

SLACTIONS 2013: Research conference on virtual worlds - Learning with simulations

Can presence improve collaboration in 3D virtual worlds?

Armando Cruz^{a,*}, Hugo Paredes^b, Benjamim Fonseca^b, Leonel Morgado^c, Paulo Martins^b

^a *Centro de Estudos em Educação, Tecnologias e Saúde, ESTGL, Instituto Politécnico de Viseu, Campus Politécnico de Viseu, Viseu, Portugal*

^b *INESC TEC (formerly INESC Porto) / UTAD, University of Trás-os-Montes e Alto Douro, 5000-801 Vila Real, Portugal*

^c *INESC TEC (formerly INESC Porto) / Universidade Aberta, Lisboa, Portugal*

Abstract

Three dimensional (3D) virtual worlds are regarded as possessing strong capabilities to support collaboration between people. The physical characteristics of the virtual environment are pointed out as responsible for that capability because they create immersive environments that we are familiar with, and are able to involve users in such a way that the feeling of being in the world is frequently reported. Presence, the perception of the virtual as if it were real, may be helpful in realizing how an easier to understand environment can improve collaboration. In this paper, based on a literature review, we look into the relationship between presence and collaboration, and the importance of presence to the understanding of collaboration in 3D virtual worlds.

© 2014 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/3.0/>).

Selection and peer-review under responsibility of the University of Trás-os- Montes e Alto Douro (UTAD)

Keywords: Presence; collaboration; 3D virtual worlds; CVEs; CSCW; development of CVEs; review.

1. Introduction

3D virtual worlds are Collaborative Virtual Environments (CVEs) that support collaboration, either for work, social interaction or gaming [1, 2, 3]. A person is within such a world by means of a graphical representation called avatar. Depending on the specific virtual world, the avatar can communicate with others by audio, video, text, and/or gestures, as well as by being present or absent; and it is possible to move around in a virtual world space, interacting with objects and other avatars. Castronova [4] stated in 2001 that a virtual world in a modern sense would have to possess three distinctive characteristics. The first is multiuser interactivity; several people act in the world at the

* Corresponding author. Tel.: +351935585500.

E-mail address: cruz.armando1@sapo.pt

same time, and their combined actions alters the world, including each other's avatars. The second is physicality, which means that not only is a person simulated by an avatar, but also that the simulation rules in the virtual world follow rules inspired by a physical world. And thirdly, persistence, that is, the simulation of the world is continuous, whether the people are using it or not. It has the ability to memorize users, the physical state and position of things in the world, and ownership. This last requirement has since been challenged by Morgado in 2009, who proposed that the critical aspects to define a system as a virtual world are the avatar-based interaction paradigm (users as avatars immersed in a world, i.e., an integral part of the world) and the ability to provide multiuser interaction support [61;62], thus abandoning the persistence requirement, which is more related to Castronova's original intent of using virtual worlds as places to perform social sciences research [63], rather the wider scope of cooperative activities in general. This will be the working definition of virtual worlds for our work. Virtual worlds have been in existence since the early days of computer gaming, but are used mostly since the 1990s [5], with particular emphasis on entertainment (gaming and social interaction) [3], but also in other, so-called "serious" fields, such as are education and distance learning [6, 7], Information Systems and Business [6, 7, 8], and Project Management [6].

We have evolved as physical beings and we understand well physical cues [8] like positioning, body orientation, the attentiveness of others, their focus on specific items, etc. These are natural skills that we have and 3D virtual worlds have the ability to allow us to apply at least some of these skills by creating an immersive virtual environment. This intuitively understandable and immersive environment together with technological facilities can be used to enhance collaboration [6]. Features like chat or voice are well known, and their importance for collaboration has already been well addressed by the scientific community, especially in the fields of Computer-Supported Cooperative Work (CSCW) and Groupware. But there are features that can be used in a more intuitive way, and they have already been recognized too but they have not been subject to the same level of scrutiny, at least not by the CSCW community. Hendaoui et al. [7] recognize the use of avatars as an important feature for interaction, and Owens et al. [6] describe three important features for interaction and collaboration: the communication is held in a way similar to the real world; there is the possibility to touch, move and change objects, which enables various modes of feedback and the expression of intentions in non-verbal, somatic ways; there is control over the avatar's appearance, behaviour, and also control over the environment. Not only are these features relevant to cooperation, they are also regarded as relevant to enhance presence. Presence is a subjective personal experience [9], believed to be related to collaboration [10, 11].

All operational features of 3D virtual worlds must have an explicit purpose, because they have to be clearly described as a requirement in order to be implemented by programmers. Thus, features like text or audio are built to enhance collaboration in an explicit manner. Many of them are common to other kinds of software, and need to be selected by the users in a determined way in order to be used. In this paper, we reflect on whether here is any contribution in the literature on Presence that can be used to explain how these features improve collaboration. We want to clarify the relationship between Presence and Collaboration, and understand how the subjective experiences in 3D virtual worlds can affect collaboration.

In the next section we present our methodology and research questions for our work. In the third section we define presence, and present the features relating presence with virtual worlds. In the fourth section, we present the features relating collaboration with virtual worlds. In the fifth section, we relate presence with collaboration, and provide answers to the research questions. Finally, in the final section we present the conclusions and future work.

2. Methodology

To research the relationship between presence and collaboration, we compare the features of 3D virtual worlds that are relevant for presence with those which are relevant for collaboration. To accomplish that, we present two reviews: one focusing on presence and the other on collaboration. With the first we intend to define presence, and reveal the relevant features of virtual worlds from a presence standpoint, and how those feature may impact presence. With the second, we intend to find the features of virtual worlds that are relevant to collaboration and their relationship with it. The objectives of our work are thus summarized in three research questions (RQ):

- (RQ1) Is presence related to collaboration?
- (RQ2) If yes, how are they related? and
- (RQ3) How can presence influence the development of virtual worlds?

The first review was based on articles retrieved from the International Society for Presence Research (ISPR) official web site [12]. A total of 381 articles were retrieved, covering a time span from 1998 to 2011. These articles were analysed in two phases. In the first phase, 89 articles were selected based in the fact that they explicitly define presence. The references made in those 89 articles were analysed in order to find the most referenced articles. 549 references were accounted for. From the 89 articles, articles with less than three references were excluded. This value was chosen because it matches nearly 10% of the number of references of the most cited article of the sample, which we consider a suitable threshold. The excluded articles totalize 70.8% of the total. The selected sample includes 35.5% of the references, and only one article belongs to the ISPR [12] publications. Table 1 summarizes these results. The first column (Article) has the references, the second (N°) the number of references to each article, and in the third (%) the relative representation of those references. In the second phase, from the preliminary analysis of the 381 articles, 186 were found to be related to virtual environments. From these, 15 were selected for being related to collaboration in 3D virtual worlds. The second review was based on an extensive review on Computer-Supported Cooperative Work (CSCW) publications [13]. The selection of publications followed strict criteria based on the analysis of relevant indicators such as number of citations and Web Impact Factor (WIF). From this review we retrieved 26 publications dedicated exclusively to collaboration on virtual worlds. These publications were analysed in search of common terms used across the literature referring to collaboration. Then, the features of the virtual worlds related to the terms were also searched. To analyse the literature, five categories were created to accommodate the subjects of the publications.

Fig. 1 (a) shows the distribution of the publications through these categories. The first category is Learning/Training with the majority of the publications reviewed (34.5%). The publications in this category are related to learning or training. The next category is Review/Survey, which accommodates reviews and surveys about virtual worlds, from potential use to their users, etc. This category is the second most represented in this review (31.0%). The third most represented (17.2%) is Social/Gaming, related to publications about the social relations in virtual worlds and/or Gaming. The other two categories are CSCW, for publications explicitly about CSCW in virtual worlds (10.3%), and Technological support for publications about technological matters (6.9%). Fig. 1 (b) shows the distribution through time of the publications and respective category. It can be seen that there has been a growth in the number of publications.

All the reviewed publications reviewed are related to collaboration in virtual worlds, but not all of them use the same terms to express it. The terms related to collaboration that we identified, based on the publications, were: Collaboration, Interaction, Communication, Cooperation, Awareness, Sharing of artifacts, Immersion, and Coordination. Figure 2 shows the total use of these terms in the publications. The use of a term in a publication, regardless of how many times it was used, was accounted for only once.

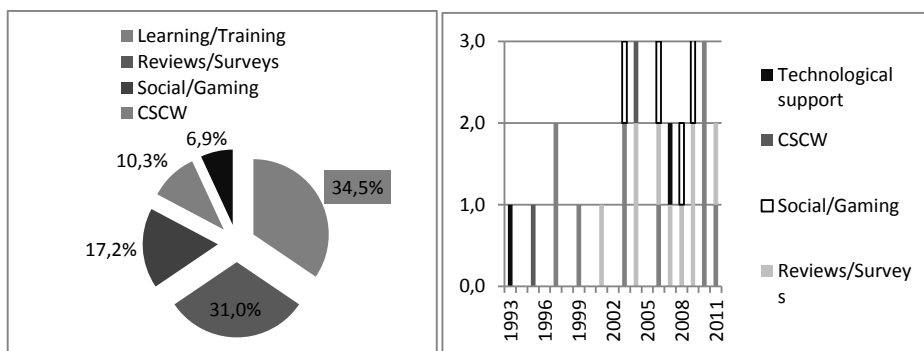


Fig. 1: (a) distribution of the publications through the categories; (b) distribution of the publications through time.

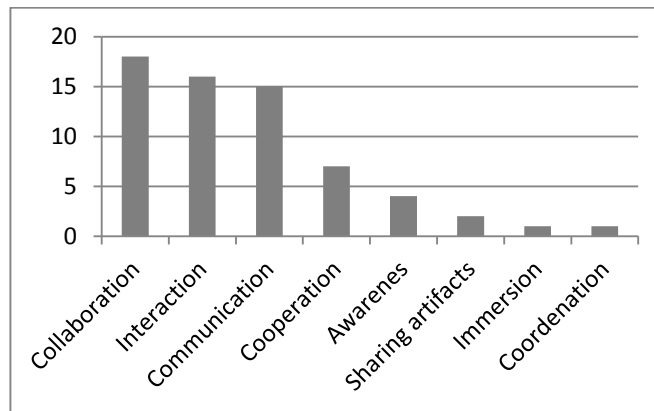


Fig. 2: Distribution of the count of terms used in the publications.

Table 1 – Articles selected for the first phase

Article	Nº	%
Lombard & Ditton, 1997 [14]	37	6.7
Heeter, 1992 [15]	17	3.1
Sheridan, 1992 [16]	15	2.7
Witmer & Singer, 1998 [17]	14	2.6
Short et al., 1976 [18]	12	2.2
Steuer, 1992 [19]	9	1.6
Barfield et al., 1995(a) [20]	7	1.3
Barfield et al., 1995(b) [21]	6	1.1
Biocca, 1997 [22]	6	1.1
Biocca et al., 2003 [23]	6	1.1
Held & Durlach, 1992 [24]	6	1.1
Loomis, 92 [25]	6	1.1
Slater & Wilbur, 1997 [9]	6	1.1
Steuer, 1995 [26]	6	1.1
Slater, Usoh & Steed, 1995 [27]	6	1.1
Kim & Biocca, 1997 [28]	4	0.7
Lee, 2004 [29]	4	0.7
Minsky, 1980 [30]	4	0.7
Slater 1999 [31]	4	0.7
Zeltzer, 1992 [32]	4	0.7
Riva, 2003 [33]	4	0.7
Lombard et al., 2000 [34]	3	0.5
Slater, Usoh & Steed, 1994 [35]	3	0.5
Welch et al., 1996 [36]	3	0.5
Hendrix & Barfield 1996 [37]	3	0.5
Total	195	35.5

3. Presence defined

From the research of efficiency of different communication media, and the satisfaction of the users, the social presence theory evolved. For the medium, social presence is a subjective quality, based on a diversity of factors such as the capability of transmitting information, non-verbal cues, expressions or focus. For the user, these factors are perceived as sensitive, even intimate, when interacting with other users [18]. Minsky [30] defined telepresence as the “sense of being physically present at a remote environment mediated by the system interface”, and Sheridan [16] as the “sense of being physically present with virtual objects at the remote teleoperator site”. Steuer [19] distinguishes “presence” from “telepresence”. They both are related to the perception of an environment, but “presence” refers to the natural environment, whereas “telepresence” is the perception of a mediated environment. Lombard & Ditton [14] argue that presence is achieved when the user does not perceive nor acknowledges the medium and, therefore, a sense of presence cannot be accomplished without a medium. So, there is no need for the use of the term “telepresence” as they both refer to the same thing. The term “presence” is the most used to refer to the “participant’s sense of being there” [21, 33], “the perceptual illusion of nonmediation” [14], “a state of consciousness, the (psychological) sense of being in the virtual environment” [9], or “the subjective experience of being in one place or environment, even when one is physically situated in another” [17]. From these definitions, it becomes evident that these concepts are independent of the technological medium used, and in fact, some authors argue that the theory of presence should be applied to all mediated environments, including television [12, 14, 26, 28, 29].

Presence has several definitions and meanings, and can be seen as multidimensional [12, 16, 21, 27, 34, 36], and some authors distinguish between different kinds of presence. Heeter [15] defines three dimensions of presence: personal presence, social presence, and environmental presence. Personal presence is a measure of the feeling of being in a virtual world, and is based on the simulation of real world perceptions, familiarity with the world, and practice in using the world; social presence refers to the existence and interaction with other beings in the world, whether they are other users or artificial agents [32]; environmental presence refers to the capability of interaction with the virtual environment. Biocca[22, 23] defines physical presence as the simulation of the virtual world in such a manner that is perceived in a way similar to how the physical world is; social presence is the user’s feeling of being with another intelligence; and self-presence is the mental model of oneself that the user has in the virtual world. Presence and immersion are distinct concepts [9, 35]. To the ISPR [12], five dimensions of presence are identified: spatial presence is when the person experiences the feeling of being in another environment instead of the one in which it physically is; sensory presence is when a person experiences the feeling of perceiving sounds, objects and people generated by technology as if they were “real”; social realism refers to the feeling of social characteristics of the environment as “real”; engagement or psychological immersion is when the perceptions of the person are focused on the virtual environment and ignores the physical one; and social presence happens when the person has the feeling of communicating with other people or another intelligence.

Researchers recognise the importance of measuring presence effectively, especially in virtual environments [16, 21, 28]. To Heeter [15], the feeling of presence is itself a subjective measure, and Slater [31] states that while immersion can be measured objectively, presence cannot because of its subjective nature. Two kinds of measures exist: objective measures, relating to physiological responses; and subjective measures, based on questionnaires [12][34]. Physiological responses, such as heart rate, blood pressure or respiration, are not yet proved to be related to presence, thus many of the measures used are questionnaire based, and they differ with the research objective, context, or concept of presence [34]. Thus, several measures imply using different techniques to measure presence.

The ISPR [12] defines presence as the psychological state of a person in which the person’s perception is unable to correctly acknowledge the role of the technology that is creating the experience. The multi-dimensional nature of presence led to the development of different measures that can be classified as subjective and objective measures [12, 34]. In table 2, a summary of both kinds of measures is presented.

Table 2: Measures of presence (adapted from [12])

Subjective	Objective
Questionnaires	Neural correlates
Continuous assessment	Behavioral
Qualitative	Task performance
Corroborative	
Psychophysiological	

4. Collaboration features in Virtual Worlds

The publications in this review cover a time span from 1993 to 2011. Such a large window of time means that earlier publications used older virtual worlds. Since these older virtual worlds gave place to newer ones in this time span, the most recent publications refer to rather different virtual worlds from the earlier ones. Examples of early virtual worlds are DIVE, MASSIVE, NPSET and SPLINE [1, 38]. From 2003, other virtual worlds are mentioned, such as EverQuest[39], Second Life, and World of Warcraft [40], among others. Second Life is addressed several times in the reviewed literature, and in Delgarno et al. [41], it's shown that Second Life is, by far, the most used virtual world in learning environments. Significantly less mentioned are: Active Worlds, OpenSimulator, and There.

Benford [42] states that collaboration in virtual environments is achieved by awareness, interaction, and body language. Embodiment, the use of avatars, is referred by several publications as being a strong contribution towards collaboration [43], especially when the avatars are customizable [3]. The use of avatars is important to awareness and interaction too [3, 44], but it has particular interest to communication, especially when they allow the use of gestures and emotions [1, 3, 6, 44, 45]. Other features that are important to support communication are text, audio, and video [1, 3, 6, 42]. The existence of a virtual physical space, as well as physical features such as aura, focus and nimbus [5, 42], enable interaction, awareness, and the sharing of artefacts[1, 42].

The reviewed literature on virtual worlds is vague regarding cooperation and coordination. Zagal et al. [46] point out the establishment of rules as an important feature to support cooperation. Owens et al. [6] state that the immediate feedback made possible by communication facilities, and the possibility of viewing each other's objects, are important to enhance coordination. In Table 3, the collaboration terms that were found and their related features are presented. Some of these features are related to more than one term. Because awareness, interaction, and gestures (that is, communication affordances) can be seen as collaboration features [42], and since most of the publications suggest that the terms are used in association with collaboration, we will assume that collaboration in virtual worlds is achieved by communication, awareness, interaction, sharing of artefacts and cooperation.

Table 3 - Collaboration terms and related features.

Collaboration terms	Features
Communication	Text, audio, video, gestures, and emotions
Awareness	Embodiment, virtual physical space, focus, and nimbus
Interaction	Embodiment, virtual physical space, aura
Sharing of artifacts	Physical space
Cooperation	Rules

Some of the collaboration terms and features presented in Table 3 are common to the literature on presence, namely, communication [47, 48, 49, 50], awareness [49], interaction, and cooperation [51]. Another term in common use in the literature is immersion. In the presence literature, Slater & Wilbur [9] distinguish immersion from presence, with immersion being the ability of technology to create the illusion. Witmer & Singer [17] define immersion as a psychological state that happens when the user feels included in an environment and interacts with

it. They also define involvement as the psychological state attained by the user in consequence of focusing the attention on certain stimuli. They consider both necessary to experience presence.

5. Presence and Collaboration in virtual worlds

Romano et al.[10] say that collaboration is related to a strong feeling of shared presence. On the other hand, Kaltenbrunner & Huxor [52] state that immersion and presence developed for 3D virtual worlds, which were created mainly for simulation and gaming, are not fit for CSCW. In general, it is recognized that immersion [10, 51, 52, 53, 54, 55, 56], non-verbal communication [11, 47, 49, 50, 57, 58], and interaction [48, 51, 59, 60] are important to create the feeling of presence. Nevertheless, exactly how presence relates to collaboration is not explained. In fact, the relationship between collaboration or CSCW and presence in 3D virtual worlds is not quite clear in the references used. However, a few facts related to collaboration are addressed that suggest a relation with presence.

Non-verbal communication, including social presence cues (proximity, orientation, eye contact and gaze, and physical appearance), and embodiment, improve virtual presence and are important for communication [47, 48, 49, 50]. Besides the importance for communication, non-verbal communication can be used to improve group awareness [49] and collaborative tasks in general [11]. Field of view, manipulation techniques and navigation capabilities improve interaction, and the immersive environment created by 3D virtual worlds enhances cooperative tasks [51]. These facts clearly reveal a relation between collaboration and presence, since communication, awareness, interaction, and cooperation are directly related to collaboration (refer to Table 3).

On one side, Biocca [22, 23] defines physical presence as the simulation of the virtual world in such a manner that it is perceived in a similar way as the physical world is. On the other side, because we understand well the physical world, the simulation of virtual worlds is easily understood and can be effectively used for collaboration [8, 6]. And Romano et al. [56] verified that low levels of collaboration are coincident with a low or null feeling of presence by the participants. Probably collaboration can exist without presence, but is clear that a strong feeling of presence can enhance collaboration, because the perception of the simulated world as if it was real/physical, helps one understand it.

Presence is a personal subjective experience and, at least in virtual worlds, strongly influenced by the environment, the avatar, and features like gestures and personalization [14, 26, 37]. The way how the psychological process of presence happens, and the reasons for several types of presence are not known [12], and so, how do environment, the avatar, and other features of virtual worlds work to improve presence cannot be explained yet. In the review about virtual worlds, the same features are referred as important but again, how do they improve collaboration is not well explained. But the features important for presence are also important for collaboration as we have seen earlier. Features like gestures, embodiment, proximity, orientation, eye contact and gaze, and others used in non-verbal communication and impacting awareness, are used in a subjective and intuitive way by users. This intuitive, tacit way of understanding the virtual world eases the use of virtual worlds, and by that enhances collaboration. Then, presence can influence the development of virtual worlds, because it can enhance collaboration by creating more intuitive virtual environments.

6. Conclusion

In this paper we summarized the theory of presence and we highlighted the features of virtual worlds related to presence and collaboration. We conclude that communication, awareness and interaction are not only important for collaboration and cooperation, but also contribute to improve presence. Presence is related to collaboration by common features, mainly non-verbal ones, such as gestures, personalization of avatars, proximity, orientation, and others. We also conclude that presence can influence collaboration because a stronger feeling of presence helps to understand the virtual world, and allows a more intuitive and easy use of it.

The intuitive or tacit use of features in virtual environments is therefore important for collaboration, and their possibilities should be researched in order to render their connection more clear. The enhanced understanding arising from this would allow presence-related features to be specified in more explicit form, making possible the creation of virtual worlds with those features in mind. Measurement of presence could be a good indication of the collaborative potential of virtual worlds, and should also be subject of more research. Thus, the importance of presence for collaboration in 3D virtual worlds, in our opinion, deserves more attention by the scientific communities interested in the collaboration subject.

References

- [1] Benford, S. Greenhalgh, C., Rodden, T., & Pycoc, J. Collaborative Virtual Environments. *Communications of the ACM* , 2001, pp. 79-85.
- [2] Yee, N. The Demographics, Motivations and Derived Experiences of Users of Massively-Multiuser Online Graphical Environments. Presence: Teleoperations and Virtual Environments, 2006.
- [3] Pinkwart, N., & Oliver, H. Cooperative virtual worlds – A viable ecollaboration pathway or merely a gaming trend? *Electronic Markets* , 2009, Vol. 19, No. 4, pp. 233-236
- [4] Castronova, E. Virtual Worlds: A First-Hand Account of Market and Society on the Cyberian Frontier. *The Gruter Institute Working Papers on Law, Economics, and Evolutionary Biology*, 2001 .
- [5] Joslin, C., Giacomo, T., & Magnenat-Thalmann, N. Collaborative Virtual Environments: From Birth to Standardization. *In Networked Virtual Environments*. IEEE Communications Magazine, 2004, pp. 28-33.
- [6] Owens, D., Davies, A., Murphy, J., Khazanchi, D., & Zigurs, I. *Real-World. IT Pro*. IEEE, 2009, pp. 34-41.
- [7] Hendaoui, A., & Thompson, M. 3D Social Virtual Worlds - Research Issues and Challenges. *Architectural Perspectives*, 2008, pp. 88-92.
- [8] Dreher, C., Reiners, T., Dreher, N., & Dreher, H. 3D Virtual Worlds Enriching Innovation and Collaboration in Information Systems Research, Development, and Commercialisation. *3rd IEEE International Conference on Digital Ecosystems and Technologies*. IEEE, 2009, pp. 168-173.
- [9] Slater, M., & Wilbur, S. A framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual environments. *Presence: Teleoperators and Virtual Environments*, 1997, pp. 603 - 616.
- [10] Romano, D., Brna, P., & Self, J. Collaborative Decision-Making and Presence in Shared Dynamic Virtual Environments. *Presence in Shared Virtual Environments Workshop*, 1998.
- [11] Franceschi, K., & Lee, R. Virtual Social Presence for Effective Collaborative E-Learning. *PRESENCE 2008 - Proceedings of the 11th Annual International Workshop on Presence*, 2008.
- [12] *The International Society for Presence Research*: <http://ispr.info/>, Retrieved at July 2013.
- [13] Correia, A. *Caracterização do Estado da Arte CSCW*. Dissertação de Mestrado, Vila Real, Portugal. 2011.
- [14] Lombard, M., & Ditton, T. At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*., 1997.
- [15] Heeter, C. Being There: The subjective experience of presence. *Presence: Teleoperators and Virtual Environments*. MIT Press, 1992.
- [16] Sheridan, T. Musings on telepresence and virtual presence. *Presence: Teleoperators and Virtual Environments*, 1992, 1:120-125.
- [17] Witmer, M., & Singer, M. *Measuring immersion in virtual environments*. Orlando: U.S. Army Research Institute for the Behavioral and Social Sciences. 1998.
- [18] Short, J. W., & Christie, B. *The social psychology of telecommunications*. London: Wiley, 1976.
- [19] Steuer, J. Defining virtual reality: Dimensions determining telepresence. *Journal of Communication*, 1992, 42(4): 73-93.
- [20] Barfield, M., & Hendrix, C. The Effect of Update Rate on the Sense of Presence in Virtual Environments. *Virtual Reality: Research, Development, Applications*, 1995, Vol. 1, pp 3-15.
- [21] Barfield, W., Zeltzer, D., Sheridan, T., & Slater, M. (1995). Presence and performance within virtual environments. In W. Barfield, & T. Furness III, *Virtual environments and advance interface design*, New York: Oxford University Press, 1995, pp. 473-513.
- [22] Biocca, F. The cyborg's dilemma: progressive embodiment in virtual environments. *Journal of Computer Mediated Communication*, 1997, 3(2).
- [23] Biocca, F., Harms, C., & Burgoon, J. Toward a More Robust Theory. *Presence: Teleoperators & Virtual Environments*, 2003, pp. 456- 481.
- [24] Held, R., & Durlach, N. Telepresence. *Presence: Teleoperators and Virtual Environments*, 1992, pp. 109-112.
- [25] Loomis, J. M. Distal attribution and presence. *Presence: Teleoperators and Virtual Environment*, 1992, pp. 113-119.
- [26] Stuer, T. Defining virtual reality: Dimensions determining telepresence. In F. Biocca, & M. Levy, *Communication in the age of virtual reality*, Hildale: NJ: Lawrence Erlbaum Associates, 1995, pp. 33-56.
- [27] Slater, M., Usoh, M., & Steed, A. (1995). Take Steps: The influence of a walking techniques on presence in virtual reality. *ACM transactions on computer-human interaction* , 1995, 2(3):201-219.
- [28] Kim, T., & Biocca, F. Telepresence via television: Two dimensions of telepresence may have different connections to memory and persuasion. *Journal of Computer-Mediated Communication* , 1997, 3 (2).
- [29] Lee, K. Presence, explicated. In *Communication Theory* , 2004, 14:27-50.
- [30] Minsky, M. *Telepresence*. Omni, 1980.
- [31] Slater, M. Measuring Presence: A Response to the Witmer and Singer Presence Questionnaire. *Presence: Teleoperators & Virtual Environments* , 1999, 8(5):560-565.
- [32] Zeltzer, D. Autonomy, Interaction and Presence. *Presence: Teleoperations and Virtual Environments* , 1992, Vol. 1, pp 127-132.
- [33] Riva, G., & Gaggioli, A. *Towards Cyber Psychology: Mind, Cognitions and Society in the Internet Age*. IOS Press, 2003.
- [34] Lombard, M., Ditton, T., Crane, D., Davis, B., Horvath, K., Rossman, J., et al. Measuring presence: A literature-based approach to the development of a standardized paper-and-pencil instrument. *Third International Workshop on Presence*, 2000.
- [35] Slater, M., Usoh, M., & Steed, A. Steps and ladders in virtual reality. In F. a. Singh, *Virtual Reality Software and Technology - Proceedings of the VRST'94 Conference*. Singapore: World Scientific, 1994, pp. 45-54.
- [36] Welch, R., Blackman, T., Liu, A., Mellers, B., & Stark, L. The Effects of Pictorial Realism, Delay of Visual Feedback, and Observer Interactivity on the Subjective Sense of Presence. *Presence: Teleoperators and Virtual Environments* , 1996, Vol. 5, pp 263-273.
- [37] Hendrix, C., & Barfield, W. The Sense of Presence within Auditory Virtual Environments. *Presence: Teleoperators and Virtual Environments* , 1996, 5(3):290-301.
- [38] Rajaei, H., & Aldhalaan, A. Advances in virtual learning environments and classrooms. *Proceedings of the 14th Communications and Networking Symposium*. San Diego, CA, USA. Society for Computer Simulation International, 2011, pp. 133-142.

- [39] Jakobsson, M., & Taylor, T. *The Sopranos Meets EverQuest Social Networking in Massively Multiplayer Online Games*. Melbourne: Umeå University, 2003.
- [40] Bainbridge, W. The Scientific Research Potential of Virtual Worlds. *Science*, 2007, Vol. 317, n° 5837, pp. 472-476.
- [41] Dalgarno, B., Lee, M., Carlson, L., Gregory, S., & Tynan, B. (2011). An Australian and New Zealand scoping study on the use of 3D immersive virtual worlds in higher education. *Australasian Journal of Educational Technology*, 2001, Vol. 27, No. 1, pp. 1-15.
- [42] Benford, S. (1993). A Spatial Model of Interaction in Large Virtual Environments. *Proceedings of the Third European Conference on Computer-Supported Cooperative Work*, Milan, Italy, 1993, pp. 109-124.
- [43] Benford, S., Bowers, J., Fahlen, L., Greenhalgh, C., & Snowdon, D. (1995). User Embodiment in Collaborative Virtual Environments. *Chi 95 Mosaic of Creativity*, Denver, USA: ACM, 1995, pp. 242-249.
- [44] Prasolova-Förland, E., & Divitini, M. *Collaborative Virtual Environments for Supporting Learning Communities: an Experience of Use*. 2003.
- [45] Neal, L. Virtual Classrooms and Communities. *ACM*, 1997, pp. 81-90.
- [46] Zagal, J., Rick, J., & Hsi, I. Collaborative games: Lessons learned from board games. In *Simulation & Gaming*. Sage Publications, 2006, Vol. 37, No. 1, pp.24-40.
- [47] Thie, S., & Wijk, J. Experimental Evaluation of Social Virtual Presence in a Decision Making Task. *Presence in Shared Virtual Environments Workshop*. 1998.
- [48] Swinth, K., & Blascovich, J. Perceiving and Responding to Others: Human-Human and Human-Computer Social Interaction. In *Collaborative Virtual Environments*, 2002, Presence 2002: 5th Annual International Workshop on Presence.
- [49] Bente, G., Rüggenberg, S., Nicole, & Krämer, C. Social Presence and Interpersonal Trust in Avatar-Based. In *Collaborative Net-Communications*, 2004, Presence 2004-7th Annual International Workshop on Presence.
- [50] Rae, J., Guimaraes, E., & Steptoe, W. Simulation versus Reproduction for Avatar Eye-Gaze. In *Immersive Collaborative Virtual Environments*, 2008, Presence 2008 - Proceedings of the 11th Annual International Workshop on Presence.
- [51] Otto, O., Roberts, D., & Wolff, R. A Study of Influential Factors on Effective Closely-Coupled Collaboration based on Single User Perceptions. *Presence 2005 - 8th Annual International Workshop on Presence*, 2005.
- [52] Kaltenbrunner, M., & Huxor, A. Multiple Presence through Auditory Bots in Virtual Environments. *Presence 2000: The Third International Workshop on Presence*, 2000.
- [53] Romano, D., & Brna, P. Active World: Manipulating Time and Point of View to Promote a Sense of Presence in a Collaborative Virtual Environment for Training in Emergency Situations. *Presence 2000: The Third International Workshop on Presence*, 2000.
- [54] Sadagic, A., Towles, H., Holden, L., Daniilidis, K., & Zeleznik, B. Tele-immersion Portal: Towards an Ultimate Synthesis of Computer Graphics and Computer Vision Systems. *Presence 2001: The 4th Annual International Workshop on Presence*, 2001.
- [55] Jordan, J., Mortensen, J., Oliveira, M., & Slater, M. Collaboration in a Mediated Haptic Environment. *Presence 2002: 5th Annual International Workshop on Presence*, 2002.
- [56] Romano, D., & Brna, P. Collaboration, Presence and Performance in Virtual Learning Environments: Can Collaboration be Used to Measure Shared Presence? *Presence 2002: 5th Annual International Workshop on Presence*, 2002..
- [57] Bente, G., & Krämer, N. Virtual gestures: Analyzing social presence effects of computer-mediated and computer-generated nonverbal behaviour. *Presence 2002: 5th Annual International Workshop on Presence*, 2002.
- [58] Gül, L. Affording Embodiment in Collaborative Virtual Environments: What is the Role of Presence in Collaborative Design? *Presence 2008 - Proceedings of the 11th Annual International Workshop on Presence*, 2008.
- [59] Manninen, T. Virtual Team Interactions in Networked Multimedia Games. *Presence 2001: The 4th Annual International Workshop on Presence*, 2001.
- [60] Györfi, J., Buhke, E., Tarlton, M., Lopez, J., & Valliath, G. VICC: Virtual Incident Command Center. *Presence 2005 - 8th Annual International Workshop on Presence*, 2006.
- [61] Morgado, L. Os mundos virtuais e o ensino-aprendizagem de procedimentos. *Educação & Cultura Contemporânea*, 2009, 13 (6): 35-48.
- [62] Morgado, L.; Varajão, J.; Coelho, D.; Rodrigues, C.; Sancin, C.; Castello, V. The Attributes and Advantages of Virtual Worlds for Real World Training. *The Journal of Virtual Worlds and Education*, 2010, 1 (1).
- [63] Castronova, E. & Falk, M. Virtual Worlds as Petri Dishes for the Social and Behavioral Sciences, *Working Paper Series of the German Council for Social and Economic Data*, 47: German Council for Social and Economic Data (RatSWD), 2008.