

Assessing User Experience in Immersive Virtual Reality Environment: A review of interconnected terms and meanings

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Abstract: This article reports a research project aiming to identify aspects that influence User Experience (UX) in Immersive Virtual Reality (IVR) environments. It used an iterative research, where IVR games were tested with end-users, and their responses helped to organize and establish a way to analyze UX in IVR. An initial literature review highlighted the need for consistency among studies, indicating discrepancies among the terms used to evaluate similar aspects of UX, varying from areas of application. This study combined different terminologies to establish a relationship between the terms, then explored how they are used in questionnaires to measure UX. A framework was developed to facilitate comparison between the terms related to UX across a diverse range of studies, methods, and evaluations of applications in Virtual Realities environments. Finally, it concludes by composing a questionnaire to evaluate the UX in IVR environments.

Keywords: Virtual environments - Presence - UX - Questionnaires design - Evaluation methods - IVR.

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Introduction

The digital space is an abstract medium created by digits and processed by a machine. This completely numerical data processed is shown in videos, images, sounds, and even virtual worlds (e.g. games and animation movies). According to Girvan (2018) virtual world is a simulated environment that represents a framework of a world that is not material or physical and affords different kinds of interactions and representations.

Flusser (2013) pointed out that in the digital medium, materials are made by electromagnetic fields which makes possible free forms material, but visible, malleable and possible to fill with textures, volume, colors and light. In recent years several non-conventional input devices have been developed allowing alternative ways of interactions and improving immersion in virtual reality (Kruijff, *et al.*, 2017).

Virtual reality is a term widely reviewed and discussed (Biocca, 1992; Burdea & Coiffet, 2003). Kirner and Siscoutto (2007) proposed that Virtual Reality is an advanced interface to computational applications, that grants the users' navigation and real time interaction in a 3D environment created by computer through multisensorial devices.

Some authors (Kirner & Kirner, 2011; Biocca & Levy, 1995; Slater, & Sanchez-Vives, 2016) differs virtual reality and immersive virtual reality (IVR). Kirner and Kirner (2011) define VR as a computational interface (created by computers) where the user can interact, in real-time, in a 3D space, using the senses though special devices (but it keeps the user

aware of the real world around), while IVR is dependent on interaction devices and head mounted displays (HMDs) or multiprojection rooms for visualization.

Recently different kinds of HMDs have being released in the market, including affordable ones. Juan, *et al.*,(2018). The models vary from tethered HMDs (based on computer processing) and mobile- rendered HMDs (HMD that runs on mobile phones). More recently, the Meta Quest 2 and 3 (Meta) were released and it works stand alone (not depending on computers or smartphones).

All those types of equipment and ways of interaction provide to the user different experiences and usually demand time for adaptation in the virtual world. In this context, the role that design elements play on virtual environment, facilitating this adaptation and positively impacting on user experiences (UX) is an area of interest, that have been increasingly explored in the last years.

UX is defined as “a person’s perceptions and responses that result from the use of a product, system or service” (ISO 9241-210). The UX in IVR assist on shape and improve it, helping to understand how the system can be enhanced to attend the user’s needs. To test the experience in IVR environment different ways was used, however, consensus has not been found in the literature.

The immersive experience and the recent popularity of HMDs devices called attention of different fields due the possibility of a user high engagement in virtual environments. Entertainment, education and training (Hvass, J., *et al.* (2017); Lee, J.,*et al* (2019); Bian, Y., *et al* (2016); Cooper, N., *et al.*,(2018); Cowan, K. and S. Ketron, (2019); David, D., *et al.*(2019); Kim, D. and Y.J. Ko,(2019), Ahir, K., *et al.*, (2019); Christian, M. *et al.* (2017), Pagano, A., *et al.*(2020), Ferguson, C.,*et al* (2020). journalism and tourism (Shin and Bioca, (2018); Peña, *et al* (2010); Errichiello, *et al.* (2019); Huang, *et al.*, (2016); Kim, and Hall (2019) technical and psychological understanding (Witmer *et al.*,(2015); Witmer, and Singer, (2018); Yu, I., *et al.*(2012); Garau, M., *et al.*,(2008); Skarbez, *et al.*(2017b); Terkildsenand Makransky(2019); Usoh, M., *et al.*(2000); Slater, and. Wilbur,(1997); Slater, *et al*(2006); Slater,(2009); Slater,(2018); Vinayagamoorthy *et al.*(2008); Schubert,*et al* (2001);Tcha- Tokey, K., *et al.*,(2016); Hudson, *et al.*(2019) and other areas keep investing in research to establish best practices to improve the UX in IVR.

Each area differs and treats the terms and analysis differently considering similar or even equal aspects. In this scenario, standardize the terms and establish their main relationship directed to the UX would help to improve consistency and can potentially help future studies. This study proposes to define which are the most important aspects that contribute to UX in IVR, how they are connected to each other and finally propose a questionnaire to measure the UX. Firstly, it was conducted an exploratory study which showed that “presence” is the most important factor to study in IVR environments. After that was designed an interactive research, and its results were combined with a bibliographical review and “presence” questionnaires review. This first part helped to establish the meaning of the terms used.

Subsequently, the questionnaires were analyzed again, but according a different point of view: understanding how they measure UX. Combining this study with the terms proposed

meanings, a framework with the terms main influences was settled. According to those terms and relations, a questionnaire was made to measure UX in IVR environments.

Issues and methodology

To shed light on UX in IVR environments three Research Questions (RQ) were proposed. The first one considers the complexity of UX and the many elements that influences it. The second research question focus on the variety of terms used to previously researches, with the same meaning. The third research question focus on the aspects relations. Using the literature reviews' and the interactive research results, was created a framework establishing the terms main relations.

- RQ1 . Do some design aspects influence the UX in IVR environment more than others?
- RQ2. Compilating the terms meaning and stablishing relations between them according to how they were used in different studies, will help future studies on providing a better comparison basis.
- RQ3. All aspects influence in each other in many ways, but it is possible to summarize these main influences.

Interactive research

Considering the IVR, a pilot study was made to identify which was the aspects that most influence on user's experience. The test had two main targets:

1. explore the aspects that influence the UX.
2. understand aspects that contribute to enhance the presence feeling on users.

To embrace different kinds of experiences, were selected three different games, each of them presenting distinct approaches of: visual aspects, control, and narrative. It helped to settle and test different situations. All the interactions (15 participants) were recorded (the users' vision and body movements). After the tests, a questionnaire was used to collect the data, to embrace more aspects of UX, the participants were interviewed showing their opinion over the questions and about each game. In the interview/questionnaire were asked about their behavior during the tests, experience, best and worst moments, what helped and hindered staying "present" in the game's universe.

The equipment used in this test was an HMD Gear VR with proper control and a smartphone Samsung S8 with a screen resolution: 2960 x 1440 pixels (Fig. 1). This HMD works with stereographic images and a binocular field of view (FOV) of 101°. The games used in the experiment were available (for free) on Oculus Store.



Fig. 1: Equipment used in interactive research and equipment during the interactive research.

The first game tested was *Dead and buried* (Oculus, 2016) a first-person shooter with a cartoonish look (Fig. 2), the player objective is to stay alive shooting in the approaching zombies. In this game the player does not walk through the scenario, the view is 360° but the action occurs just in 180° and the difficult increase gradually during the game.



Fig. 2: Frames of *Dead and buried* (Oculus, 2016).

The second game played was *Tomb Raider VR: Lara's Escape* (Warner Bros, 2018) an adventure game with realistic shadows, textures, and proportions (Fig. 3). In this game the player walks through an established path, solve puzzles, and uses different tools (all commanded by the same button on joystick), The vision is 360°, the action occurs in all field, but the game induces the player to look forward prioritizing quick actions. The narrative is linear but not much emphasized.



Fig. 3: Frames of Tomb Raider VR: Lara's Escape (Warner Bros, 2018).

The third game was Play With Me (C6H8O7, 2016) a thriller/terror game that uses the narrative to involve the user. The visual is close to the realism but some elements are disproportionate (Fig. 4). The player is encouraged to explore a house (open scenario with 360° view) looking for pieces to open a door. The game uses jump scares and a dark environment to contribute to the thriller.

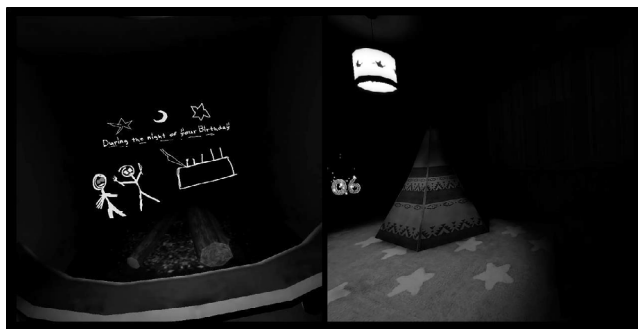


Fig. 4: Frames of Play With Me (C6H8O7, 2016).

During the test, the game-play took around 21 minutes (7 minutes per game), and the interview around 15 minutes per participant. The questionnaire (17 questions) guided the structured interview, the first three questions presents quantitative results (Table 1) focusing on the user experience, feeling of presence and interaction.

After the interaction, the participant was interviewed, individually. The first question asked directly to the user “What the degree of presence you felt in the games scenarios?”, the second question “Which level of weirdness the games’ visual provoked on you” and the

third question “Which is the interaction importance in the games’ universe?”. All of them were evaluated in a 1-6 scale. Figure 5 shows the results.

Game	Dead and buried	Tomb Raider VR	Play with me
Q1: Presence felt (average 1-6)	4	4,73	5,2
Q2: Level of weirdness (average 1-6)	2	2,13	2,66
Q3: The importance of interaction to presence (average 1-6)	3,86	4,6	5,2

Fig. 5: User test results

These first three questions demonstrate that even in a scenario where some objects present incongruences and weirdness, the presence can be high. It emphasizes the player capability of adaptation in favor of the experience. These results are reinforced by another question “Which was the game that you felt more presence”: 1 person said Dead and Buried, 5 answered Tomb Raider VR; and 9 Play with me.

Table 1 also reveals that the interaction importance depends on how the game was created, its objectives and how it calls the players attention (the narrative, challenges, and tasks). During the interview, the players mentioned that some problems with joystick calibration, and an established path to walk hindered the feeling of presence.

These three questions helped to understand which aspects have influenced on the experience (positively and negatively) and how they contribute to enhance the presence feeling on users.

The user test also showed that the feeling of a “real” situation in IVR, even knowing it was just a game, the Place Illusion according to Slater (2009) was reported in all three games: 11 participants have it playing Dead and Buried and Tomb Raider VR (in varying degrees), and all the participants have it playing Play With Me.

The participants also related how was the playing experience in each game, in different situations of the gameplay, the pros, and cons noticed about joystick, narrative, elements and objects showed in each game, visual and audio constructions. Helping to understand how the experience was shaped. Considering the immersive environment, the sensation of being “inside” of the game world was the most mentioned. The participants also mentioned other aspects that influenced on it (the main aspects were listed and explained in the following section).

This test pointed that the stimuli provided by the IVR environment, is a sum of many aspects (such as visual and control adaptation, previously experiences, game preferences, and sensations provoked by the game itself) and each of them influence in UX in a different way. Finally putting all the results together was possible to settle the most important terms connected to the UX in IVR environments, their relations, and connections.

Aspects of Immersive Virtual Environments¹

In the literature the feeling that disconnect the users from the reality and transport them to the virtual reality environment has been described and evaluated by aspects like immersion, presence, involvement, realism, sense of “being there”, engagement, flow, and others.

According to the user test results summed with literature review and questionnaires review, the terms and their definitions were settled.

Presence: Slater and Wilbur (1997) uses presence as a state of consciousness related to the “sense of being in a place”. To Witmer and Singer (1998) the presence requires the union of involvement and immersion.

Presence is considered in this study as the feeling of being in a place supported by the illusion of non-mediation and influenced by the user’s psychological state and dependent on personal interests (personal likes and predilection).

Immersion: Immersion and presence were discussed by many authors, sometimes as synonyms.

This paper looks to immersion and presence as complementary ideas considering the equipment limitations and user’s characteristics (such as personal interests, mood, and physical limitations). Looking through these aspects, Immersion is considered in this paper as dependent of the equipment.

Involvement/Engagement: Involvement or engagement, as described by Witmer and Singer (1998) are the involvement (or engagement) is a psychological state experienced according to the energy and attention on a “coherent set of stimuli or meaningfully related activities and events”. If users focus more attention on the virtual environment, they usually tend to feel more presence, and if the challenges provided are combined with their experience, the attention is increased reaching the flow state.

Engagement can also be understood as an user multifactorial construct interconnected with (psychological) processes (Kruijff *et al.*, 2017).

Flow: The flow theory was developed for Csikszentmihalyi (2014) to study presence and user’s engagement in different kinds of activities. “Flow is a subjective state that people report when they are completely involved in something to the point of forgetting time, fatigue, and everything else but the activity itself”.

To achieve the flow it is necessary a balance between the difficulties and the person's abilities, if the challenge is too difficult, the person will feel frustrated, if it is too easy it becomes monotonous (Csikszentmihalyi, 2014). The flow is considered in this work as a deeper state of involvement or engagement.

Telepresence: The user of an IVR environment dial with two environments at once: the virtual one, and the real one (the user are, physically in a real place, dealing with real objects) (Steuer, 1992).

This paper considers that telepresence connects physical sensations and the reproduction of them in IVR environments. For example, the use of haptic gloves (which simulate touch) and devices that replicate smells, increasing the physical stimulation consequently increases the telepresence. Many devices are available in the market to stimulate telepresence (i.e. treadmills, haptic gloves, and haptic clothes).

Coherence: Considering Flusser (2013) point: that the images are formed in electromagnetic fields that can be filled with textures and materials simulations. Looking through the side of the environment structure (not necessarily the physical sensations, but the mental meaning), the concept of coherence can be defined as a set of rules and mechanisms that makes sense within an environment, not necessarily coping all the real world: in a fantasy world where flying makes sense, the user will fly and feel coherence in doing that.

The coherence is also related to the equipment used and its response and influenced by the telepresence in IVR (calibration and response).

Realism: IVRs training material for military or medical training usually need features that remind people of real situations. It might be visual, sounds, control or other.

Ribbens *et al.* (2016) point six dimensions of realism in video games context, each of them connecting to one aspect of the real life: Simulation realism, freedom of choice, social realism, perceptual pervasiveness, (character) involvement, Authenticity (Ribbens *et al.*, 2016). Those items are connected to different aspects described in this paper or more than one put together. As realism, this work considers the human five senses (in part close to perceptual pervasiveness concept described by Ribbens *et al* (2016): it is conceived to looks real, e.g. the movie Jurassic Park used realistic sounds for the dinosaurs noises.

Fidelity: To Skarbez *et. al.* (2017a) "fidelity" is the emulation of the real world, it can be physical, functional and psychological. The physical is related to simulation of sounds, appearance, environment physics, and others, functional is associated with correct representation of functions, e.g. for repairing a machine where the functionality of each part works, it doesn't matter if visually they look cartoonish since it is reliable for that purpose and psychological, simulate factors experienced in real-world (e.g. fear and anger).

This three fidelity definitions are connected with other aspects in IVR environments: physical (abiding the realism in its physical characteristics e.g. the interpretation of the light in images), psychological (related to the user involvement), and functional (related to immersion).

All the aspects mentioned in this work should not be measured as a high/low dichotomy, rather they are in a wide range of continuum, where many aspects (of the system and user's) contribute for. More details about the terms can be found in the full research at link: <https://repositorio.unesp.br/items/99c062db-dc7f-4e56-ade2-c10ecb7a79d9> (p. 54-61)

Measuring the experience: questionnaires

Various methods were used to evaluate the efficiency of IVR in promoting satisfactory experience to the user. Recent studies explored IVR across diverse domains. Literature commonly uses questionnaires or combines them with physiological data (e.g., heart rate or skin response) for evaluation. However, correlating physiological changes with user experience is challenging. For instance, if a user fears rats in IVR, increased heart rate may not signify presence but fear. Thus, questionnaires remain vital.

Considering that presence and UX are subjective, there is no existing method that embraces all the criteria to measure them exactly. Skarbez *et al.* pointed out that the most used method to analyze virtual environments is the application of post-experimental questionnaires (Skarbez *et al.*, 2017b).

To UX measurement in IVR environments, some questionnaires were analyzed, according to the access and use of them. The interactive research and the literature review pointed to “presence feeling” emerged as a central theme. The second step was to conduct an extensive search across scientific literature to identify relevant papers using questionnaires to assess presence in virtual environments, regardless of the platform. We then selected questionnaires suitable for evaluating IVR presence, considering their scales and subscales. Unfortunately, some questionnaires were not published (or fully published) in their respective papers, so it was necessary to look in laboratory websites and different papers to have them. Totally was evaluated 21 questionnaires in different areas, and 10 were eliminated because they do not fit in the concept of presence defined to study in this work.

The 11 left were analyzed and are presented in Figure 6. The questionnaires helped in consider different perspectives of the terms used, and how there were analyzed under distinctive points of view, offering a wild range of how the terms are used in different areas. It helped to stablish some definitions, but most important fixed the framework structure (their connections and dependencies of each other).

The questions were divided into two groups according to their construction “Direct questions” and “Indirect questions”. To determine if questions were direct or indirect was considered the factor that the question fits in the questionnaire (e.g. for the factor “Involvement” a question like “How much were you able to control events?” is considered indirect - it does not ask directly about involvement - a question like “How much did the visual aspects of the environment involve you” was considered direct).

Questionnaires name	Environment tested	Additional notes
Igroup Presence Questionnaire (PQ) (Schubert, Friedmann & Regenbrecht, 2001)	Immersive and Non-Immersive Virtual Reality, Text-based Virtual Environments	-The questionnaire uses some questions from other questionnaires, the authors make the references clear. -6 questions measure more than one factor, some are direct in one and indirect in other. To avoid misunderstandings, they will not be considered as direct or indirect questions. -The questionnaire is available in English, German, Dutch and French in this link: http://www.igroup.org/pq/ipq/download.php#English
Presence questionnaire (PQ2) (Witmer & Singer, 1998)	Immersive Virtual Reality	_____
Presence questionnaire (PQ3) (Witmer, Jerome & Singer, 2005)	Immersive Virtual Reality	-Update of PQ2.
Slater, Usoh, and Steed (SUS) (Slater, Usoh & Steed, 2000)	Immersive Virtual Reality compared to real world	-Works with three themes: the sense of being in the virtual environment, the extent to which the virtual environment becomes the dominant reality, and the extent to which the virtual environment is remembered as a "place."
Unified UX in IVE Questionnaire (Tcha-Toké y, Christmann, Loup-Escande & Richir, 2016)	Immersive Virtual Reality	-It is a unified questionnaire based on nine other existing questionnaires. -Originally made in French and translated to English.
MEC Spatial Presence Questionnaire (MEC-SPQ) (Vorderer, et al., 2004)	Text; film; hypertext; Virtual environment (It's not specified if it was used Immersive Virtual Environment or Non-Immersive Virtual Environment)	-The questionnaire was created in English and translated for German and Portuguese.
Q2 + Q3 questionnaires (Juan, García-García, Mollá & López, 2018)	Augmented Reality	-The study used other 2 questionnaires, the first one (a 4 questions questionnaire) to confirm that the participant had stereopsis (protocol suggested by [59] and the second to regarding the device that the user had the best 3D experience
The Temple Presence Inventory (TPI) (Lombard, Weinstein & Dilton, 2011) (Lombard & Dilton, 1997)	IMAX cinema and black and white screen	-It is divided into 8 parts -The questionnaire was developed and validated under traditional psychological ways of measurement procedures. -Available at: http://matthewlombard.com/research/p2_ab.html
Multi-stage survey (Sheen & Biocca, 2008)	Immersive Virtual Reality	-The questionnaire is based on previous studies. It measures 7 items with 3 questions per item.
UX questionnaire (author's questionnaire, 2020)	Immersive Virtual Reality	-It was created with direct questions and essay questions -Applied as a structure interview -The questionnaire was created and used in Portuguese
Immersive Tendency Questionnaire ITQ (Witmer & Singer, 1998)	_____	_____
Immersive Tendency Questionnaire (ITQ2) (Shin & Biocca, 2018)	_____	-It was based on previously ITQ questionnaires

Fig. 6: Questionnaires analyzed – general view.

Considering the research's focus on establishing the terms and their main relations, each questionnaire was analyzed according to the factors presented, some of them were excluded because they were related to the specific field that the questionnaires were created for.

Results and Discussion

Considering the aforementioned definition of Virtual Reality, proposed by Kirner and Siscoutto (2007), the hardware and software must present an interaction in real time, a 3D environment and senses devices for interaction. Connecting with Kirner and Kirner (2011) definition, VR also must have a HMD or multiprojection rooms for visualisation .

After evaluating the terms used in immersive virtual environments under different perspectives (interactive research and literature reviews) a framework (Fig. 7) was created to expose the main relation of the terms studied. Also connecting with the software/hardware used in VR environments.

The framework proposes a strong connection between UX and presence, the arrows indicate de dependence and influence between the terms (e.g. immersion influences presence and it is influenced by the control/equipment).

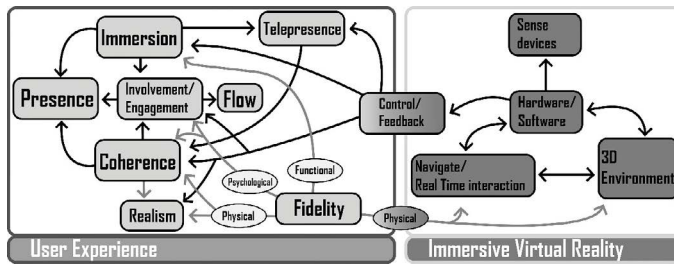


Fig. 7: A framework to represent the factor relation regarding UX in IVR.

Considering that many of the terms are subjective states, the way the questions are asked can influence how they are measured. Questionnaires that use indirect questions might configure a better approach to understand the degree of presence experienced by the user and have an answer closer to the real user feeling. For example, ask if the user remembers to be in a place or remember that place more like an image seen, reflects better the presence analysis, than just ask if the game is visually appealing. Direct questions are designed to be straight to the objective (e.g. “Did you feel happy about this situation?”) it might lead the user to deduce what the evaluation expects and even give an answer biased. Indirect questions (e.g. “Did you feel that you could sit in the chair?” for an IVR that shows a chair) on the other hand, propose to the user to bring the feeling back when filling out the questionnaire. Some factors such as “technology adoption” and “sensor fidelity” might be difficult to analyze indirectly, but they do not require so much of the user’s memory of a virtual place.

UX can be considered a wild field of sensations and mechanisms that induces the user to feel in a specific way; the evaluation of the experience demands the evaluation of different inherent characteristics of the application. Each author chose one path to find a way to appraise the UX, and some of them (Witmer *et al.*,(2005), Tcha-Tokey, K., *et al.*, (2016) look for embracing many features. To the UX evaluation, it is indicated to look deep into

distinct aspects. Another point to concern is that an extensive questionnaire will take more time to fill, and that can be tiresome, these conditions might also influence on the results. In other words, the ideal is to balance between direct and indirect questions, depending on the research objective, but not keeping it too extensive.

During the questionnaires analysis was noticed that some questions were repeated, and some are remarkably close to others. Some authors like Juan, *et al.*(2018); Shin and Biocca,(2018); Vorderer *et al.*(2004)., Schubert *et al.* (2001); Tcha-Tokey, K., *et al.*, (2016) tended to use more objective questions suggesting positive or negative sensations e.g.: "I got tense in the virtual environment" Tcha-Tokey, *et al.*, (2016). Usoh *et al* (2000) try to recreate the users' memory of feelings to capture the sensation that they had during the interaction time Witmer, *et al* (2005); Witmer and Singer(1998) (in the presence questionnaires – PQ2 and PQ3) use more direct questions about the user's feelings and sensations e. g.: "How much were you able to control events?". There is not a consensus of a right or wrong approach, but questions related to the sense of "being there" were found in all questionnaires, some of them (TPI) - Lombard *et al.*(2011), Vasconcelos-Raposo *et al.*, (2019), MEC - Vorderer., *et al* (2004) use many questions to analyze this item.

To measure presence the indirect approach seems closer to the real feeling of presence, considering the points mentioned above. Involvement/engagement (which also helps to reach the presence state) and flow (a deeper state of involvement/engagement) are measured in different ways by questionnaires, but subjective questions can bring the person closer to the memory of the feeling during the interaction moment. Considering these findings, a questionnaire with predominance of indirect questions, is more effective to measure presence, involvement/engagement and flow.

Coherence is a factor approached in many questionnaires regarding presence, it considers the user's feeling that the environment is concise and works in its own rules (even the fantastical ones). If the person feels a coherent environment, the presence is increased. Coherence is also influenced by physical and psychological fidelity, and these three factors can be appraised using direct or indirect questions, depending on the aspect evaluated.

For IVR, immersion is also a factor approached by many questionnaires, the environment usually is pointed as more immersive and less immersive (Lombard & Ditton, 1997) considering the technology used. During the literature review was noticed a lack of works interested in evaluating how the same user experience different kinds of immersive equipment (e.g. haptic gloves and treadmill) in IVR comparing them to the presence felt. Features such as realism, telepresence, immersion, functional fidelity, and control and equipment, can be evaluated by direct or indirect questions, but considering these features connection with devices and hardware characteristics, direct questions appears to lead to a reliable evaluation.

Presence is influenced mainly by three other elements: immersion (regarding the equipment), involvement/engagement and environment coherence. These three elements influence and are influenced by the others exposed in the framework, but different areas might need to emphasize different parts of the framework or add different terms regarding the aim of the evaluation. Fidelity (physical) is related to the virtual environments that aims to copy the real world, it is not a mandatory factor required in every system.

This framework represents a general idea about the terms uses and influences, all related to UX and IVR. It was planned to embrace different areas and work as a guide to construct questionnaires related to this area. An example of questionnaire based on the framework is as follow (Fig. 8):

EXAMPLE OF QUESTIONNAIRE

PRESENCE

1. I felt like the objects in the presentation surrounded me (VORDERER et al, 2004).
2. The objects in the presentation gave me the feeling that I could do thing with it (VORDERER et al, 2004).
3. How often when an object seemed to be headed toward you did you want to move to get out of its way?

INVOLVEMENT/ENGAGEMENT

1. How aware were you of the real world surrounding while navigating in the virtual world? i. e. Sounds, room, temperature, other people, etc (WITMER & SINGER, 1998).
2. How often did you make a sound out loud (e.g. laugh or speak) in response to someone you saw/heard in the media environment? (LOMBARD, WEINSTEIN and DITTON, 2011).
3. How often did you smile in response to someone you saw/heard in the media environment? (LOMBARD, WEINSTEIN and DITTON, 2011).

COHERENCE

1. How much did the control devices interfere with the performance of assigned tasks or with other activities? (WITMER, JEROME and SINGER, 2005).
2. I was able to make a good estimate of how far apart things were from each other (VORDERER et al, 2004).
3. In my mind's eye, the virtual environment makes sense (e. g. visual, audio, actions).

FLOW

1. Time seemed to speed up.
2. When I mention the experience in the virtual environment, I feel emotions I would like to share.
3. I didn't care about things that were happening outside the virtual environment.

FIDELITY (PHYSICAL)

1. How well could you identify sounds?(WITMER, JEROME and SINGER, 2005).
2. How well could you examine objects from multiple viewpoints? (WITMER, JEROME and SINGER, 2005).
3. I think the virtual environment (visual, audio, movement, control...) doesn't look right.

FIDELITY (PSYCHOLOGICAL)

1. It was so exciting that I could stay in the virtual environment for hours (TCHA-TOKEY et al, 2016).
2. I found my mind wandering while I was in the virtual environment (TCHA-TOKEY et al, 2016).
3. I felt empathy/fear from the objects/ creatures that I saw in the Virtual Environment.

FIDELITY (FUNCTIONAL)

1. The instructions showed in the virtual environment, were easy to follow.
2. I easily got my tasks done
3. The navigation and guidance were clear.

Fig. 8: Example of questionnaire based on the framework

Conclusion

This paper aims to contribute to the user experience area by testing different IVR environment games, reviewing past studies, related to the aspects that help to frame user experience in immersive virtual reality (the terms used to describe the experience of IVR and how they are translated in IVR questionnaires). The approach used helped to develop a framework connecting UX in IVR.

It demonstrated that some aspects influence in the sense of presence more than others, finally influencing in UX in different ways, but not necessarily more than others. It depends on the user and the application intention and approach.

Framing the terms and establishing their main relations have shown a possibility to create a generic questionnaire, to be used in different areas in presence tests in IVR environments. It will help to establish patterns and consequently evaluate IVR in a same perspective but embracing different points, without adaptations and misinterpretations. The next step is to validate a questionnaire using an IVR environment.

Note:

1. The entire description of the terms, comparing and discussing the authors found in literature, is found in Sampedro (2021, p. 54 - 61).

References

- Ahir, K., *et al.*,(2019). *Application on Virtual Reality for Enhanced Education Learning, Military Training and Sports*. *Augmented Human Research*. **5**(1): p. 7.
- Bian, Y., *et al.*,(2016). *A framework for physiological indicators of flow in VR games: construction and preliminary evaluation*. *Personal and Ubiquitous Computing*. **20**(5): p. 821-832.
- Biocca, F.(1992). *Virtual Reality Technology: A Tutorial*. *Journal of Communication*, **42**(4): p. 49.
- Biocca, F. and M.R. Levy,(1995). *Communication in the age of virtual reality*, Hillsdale, NJ: Lawrence Erlbaum Associates.
- Burdea, G. and P. Coiffet,(2003). *Virtual Reality Technology*. 2nd ed., Hoboken, New Jersey: Wiley Interscience.
- C6H8O7.(2016). *Play With Me* [Video game].
- Cooper, N., *et al.*, (2018). *The effects of substitute multisensory feedback on task performance and the sense of presence in a virtual reality environment*. *PLOS ONE*, **13**(2): p. e0191846.
- Cowan, K. and S. Ketron, (2019). *A dual model of product involvement for effective virtual reality: The roles of imagination, co-creation, telepresence, and interactivity*. *Journal of Business Research*, **100**: p. 483-492.

- Christian, M., Š. Zane, and S. Allan, (2017). *Virtualisation devices for student learning: Comparison between desktop-based (Oculus Rift) and mobile-based (Gear VR) virtual reality in medical and health science education*. Australasian Journal of Educational Technology, 2. 33(6).
- Csikszentmihalyi, M.,(2014). *Flow and the Foundations of Positive Psychology: The Collected Works of Mihaly Csikszentmihalyi*, Dordrecht, NETHERLANDS, THE: Springer.
- David, D., *et al.*, (2019). *Development of Escape Room Game using VR Technology*. The 4th International Conference on Computer Science and Computational Intelligence (ICC-SCI 2019) : Enabling Collaboration to Escalate Impact of Research Results for Society, 157: p. 646-652.
- Errichiello, L., *et al.*(2019). *Exploring the implications of wearable virtual reality technology for museum visitors' experience: A cluster analysis*. International Journal of Tourism Research, 21(5): p. 590-605.
- Ferguson, C., E.L. van den Broek, and H. van Oostendorp, (2020). *On the role of interaction mode and story structure in virtual reality serious games*. 143: p. 103671
- Flusser, V.(2013). *O mundo codificado*, São Paulo: Cosacnaify. 224.
- Girvan, C.,(2018). What is a virtual world? Definition and classification. 66(5): p. 1087-1100.
- Garau, M., *et al.*,(2008). *Temporal and Spatial Variations in Presence: Qualitative Analysis of Interviews from an Experiment on Breaks in Presence*. Presence. 17(3): p. 293-309.
- Huang, Y.C., *et al.*,(2016). *Exploring the Implications of Virtual Reality Technology in Tourism Marketing: An Integrated Research Framework*. International Journal of Tourism Research. 18(2): p. 116-128.
- Hudson, S., *et al.*,(2019). *With or without you? Interaction and immersion in a virtual reality experience*. Journal of Business Research, 2019. 100: p. 459-468.
- Hvass, J., *et al.* (2017). *Visual realism and presence in a virtual reality game*. in 2017 3DTV Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON).
- ISO. (2019). *User Experience*. In Online Browsing Platform (OBP). Retrieved October 26, 2023, from <https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-2:v1:en>
- Juan, C., *et al.*,(2018). *User's Perceptions Using Low-End and High-End Mobile-Rendered HMDs: A Comparative Study*. Computers. p. 15.
- Kim, D. and Y.J. Ko,(2019). *The impact of virtual reality (VR) technology on sport spectators' flow experience and satisfaction*. Computers in Human Behavior. 93: p. 346-356.
- Kim, M.J. and C.M. Hall, (2019) *A hedonic motivation model in virtual reality tourism: Comparing visitors and non-visitors*. International Journal of Information Management. 46: p. 236-249.
- Kruijff, E., *et al.* (2017), *Designed emotions: challenges and potential methodologies for improving multisensory cues to enhance user engagement in immersive systems*. 33(4): p. 471-488.
- Kirner, C. and T.G. Kirner, (2011). *Evolução e Tendências da Realidade Virtual e da Realidade Aumentada*, in *Realidade Virtual e Aumentada: Aplicações e Tendências*, E.S.S.B.d. Computação, Editor.: Uberlândia-MG. p. 16.

- Kirner, C. and R.A. Siscoutto. (2007). *Fundamentos de Realidade Virtual e Aumentada in Realidade Virtual e Aumentada: Conceitos, projetos e Aplicações*, C. Kirner and R.A. Siscoutto, Editors., Editora SBC - Sociedade Brasileira de Computação: Porto Alegre.
- Lee, J., J. Kim, and J.Y. Choi,(2019). *The adoption of virtual reality devices: The technology acceptance model integrating enjoyment, social interaction, and strength of the social ties*. *Telematics and Informatics*. **39**: p. 37-48.
- Lombard, M. and T. Ditton, (1997). *At the Heart of It All: The Concept of Presence*. *Journal of Computer-Mediated Communication*. 3(2).
- Lombard, M., L. Weinstein, and T. Ditton,(2011). *Measuring telepresence: The validity of the Temple Presence Inventory (TPI) in a gaming context.: 2011 annual conference of the International Society for Presence, Research (ISPR)*, Edinburgh, Scotland.
- Oculus. (2016). *Dead and buried [Video game]*.
- Pagano, A., *et al.*,(2020). *ArkaeVision VR Game: User Experience Research between Real and Virtual Paestum*. MDPI AG: Applied Sciences. p. 38.
- Peña, N.d.l., *et al.*,(2010). *Immersive Journalism: Immersive Virtual Reality for the First-Person Experience of News*. *Presence: Teleoperators and Virtual Environments*, **19**(4): p. 291-301.
- Ribbens, W., *et al.*, (2016). *Perceived realism in shooting games: Towards scale validation*. **64**: p. 308-318.
- Sampedro, P.P. (2021). *Elementos da Experiência do Usuário em ambientes de Realidade Virtual*. 2021. 211f. Tese de Doutorado apresentado ao Programa de Pós-Graduação em Mídia e Tecnologia - FAAC - UNESP, sob a orientação da Profa Dra. Vânia Cristina Pires Nogueira Valente, Bauru.
- Schubert, T., F. Friedmann, and H. Regenbrecht, (2001). *The Experience of Presence: Factor Analytic Insights*. *Presence: Teleoperators and Virtual Environments*,**10**(3): p. 266-281.
- Shin, D. and F. Biocca, (2018). *Exploring immersive experience in journalism*. *New Media & Society*, **20**(8): p. 2800-2823.
- Skarbez, R., J. Frederick P. Brooks, and M.C. Whitton, (2017a). *A Survey of Presence and Related Concepts*. *ACM Comput. Surv.* **50**(6): p. Article 96.
- Skarbez, R., *et al.*,(2017b) *A Psychophysical Experiment Regarding Components of the Plausibility Illusion*. *IEEE Transactions on Visualization and Computer Graphics*, **23**(4): p. 1369-1378.
- Skarbez, R., F.P. Brooks, and M.C. Whitton. (2017c). *Immersion and coherence in a visual cliff environment*. in *2017 IEEE Virtual Reality (VR)*.
- Slater, M. and S. Wilbur,(1997). *A framework for immersive virtual environments five: Speculations on the role of presence in virtual environments*. *Presence: Teleoper. Virtual Environ.* **6**(6): p. 603– 616.
- Slater, M., *et al.*,(2006). *Analysis of physiological responses to a social situation in an immersive virtual environment*. *Presence: Teleoper. Virtual Environ.* **15**(5): p. 553–569.
- Slater, M.(2009). *Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments*. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*. **364**(1535): p. 3549-3557.
- Slater, M. and M.V. Sanchez-Vives, (2016). *Enhancing Our Lives with Immersive Virtual Reality*. *Frontiers in Robotics and AI*, **3**(74).

- Slater, M.(2018), *Immersion and the illusion of presence in virtual reality*. British Journal of Psychology. **109**(3): p. 431-433.
- Steuer, J. (1992). Defining Virtual Reality: Dimensions Determining Telepresence.. *42*(4): p. 73-93.
- Tcha-Tokey, K., *et al.*,(2016). Proposition and Validation of a Questionnaire to Measure the User Experience in Immersive Virtual Environments. *International Journal of Virtual Reality*, *16*(1): p. 33- 48.
- Terkildsen, T. and G. Makransky,(2019). *Measuring presence in video games: An investigation of the potential use of physiological measures as indicators of presence*. *International Journal of Human- Computer Studies*. **126**: p. 64-80.
- Usoh, M., *et al.*(2000), Using Presence Questionnaires in Reality. *Presence: Teleoper. Virtual Environ.*. *9*(5): p. 497-503.
- Vasconcelos-Raposo, J., *et al.*,(2019). Adaptation and Validation of the Temple Presence Inventory in a Portuguese Population. *International Journal of Human-Computer Interaction*, *35*(6): p. 441-447.
- Vinayagamoorthy, V., A. Steed, and M. Slater, (2008). *The Impact of a Character Posture Model on the Communication of Affect in an Immersive Virtual Environment*. *IEEE Transactions on Visualization and Computer Graphics*, 2008. **14**(5): p. 965-982.
- Vorderer, P., *et al.*,(2004). Development of the MEC Spatial Presence Questionnaire (MEC-SPQ).: Unpublished report to the European Community, Project Presence: MEC (IST-2001-37661). Hannover, Munich, Helsinki, Porto, Zurich.
- Warner Bros. (2018). *Tomb Raider VR: Lara's Escape* [Video game].
- Witmer, B.G., C.J. Jerome, and M.J. Singer,(2005). The factor structure of the presence questionnaire. *Presence: Teleoper. Virtual Environ.*. *14*(3): p. 298-312..
- Witmer, B.G. and M.J. Singer,(1998). Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence: Teleoperators and Virtual Environments*. *7*(3): p. 225-240.
- Yu, I., *et al.*,(2012). *Visual Realism Enhances Realistic Response in an Immersive Virtual Environment - Part 2*. *IEEE Computer Graphics and Applications*, **32**(6): p. 36-45.

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Resúmen: Este artículo informa sobre un proyecto de investigación que tiene como objetivo identificar aspectos que influyen en la Experiencia del Usuario (UX) en entornos de Realidad Virtual Inmersiva (IVR). Se utilizó una investigación iterativa, donde se probaron juegos de IVR con usuarios finales y sus respuestas ayudaron a organizar y establecer

una forma de analizar la UX en IVR. Una revisión bibliográfica inicial resaltó la necesidad de coherencia entre los estudios, indicando discrepancias entre los términos utilizados para evaluar aspectos similares de la UX, que varían según las áreas de aplicación. Este estudio combinó diferentes terminologías para establecer una relación entre los términos, luego exploró cómo se utilizan en cuestionarios para medir la UX. Se desarrolló un 'framework' para facilitar la comparación entre los términos relacionados con la UX en una amplia gama de estudios, métodos y evaluaciones de aplicaciones en entornos de Realidades Virtuales. Finalmente, concluye al componer un cuestionario para evaluar la UX en entornos de IVR.

Palabras clave: Entornos virtuales - Presencia - UX -Diseño de cuestionarios - Métodos de evaluación - IVR.

Resumo: Este artigo relata um projeto de pesquisa com o objetivo de identificar aspectos que influenciam a Experiência do Usuário (UX) em ambientes de Realidade Virtual Imersiva (IVR). Para sua construção foi utilizada uma pesquisa iterativa, onde jogos em IVR foram testados com usuários finais, e suas respostas ajudaram a organizar e estabelecer uma forma de analisar UX em IVR. Uma revisão inicial da literatura destacou a necessidade da consistência entre os estudos, indicando discrepâncias entre os termos usados para avaliar aspectos semelhantes de UX, variando de acordo com as áreas de aplicação. Este estudo combinou diferentes terminologias para estabelecer uma relação entre os termos e, em seguida, explorou como eles são usados em questionários para medir a UX. Um framework foi desenvolvido para facilitar a comparação entre os termos relacionados à UX em uma ampla gama de estudos, métodos e avaliações de aplicações em ambientes de Realidades Virtuais. O trabalho é concluído com a elaboração de um questionário para avaliar a UX em ambientes IVR.

Palavras-chave: Ambientes Virtuais - Presença - UX - Design de questionários - Métodos de avaliação - IVR.

[Las traducciones de los abstracts fueron supervisadas por su autor]
