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Presence and cybersickness in immersive content: Effects of content type, exposure time and gender

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ABSTRACT

As the usage of head-mounted displays (HMD) increases, it is important to establish best usage practices to ensure the appropriate use of Virtual Reality (VR) equipment. Among the factors that can contribute to a better user experience are exposure time, the content type and the gender of the user. This study evaluates the impact of these variables on users' Sense of Presence and Cybersickness when visualising 360° content using HMDs. Two types of 360° content (captured video *vs.* virtual environment) were evaluated across four different exposure times (1, 3, 5 and 7 min). Regarding Sense of Presence, the results revealed a statistically significant difference for Content Type, Gender, and Content Type × Gender. Regarding Cybersickness, no statistically significant results were found for any of the independent variables. Overall, the results encourage the use of synthesized environments for a female audience; for non-interactive environments, captured environments are more effective than synthesized environments; and exposure time is not a concern for experiences lasting between 1 and 7 min.

1. Introduction

The term Virtual Reality (VR) is often defined as a virtual medium constructed with the goal of transporting users into a Virtual Environment (VE) [1]. Despite the recent trend towards VR, the technology has been present since the 1930s when Link Edwin [2] proposed a technological VR that consisted of a flight simulator built to train pilots [2]. Another early contributor to the VR field was the Sensorama proposed by Heilig [3], which was an immersive multisensory cinema booth where seated users watched a predetermined video while the system stimulated multiple senses. Sensorama included a stereoscopic 3D display that is considered the origin of the head-mounted display (HMD) concept. The display consisted of a simple mask equipped with a stereoscopic display [4]. The HMD concept was evolved by Sutherland [5] who proposed the first HMD that also supported interactions with a VE. While these early VR systems were innovative, they were not adopted in practice because they required complex equipment, and the stimulus quality did not meet the requirements for user satisfaction or technology adoption. Currently, technology has evolved to a point where it is possible to deliver satisfactory VR experiences at affordable prices, which are key factors that have contributed to the rising popularity of VR.

The nature of VR opens opportunities in numerous application fields such as entertainment [6,7], training and certification [8–11], health [12,13] and education [14–16]. Although many VR applications have been proposed in these and similar fields, VR can be extended to practically any other field. Along with the increasing spread of VR technologies and their applicability to a variety of domains, it is important to ensure that VEs are able to effectively meet their design goals.

This study was inspired by preliminary work [17] that addressed the impact of habituation to the technology. To the best of our knowledge, there is a lack of work in this area, especially regarding the optimal duration of exposure to VR content; the existing literature seems to consider only habituation over time and number of usages [18,19]. Building on the work of Melo et al. [17], the contribution of this study is that it adds a new dimension by considering two new independent variables: the content type and user characteristics (namely, gender). In this study, we examine the effects of content type, exposure time and gender on the sense of presence and cybersickness. Such variables are pertinent because both have been shown to have an impact on the sense of presence and/or cybersickness [20–22].

The motivation for this work arose from the fact that HMD usage is increasing rapidly and that few to no guidelines exist regarding a user's ideal exposure duration when using an HMD to view

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360° video content. No studies exist that have addressed the usage duration necessary to engage users and deliver a better VR experience. Therefore, it is pertinent to study the topic with the goal of identifying the amount of time a stimulus should last to ensure a better experience and to make the best use of 360° visualizations. This will promote the usage of HMDs and, consequently, increase their effectiveness to reach intended goals for this technology, such as product demonstrations, treatments, education, and so on. The paper is structured as follows: a Related Work section that reports pertinent related studies; Materials and Methods section that explains the methodology adopted for the experimental study as well as all the materials used; Results section that reports all the results obtained in the experimental study; Discussion section where results are discussed and compared with the literature; and Conclusions where the main highlights of the paper are summarized and some final remarks are presented.

2. Related work

One of the most agreed-upon metrics in the literature for evaluating the effectiveness of VEs is the "Sense of Presence" reported by users exposed to a VE. Even though this metric is consensual, authors disagree about the concept's definition and its measurement approach [23,24]. Slater et al. [25], for instance, defined presence as the user's feeling of being more present in the VE than in the physical environment where the experience is taking place together with the feeling of having "visited" the VE rather than simply having experienced virtual content. In contrast, Witmer and Singer [23] defined presence as "a psychological state of "being there" mediated by an environment that engages the users' senses, captures their attention, and fosters their active involvement". In this work, we adopt the concept of presence as defined by Witmer and Singer [23] - a subjective sense of "being in" a VE. To evaluate Sense of Presence in a VE, the literature has proposed several metrics that can be broadly divided into two categories: objective (metrics not dependent on user feedback -physiological data such as cardiovascular measures, skin measures, or task performance measures) and subjective measures (metrics based on user feedback about the virtual experience based primarily on questionnaire responses such as the Slater-Usoh-Steed Questionnaire [25], the Presence Questionnaire [23], or the Igroup Presence Questionnaire [26]).

The present work adopts the iPQp [27], a properly validated (adapted and translated) Portuguese version of the widely used IPQ questionnaire [26] that maintains the validity of the original questionnaire. The IPQ was developed to assess the sense of presence in VEs. It is composed of four subscales: Spatial Presence, Involvement, Experienced Realism and "a sense of being there" (henceforth referred to as Overall Sense of Presence). The Spatial Presence subscale refers to the sense of being physically present in the VE. The Involvement subscale measures the attention devoted to the VE as well as the involvement experienced. The Experienced Realism subscale measures the subjective experience of realism, and the Overall Sense of Presence subscale, as the name suggests, measures the subjective feeling of being present in the VE. In total, the questionnaire includes 14 five-level Likert scale questions for users to answer.

Cybersickness is another well-known metric for evaluating VEs. Cybersickness can be described as a set of symptoms such as fatigue, headache, eye strain, stomach awareness or nausea that can occur during and/or after exposure to a VE [28]. The manifestation of these symptoms can compromise the usability of the VE and, consequently, affect its usage. Moreover, cybersickness has already been negatively associated with Sense of Presence because the symptoms can lead users to lose their focus on the VE and, consequently, feel less present in the VE [23]. To evaluate the Sense of Presence, cybersickness can be measured using both objective (e.g., galvanic skin response) and subjective metrics (e.g., questionnaires such as the Simulator Sickness Questionnaire (SSQ) [29]). For the present research, a Portuguese translation of the SSQ [29] was adopted. The translation was performed by our research team and followed a rigorous two-step process involving both translation/back translation method and a content validity assessment. The SSQ is widely used to identify possible symptoms felt by users after being exposed to VR systems. The questionnaire consists of 16 items, and each item represents a different symptom (p. e.g., fatigue, headache, nausea, vertigo) that users classify on a four-level scale that describes the severity of the symptom (none, slight, moderate, and severe). The questionnaire is composed of four self-explanatory subscales: Nausea, Oculomotor Discomfort, Disorientation, and Cybersickness.

Evaluations of Sense of Presence and Cybersickness when using HMDs has already been addressed by a number of works such as Baños et al. [21] or Sharples et al. [30]. Baños et al. [21] compared three immersive systems (a desktop display, a projected wall, and an HMD) across two VEs and reported that the HMD, along with the projected wall, achieved higher levels of presence; however, there were no significant differences between the conditions. The HMD was also reported as raising more negative effects, such as dizziness or nausea. Sharples et al. [30] studied the effect of cybersickness across different displays (HMD, desktop, projection and reality theatre) and found similar results: the HMD induced more symptoms and side effects when using VR systems. This close relationship between Sense of Presence and Cybersickness symptoms has motivated studies such as Bailey and Witmer [31], Cobb et al. [32], and Duh et al. [33]. Both Bailey and Witmer [31] and Cobb et al. [32] reported a negative correlation between presence and cybersickness, which they attributed to the fact that the symptoms experienced by users distract them from the VE itself, which affects its sense of presence. Later, Duh et al. [33] found a positive correlation between the two metrics but they attribute this to the fact that the VE used in their experiments was less interactive than the scenarios used by other authors.

Factors that impact the sense of presence and/or cybersickness include the device characteristics (e.g., field-of-view, frame rate, resolution or head-tracking [34,35]), the user characteristics (e.g., cognitive abilities, personality, or personal experience [36–38]), the coherence between the virtual stimuli and the physical stimuli (e.g., induced motion, incoherent stimuli [39,40]), the habituation to the technology [17–19], or the nature of the content [21].

The nature of the stimulus is known to have an influence on users' reported sense of presence and/or cybersickness. For instance, Baños et al. [21] study revealed that participants found non-emotional content more immersive than emotional content. The same topic was studied by Rand et al. [22], who compared two VR platforms for rehabilitation: navigation on a projected video-captured VR platform *vs.* navigation on a virtual world using HMD. The study demonstrated the importance of considering not only the attributes of the VR platform but also the user's characteristics to obtain the greatest value from VR applications.

Regarding the Exposure Times variable, some studies [18,19] consider only the habituation over time and the number of usages. Melo et al. [17], to the best of our knowledge, is the only study to address Sense of Presence across different exposure times (1, 3, 5, or 7). Their preliminary results showed no statistically significant differences amongst the tested times. A deeper analysis of the results divided by gender revealed that although no differences existed among exposure times, male participants required more time to reach higher levels of Sense of Presence than did female participants. Such results did not meet the author's initial expectation that different exposure times would have an impact on Sense of Presence. Moreover, the results

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