Behaviour & Information Technology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tbit20

Assessing presence in virtual environments: adaptation of the psychometric properties of the Presence Questionnaire to the Portuguese populations

J. Vasconcelos-Raposo, M. Melo, Luís Barbosa, C. Teixeira, L. Cabral & M. Bessa

To cite this article: J. Vasconcelos-Raposo, M. Melo, Luís Barbosa, C. Teixeira, L. Cabral & M. Bessa (2021) Assessing presence in virtual environments: adaptation of the psychometric properties of the Presence Questionnaire to the Portuguese populations, Behaviour & Information Technology, 40:13, 1417-1427, DOI: 10.1080/0144929X.2020.1754911

To link to this article: https://doi.org/10.1080/0144929X.2020.1754911

Published online: 16 Apr 2020.

BEHAVIOUR & INFORMATION TECHNOLOGY
2021, VOL. 40, NO. 13, 1417–1427
https://doi.org/10.1080/0144929X.2020.1754911

Assessing presence in virtual environments: adaptation of the psychometric properties of the Presence Questionnaire to the Portuguese populations

J. Vasconcelos-Raposo [a,b], M. Melo [a], Luís Barbosa[a,b], C. Teixeira[b], L. Cabral[b,c,d] and M. Bessa [a,b]

[a]INESC TEC, Porto, Portugal; [b]UTAD, Vila Real, Portugal; [c]Instituto Politécnico de Bragança, Bragança, Portugal; [d]CITCEM, Porto, Portugal

ABSTRACT

Virtual Reality applications have the goal of transporting their users to a given virtual environment (VE). Thus, Presence is a consensual metric for evaluating the VEs' effectiveness. The present study adapts the Presence Questionnaire (PQ) for the Portuguese-speaking population, maintaining the validity of the contents and concepts, to ascertain the psychometric properties of the instrument.The adaptation to Portuguese was achieved through the standard adaptation process of translation and back-translation process. The sample consisted of 451 individuals (268 males and 183 females). Factor reliability ranged from 0.63 to 0.86. Confirmatory factor analysis produced a theoretical model of 21 items distributed among seven factors, where the covariance between some residual item errors was established. The fit indices obtained were $\chi^2/df = 2.077$, GFI = 0.936, CFI = 0.937, RMSEA = 0.049, P [RMSEA $\leq$ 0.05], MECVI = 1.070. Results obtained allowed us to consider that the adapted Portuguese version of the PQ, with 21 items, forms a robust and valid questionnaire whose use is recommended to evaluate Presence in virtual reality research programmes, provided that they use samples of the Portuguese language (Europe).

ARTICLE HISTORY
Received 19 July 2018
Accepted 7 April 2020

KEYWORDS
Virtual reality; human-computer interaction; subjective evaluation; presence

1. Introduction

Virtual reality (VR) is a technology that allows users to interact with a simulated multisensory environment and receive real-time feedback according to their performance (Saposnik and Levin 2011). VR aims to transport users to a virtual environment (VE) and, because it differs from other technologies, such as television, allows user interaction and immersion in the VE to which it is exposed (Schuemie et al. 2001).

For a better understanding of the phenomenon of VR, it is necessary to understand the concept of Presence, which is specifically associated mainly with this technology. Presence, as a concept in the context of VR, can be characterised as a process in which the user feels connected or involved in a given environment or given certain virtual stimuli (Schubert, Friedmann, and Regenbrecht 2001; Lee 2004). According to Ellis (1996) and Slater and Wilbur (1997), Presence is easily defined as the sensation of being in a particular VR medium while the body is in a different place. However, many factors contribute to the development of the sense of presence. Namely, the mechanisms to display the virtual data and how users can interact with the system (Sanchez-Vives and Slater 2005) being that more natural interfaces and more coherent feedback from the VE the higher the sense of presence developed (Skarbez 2016). Such particularities add to the discussion that, to elicit a sense of presence, credibility is a crucial factor that should be at a level that is capable of deluding the user's perception (Bouvier 2008). In that line of thinking, there is Slater's proposal of two constructs that explain the user experience in a VE: Place Illusion and Plausibility illusion (Slater 2009). By Place Illusion, authors refer to the classic concept of presence as the feeling of 'being there' while Plausibility illusion is associated with the credibility of the experience and to which extent it has the capability of creating the illusion that the virtual experience is real.

The growing popularity of VR technologies and applications demand proper tools for evaluating VEs. However, the existing metrics are mainly validated only for the English-speaking population. If one intends to use the same metrics in other languages, a naive translation can not be enough as translation is also an interpretive act and the true meaning of the original questions may get lost in the translation process (Van Nes et al. 2010). Therefore, there is a need for ensuring that there are valid tools to assess Presence in other languages to reach a broader audience. There are almost none metrics that have been properly adapted and validated to use with Portuguese (Europe) population. The main objective of this research is to adapt and validate the

CONTACT M. Melo mcmelo@inesctec.pt

Questionnaire of Presence for the Portuguese language (Europe) by considering the semantics and the use of valid concepts to adapt all questionnaire items. Using the techniques of descriptive statistics and confirmatory factorial analysis (CFA), the three versions of PQ are here compared (19, 29 and 32 items) such that by using the identified psychometric properties, and we select the most robust version to be used in research projects in Portuguese. As output, we obtained a robust and valid version of the PQ questionnaire whose use is recommended to evaluate Presence in VR with Portuguese samples.

The remainder of the paper is organised as follows: the Related Work section describes relevant work for the purposes of this work, namely application fields and subjective metrics for assessing Presence in VEs. Section 3 (Material and Methods) describes the methods, instruments, procedure and the sample of this study. The fourth section (Results) presents the results obtained from the adaptation and validation of the Presence Questionnaire for the Portuguese population. The Discussion section discusses the results obtained against the original PQ version and Conclusions section includes the final remarks of the work.

2. Related work

Currently, VR encompasses a wide variety of opportunities for use, particularly in a psychological therapeutic context (Schuemie et al. 2001; Gerardi et al. 2010). Thus, it is often employed as an alternative to the in vivo exposure (Gerardi et al. 2010) that is used in the treatment of different anxiety disorders (Emmelkamp et al. 2002; Cobb and Sharkey 2007; Gerardi et al. 2010) and in treating acrophobia (Emmelkamp et al. 2001). Other examples of pertinent works are in claustrophobia (Botella et al. 1998), social phobia or social anxiety (Parsons and Rizzo 2008), fear of flying (Rothbaum et al. 1996), fear of driving (Wald and Taylor 2003) or cynophobia (Suied et al. 2013).

VR is also applied in the treatment of post-traumatic stress disorder (Rothbaum et al. 2001; Difede and Hoffman 2002), in panic disorders with or without agoraphobia (Botella et al. 2007), and situations of paranoid ideation (Freeman, Pugh, and Garety 2008). VR is also used in other clinical contexts, such as surgical training (Seymour et al. 2002; Gallagher et al. 2005; Ahlberg et al. 2007) and neuro-rehabilitation contexts (e.g. recovery after a stroke) (Gershon et al. 2004; Saposnik and Levin 2011). The purpose of these simulations is to acquire and improve capabilities that can later be used in real contexts (Seymour et al. 2002).

In the sporting context, VR is used to understand and overcome the limitations associated with the performance of athletes in situations of perception-action since it enables the collection of data on their biomechanical, physiological and neurological responses (Bideau et al. 2010).

Both corporate and governmental entities have invested in this technology to create new conditions and opportunities for training and learning through VR simulations of military operations (Zyda 2005). For example, to train pilots, both the Air Force and aeronautical schools use this type of technology to develop the skills that are required to handle an aeroplane. This approach mitigates the risks and possible costs associated with any damage caused by mistakes during the initial stages of learning (Taylor et al. 1997).

Currently, there are several instruments designed to evaluate Presence that range from objective metrics such as physiological measures (Sheridan 1992) or breaks in presence (Slater and Steed 2000) to subjective metrics that include the as Slater-Usoh-Steed Presence Questionnaire (SUS) (Slater, Usoh, and Steed 1994), Presence Questionnaire (PQ) (Witmer and Singer 1998), ITC-Sense of Presence Inventory (ITC-SOPI) (Lessiter et al. 2001), Igroup Presence Questionnaire (IPQ) (Schubert, Friedmann, and Regenbrecht 2001), the MEC-SPQ spatial presence questionnaire (Vorderer et al. 2004), or the Temple Presence Inventory (Lombard, Ditton, and Weinstein 2009).

The Sense of Presence has been widely studied by different authors, being that different theories and definitions have been proposed (please refer to Skarbez, Brooks, and Whitton 2017 for a comprehensive overview of presence theorising). For the purpose of this paper, the authors will follow the definition of Slater and Wilbur (1997) that define the Sense of Presence as the psychological sense of physically being in the VE. Consequently, the PQ was the instrument adopted for this study as it is the one that best characterises such definition of the Sense of Presence. The PQ, developed by Witmer and Singer (1994, 1998), is, perhaps, the most frequently used instrument across a variety of research scenarios (e.g. Renaud et al. 2002; Vora et al. 2002). Three theoretical models were proposed for the PQ: a 32 items version, a 19 items version, and more recently a 29 items version. The 32-item PQ version (Witmer and Singer 1994) was the initial PQ proposal and was divided into seven subscales:

- Sensory exploration: degree to which the user's senses are engaged to explore the VE;
- Involvement: degree to which the user is involved in the virtual experience;

- Interface Awareness: awareness of the participant regarding the display of the VE and the control devices for interacting with it;
- Control Responsiveness: perception of how quickly and properly the VE responds to the interactions of the user;
- Reality/Fidelity: consistency between the virtual experiences and the real world experiences;
- Adjustment/adaptation: how the participants adjust to the idiosyncrasies of the VE.
- Immersion: sum of the total of all questions of all subscales.

Using the factorial analysis technique, the PQ was later revised and reduced to 19 items divided into three subscales (Witmer and Singer 1998):

- Involvement/Control: perceived ability to control the events that occur in the interaction with the VR environment, the VE responsiveness to users' actions, the extent to which the visual aspects of the VE are involving, and to which extent the user becomes involved with the virtual experience;
- Natural: naturalness of the interactions, the extent to which the virtual experience is consistent with reality, and how natural is the locomotion experience in the VE;
- Interface Quality: extent to which playback devices interfere with the execution of tasks as well as the extent to which this does not interfere with users' concentration in performing tasks in a virtual environment.

Later, however, the authors of the original model re-evaluated the number of items needed. Thus, in addition to the 19 previously selected items, three items for auditory stimuli and two for tactile ones were added, as was the case in the first version. In addition to these five, eight more were added, bringing the questionnaire total to 32 items (Witmer and Singer 1998; Witmer, Jerome, and Singer 2005). Subsequently, Witmer, Jerome, and Singer (2005) conducted an investigation involving three studies to determine the correct number of factors that would represent the structure of the PQ in its final version and relate them to the factors previously verified in the previous version (Witmer and Singer 1998). An initial analysis revealed six factors: Involvement, Auditory Fidelity, Adaptation/Immersion, Interface Quality, Consistent with Expectations, and Haptic/Visual Fidelity. However, authors performed additional factorial analyses and calculation of the internal consistency of the factors that resulted in the discard of the Consistent with Expectations and Haptic/Visual Fidelity factors. Consequently, the 29-item revised version includes four subscales (Witmer, Jerome, and Singer 2005):

- Involvement: perception of being involved by the VE while interacting with it continuously;
- Sensory Fidelity: fidelity of the senses in the VE;
- Adaptation/Immersion: how individuals can feel the various characteristics of the VE;
- Interface Quality: user's ability to quickly adapt to the interface and to the VE.

The translation and proper validation of these tools is critical as a simple translation can compromise the validate the original validity of the tool due to the subjective interpretation of the questionnaire. Another factor is that the proper language influences how the meaning is constructed (Van Nes et al. 2010). To be valid, the translation should minimise as much as possible the difference in the interpretation of meanings across languages (Polkinghorne 2005). Regarding properly adapted and validated tools for measuring Presence using Portuguese samples, to the best of our knowledge, they are almost non-existent. Still, from the literature, we can identify the Portuguese (Europe) version of the iPQ (Vasconcelos-Raposo et al. 2016) and the Portuguese (Brazil) version of the PQ (Rigoli et al. 2009; Silva et al. 2016) that, despite the exploratory analysis, there was no confirmatory analysis to validate it as a viable option. Also, a Portuguese (Brazil) version might not be suitable to a Portuguese (Europe) sample due to the divergence between the two dialects due to the syntactic and semantic factors (Gonçalves, Cunha, and Silvano 2010; da Silva 2016). The main goal of this paper is to provide a scientifically valid Portuguese version of the PQ that maintains the psychometric properties of the original English version of the PQ.

3. Material and methods

This study aims to adapt and validate the PQ for the Portuguese-speaking population, maintaining a semantic equivalent to the original version as well as the validity of the contents and concepts through Confirmatory Factorial Analysis. The study considers the three theoretical models proposed by the original authors along the time: the 32 item version, the 29 item version, and the 19 item version.

3.1. Translation and cultural adaptation process

Initially, the original 32-item Presence Questionnaire was translated through the back translation method following the methodologies proposed by Brislin (1970)

and Hambleton and Zenisky (2010). Please note that the 32-item version is the longer version and the items that compose the 29 and the 19 item versions are included in the 32 item version. The translation was carried by four researchers fluent in both English and Portuguese participated in the translation. The areas of training of researchers were Psychology, with a specialisation in psychometrics, and Computer Science, with a specialisation in VR. One of the researchers translated the instrument from English to Portuguese. Then, three researchers performed the translation from Portuguese to English without checking their original format to analyse how this translation compares to the original version (Freire and Almeida 2008; Hambleton and Zenisky 2010). Later, the validity of the content was studied by the same professionals, each one indicating their agreement with the inclusion of the questions in the proposed dimensions in theory. Then, the percentage of agreement and relevance of the items in the respective factors was estimated using a 10-point scale (1 = not relevant, and 10 = extremely relevant), which was later converted into the content validity index (Waltz, Strickland, and Lenz 1991). The results showed values higher than 80%, which indicated the adequacy of the items and that the respective factors cover them.

3.2. Sample

The sample consisted of 451 participants (268 males and 183 females) aged between 17 and 56 years (M=24.54; SD=6.7). All participants were recruited from higher education institutions located in the north of Portugal. Five individuals were excluded because they presented vision and nausea problems during the experiment. Of the total, 81.9% mentioned some familiarity with virtual reality equipment. Most (82.7%) had never used virtual reality glasses, and 95.8% had never experienced any virtual experience similar to the one they underwent in this investigation (using the Oculus Rift Head Mount Display). Likewise, most of the participants had experience in the use of computers ranging from a basic level (11.3%) to intermediate (26.8%) and good (61.9%). The frequency with which they play computer or online games was 1 to 2 times a week (38.6%), 3 to 4 times (15.7%), 5 to 6 times (10.6%), or every day (13.5%). Most participants did not wear contact lenses (61.6%) or hearing aids (99.3%).

3.3. Instruments

3.3.1. Questionnaire

The 32-item version of the PQ consists of a 32-item self-report questionnaire, developed by Witmer and Singer (1998), and comprises 7 subscales: Involvement (11 items), Natural (3 items), Interface Quality (3 items), Resolution (2 items), Auditory (3 items), Haptic (2 items) and Immersion (8 items). All questions are presented on a five-point Likert scale.

3.3.2. Virtual environment

To evaluate the questionnaire, subjects were exposed to virtual environments, which would provide different stimuli to attempt to induce presence, and after which they would answer the questionnaire. For the stimulus itself, we used the VR experience 'Don't let go!' (Skydome Studios 2014), a game-like app that consists of a first-person experience where the user is behind a desk and must hold both Ctrl keys while they are confronted with a series of events intended to induce fear and cause the user to release the Ctrl keys. This strategy sought to ensure that participants did not release the Ctrl keys accidentally; nevertheless, they could quit the experiment at any time they wanted by knocking twice, as instructed.

For presenting the stimuli, an Asus N550JK-CN104H laptop computer equipped with an Intel Core i7 4700HQ CPU, an NVIDIA GeForce GTX850M with 4 GB DDR3 graphic card, and 16 GB of RAM with an added SSD drive was used. To simulate the interaction, the subjects had in front of them a Microsoft Wired 600 keyboard that was not attached to the laptop. The headphones used were the Bose QuietComfort 15 model, which provides very effective active acoustic noise cancelling. The HMD used was the Oculus Rift DK2. The resolution used was FHD (1920 × 1080) with an average framerate of 60 FPS.

3.4. Experimental protocol

Once the required authorisation from the institutional authorities (i.e. ethical committees) was obtained, the experimental study started. Before each experiment, all participants were informed about the procedures and briefed about what to expect and how to proceed when interacting with the elements presented in the virtual environment properly. All participants were informed that their participation involved no risk to their well-being and that they could immediately abandon their participation at any time they wanted to do so during the experiment by knocking twice on the table where they stood. Then, participants were asked to sign a free and informed consent agreement, which formalised their acceptance to take part in the study.

Each participant took an average of 15 minutes to complete the experimental procedure. The virtual experiment lasted approximately 3:45 minutes. A booth was placed in the experimental room to isolate participants

from the surrounding environment during the experiments. Inside the booth, there was a table where the user stood, a keyboard, a pair of headphones, and the Oculus Rift. Participants were assisted with putting the equipment in place. Immediately after finishing this phase, subjects were asked to go to another room where they would fill out the PQ questionnaire in a calm and serene environment. All collected data maintained the anonymity of the participants.

3.5. Statistical procedures

Descriptive statistics were calculated for each item and each dimension (mean, standard deviation). The values of skewness and kurtosis were also calculated to verify the asymmetry of the distribution. Subsequently, Cronbach's α was calculated to verify the internal consistency of the data. The three theoretical versions of the PQ were considered in all the statistical procedures.

To validate the PQ for the Portuguese (Europe) population, an exploratory factorial analysis was performed. Regarding the extraction of factors, the procedures used were the principal component analysis and Varimax rotation. We accepted the recommendations of Tabachnick and Fidell (2007) of .32 for the loading factors.

To perform the confirmatory factor analysis, Amos was used (v.20, SPSS, IBM Company, Chicago, IL, USA) to test 3 theoretical PQ models proposed by the authors of the questionnaire Witmer and Singer (1998) and Witmer, Jerome, and Singer (2005). The adequacy of the instrument was analysed through the fit indices obtained. The statistical procedures have taken into account the guidelines recommended by Kline (2011).

To evaluate the adequacy of the factorial structure, the following indices were used: the χ^2 (chi-square) score indicates when the adjustment value is not significant ($p > 0.05$); however, the results of this test *perse* are questionable because of its vulnerability to the sample size. Thus, in order to overcome this limitation, a correction procedure was used by calculating the ratio of chi-square to degrees of freedom (df), represented by χ^2/df (Jöreskog and Sörbom 1996). According to Marôco (2014), the value 2.0 should be used as a reference to determine the acceptance of the model. The CFI (Comparative Fit Index) and GFI (Goodness Fit Index) indices allow the quality of the theoretical model to be evaluated and generate values in the range of 0 to 1, accepting results superior to 0.90 as indicators of good model adjustment (Bentler and Bonett 1980; Marôco 2014)). We also considered the value 0.95 to be indicative of very good model adjustment (Hu and Bentler 1999; Marôco 2014). For the RMSEA (Root Mean Square Error of Approximation), Marôco (2014) considers that the value should be equal to or less than 0.10 to show good model adjustment, with 0.05 being used as an indicator of a very good adjustment (Marôco 2014). Browne and Cudeck (1992), however, argue that RMSEA should be equal to or less than 0.08, whereas Hu and Bentler (1999) theorise that a value equal to or lower than 0.06 should be considered. The adopted procedures have taken into account the recommendations of Kline (2011).

The composite reliability and the mean variance extracted for each factor were calculated using the formula suggested by Marôco (2014). The existence of outliers was analysed by calculating the square distance of Mahalanobis (D^2), and the normality of the variables was studied by checking the unequal and multivariate skewness and kurtosis coefficients.

4. Results

To simplify the reading of the results, only descriptive statistics (mean and standard deviation) and univariate measures (skewness (*SK*) and kurtosis (*KU*)) of the factors are included here (see Table 1). The coefficients of *SK* and *KU* were calculated for each item, with results in the range from −1.501 and 0.702 and −1.078 and 2.193, respectively, which allowed us to confirm the normal distribution of the sample ($|SK| < 3$ and $|KU| < 10$) Marôco (2014).

The analysis of the values of Cronbach's α (see Table 1) established that the internal consistency of the data was good for the Auditory factor, with values higher than .80. In the remaining factors, a satisfactory internal consistency was verified, with values greater than .50 and less than .80. The total internal consistency of the PQ was good, with values greater than .80 (Cronbach's $\alpha = 0.833$).

It is emphasised that the participants came from similar socio-cultural spheres and had similar experiences with VR: 81.9% had some familiarity with VR. It was found that this knowledge was based on an understanding of how the technology works and not necessarily on prior use. The percentage corresponding to the

Table 1. Descriptive and univariate analyses of the normality and Cronbach's *α* of the factors.

	M ± *SD*	Skewness	Kurtosis	Cronbach's *α*
Involvement	20.17 ± 2.70	−0.288	0.154	0.66
Natural	10.15 ± 3.37	−0.231	−0.193	0.66
Interface Quality	6.93 ± −0.84	−0.161	−0.422	0.63
Resolution	7.62 ± 1.73	−0.661	0.301	0.73
Auditory	8.80 ± 1.28	−0.904	0.704	0.86
Haptic	4.65 ± 2.12	0.326	−0.876	0.67
Immersion	20.02 ± 2.95	−0.371	0.108	0.71

withdrawal of 13 participants was also determined (2.9% of the sample), which did not constitute a threat to the internal validity of the data.

4.1. Confirmatory factor analysis

The factorial validity of the three versions of PQ was analysed by confirmatory factor analyses with the AMOS software, as described by Marôco (2014). No variables whose *SK* and *KU* values compromised the distribution normality were observed ($|SK| < 3$ and $|KU|10$). A set of observations in which the D2 values suggested that they were outliers were excluded before the adaptation of the models. The general quality of fit of the models was studied based on the indices and reference values described by Marôco (2014): chi^2/df, CFI, GFI, RMSEA, P [RMSEA ≤ 0.05] and MECVI. On the other hand, the local quality of adjustment was analysed through the factorial weights and the individual reliability of the items. The adjustment of the model was carried out from modification indices superior to 11, with $p<0.01$, as calculated by AMOS and based on theoretical considerations.

In the execution of the confirmatory factor analysis, 3 theoretical PQ models were considered: the structure of 19 items (Witmer and Singer 1998), 32 items (the 19 of the previous version plus 13 new items), and the 29 items that consisted of an improved version of the 32-item version (Witmer, Jerome, and Singer 2005). The Portuguese adaptation of the PQ was tested in a sample of 451 university students from northern Portugal, and the CFA values are presented in Table 2. From the comparison of the obtained models, the possibility of elaborating a correction in the 19-item version was not considered, eliminating one item that presented a negative factorial load inferior to 0.3. The elimination of this item would result in a scale of two items, which contradicts the recommendations of the speciality literature regarding the minimum number of items per scale. It is recommended that an AIC value be taken as reference for the decision regarding the model that best fits the sample studied. When reviewing at the values obtained in the different indices, however, we chose to select the scale that presented a higher number of indices that satisfied the theoretically pre-defined decision criteria.

From the observed values (presented in Table 2), it was verified that the 32-item version revealed the most adequate adjustment results. Subsequently, several measurement errors were correlated: e1–e2, e1–e6, e1–e11, e2–e6, e3–e8, e5–e10, e8–e9, e9–e10 belonging to the Involvement factor; and e26–e27, e26–e29, e27–e29, and 28–e32 relative to the Immersion factor. These corrections allowed an improvement in the quality of adjustment ($\chi^2/df = 3.863$, GFI $= 0.800$, CFI $= 0.733$, RMSEA $= 0.080$, P [RMSEA ≤ 0.05], MECVI $= 4169$), but the adjustment was not yet sufficiently robust to allow support for this theoretical model. The items whose modifying indices indicated their saturation in different factors from those to which they originally belonged were then excluded. The decision to remove the items was also based on the existence of factor loads with values lower than 0.4. Thus, 11 items were eliminated: 6 from the Involvement factor, 1 from the Interface Quality factor, 1 from the Auditory factor, and 3 from the Immersion factor (refer to Appendix 1 for a detailed description of the deleted items). The model had 21 items in total, and these corrections enabled the achievement of values with quality adjustment ($\chi^2/df = 2.077$, GFI $= 0.936$, CFI $= 0.937$, RMSEA $= 0.049$, P [RMSEA ≤ 0.05], MECVI $= 1.070$).

Table 2. Confirmatory factor analysis results for the 3 versions of the PQ questionnaire.

	N	χ^2/df	GFI	CFI	RSMEA	AIC	MECVI
19-item version	451	2.928	0.952	0.936	0.065	199.632	0.443
29-item version	451	2.794	0.902	0.891	0.063	601.719	1.338
32-item version	451	2.077	0.936	0.937	0.049	474.583	1.070

4.2. Reliability and discriminant validity

The composite reliability obtained in each factor consisted of the following values: Involvement (I) $= 0.667$, Natural (N) $= 0.675$, Interface Quality (IQ) $= 0.636$, Resolution (R) $= 0.731$, Auditory (A) $= 0.869$, Haptic (H) $= 0.679$ and Immersion (Im) $= 0.750$. Overall, all factors presented good composite reliability results, with values above 0.7 or very close to this indicator. Subsequently, the discriminant validity of the factors was analysed by comparing the values of the mean extracted variance (VEM) with the square of the correlation between the factors (Marôco 2014). It is considered that there is a discriminating validity when the VEM of the factors is superior to the square of the correlations of the same factors. It was found that the VEM of the factors varied between 0.351 and 0.77, whereas r^2 varied between 0.001 and 0.166. Therefore, the comparison between the VEM values and the squares of the correlations between factors showed that there is a discriminant validity in all seven factors since all values of VEM are higher than those of r^2. Thus, the adequate adjustment and validity results support the decision to consider the theoretical model obtained with 21 items, adapted to the Portuguese language, originally developed

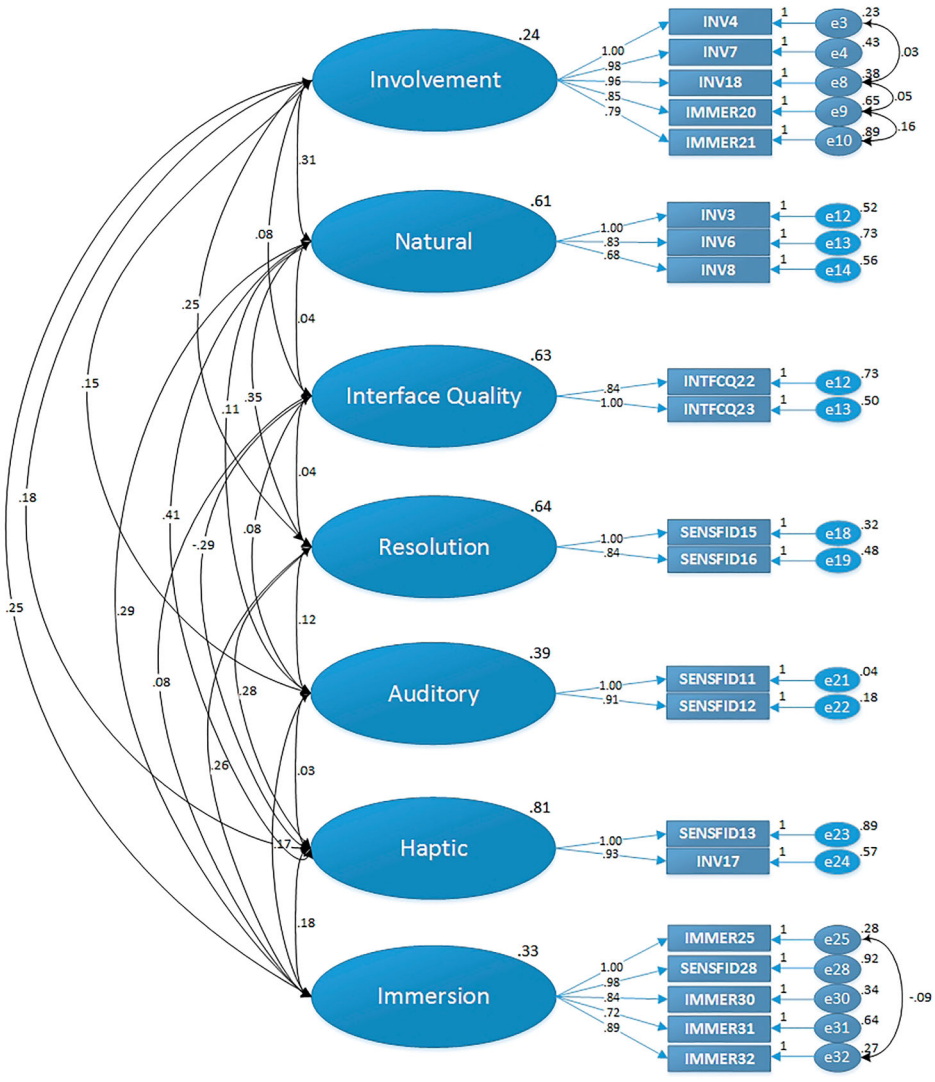

Figure 1. Theoretical model PQ for the Portuguese population.

by Witmer and Singer (1998) with 32 items, as the most robust version of PQ. It is therefore advisable to use this instrument in research projects with Portuguese language samples (Europe). The final version is made up of seven factors that combine 21 items that explained 58.5% of the variance: Involvement – 5 items, Natural – 3 items, Interface Quality – 2 items, Resolution – 2 items, Auditory – 2 items, Haptic – 2 items, Immersion – 5 items (see Figure 1).

5. Discussion

In the research carried out in the area of VR, the Presence appears as a crucial concept in the understanding and analysis of users' perception and satisfaction during the virtual simulation. In this sense, and considering that there is only one validated instrument for the Portuguese-speaking population that measures the human experience in virtual simulations, it is necessary to develop studies that allow the development or adaptation of more psychometric instruments that can be used in this area. It is emphasised that the instruments of evaluation are associated with the cultural and linguistic environment where they are developed; therefore, they must be translated and validated if they are to be applied in different environments. Two main works address Portuguese samples: iPQp (Vasconcelos-Raposo et al. 2016) and the Brazilian Portuguese version of the PQ (Silva et al. 2016). Our work is an addition to this previous contributes as is a viable and valid alternative for the iPQp and the Brazilian Portuguese version of the PQ questionnaire does not present a confirmatory analysis that testifies its applicability to European Portuguese samples. Also, we might have into account the possible impact of applying a Brazilian Portuguese questionnaire to a European Portuguese sample. There are psychometric

properties and socio-cultural aspects that can affect the participants' understanding of the questions and their answers (Gonçalves, Cunha, and Silvano 2010; da Silva 2016).

This study aimed to validate the adaptation of PQ, originally developed by Witmer and Singer (1998), to the Portuguese language, using a sample of 451 university students from the north of Portugal. In accomplishing this adaptation, an analysis of the semantics and content of the items was carried out in order to improve the validity of the constructs and their internal consistency. Comparing the obtained version with the original, 11 items were removed, but with the necessary changes and corrections, good adjustment results were achieved in all indices. The discriminant validity was verified in all factors, and the calculated convergent validity values were lower than desirable in three factors (i.e. Involvement, Natural and Immersion) and desirable in the remainder. Considering these results, the validation of the final version of 21 PQ items for the Portuguese language is accepted, and the alternative versions examined in this study are rejected. It is also emphasised that the confirmatory factorial analyses carried out respects the structure proposed in the original theoretical model, and thus complying with validation theory (Cheung, van de Vijver, and Leong 2011). These procedures allow an adaptation equivalent to the original, even when using different cultural and linguistic groups, allowing the maintenance of concepts and content that guarantee the proper interpretation and effectiveness of the instrument. Thus, for comparisons between sociocultural contexts in the translation of items should consider the necessary semantic adjustments in order to preserve the intentional theoretical purpose of the items cross-culturally. To further validate the different adaptations of questionnaires across different sociocultural specificities, the use of objective metrics could be adopted to be correlated with the subjective metrics.

6. Conclusions

The main contribution of this study was to conduct an adaptation of the PQ to the Portuguese language that, by maintaining its psychometric properties, is a scientifically valid research tool that enables researchers to study Presence with samples of Portuguese Language. The main objective of this study was achieved, and the results of the confirmatory factorial analysis revealed that the 21-item version obtained, initially with 32 items, has excellent psychometric properties, which is why the validation of this version is supported in Portuguese. The model initially proposed by the original theoretical model was supported, despite the exclusion of 11 items. Thus, this adapted version of PQ should be used in VR research projects with Portuguese participants, given that this instrument is correctly validated for this population. It is recommended that further studies be conducted with this instrument in order to deepen the information obtained here. Future researchers in this field should recruit a larger number of participants, possibly with more experience with VR equipment, who also come from diverse socio-cultural backgrounds.

We conclude with the recommendation to use the 21-item version of PQ in VR research programmes, given that the results achieved ensure that this instrument is quite robust to measure Presence in Portuguese (Europe) language samples. Note that the items of this version are elaborated respecting the existent linguistic differences that exists between the different Portuguese speaking countries. Thus, it is recommended that researchers of Portuguese speaking countries make the necessary adjustments to their sociocultural (linguistic) specificities.

Acknowledgments

This work is financed by the ERDF – European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation -- COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT -- Fundação para a Ciência e a Tecnologia within project POCI-01-0145-FEDER-028618 entitled PERFECT – Perceptual Equivalence in virtual Reality For authEntiC Training. All the works were conducted at MASSIVE Virtual Reality Laboratory, and INESC TEC / UTAD Laboratory.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work is financed by the ERDF – European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation – COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT – Fundação para a Ciência e a Tecnologia within project POCI-01-0145-FEDER-028618 entitled PERFECT – Perceptual Equivalence in virtual Reality For authEntiC Training.

ORCID

J. Vasconcelos-Raposo http://orcid.org/0000-0002-3456-9727
M. Melo http://orcid.org/0000-0003-4050-3473
M. Bessa http://orcid.org/0000-0002-3002-704X

References

Ahlberg, Gunnar, Lars Enochsson, Anthony G. Gallagher, Leif Hedman, Christian Hogman, David A. McClusky, Stig Ramel, C. Daniel Smith, and Dag Arvidsson. 2007. "Proficiency-Based Virtual Reality Training Significantly Reduces the Error Rate for Residents During Their First 10 Laparoscopic Cholecystectomies." *The American Journal of Surgery* 193 (6): 797–804.

Bentler, Peter M., and Douglas G. Bonett. 1980. "Significance Tests and Goodness of Fit in the Analysis of Covariance Structures." *Psychological Bulletin* 88 (3): 588.

Bideau, Benoit, Richard Kulpa, Nicolas Vignais, Sébastien Brault, Franck Multon, and Cathy Craig. 2010. "Using Virtual Reality to Analyze Sports Performance." *IEEE Computer Graphics and Applications* 30 (2): 14–21.

Botella, C., R. M. Baños, C. Perpiñá, H. Villa, Mu Alcaniz, and A. Rey. 1998. "Virtual Reality Treatment of Claustrophobia: A Case Report." *Behaviour Research and Therapy* 36 (2): 239–246.

Botella, C., A. García-Palacios, H. Villa, R. M. Baños, Soledad Quero, M. Alcañiz, and G. Riva. 2007. "Virtual Reality Exposure in the Treatment of Panic Disorder and Agoraphobia: A Controlled Study." *Clinical Psychology & Psychotherapy* 14 (3): 164–175.

Bouvier, Patrice. 2008. "The Five Pillars of Presence: Guidelines to Reach Presence." *Proceedings of the 11th Annual International Workshop on Presence*, 246–249, Padova, 16–18 October 2008.

Brislin, Richard W. 1970. "Back-Translation for Cross-Cultural Research." *Journal of Cross-Cultural Psychology* 1 (3): 185–216.

Browne, Michael W., and Robert Cudeck. 1992. "Alternative Ways of Assessing Model Fit." *Sociological Methods & Research* 21 (2): 230–258.

Cheung, Fanny M., Fons J. R. van de Vijver, and Frederick T. L. Leong. 2011. "Toward a New Approach to the Study of Personality in Culture." *American Psychologist* 66 (7): 593.

Cobb, S. V. G., and Paul M. Sharkey. 2007. "A Decade of Research and Development in Disability, Virtual Reality and Associated Technologies: Review of ICDVRAT 1996-2006." *IJVR* 6 (2): 51–68.

da Silva, Augusto Soares. 2016. "3) Sociolinguística cognitiva e o estudo da convergência/divergência entre o português europeu e o português brasileiro." *Revista Veredas* 10 (1 e 2).

Difede, Joann, and Hunter G. Hoffman. 2002. "Virtual Reality Exposure Therapy for World Trade Center Post-Traumatic Stress Disorder: A Case Report." *Cyberpsychology & Behavior* 5 (6): 529–535.

Ellis, Stephen R. 1996. "Presence of Mind: A Reaction to Thomas Sheridan's "Further Musings on the Psychophysics of Presence"." *Presence: Teleoperators & Virtual Environments* 5 (2): 247–259.

Emmelkamp, Paul M. G., Mary Bruynzeel, Leonie Drost, and Charles A. P. G. van der Mast. 2001. "Virtual Reality Treatment in Acrophobia: A Comparison with Exposure in Vivo." *CyberPsychology & Behavior* 4 (3): 335–339.

Emmelkamp, P. M. G., M. Krijn, A. M. Hulsbosch, S. De Vries, M. J. Schuemie, and C. A. P. G. Van der Mast. 2002. "Virtual Reality Treatment Versus Exposure in Vivo: A Comparative Evaluation in Acrophobia." *Behaviour Research and Therapy* 40 (5): 509–516.

Freeman, Daniel, Katherine Pugh, and Philippa Garety. 2008. "Jumping to Conclusions and Paranoid Ideation in the General Population." *Schizophrenia Research* 102 (1): 254–260.

Freire, Teresa, and Leandro S. Almeida. 2008. *Metodologia da investigação em psicologia e educação*. Psiquilíbrios Edições.

Gallagher, Anthony G., E. Matt Ritter, Howard Champion, Gerald Higgins, Marvin P. Fried, Gerald Moses, C. Daniel Smith, and Richard M. Satava. 2005. "Virtual Reality Simulation for the Operating Room: Proficiency-Based Training as a Paradigm Shift in Surgical Skills Training." *Annals of Surgery*241 (2): 364–372.

Gerardi, Maryrose, Judith Cukor, JoAnn Difede, Albert Rizzo, and Barbara Olasov Rothbaum. 2010. "Virtual Reality Exposure Therapy for Post-Traumatic Stress Disorder and Other Anxiety Disorders." *Current Psychiatry Reports* 12 (4): 298–305.

Gershon, Jonathan, Elana Zimand, Melissa Pickering, Barbara Olasov Rothbaum, and Larry Hodges. 2004. "A Pilot and Feasibility Study of Virtual Reality as a Distraction for Children with Cancer." *Journal of the American Academy of Child & Adolescent Psychiatry* 43 (10): 1243–1249.

Gonçalves, Anabela, Luís Filipe Cunha, and Purificação Silvano. 2010. "Interpretação temporal dos domínios infinitivos na construção de reestruturação do Português europeu." *Textos Seleccionados do XXV Encontro Nacional da Associação Portuguesa de Linguística*, 435–447. Porto: APL.

Hambleton, R. K., and A. L. Zenisky. 2010. "Translating and Adapting Tests for Cross-Cultural Assessments." In *Cross-Cultural Research Methods in Psychology*, edited by D. Matsumoto and F. J. R. van de Vijver, 46–70. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511779381.004.

Hu, Li-tze, and Peter M. Bentler. 1999. "Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives." *Structural Equation Modeling: A Multidisciplinary Journal* 6 (1): 1–55.

Jöreskog, Karl G., and Dag Sörbom. 1996. *LISREL 8: User's Reference Guide*. Lincolnwood, IL: Scientific Software International.

Kline, Rex. 2011. *Principles and Practice of Structural Equation Modeling*. New York: Guilford Publications.

Lee, Kwan Min. 2004. "Presence, Explicated." *Communication Theory* 14 (1): 27–50.

Lessiter, Jane, Jonathan Freeman, Edmund Keogh, and Jules Davidoff. 2001. "A Cross-Media Presence Questionnaire: The ITC-Sense of Presence Inventory." *Presence: Teleoperators and Virtual Environments* 10 (3): 282–297.

Lombard, Matthew, Theresa B. Ditton, and Lisa Weinstein. 2009. "Measuring Presence: The Temple Presence Inventory." *Proceedings of the 12th Annual International Workshop on Presence*, Los Angeles, CA, 1–15.

Marôco, João. 2014. *Análise de equações estruturais: Fundamentos teóricos, software & aplicações*. 2nd ed. Pêro Pinheiro: Pêro Pinheiro.

Parsons, Thomas D., and Albert A. Rizzo. 2008. "Affective Outcomes of Virtual Reality Exposure Therapy for Anxiety and Specific Phobias: A Meta-analysis." *Journal of Behavior Therapy and Experimental Psychiatry* 39 (3): 250–261.

Polkinghorne, Donald E. 2005. "Language and Meaning: Data Collection in Qualitative Research." *Journal of Counseling Psychology* 52 (2): 137.

Renaud, Patrice, Joanne L. Rouleau, Luc Granger, Ian Barsetti, and Stéphane Bouchard. 2002. "Measuring Sexual Preferences in Virtual Reality: A Pilot Study." *CyberPsychology & Behavior* 5 (1): 1–9.

Rigoli, Marcelo Montagner, Beatriz de Oliveira Meneguelo Lobo, Alice Rewusaat Justo, Luiza Luiza Menezes Correia, Bruno do Nascimento Schneider, Rafael Rieder, and Márcio Sarroglia Pinho. 2009. "Desenvolvimento da versão brasileira do Questionário de Presença para uso no Tratamento Cognitivo-Comportamental com Realidade Virtual no Transtorno de Estresse Pós-Traumático." *Salão de Iniciação Científica (21.: 2009 out. 19–23: Porto Alegre, RS). Livro de resumos*. Porto Alegre: UFRGS.

Rothbaum, Barbara O., Larry F. Hodges, David Ready, Ken Graap, and Renato D. Alarcon. 2001. "Virtual Reality Exposure Therapy for Vietnam Veterans with Posttraumatic Stress Disorder." *The Journal of Clinical Psychiatry* 62 (8): 617–622.

Rothbaum, Barbara Olasov, Larry Hodges, Benjamin A. Watson, G. Drew Kessler, and Dan Opdyke. 1996. "Virtual Reality Exposure Therapy in the Treatment of Fear of Flying: A Case Report." *Behaviour Research and Therapy* 34 (5): 477–481.

Sanchez-Vives, Maria V., and Mel Slater. 2005. "From Presence to Consciousness Through Virtual Reality." *Nature Reviews Neuroscience* 6 (4): 332.

Saposnik, Gustavo, Mindy. Levin, Stroke Outcome Research Canada (SORCan) Working Group, et al.2011. "Virtual Reality in Stroke Rehabilitation." *Stroke* 42 (5): 1380–1386.

Schubert, Thomas, Frank Friedmann, and Holger Regenbrecht. 2001. "The Experience of Presence: Factor Analytic Insights." *Presence: Teleoperators and Virtual Environments* 10 (3): 266–281.

Schuemie, Martijn J., Peter Van Der Straaten, Merel Krijn, and Charles A. P. G. Van Der Mast. 2001. "Research on Presence in Virtual Reality: A Survey." *CyberPsychology & Behavior* 4 (2): 183–201.

Seymour, Neal E., Anthony G. Gallagher, Sanziana A. Roman, Michael K. O'brien, Vipin K. Bansal, Dana K. Andersen, and Richard M. Satava. 2002. "Virtual Reality Training Improves Operating Room Performance: Results of a Randomized, Double-Blinded Study." *Annals of Surgery* 236 (4): 458–464.

Sheridan, Thomas B. 1992. "Musings on Telepresence and Virtual Presence." *Presence: Teleoperators & Virtual Environments* 1 (1): 120–126.

Silva, Gustavo R., Júlia C. Donat, Marcelo M. Rigoli, Fernando R. de Oliveira, and Christian H. Kristensen. 2016. "A Questionnaire for Measuring Presence in Virtual Environments: Factor Analysis of the Presence Questionnaire and Adaptation Into Brazilian Portuguese." *Virtual Reality* 20 (4): 237–242. https://doi.org/10.1007/s10055-016-0295-7.

Skarbez, Richard T. 2016. "Plausibility Illusion in Virtual Environments." PhD diss., The University of North Carolina at Chapel Hill.

Skarbez, Richard T., Frederick P. Brooks Jr., and Mary C Whitton. 2017. "A Survey of Presence and Related Concepts." *ACM Computing Surveys* 50 (6): 961–9639. http://doi.acm.org/10.1145/3134301.

Skydome Studios. 2014. "Don't let go! (Version 1.2)." Accessed 2014-12-02. https://share.oculus.com/app/dont-let-go.

Slater, Mel. 2009. "Place Illusion and Plausibility Can Lead to Realistic Behaviour in Immersive Virtual Environments." *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1535): 3549–3557.

Slater, Mel, and Anthony Steed. 2000. "A Virtual Presence Counter." *Presence: Teleoperators & Virtual Environments* 9 (5): 413–434.

Slater, Mel, Martin Usoh, and Anthony Steed. 1994. "Depth of Presence in Virtual Environments." *Presence: Teleoperators & Virtual Environments* 3 (2): 130–144.

Slater, Mel, and Sylvia Wilbur. 1997. "A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments." *Presence: Teleoperators and Virtual Environments* 6 (6): 603–616.

Suied, Clara, George Drettakis, Olivier Warusfel, and Isabelle Viaud-Delmon. 2013. "Auditory-visual Virtual Reality As a Diagnostic and Therapeutic Tool for Cynophobia." *Cyberpsychology, Behavior, and Social Networking* 16 (2): 145–152.

Tabachnick, Barbara G., and Linda S. Fidell. 2007. *Experimental Designs Using ANOVA*. Belmont, CA: Thomson/Brooks/Cole.

Taylor, Henry L., Gavan Lintern, Charles L. Hulin, Donald Talleur, and Tom Emanuel. 1997. *Transfer of Training Effectiveness of Personal Computer-Based Aviation Training Devices*. Technical Report. DTIC Document.

Van Nes, Fenna, Tineke Abma, Hans Jonsson, and Dorly Deeg. 2010. "Language Differences in Qualitative Research: is Meaning Lost in Translation?" *European Journal of Ageing* 7 (4): 313–316.

Vasconcelos-Raposo, J., M. Bessa, M. Melo, L. Barbosa, R. Rodrigues, C. M. Teixeira, L. Cabral, and A. Augusto Sousa. 2016. "Adaptation and Validation of the Igroup Presence Questionnaire (IPQ) in a Portuguese Sample." *Presence: Teleoperators & Virtual Environments* 25 (3): 191–203.

Vora, Jeenal, Santosh Nair, Anand K. Gramopadhye, Andrew T. Duchowski, Brian J. Melloy, and Barbara Kanki. 2002. "Using Virtual Reality Technology for Aircraft Visual Inspection Training: Presence and Comparison Studies." *Applied Ergonomics* 33 (6): 559–570.

Vorderer, Peter, Werner Wirth, Feliz Ribeiro Gouveia, Frank Biocca, Timo Saari, Lutz Jäncke, and Saskia Böcking, et al. 2004. "MEC Spatial Presence Questionnaire."

Wald, Jaye, and Steven Taylor. 2003. "Preliminary Research on the Efficacy of Virtual Reality Exposure Therapy to Treat Driving Phobia." *CyberPsychology & Behavior* 6 (5): 459–465.

Waltz, Carolyn Feher, Ora Strickland, and Elizabeth R. Lenz. 1991. *Measurement in Nursing Research*. Philadelphia: FA Davis Company.

Witmer, Bob G., Christian J. Jerome, and Michael J. Singer. 2005. "The Factor Structure of the Presence Questionnaire." *Presence: Teleoperators and Virtual Environments* 14 (3): 298–312.

Witmer, Bob G., and Michael F. Singer. 1994. *Measuring Presence in Virtual Environments*. Technical Report. Army Research Inst for the Behavioral and Social Sciences Alexandria Va.

Witmer, Bob G., and Michael J. Singer. 1998. "Measuring Presence in Virtual Environments: A Presence Questionnaire." *Presence: Teleoperators and Virtual Environments* 7 (3): 225–240.

Zyda, Michael. 2005. "From Visual Simulation to Virtual Reality to Games." *Computer* 38 (9): 25–32.

Appendices

Appendix 1. Presence questionnaire – validated Portuguese version

(1) Quão natural te pareceram as tuas interações com o ambiente?
(2) Em que medida os aspetos visuais do ambiente te envolveram?
(3) Quão natural era o mecanismo utilizado para controlar os movimentos através do ambiente?
(4) Quão convincente foi a sensação dos objetos estarem a mover-se pelo espaço?
(5) Quão consistentes te pareceram ser as experiências no ambiente virtual em comparação com as experiências do mundo real?
(6) Quão bem conseguiste identificar os sons?
(7) Quão bem conseguiste localizar os sons?
(8) Quão bem conseguiste inspecionar ou pesquisar ativamente no ambiente virtual utilizando o tato?
(9) Quão de perto conseguiste examinar objetos?
(10) Quão bem conseguiste examinar objetos a partir de múltiplos pontos de vista?
(11) Quão bem conseguiste mover ou manipular objetos no ambiente virtual?
(12) Quão envolvido estiveste na experiência do ambiente virtual?
(13) Quão rapidamente te adaptaste à experiência no ambiente virtual?
(14) Quão à vontade te sentiste no final de experiência em relação às ações de mover e interagir com o ambiente virtual?
(15) Em que medida a qualidade da imagem reproduzida interferiu ou distraiu na realização das tarefas atribuídas ou exigidas?
(16) Em que medida os dispositivos de controlo utilizados interferiram no teu desempenho na realização das tarefas atribuídas ou de quaisquer outras tarefas?
(17) Quão completamente estavam os teus sentidos envolvidos na experiência?
(18) Estiveste envolvido na tarefa experimental ao ponto de perderes a noção do tempo?
(19) Houve momentos durante a experiência no ambiente virtual durante os quais te sentiste completamente concentrado na tarefa ou no ambiente?
(20) Quão facilmente te adaptaste aos dispositivos de controlo utilizados para interagir com o ambiente virtual?
(21) A informação fornecida através dos diferentes sentidos no ambiente virtual (p. ex., a visão, toque ou audição) foi consistente?

Appendix 2. Presence Questionnaire – identification of items removed in the Portuguese version

1 ~~How much were you able to control events?~~
2 ~~How responsive was the environment to actions that you initiated (or performed)?~~
3 How natural did your interactions with the environment seem?
4 How much did the visual aspects of the environment involve you?
5 ~~How much did the auditory aspects of the environment involve you?~~
6 How natural was the mechanism which controlled movement through the environment?
7 How compelling was your sense of objects moving through space?
8 How much did your experiences in the virtual environment seem consistent with your real world experiences?
9 ~~Were you able to anticipate what would happen next in response to the actions that you performed?~~
10 ~~How completely were you able to actively survey or search the environment using vision?~~
11 How well could you identify sounds?
12 How well could you localise sounds?
13 How well could you actively survey or search the virtual environment using touch?
14 ~~How compelling was your sense of moving around inside the virtual environment?~~
15 How closely were you able to examine objects?
16 How well could you examine objects from multiple viewpoints?
17 How well could you move or manipulate objects in the virtual environment?
18 How involved were you in the virtual environment experience?
19 ~~How much delay did you experience between your actions and expected outcomes?~~
20 How quickly did you adjust to the virtual environment experience?
21 How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?
22 How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?
23 How much did the control devices interfere with the performance of assigned tasks or with other activities?
24 ~~How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?~~
25 How completely were your senses engaged in this experience?
26 ~~To what extent did events occurring outside the virtual environment distract from your experience in the virtual environment?~~
27 ~~Overall, how much did you focus on using the display and control devices instead of the virtual experience and experimental tasks?~~
28 Were you involved in the experimental task to the extent that you lost track of time?
29 ~~How easy was it to identify objects through physical interaction, like touching an object, walking over a surface, or bumping into a wall or object?~~
30 Were there moments during the virtual environment experience when you felt completely focussed on the task or environment?
31 How easily did you adjust to the control devices used to interact with the virtual environment?
32 Was the information provided through different senses in the virtual environment (e.g. vision, hearing, touch) consistent?