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ORIGINAL ARTICLE

A questionnaire for measuring presence in virtual environments: factor analysis of the presence questionnaire and adaptation into Brazilian Portuguese

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Abstract The increasing use of virtual reality (VR) environments in different domains of research and psychotherapy offers advantages over traditional treatment approaches. However, in order to feel immersed and involved by the VR experience, participants require VR scenarios that promote the subjective feeling of "being there," i.e., presence. The most utilized mean of operationalization of presence is through self-report scales and questionnaires. This article aims to report the translation and adaptation of the presence questionnaire (PQ) into Brazilian Portuguese, comparing the factorial distribution of the adapted version with the original PQ. Translation and back-translations were conducted by a team of Brazilian psychologists and computer science professionals with experience on the field. Participants ($n = 100$) answered the Brazilian version of the questionnaire after wearing a head-mounted display (HMD) and driving a virtual automobile in a VR scenario. The principal component analysis of the translated version generated factors consistently with the original study; however, items that had equivocal construct adequacy in the original PQ changed factors. The factor structure of the PQ is discussed. The growing use of VR environments requires instruments assessing the presence of immersed individuals, and the Brazilian Portuguese version of the PQ appears to be a viable option.

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1 Introduction

Virtual reality (VR) environments simulate natural events and social interactions through real-time computer graphics, body-tracking devices, visual displays and other sensory input devices. The use of VR in human research offers certain advantages over other approaches, such as control over the experiment (e.g., VR allows naturalistic interactive behaviors taking place, while brain activity is monitored via imaging or direct recording) (Bohil et al. 2011; Powers and Emmelkamp 2008). VR has been utilized in different domains of psychotherapy research, especially in the treatment of anxiety disorders (Parsons and Rizzo 2008).

Researchers utilize VR environments for treating fear of flying (Krijn et al. 2007; Maltby et al. 2002; Rothbaum et al. 2006), fear of spiders (Garcia-Palacios et al. 2002), fear of heights (Dominique et al. 2011; Emmelkamp et al. 2002), panic disorder and agoraphobia (Botella et al. 2007), PTSD (Difede et al. 2007; Rizzo et al. 2010), social phobia (Anderson et al. 2003; Klinger et al. 2005), among others. In Brazil, a recent and rapid growth in the use of VR for health purposes is noticeable, primarily among research groups developing tools for professional training, collaborative interfaces and motor and cognitive rehabilitation (Nunes et al. 2011). Currently, virtual environments are in development for VR exposure therapy with Brazilian trauma victims, as no VR scenario published until this moment encompasses the specific types of urban interpersonal trauma

which are most recurrent in Brazil, such as bank heists (Gerardi et al. 2010; Murray et al. 2013).

In order to be an adequate mediator for the intervention's purpose, a VR scenario is required to meet certain basic requirements that allow individuals to be involved in the sensory experience, capturing their attention and overriding the "real" experience in favor of the virtual reality. Immersion in the virtual environment is promoted through equipment able to generate a verisimilar experience, what can be achieved through a head-mounted display (HMD) with head-tracking, realistic virtual graphics and interactions, spatial sound reproduction or other realistic sensory mediators (Krijn et al. 2004; Takatalo et al. 2008).

The immersive equipment is utilized to generate a sense of presence, which can be defined as an illusion of non-mediation toward the virtual experience, or a subjective feeling of "being there." This means that such technology leads the individual to temporarily perceiving his interactions and sensations as independent of the VR apparatus, as if he was seeing, moving, touching or interacting with the virtual stimuli directly. Presence could be therefore understood as a subjective feeling that results from the relationship between the quality of the immersive equipment and individual characteristics. Many researchers have attempted to define and measure the presence in VR environments, since known VR-based treatments require that the individual engages in the virtual experience (Hoffman et al. 2003; Krijn et al. 2004; Slater 2004; Witmer and Singer 1998).

The most utilized method for measuring and quantifying the subjective feeling of presence is through self-report scales and questionnaires. Witmer and Singer (1998) developed a presence questionnaire (PQ) with the objective of measuring presence, with 33 items in a 7-point Likert scale. Component analysis of the PQ resulted in four main factors involved in presence: (1) Involvement, with items assessing a state achieved by focusing one's attention and mental energy into coherent or meaningfully related stimuli, activities or events; (2) Adaptation/Immersion, regarding a sense of being enveloped, included in and interacting with a continuous stream of experiences and stimuli; (3) Sensory Fidelity, related to visual, auditory and haptic perceptions of the VR scenario; and (4) Interface Quality, assessing the influence of visual and control interfaces in the VR experience (Witmer et al. 2005). The growing use of VR in Brazil raises the need of adequate tools for measuring presence; therefore, the aim of the present study is to translate and adapt the presence questionnaire into Brazilian Portuguese, comparing the factor distribution of the adapted version with the original PQ.

2 Method

2.1 Translation and adaptation

The original version of the PQ was obtained with the authors as well as their consent for the translation and adaptation processes. First, two independent translations into Brazilian Portuguese were made by one psychologist and one computer science professional with experience in virtual reality and English proficiency. Both translations were then back-translated by two other professionals with the same skills and a professional translator, what resulted in three independent back-translations. After this step, a preliminary unified version was obtained through a consensus meeting held with seven psychologists aiming to assess semantic adaptation.

2.2 Sample

A sample of 100 college students (71 female) with a mean age of 24 years (SD = 7.33) participated in the study, approved by the Ethics Committee in Research of the Pontifical Catholic University of Rio Grande do Sul (08/04338). Participants were required to be adult students of undergraduate or graduate programs in a local university. No exclusion criteria were utilized.

2.3 Procedures

Students were invited to participate through signs in hallways and messages in digital social network. Participants then received an explanation about procedures and objectives of the study and signed an informed consent form. They were requested to sit on a chair in a room (6 m^2) with dimmed lights and to wear VR goggles (Vuzix Eyewear VR920, 640 × 480 resolution), which contained a built in head-tracking device and were connected to a *Lenovo* T400 laptop.

The virtual environment put the participant in first-person view at the driver's seat of an automobile in a city with buildings, streets, traffic lights and other moving cars and pedestrians. Besides the visual and auditory elements of the city, parts of the car were also visible (i.e., steering wheel, wing and rearview mirrors, frame of the windshield, panel), depending on which direction participants were facing at each moment. Visual body representations of the participant (i.e., arms, hands) were not included in the VR scenario. Sound stimuli included the engine sounds of accelerating and crashing sounds. A two-axis joystick was utilized for accelerating and slowing down (y-axis) and turning the direction of the car (x-axis). The objective was to follow the researcher's directions through the virtual city

in a predetermined itinerary, avoiding collisions with other vehicles and pedestrians crossing the streets under red traffic lights. At a predetermined location, the researcher warned the participant that a police officer would show up in the VR environment requesting the driver to stop. After that event, participants were requested to park the vehicle and to take off the VR goggles, as the researcher presented them with the PQ. The instruction given was the following: "now you will receive a questionnaire about your experience in the virtual environment. Answer as sincerely as possible."

2.4 Statistical analysis

Descriptive analyses and exploratory factorial analysis extraction methods (maximum variance, principal axis factorial analysis and principal component analysis) were conducted. The objective of the exploratory factor analysis was to verify whether our adapted questionnaire would independently form a factor solution similar to that of the original validation study (Witmer et al. 2005), and whether the factors would reflect similar latent variables. The principal component analysis was conducted with 29 of the 34 items of the PQ, as in the original validation study, with a non-orthogonal rotation (*oblimin*) and Kaiser's normalization.

Components' extraction and retention procedures were as follows: (a) Kaiser's test, which recommends the retention of components with eigenvalues greater than 1, based on the theory that eigenvalues represent the amount of variance explained by a factor—and an eigenvalue of 1 represents a substantial amount of variance (Field 2009), and (b) scree plot observation, used to identify the optimal number of factors that must be extracted before the amount of unique variance begins to dominate the structure of common variance. However, according to Stevens (1992), the scree plot is not a selection criteria recommended to a sample smaller than 200 subjects, as the one in case ($n = 100$); (c) finally, the latent root was used, in which any factor must account for the variance of at least one variable (Hair et al. 2009).

Analysis regarding the PQ's reliability was also conducted in this procedure. The reliability in question refers to its semantic coherence, which can be evaluated by its consistency and stability (Fachel et al. 2000). The reliability regarding internal consistency was assessed through Cronbach's alpha, which is the average of all correlation coefficients between all items (Cozby 2003). Analysis was conducted with SPSS, including sample adequacy tests (KMO and Bartlett), instrument reliability tests and factor analysis tests to verify the natural grouping of items.

3 Results

3.1 Psychometric analysis

A principal component analysis was conducted with 29 items from the translated version of the PQ to Portuguese (Witmer et al. 2005). A Kaiser–Meyer–Olkin (KMO) measure of .79 indicated sampling adequacy and good preconditions for the principal component factor analysis. The Cronbach's alpha of the scale was .89, indicating strong internal consistency.

The four-factor model accounted for 54.07 % of total variance. Factor 1 accounted for 29.87 % of variance and included items 5, 7, 8, 11, 12, 13, 26 and 29. Factor 2 accounted for 9.64 % of the variance and included items 1, 2, 9, 10, 14, 15, 16, 17, 20, 21 and 28. Factor 3 accounted for 8.32 % of the variance and included items 19, 22, 23 and 24. Factor 4 accounted for 6.23 % of the variance and included items 3, 4, 6, 7, 18, 25 and 27. Internal consistency reliability coefficients were computed for each of the four factors using Cronbach's alpha. Except for factor 3 ($\alpha = .26$), which consists of only four items, the reliability coefficients were considered good: factor 1 ($\alpha = .83$), factor 2 ($\alpha = .86$) and factor 4 ($\alpha = .74$).

Factor loadings for each of the PQ items are presented in Table 1. All items had a loading of at least .30 on one or more factors. Items were assigned to only one factor, based on the highest loading. As in the original study, a qualitative analysis was conducted to decide over the placement of items with similar loadings on more than a single factor, based on construct adequacy. Item distribution across factors is presented in Table 2, both for the original and adapted versions.

4 Discussion

The items of this translated version of the PQ formed factors consistently with the original study. Although some items have changed factors, we believed that this actually improved theoretical adequacy. Item 29 ("was the information provided through different senses in the virtual environment [e.g., vision, hearing, touch] consistent?"), for example, had a higher factorial load in the Sensory Fidelity factor (i.e., related to visual, auditory and haptic items) instead of the Adaptation/Immersion factor (i.e., perception of a continuous stream of experiences and stimuli with which one interacts and feels enveloped by) of the original study.

The Involvement factor, in the original factor structure, encompassed items concerning how natural the elements of the scenario seemed to be and regarding the degree of

Table 1 Item loadings on each factor

	Component			
	1	2	3	4
Question1		−.670		
Question2		−.307	.305	
Question3				.302
Question4				.518
Question5	.827			
Question6				.345
Question7	.568			.335
Question8	.388			
Question9		−.686		
Question10		−.483		
Question11	.914			
Question12	.840			
Question13	.454			
Question14	.352	−.441		
Question15		−.484		
Question16		−.458		
Question17		−.610		
Question18				.796
Question19			.736	
Question20		−.830		
Question21		−.771		
Question22			.738	
Question23			.807	
Question24		−.301	−.501	
Question25				.880
Question26	.331			
Question27				.842
Question28		−.850		
Question29	.453			.352

Loading values below .3 are not presented

perceived control over aspects of the VR environment. However, these concepts also define items in the Adaptation/Immersion factor. In fact, Witmer et al. (2005) described the Adaptation/Immersion component as unstable across validation studies and very interdependent with the Involvement factor. In our study, four items (1, 10, 14 and 17) originally included in the Involvement component changed to Adaptation/Immersion, while two (25 and 27) originally in Adaptation/Immersion had higher loadings in Involvement. The number of interchanged items is significant; however, item adequacy with the central construct seems to be maintained. For example, item 27 (i.e., "Were there moments during the virtual environment experience when you felt completely focused on the task or environment?") contains a central aspect of the Involvement concept: the focusing of attention and mental energy in activities inside the VR scenario.

Items 7, 8 and 26 had higher loadings in the Sensory Fidelity factor than in Involvement, what seems to indicate that our sample weighted sensory aspects of the items more than in the original study. Item 26 (i.e., "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?" was correlated with other Sensory Fidelity items likely due to the haptic portion of the VR experience (i.e., "touching an object"), rather than on the Involvement aspect (i.e., focusing on the interaction).

Our findings, along with those of the previous validation studies (Witmer et al. 2005), support that presence is a construct extremely difficult to measure precisely and likely due to its subjective nature. The elements that contribute to the "feeling of being there" are closely interdependent and seem variable across samples regarding their interpretation by participants (e.g., from a different cultural context). Slater and colleagues (e.g., Slater et al. 1994) have utilized single-item measures of presence, such as asking participants "to what extent did you experience a sense of being 'really there' in the virtual environment? (1) not at all really there, (2) there to a small extent, (3) there to some extent, (4) a definite sense of being there, (5) a strong experience of being there, (6) totally there." Bouchard et al. (2008) utilized both the presence questionnaire and a single presence rating, obtaining contrasting results for these two different measures of presence. Furthermore, the point has been made that measuring presence through questionnaires is impracticable (Slater 2004).

Limitations of this study include our sample of college students, which may be unrepresentative of others who utilize VR environments (e.g., during VR exposure therapy) and of the Brazilian population. Previous experience with VR was not controlled. Despite the low total variance of 54.07 %, the items of the PQ were coherently distributed across factors in this study. The central issue in measuring presence appears to be that the underlying constructs are not clearly differentiated. As the authors of the original scale have stated, the diverse factor distributions of different presence questionnaires may reflect the structure of each questionnaire's rationale, more than the underlying structure of a general presence concept (Witmer et al. 2005). Future studies should validate this version with a larger sample, investigating convergent and divergent validity of the scale with other measures of presence.

The original version of the PQ was translated and adapted in a manner to retain the conceptual properties of the elements of presence, which should be further investigated. With the growing utilization of VR environments (e.g., driver schools, videogames, psychotherapy protocols) (Riva 2005), a questionnaire to assess the sense of "being there" is highly relevant in order to evaluate adequacy of such environments in truly engaging their users in the virtual experience.

Table 2 Items distributed into factors for both versions of the PQ

Original items	Adapted items
(AI) 09. Were you able to anticipate what would happen next in response to the actions that you performed?	(AI) 09. Você foi capaz de antecipar o que aconteceria a seguir em resposta às ações que você desempenhou?
(AI) 20. How quickly did you adjust to the virtual environment experience?	(AI) 20. Quão rápido você se adaptou à experiência no ambiente virtual?
(AI) 21. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	(AI) 21. O quão proficiente em mover e interagir com o ambiente virtual, você se sentiu ao final da experiência?
(AI) 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?	(IQ) 24. Quão bem você pode se concentrar nas tarefas ou atividades exigidas ao invés de se concentrar nos mecanismos utilizados para realizar essas tarefas ou atividades?
(AI) 25. How completely were your senses engaged in this experience?	(IN) 25. Quão completamente os seus sentidos estavam envolvidos nessa experiência?
(AI) 27. Were there moments during the virtual environment experience when you felt completely focused on the task or environment?	(IN) 27. Houve momentos durante a experiência no ambiente virtual em que você se sentiu completamente focado na tarefa ou no ambiente?
(AI) 28. How easily did you adjust to the control devices used to interact with the virtual environment?	(AI) 28. O quão facilmente você se ajustou aos dispositivos de controle usados para interagir com o ambiente virtual?
(AI) 29. Was the information provided through different senses in the virtual environment (e.g., vision, hearing, touch) consistent?	(SF) 29. A informação provida aos diferentes sentidos (ex.: visão, audição, tato) pelo ambiente virtual foi consistente?
(IN) 01. How much were you able to control events?	(AI) 01. O quanto você foi capaz de controlar eventos?
(IN) 02. How responsive was the environment to actions that you initiated (or performed)?	(IQ) 02. O quanto o ambiente foi responsivo às ações que você iniciou ou desempenhou?
(IN) 03. How natural did your interactions with the environment seem?	(IN) 03. Quão natural pareceram suas interações com o ambiente?
(IN) 04. How much did the visual aspects of the environment involve you?	(IN) 04. O quanto os aspectos visuais do ambiente envolveram você?
(IN) 06. How natural was the mechanism which controlled movement through the environment?	(IN) 06. Quão natural foi o mecanismo que controlava o movimento no ambiente?
(IN) 07. How compelling was your sense of objects moving through space?	(SF) 07. O quão convincente foi sua sensação sobre os objetos se movendo pelo espaço?
(IN) 08. How much did your experiences in the virtual environment seem consistent with your real world experiences?	(SF) 08. O quanto as suas experiências no ambiente virtual se pareceram com suas experiências no mundo real?
(IN) 10. How completely were you able to actively survey or search the environment using vision?	(AI) 10. O quão capaz você foi de, ativamente, explorar ou investigar o ambiente usando a visão?
(IN) 14. How compelling was your sense of moving around inside the virtual environment?	(AI) 14. Quão convincente foi sua sensação de mover-se dentro do ambiente virtual?
(IN) 17. How well could you move or manipulate objects in the virtual environment?	(AI) 17. Quão bem você pôde de mover ou manipular objetos no ambiente virtual?
(IN) 18. How involved were you in the virtual environment experience?	(IN) 18. O quão envolvido você estava na experiência do ambiente virtual?
(IN) 26. 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?	(SF) 26. O quão fácil foi identificar objetos por meio da interação física, como tocar um objeto, caminhar sobre uma superfície ou esbarrar em uma parede ou objeto?
(IQ) 19. How much delay did you experience between your actions and expected outcomes?	(IQ) 19. Quanta demora você experienciou entre suas ações e os desfechos esperados?
(IQ) 22. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?	(IQ) 22. O quanto a qualidade do dispositivo de visualização interferiu ou distraiu você na performance das tarefas designadas ou atividades requeridas?
(IQ) 23. How much did the control devices interfere with the performance of assigned tasks or with other activities?	(IQ) 23. O quanto os dispositivos de controle interferiram no desempenho das tarefas determinadas ou nas demais atividades?
(SF) 05. How much did the auditory aspects of the environment involve you?	(SF) 05. O quanto os aspectos sonoros do ambiente envolveram você?
(SF) 11. How well could you identify sounds?	(SF) 11. Quão bem você conseguiu identificar sons?
(SF) 12. How well could you localize sounds?	(SF) 12. Quão bem você conseguiu localizar sons?
(SF) 13. How well could you actively survey or search the virtual environment using touch?	(SF) 13. Quão bem você foi capaz de, ativamente, explorar o ambiente usando o tato?

Table 2 continued

Original items	Adapted items
(SF) 15. How closely were you able to examine objects?	(AI) 15. O quão detalhadamente você foi capaz de examinar objetos?
(SF) 16. How well could you examine objects from multiple viewpoints?	(AI) 16. Quão bem você foi capaz de observar objetos sob vários ângulos?

AI Adaptation/Immersion, *IN* Involvement, *IQ* Interface Quality, *SF* Sensory Fidelity

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