to education, it allows students to experience subject matter that would be difficult if not impossible through conventional methods, in addition to providing a more stimulating and motivating environment, where learning can be both challenging and fun. These aspects are special factors for those who work alone at home, as is the case of distance education students (Whitelock et al., 2000).

There are different levels of immersion in VR. With the use of Head-Mounted Displays (HMD), such as Oculus Rift or HTC Vive, VR systems can be fully immersive, when the users' field of view is obstructed by the display (Christou, 2010). That is when the stimuli from the physical reality are suppressed, and from the VE are increased. However, besides the need for costly devices, these settings involve high-end computer systems and specific technical knowledge, somehow restricting the widespread use in formal education. Schott & Marshall (2018) add the disadvantage of cybersickness, saying that we are still unable to display fully immersive and believable VE without making a significant number of users feel nauseous.

Virtual world platforms, on the other hand, are desktop-based semi-immersive VR systems, which only require a conventional workstation for use, with interaction provided by a default monitor interface and controlling devices like mouse and keyboard (Christou, 2010). Two known examples are the Second Life and the OpenSimulator (OpenSim), which are user-friendly platforms, with a sizable developing community since the 2000s. Even though unable to provide the same kind of immersive and realistic experience, users can still interact in first or third-person perspective, navigating freely through a VE (Leung, Zulkernine & Isah, 2018). Therefore, it becomes an affordable alternative, especially feasible to be widely used in distance education.

When users are projected in a VE, usually through their avatars, they can have the feeling of "being there", which is called the sense of presence. It refers to the psychological state of experiencing more the VE rather than the actual physical location, or the perceptual illusion that the experience is non-mediated (Lombard & Ditton, 1997). By allowing students to feel authentic, this construct is considered a key feature to ensure the transfer of knowledge from virtual to real world (Dengel & Mäzdefrau, 2018).

Although the sense of presence is usually associated with higher levels of immersion, studies have argued that equivalent ratings can be achieved

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in semi-immersive conditions (e.g. Schroeder et al., 2017). Additionally, Lee, Wong & Fung (2010) found that the sense of presence was significantly and positively correlated to learning outcomes in such settings. In the study of Natsis et al. (2012), it was in the monoscopic viewing condition (semi-immersive) that users achieved better learning outcomes.

Usability, by its turn, is a factor that seems to influence both performance (Schroeder et al., 2017) and the sense of presence in a VE (Chow, 2016). Szczurowski & Smith (2017), for example, explain that failed interactions, which do not match expected results, are likely to have a negative impact on the sense of presence. Consequently, if users lack the intention to engage in interaction with a VE, they will likely feel present in the immediate physical environment rather than in a mediated one. On the other hand, if they find a VE to be useful and feel confident in using it, they will be more willing to suspend the disbelief and allocate attentional resources to the mediated environment (Chow, 2016).

However, although the desktop-based virtual world platforms have been explored for over 20 years, few interface advancements concerning usability (e.g. realism and natural ways of interaction) were observed, aggravating a scenario in which the student is, usually, unfamiliar with the VR technology. Generally, studies focus on investigating the users' perceptions, creating a gap of experts' opinion.

In this sense, the objective of this study is to perform an evaluation of an educational virtual world with VR experts, before applying it with the target audience of distance education students. We believe they can have a more critical look, by knowing the best of what the VR technology can offer, and on the other hand, being aware of its overall limitations and drawbacks. The evaluation is made under the perspective of important aspects for learning in VE (usability and sense of presence), by means of the following research questions (RQ).

RQ1. What is the VR experts' usability evaluation of an educational virtual world?

RQ2. What is the VR experts' sense of presence in an educational virtual world?

Giving that the sense of presence has been associated with a distorted experience of time relative to the outside world; that is, a loss of the track of time (Wallis & Tichon, 2013), a third RQ is proposed:

RQ3. Did the VR experts' lost track of time in an educational virtual world?

Few studies have included those specific variables in the investigation of educational virtual worlds. Ntokas, Maratou & Xenos (2015), for instance, present a usability and presence evaluation of an OpenSim virtual world which simulated a Computer Science scenario. Overall, the results for usability were considered acceptable, and for the sense of presence were high. The authors conclude that the VE contributed with an average improvement of 19.4% of the students' learning, suggesting as future work the investigation of correlations between usability, presence and educational value.

Naya & Ibáñez (2015), by their turn, analysed the experience of young students in a virtual field trip, also based on OpenSim. The objective was testing the viability of the virtual world as a platform for educational activities. Three main aspects were analysed: usability, presence, and learning. The authors conclude that the use of virtual worlds may be limited yet still powerful and thus not negligible.

The difference of this study consists of evaluating these variables (except learning) with a sample of VR experts, adding the temporal dissociation in the investigation of the sense of presence. We consider as VR experts professionals and academics with, at least, one year of experience in developing and investigating the use of VR technology, employing high-tech systems, devices and tools.

2 MATERIALS AND METHOD

This research has an explorative case study design. In the following sections, we present the subjects, the educational activity developed in the virtual world, the instruments and the procedure.

2.1 Subjects

We used a non-probability convenience sampling, composed by 11 VR experts, being 10 (90.90%) male and 1 (9.09%) female, aged 21-32 years (M=25.18, SD=3.34), who are investigators and developers in the MASSIVE laboratory (acronym for Multimodal Acknowledgeable multiSenSory Immersive Virtual Environments) from the INESC TEC, Portugal. Their time of work with VR technology ranges from 1 to 10 years (M=3.00, SD=2.65). They were asked if they have previously used a virtual world platform like Second Life or OpenSim. Five answered yes (45.45%), and only two have used it for development purposes. That is, the majority have just worked with more updated high-tech platforms, such as the Unity engine and 3D Max.

Finally, participants were asked to rate their level of interest in the subject addressed in the virtual world, in a 5-point Likert scale. Five demonstrated a level of interest (45,45%), and four manifested a level of disinterest (36,36%). The remaining two (18,18%) rated themselves in the neutral point of the scale. Thus, the sample is divided regarding the interest in the subject presented in the VE.

2.2 The Virtual World Activity

The OpenSim virtual world is part of the AVATAR Project (Portuguese acronym for Virtual Learning Environment and Remote Academic Work), from the Federal University of Rio Grande do Sul, Brazil. It was implemented the version 0.8.1.1 in client-server mode. With a bandwidth of 100Mbps, it supports a load of approximately 20 users simultaneously. The Singularity viewer, also free, is the software installed on the client-side to render the 3D graphical part, selected due to the compatibility with the native language of the participants (Portuguese).

Focusing on the discipline of Financial Mathematics, the virtual world activity covers the curricular topics of percentage, simple and compound interest. It occurs in a building simulating an accounting firm, populated by automated Non-Player Characters (NPC). They express themselves bodily, tapping on the keyboard at their workstations, and verbally, participating in a textual narrative about the company processes. As one way to evoke a greater level of presence is the use of sound (Whitelock et al., 2000), office-related background sounds are triggered by the avatar's presence throughout the environment.

The 3D objects that compose the scenarios were created in part manually, and in part by importing files from free online repositories. Didactic videos from the Youtube repository were added. The scripts were programmed in Linden Scripting Language (LSL), including one routine to register the time each user spent in the VE.

Students navigate the VE in a third-person perspective, and are given the role of a trainee on the first day of work, having to pass through five offices in order to be admitted. Fifteen objective questions are proposed along the way (a quiz with three questions in each office).

At each office, the student is received by the "chief", who briefly explains the responsibilities of the department, and then requests to answer the quiz, which was developed using the Heads-Up Display (HUD) device (Figure 1 - top). Among the choices of answer, there is the button "Help", which rotates the user's chair to a screen with a short didactic video related to the subject matter. There is also a "Calculator" button to help solving the questions.

After going through the five offices, the student receives the news that he/she has been accepted into the company and can start the internship. Then, is instructed to sit in a workstation, placed in a room similar to a corporate workspace (Figure 1 – bottom), in which is congratulated and receives the total score in the activity. The estimated time to perform the activity is around 40 minutes.

Figure 1: Screen capture of the quiz (top) and the workspace (bottom).

In this sense, the virtual world activity has two main educational objectives for distance education:

1. To provide students with a differentiated fixing exercise, in which they will practice the knowledge acquired in the discipline;
2. To provide students with the opportunity to engage and reflect on the socio-cultural practices of the accountant profession, experiencing the real-world task of being admitted in a company.

The virtual world can be applied to a number of courses with the Financial Mathematics discipline, and with other topics/areas, following the same or a different type of narrative, as for example Human Resource Management or Business Administration.

2.3 Instruments

The following three main instruments were used to collect the data.

1. General Perceptions questionnaire: three 5-point Likert scale questions and three open questions that were elaborated focusing on the overall feedback regarding the pros and cons of the virtual world.

2. System Usability Scale (SUS): ten 5-point Likert scale questions (Brooke, 1996), interweaving positive and negative assertions. We used the validated Portuguese version from Martins et al. (2016).
3. ITC Sense of Presence Inventory (ITC-SOPI): forty-four 7-point Likert scale questions (Lessiter et al., 2001). The items are divided into four dimensions: Ecological Validity/Naturalness (EVN), Engagement (E), Spatial Presence (SP) and Negative Effects (NE). We used a reduced 35 item Portuguese version from Vasconcelos-Raposo et al. (2018).

Given that the sense of presence is related to the sense of losing track of time (Wallis & Tichon, 2013), we also analyse the user's estimated time in the VE, to compare it with the actual time of experience.

2.4 Procedure

Participants were informed about the overall purpose of the study and signed a consent and demographics form. Then, they were individually seated on a workstation with headphones and were explained the actions necessary to perform the activity. They were requested to observe the operation and features of the virtual world, thinking on the practical use by the target audience. Time limits were not established. After the experience, they were asked to answer the instruments in printed format, being requested to consider their expertise in VR technology. Finally, they were thanked and dismissed.

3 RESULTS

The presentation of results is divided by instruments of research. To allow a fast identification of pros and cons (or strengths and weaknesses) the scores are presented in decreasing order.

3.1 General Perceptions

Table 2 shows the results of the three closed questions of this instrument, indicating that the idea of using such virtual worlds platform in the distance education (GP1) was the most positively evaluated item (M=4.73, SD=0.47). Similarly, participants almost totally agreed that they would like to have this resource at their disposal if they were distance education students (GP2, M=4.45, SD=0.82).

When asked about how well the virtual world can prepare students for the real-world task portraited in it (GP3), although in less proportion, participants agreed with this possibility (M=4.27, SD=0.65).

Table 2: General perceptions evaluation.

Question	M	SD
GP1. Is using the virtual world a good idea for the distance education mode of instruction?	4.73	0.47
GP2. If you were a student of a distance education, would you like to have a similar virtual world at your disposition?	4.45	0.82
GP3. How well can virtual world training prepare for the real world task portraited in it?	4.27	0.65

In the sequence, the first open question asked the experts' opinion about the strengths of the virtual world (GP4). In general terms, they mentioned that the OpenSim platform makes it easy to simulate environments, any situation, anywhere. They emphasized as positive the various spaces of the VE, that it is aesthetically well developed, and the interaction with characters, mentioning that "avatars help in realism". Also, the opportunity to explore the work world without leaving home was highlighted, saying that "distance is no longer an obstacle". Besides that, they added the possibility of a having a preview of how a company can actually be, the ability to get their full attention, and that "there is a connection between two worlds (real and virtual)".

Similarly, participants were asked to talk about the weaknesses of the virtual world (GP5). They mentioned the lack of: a) interactivity from the avatars; b) uninterrupted background sounds; c) immersion and multi-sensorial levels of immersion (e.g. haptic). Furthermore, they highlighted the technological limitations of the OpenSim platform, with the failures of connection, the (too much) lag and delayed response in actions, and that a long exposure may eventually create eye fatigue or headache.

Finally, participants were asked to provide overall feedback, with suggestions of improvements for the virtual world (GP6). One said that it's difficult to improve it because it seems to be already using the full capabilities of the software, which was corroborated by other two who mentioned changing the game engine or improving graphics and interactivity. The remaining suggested a stronger interaction with the avatars and to enrich the stimuli at the auditory sense level, with the use of more background sounds throughout the VE.

3.2 Usability Evaluation

By performing the SUS analysis procedure, the overall result obtained was 68.40, which represents an 'OK' (acceptable) usability evaluation, on the C percentile (Brooke, 1996).

Table 3 presents the usability results, maintaining the original mean values of reverse items. It shows that the five positive assertions received scores ranging from 3.27 to 4.00, allowing to infer that none of the usability items was totally approved.

Table 3: The SUS evaluation.

System Usability Scale items	M	SD
U7. I would imagine that most people would learn to use this system very quickly	4.00	1.01
U5. I found the various functions in this system were well integrated	3.82	1.17
U3. I thought the system was easy to use	3.73	0.90
U9. I felt very confident using the system	3.55	1.33
U1. I think that I would like to use this system frequently	3.27	0.60
U10. I needed to learn a lot of things before I could get going with this system	2.45	1.14
U2. I found the system unnecessarily complex	2.18	1.00
U4. I think that I would need the support of a technical person to be able to use this system	2.18	1.14
U6. I thought there was too much inconsistency in this system	2.09	1.04
U8. I found the system very cumbersome to use	2.09	1.10

The questions with the highest score address that most people would learn to use the system very quickly (U7, M=4.00, SD=1.01), and that its various functions were well integrated (U5, M=3.82, SD=1.17). Subsequently, the system was considered easy to use (U3, M=3.73, SD=0.90), with participants feeling confident in using it (U9, M=3.55, SD=1.33). The positive assertion with the lowest score questioned if they would like to use the system frequently (U1), receiving an evaluation close to the neutral point of the scale (M=3.27, SD=0.60). However, it is not an objective of the virtual world to be revisited, as it was configured as an activity to be performed once.

In the bottom half of Table 3 are the negative assertions. That is, lower scores correspond to better evaluation. As a result, the scores ranged from 2.45 to 2.09, which represents a partial disagreement with the aspects addressed, but not a total disagreement as it would be ideally expected. The less disagreement (more negative evaluation) occurred regarding the need for the user to learn many things before get going with the system (U10, M=2.45, SD=1.14).

In the sequence, participants partially disagreed that the system was unnecessarily complex (U2, M=2.18, SD=1.00) and that they would need the support of a technical person to be able to use it (U4, M=2.18, SD=1.14). Finally, the items with the most disagreement (more positive evaluation) refer to the system having too much inconsistency (U6, M=2.09, SD=1.04) and being very cumbersome to use (U8, M=2.09, SD=1.10).

3.3 Sense of Presence Evaluation

Figure 2 presents a graphic with the ITC-SOPI results, identifying each item's dimension by colour. It allows observing that just one item (P17) received a mean score in the "partially agree" point of the scale (M=4.09, SD=0.83), and the remaining received lower scores. This item refers to sensing that the scenes depicted in the VE could really occur in the real world. Thus, it can be inferred that participants agreed that the virtual world was successful in its attempt to simulating an accounting company.

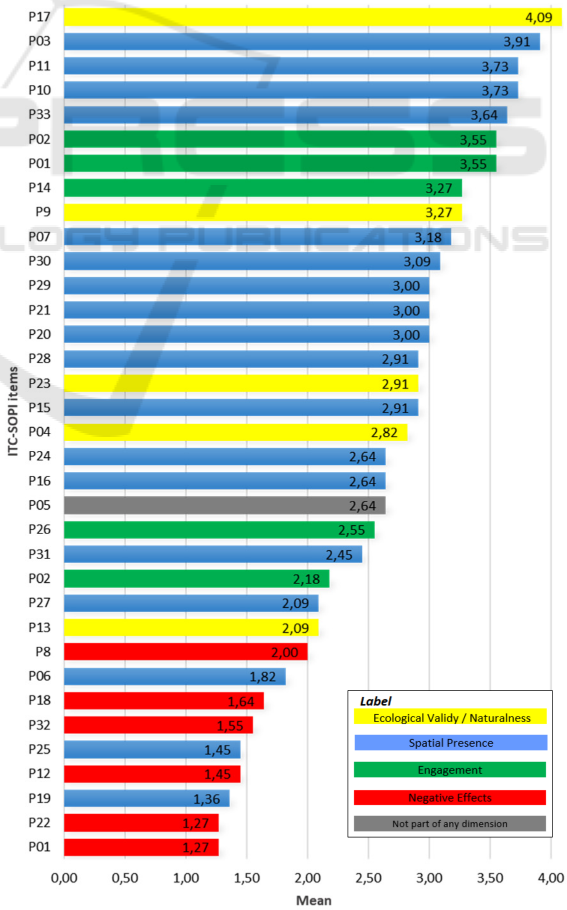

Figure 2: The ITC-SOPI results.

Other six questions received mean scores with values higher than 3.50, but lower than 4.00, which indicates neutral to a partial agreement. They refer to subjects feeling that they could interact with the VE (P3, M=3.91, SD=0.70), that they were not just watching something (P10, M=3.73, SD=0.90), that they had the sensation of moving in response to the VE (P11, M=3.73, SD=0.79), that they felt participating (P33, M=3.64, SD=0.92) and involved with the VE (P1, M=3.55, SD=0.69), and that they lost track of time (P2, M=3.55, SD=1.04). Thus, these aspects, which refer mostly to the SP dimension (~66.66%), although not fully contemplated, emerged as with the more potential to stimulate the participants' sense of presence in the virtual world.

The last ten items, in the lower extreme of Figure 2, are mostly from the NE dimension (60%), which, as it would be expected, received the lowest mean scores. The items with the most disagreement (partially to totally), thus most positively evaluated, refer to participants feelings nauseous (P22, M=1.27, SD=0.65) and disoriented (P1, M=1.27, SD=0.47). The disagreement was less for the NE items referring to the feelings of eye strain (P18, M=1.64, SD=1.12), headache (P32, M=1.55, SD=1.21) and dizziness (P12, M=1.45, SD=0.82). The negative effect with the highest score (M=2.00, SD=1.18, partially disagree), refer to participants feeling tired (P8).

However, the other 40% of items in the lower extreme of Figure 2 are from the SP dimension, indicating that participants partially disagreed that all their senses were stimulated at the same time (P27, M=2.09, SD=1.14) and that the characters and/or objects could almost touch them (P6, M=1.82, SD=0.60). Participants more strongly disagreed that the temperature changed to match the scenes (P25, M=1.45, SD=0.82) and that they could almost smell different features of the VE (P19, M=1.36, SD=0.67). Although these aspects can be related to immersion and imagination of users while interacting with a VE, they can be more easily stimulated physically by multi-sensory devices, which are usually not contemplated by virtual world platforms.

Shapiro Wilks' test indicated that data from the ITC-SOPI dimensions (except the NE) and the SUS score do not have a normal distribution. Therefore, the Spearman's correlation test was run, showing a positive significant correlation between the EVN dimension and the SUS score (r=0.815, p=0.002).

In a complementary analysis of the sense of presence, it was investigated if subjects lost track of time while performing the activity. To this end, their estimated time was compared with the actual time of experience, detected by the system logs. Signs of losing track of time were inferred when this difference was higher than five minutes. Table 4 presents the results of each participant, showing the majority of cases (n=6, 54.54%) in this situation. From these, four (~67%) spent more time than estimated (More Than Estimated=MTE), and just two (~33%) spent less time than estimated (Less Than Estimated=LTE). The differences were also more discrepant in the first case, with individuals spending almost double the time estimated (ID 5 and ID 7).

Table 4: Time of the experiences in the virtual world.

ID	Estimated time (min.)	Actual time (hh:mm:ss)	Difference (more than 5 min.)
1	10	00:13:30	No
2	20	00:21:45	No
3	15	00:18:22	No
4	60	00:50:52	LTE
5	30	00:56:51	MTE
6	30	00:46:32	MTE
7	18	00:32:10	MTE
8	30	00:38:35	MTE
9	25	00:28:04	No
10	15	00:18:12	No
11	40	00:34:45	LTE

However, although the dissociation of time can be an indication of the sense of presence (Wallis & Tichon, 2013), it was not observed any pattern of association between these values and the ITC-SOPI scores.

4 DISCUSSION

The results show that, although knowing more cutting edge technologies, the VR experts were positive to the idea of using the OpenSim platform in the distance education mode of instruction, mentioning that it has the potential to prepare students for the real-world task of being admitted in an accounting company. The opportunity to explore the work world without leaving home was highlighted.

Concerning suggestions of improvements, one refers to increasing the auditory stimuli, making it uninterrupted, as there were moments with no background sounds, causing discomfort while using headphones. Even though participants did not clearly make this connection, it allows agreeing with Whitelock et al. (2000), when arguing that this an important component for the sense of presence.

As negative points, the VR experts emphasized the technological limitations of the OpenSim platform, as slowness and failures in interaction. In this sense, they see as difficult the possibility of improvements, due to software limitations. Although the OpenSim community is still active, with the last version (0.9.1.1) launched in January 2020, few real advancements from previous versions were observed. We speculate that, besides the platform code foundation limitations, there's an effort to maintain the easiness of access and development, limiting the evolution of this open-source project.

In what concerns usability, none of the SUS items was totally approved; a result that can also be linked with the platform limitations. The aspect most positively evaluated corresponds to the fast speed in which people would learn to use the system. Despite that, the importance of instruction was highlighted, pointing out the need for users to learn many things before using the system properly. This result suggests an agreement with the study of Naya & Ibáñez (2015), in which the operation of the interface obtained very high marks, even though their participants were children in their first experience.

In the matter of the sense of presence, in accordance with the general perceptions feedback, the most positively evaluated aspect refers to participants agreeing that the scenes depicted in the virtual world could really occur in the real world. Also, they highlighted as positive the feeling of interacting with a VE instead of just being watching something, as it would be, for example, in a video about the subject. Another aspect that contributes with the inferring of presence, lies on the fact that most VR experts were not correct on guessing the time spent in the VE, spending mostly more time than estimated. This result corroborates with the self-report on the ITC-SOPI instrument, in which participants demonstrated a neutral to a partial agreement regarding losing the track of time. Thus, it can be suggested that they had a feeling of dissociation of time while doing the activity in the OpenSim platform.

Besides that, the Spatial Presence dimension emerged as with the more potential to stimulate the user's sense of presence. However, some items from this dimension, related to level of multi-sensorial stimuli, were also raised as weakest points, a result that would be expected by the use of a desktop-based VR interface with no addition of multi-sensorial devices. This contradictory finding can also be related to the divergent opinions regarding participants' level of interest on the subject matter of the VE. In the study of Natsis et al. (2012), for example, students who were more interested in the subject experienced higher levels of spatial presence.

The negative effect that emerged as with the more potential to prejudice (or reduce) participants' sense of presence refers to the feeling tiredness. This finding can also be linked with the problems in the OpenSim platform, evidenced in the previous analysis, which could have made them feel bored. Given that there's not much to do about the limitations of the platform itself, and that more interaction with the VE could also mean more problems, one action that could alleviate this negative effect is to reduce the size of the virtual world, consequently reducing the time of experience.

The data from the usability evaluation and the Ecological Validity/Naturalness dimension of the sense of presence were positively correlated. This dimension is related to believability, realism, naturalness and solidity of the environment. In this sense, we corroborate with research that suggest that these aspects are intrinsically associated, and therefore must be planned together (Chow 2016).

5 CONCLUSION

In this study, a semi-immersive VR alternative, a virtual world activity developed on a desktop-based educational OpenSim platform, was evaluated by VR experts. Usability and sense of presence issues were diagnosed through specialized feedback, collecting suggestions to optimize the experience of a target audience of distance education students.

Answering the research questions, the usability evaluation can be classified as intermediate. That is, the VR experts see the potential of allowing students to easily participate in a simulation of a company, and the positive aspects of such an approach as a learning tool, especially to distance education students, which usually work alone at home, and have few or no opportunity of professional practices. However, the weaknesses of the platform were not denied, as slowness and failures in the interaction. The component analysis gave us indications of improvement points that should be prioritized.

The sense of presence evaluation can be classified as positive. Participants demonstrated that a level of realism was achieved, even with graphics far from detailed. Tiresome was highlighted as a negative aspect that must be treated in order to improve the user's sense of presence. This finding indicates the need for balance between a clean interface and levels of interactivity between avatar and objects. It contraries the study of Naya & Ibáñez (2015), using the same platform, in which the activity lasted about two hours. The authors claim that this is a similar time to the real-world activity they simulated (a museum visit), and obtained high rates for sense of presence.

Usability and the dimension referring to realism in the sense of presence were positively correlated, indicating that improvements in usability can reflect on the believability of the VE. Alternatively, it means that a better usability of the system can collaborate to higher sense of presence and its associated benefits.

To answer the last research question, it was identified that the VR experts did lose the tracking of time while performing the activity. That is, it retained their attention to a point in which they did not see time passing by. This result demonstrates that even not so realistic semi-immersive desktop-based VR platforms have the potential to promote the concentration of users and retain their attention, which are useful aspects for education. Also, it shows indications of presence through dissociation of time.

Besides the drawbacks inherent of a case study, with the use of a small convenience sample, the divergent level of participants' interest on the subject addressed in the virtual world is a limitation of the study, which might have contributed to the impossibility of correlating all dimensions of presence to usability, or the dissociation of time to the ratings of presence. Further research should focus on investigating a larger sample, allowing to compare the outcomes with different groups of interest on the subject. In addition, it would be useful to compare the results with a sample of non-VR experts, and with the same virtual world in a full immersive setting.

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