Sense of Presence for Human Behavior Studies

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Sense of presence is a key element of the user experience in the study of virtual environments. Understanding it is essential for disciplines, such as architecture and environmental psychology, that study human responses using simulated environments.

Keywords: sense of presence ; spatial presence ; virtual environments ; virtual reality ; virtual environments ; architecture ; human behavior ; sensory modalities ; multimodal ; emotion

1. Introduction

Sense of presence, a central element in the human experience in virtual environments (VE) [1][2] has been widely studied. It has been defined as a psychological state or a subjective perception where technology mediates the experience of the individual, but the environment is perceived as if that technology were not involved [3]. Lombard and Ditton [4] described it as the “perceptual illusion of non-mediation,” in which the technology and the external physical environment fade from the user’s phenomenological consciousness. This “illusion” implies continuous (real-time) responses of the human sensory, cognitive and affective processing systems to objects and entities in a person’s environment.

Sense of presence is a multidimensional concept [3][5]; that is, different types exist. Comparatively little is known about what types do exist, but scholars have proposed several dimensions (in many cases non-orthogonal or overlapping) [3]. Researchers are beginning to empirically evaluate the validity of some of these dimensions. Very often there has been confusion about how to study presence and its determinants and consequences. Among the most recognized dimensions of presence are spatial presence, co-presence, social presence and self-presence [3][6]. Of these, spatial presence has been defined as “a sense of being there” [3]. However, this conceptualization has sometimes been crossed with the general notion of presence, also sometimes described as the subjective experience of being in a place or environment, even when one is physically elsewhere [7][8].

Understanding the factors that modulate the subjective experience of presence is essential for disciplines that study human responses using virtual environments [9]. One field where this is particularly important is research into human behavior in architectural and urban spaces. The human experience in built environments has been defined as a mental state affected by environmental variables, reflecting in psychological, physiological and emotional responses [10]. A key challenge is the creation of controlled contexts that will allow researchers to quantify the impact of architectural design on that experience [10][11]. Virtual environments allow researchers to create controlled simulations of everyday situations, thus accessing contexts where physical presence is not possible [12]. They also make it possible to test proposals more quickly and economically than do physical models [10][13]. The versatility of virtual modeling tools facilitates the simple manipulation of variables, either individually or together, which improves experimental controls and the understanding of cause–effect relationships [10].

The effectiveness of virtual environments is commonly evaluated through the sense of presence they evoke in the user [7][14]. Loomis [15] theorized that “complete presence” is achieved when there is equivalence in sensory and cognitive experiences between the simulated and physical worlds. The human experience in the physical world is inherently multisensory [16]; therefore, it is natural that the number and consistency of sensory outputs in a simulated environment are determinants of sense of presence [4][17][18].

However, several authors have argued that presence is determined by two general categories of variables, that is, media characteristics and user characteristics [1][4][19]. Media characteristics are display properties (e.g., screen resolution), content (e.g., objects, actors and events that make up the environmental context) and the ability to interact with and modify the medium [17]. User profile characteristics range over sociodemographic variables, perceptual, cognitive and motor skills, previous experiences and personality differences [1].

Some researchers have begun to examine the relationships between these media and user characteristics in terms of presence and the attributes of virtual environments. This approach takes into account landscape typologies [12][20], affective environments [1][10][12] and environmental variables such as smells, temperature, textures and other multimodal sensory qualities inherent in the built environment [21][22][23][24], and perceived morphological spatial attributes [19]. In environments “without physical boundaries” (i.e., the body), participants must engage in a variety of proxemics or cognitive functions in spatial domains (e.g., spatial positioning, spatial performance, spatial development, appropriation, socio-spatial interactivity) to solve problems and achieve goals [25]. Understanding human responses to different spatial configurations is key in architectural practice. Several studies have examined behavioral, psychological, physiological and emotional reactions to variables of the virtual built environment [5][21][26][27]. This approach integrates architecture, neuroscience and environmental psychology. Architectural research provides design characteristics that elicit different experiences in users (e.g., relaxing, restorative, motivating). Environmental psychology defines experiences in specific settings, and neuroscience provides means and methods to objectively measure these experiences [10].

However, there is no consensus on a comprehensive methodology to explain the impact of spatial variables on the human experience and presence [10]. The literature provides subjective and objective measurement approaches [28]. Subjective approaches use post-experience questionnaires to obtain conscious judgments of the psychological states evoked by environments [7][29]. However, answering questionnaires can cause a break in presence (BIP), potentially affecting evaluations [30]. Objective measures record automatic responses, such as heart rate, galvanic skin response and neurological signals, without conscious deliberation [26][31]. They are less frequently employed because they require specialized equipment and complex data analysis [32]. Both approaches have limitations, so the triangulation of subjective and objective measures would provide an enhanced understanding of presence.

2. Sense of Presence for Human Behavior Studies

2.1. Identification of the Dimensions of Presence

The results of the analyses support the notion that presence is a multidimensional phenomenon with various competing theoretical conceptualizations [5][12][32][33]. However, the diversity of definitions found during the analysis of presence dimensions shows that research in the field is in a preliminary phase, and that it is still far from having solid and agreed conceptual frameworks [3]. Work is needed to achieve greater definitional coherence to consolidate knowledge about this multidimensional concept. Thus, future studies should seek to integrate existing definitions to propose a more comprehensive conceptualization of the phenomenon, incorporating previous contributions. Similarly, researchers should make their adherence to any particular definition explicit and justify their position when carrying out studies into presence. It is key that future studies use the terminology on the dimensions of presence in a rigorous way, adjusted to the specific phenomenon they are examining. This will facilitate progress in the conceptual delimitation of each presence dimension and in the solid construction of knowledge in the field.

2.2. Methodologies Used to Quantify Sense of Presence

While post-experience virtual questionnaires are useful, several authors warn that they provide a limited view by relying completely on participants’ conscious judgments [31]. This is because presence involves multiple cognitive, affective and physiological processes [4] that operate outside the individual’s conscious deliberation [32]. Therefore, it is key to complement questionnaire analyses with objective measures that address automatic responses such as facial expressions, physiological responses and emerging behavior patterns [31]. It will be essential to increase the use of this type of objective indicator, together with the triangulation of subjective and objective techniques, to achieve a more comprehensive and solid understanding of the complex phenomenon of sense of presence. This will also require methodological advances to improve the viability and analysis of objective measures in virtual environment contexts.

There is great diversity of methodological approaches and a general lack of standardization in measuring sense of presence. This situation was observed across many investigations into this complex, multidimensional phenomenon [1][5][7][9][12][19][20][22][29][31][32]. The results showed that a wide variety of scales and questionnaires have been used to measure sense of presence in the examined studies, and that there has been little coincidence in the measuring instruments. The scale most utilized was the ITC-SOPI [29], employed in five of the works, followed by the Presence Questionnaire (PQ) of Witmer and Singer [7] and the Presence Questionnaire (SUS) of Slater, Usoh and Steed [34], both used in three studies. The authors of five articles developed their own sense of presence measures. The most examined subdimensions were spatial presence (12 times), involvement/user attention (7 times) and subjective sense of realism (6 times).

Even in research using the same scale, such as the ITC-SOPI, different questionnaires were employed, based on the conceptual frameworks used, for example, to evaluate attention/involvement [22] and affective responses [5][12][20][24][26].

This situation hinders the tabulation and categorization of methodologies, as some constructs (e.g., attention) appear in the presence scale in some studies, while in others they are complementary determinants.

The variety of scales, techniques and operationalized constructs makes it difficult to directly compare studies and systematically replicate results. As the instruments used to measure sense of presence differ, and there is no unified definition of its dimensions, it is unclear to what extent the various investigations are examining the same phenomenon. This hampers coordinated advancement in building knowledge about sense of presence and its determinants. Overcoming these conceptual and methodological limitations will be key for consolidating research in the field. Greater standardization of psychometric and physiological scales and techniques is required. This will facilitate the more precise measurement of sense of presence and allow effective comparisons to be made between studies.

2.3. Set-Ups (Support and Format) and Technology Conditions

The results of the analysis of the set-ups used provide a framework for future studies aimed at determining the differential impact of different immersive supports and formats on the intensity and qualities of sense of presence. It has been demonstrated that device type can influence reported levels of presence and, in turn, that the influence of the device depends on the characteristics of the virtual environment being viewed [1]. Thus, future research should continue to examine the differential impact of different virtual environment configurations and user profile characteristics on the intensity and characteristics of sense of presence. Similarly, the spectrum of supports examined needs to be expanded beyond the predominant HMD, and explore emerging technologies such as augmented reality, mixed reality and 360° video spheres, barely incorporated so far into this field of study. In addition, noting that HMDs are an emerging technology in continuous evolution, different HMD supports should be compared with the aim of analyzing the influence of their different features on users' perceptions of environmental variables and experience of sense of presence. This would make it possible to detect technological qualities beyond the type of support used, examining aspects such as ergonomics, interpupillary distance (IPD), optical quality, spherical and chromatic aberrations, focus distance and external light isolation.

On the other hand, there is growing interest in more complex and hybrid formats that seek to increase multimodal immersion and activate emotional responses in participants. It is noteworthy that only two studies [12][21] examined the case of a digital twin of a physical built environment. Researchers should incorporate a greater variety of multimedia formats, such as more detailed architectural simulations, extended reality environments and BIM methodologies to expand knowledge about the possibilities offered by different technologies in the architectural discipline. This will provide evidence on how different technological and architectural specific characteristics can affect the intensity and qualities of sense of presence.

Other research has examined the effect of different multisensory configurations on sense of presence, agreeing on the importance of perceptual richness. It has been shown that using multiple audio channels [31][35][36] and adding spatial features to sound and spatialized audio [9][35] increase sense of presence. Similarly, research has highlighted that the quantity and consistency of sensory outputs in a simulated environment are determinants of presence [23][24][32]. These results emphasize the importance of comprehensively studying the multiple sensory attributes of virtual environments to increase our understanding of sense of presence. It is clear that, irrespective of the device used, aspects such as visual, auditory and multisensory richness provide more immersive experiences. Therefore, future research should examine the interrelationships between technological qualities and the perceptual, cognitive and affective responses of different user profiles.

2.4. Sense of Presence, Environmental Stimuli and Scenarios

Several primary studies revealed that different environmental variables and spatial attributes have significant effects on the intensity and qualities of presence experienced. Specifically, presence was modulated when manipulating sounds [23][35], smells [22][23][26][32][37], temperature [21][23], texture [24], spatiality [19], socio-spatial qualities [20][37], etc. Taking a more global approach, a solid line of research related to the interactions between the different landscape typologies of scenarios and sense of presence was also found [1][5][12][20].

These results emphasize the need to study the experience of presence in interrelation with the characteristics of the built context, since they directly affect its spatial presence dimension, the subjective feeling of "being there" in a virtual environment, as well as other dimensions. Therefore, researchers should go beyond investigating presence as an isolated phenomenon, and to move toward conceiving it within a comprehensive framework of interaction between the properties of the simulated environment and the internal processes of users and their individual characteristics. Only through an ecological approach will it be possible to identify optimal design principles for virtual environments that will make them

capable of evoking high levels of spatial presence. This will also make it possible to understand how different built space configurations impact on the cognition, affectivity and behaviors of users.

2.5. Sense of Presence and User Profile

Some studies showed the existence of individual differences in responses to sensory stimuli based on variables such as previous familiarity with the built environment [26]. These results emphasize the need to take into account users' profiles when investigating the presence experience, and not only the attributes of the medium. Aspects such as age, gender, spatial abilities, personality traits and perceptual–cognitive abilities can modulate the intensity and qualities of presence experienced in the same virtual environment [1]. Therefore, these individual variables should be examined to adequately explain the differential responses of different users. Incorporating this more comprehensive perspective will allow virtual environments to be optimized to evoke presence based on the specific needs and characteristics of the target users. Similarly, it will enable more effective personalization of immersive experiences.

2.6. Sense of Presence and Architecture, Neuroscience and Environmental Psychology

Several studies highlighted the high potential of virtual environments for testing architectural design concepts, allowing researchers to easilly evaluate alternatives before building commences [20][38]. However, to fully take advantage of these possibilities, built environment representations capable of evoking a strong sense of spatial presence in users must be created. Although these works provide certain preliminary guidelines, there are still no solid principles and consolidated evidence on how to optimize spatial presence in virtual environments [38]. Identifying effective guidelines for the optimal design to evoke a sense of presence therefore is a key challenge that must be overcome to realize the potential advantages of virtual environments in architecture and urban planning. In this sense, a promising path is the integration of disciplines such as architecture, neuroscience and environmental psychology: this can provide complementary perspectives on the human experience in built environments [10]. However, this integration is nascent and must be reinforced to comprehensively understand the cognitive, affective and behavioral processes that underlie sense of presence. Only by taking a holistic approach, with multidisciplinary contributions, will it be possible to identify and implement optimal design solutions that provide spatial experiences with heightened sense of presence.

Some previous research has explored combinations of theoretical perspectives and complementary methodologies in fields such as architecture, environmental psychology and neuroscience, setting important precedents. It has been shown that relationships exist between physiological responses and reported levels of sense of presence, such as body temperature and electroencephalogram measurements [26][31]. Similarly, it has been established that relationships exist between the evocation of sense of presence and users' behavioral responses in the built environment [5][21][22][26][27][33]. These studies highlighted the importance of adopting interdisciplinary and transdisciplinary perspectives to investigate complex phenomena such as sense of presence and its dimensions. Taking advantage of neuroscience, psychophysiology and design sciences, among others, will provide a more comprehensive understanding of the human experience in virtual media.

2.7. Summary

The results showing the effects exerted by different environmental variables and spatial attributes reaffirm the importance of conceiving presence in interrelation with the built context. Harnessing the potential of virtual environments in architecture requires optimizing the experience of spatial presence, for which even more evidence is needed. In summary, the value of studying presence from a multidisciplinary orientation is highlighted: this will allow researchers to identify principles that will help them virtualize built environments capable of evoking sense of presence. This will be cross-cuttingly useful for the various disciplines involved in researching and modeling human experience through virtual environments.

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