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Technical Section

The effects of body position on Reflexive Motor Acts and the sense of presence in virtual environments

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ABSTRACT

The purpose of this study was to measure the subject's sense of presence while they performed a task (riding a bicycle downhill) in a virtual reality (VR) environment and to compare it by body position (standing vs. sitting) and gender. The sample consisted of 35 subjects (19 male and 16 female) between 17 and 33 years of age. A translated and validated Portuguese version of the Igroup Presence Questionnaire (IPQp) and the Reflexive Motor Acts (RMAs), based on direct observation, were used as metrics. The results showed significant differences between body position at the level of Experienced Realism, Spatial Presence and Overall Sense of Presence. When measuring RMAs, it was demonstrated that people in the sitting position presented a higher frequency. We concluded that body position influences perceptions of credibility, which has an impact on the sense of presence. No differences were identified between the genders.

1. Introduction

In recent years, virtual reality (VR) technology has been rapidly evolving from low-cost head-mounted displays (HMD) to omnidirectional treadmills and virtual smell dispensers. Entertainment, simulation, recreation, rehabilitation, medicine and other fields can benefit from this technological boom, creating new applications that can provide users with novel experiences, training tools, and entertainment applications at an affordable cost. Many of the applications developed for VR aim to achieve a common goal, namely, to transport users to virtual environments (VEs) and enable them to experience the feeling of being physically present in the VE provided [1–3]. To be successful, one must create high fidelity VR systems that look authentic, and therefore the believability/credibility of the delivered VEs is of paramount importance.

One of the growing areas of application is in the context of health, be it therapeutic or preventive. The multiple contexts in which VEs are applied represent great challenges for programmers, namely because the contexts of VR use tend to become more dynamic in a world where sedentarism tends to be contradicted. One of the most used pieces of equipment in gymnasiums is the stationary bicycle, which throughout the decades has been one of the pieces of equipment that has received greater attention in terms of innovations.

The problems being addressed in the present research are: (1) how tolerant the vestibular system is to conflicting information being provided during the interaction between subjects and the equipment used in laboratory experimentation; and (2) how eventual sensorial conflicts that emerge while performing the assigned task affect the sense of presence. To address the overall questions, we set as the specific goals the following: (1) compare two body positions (standing and sitting on a bike); (2) compare by gender and body position the levels of realness, spatial involvement, overall presence and RMAs.

In this paper, we present an experimental study to address the above-identified research questions having as scenario a downhill bicycle ride. Subject's Sense of Presence and RMAs were measured and results led us to conclude that body position influences perceptions of credibility, which has an impact on the sense of presence.

The paper is organized as follows: Section 2 discusses the relevant previous work conducted in this field, namely in body position, gender, credibility and presence. Section 3 describes the methodology used this work. This includes information about the participants, equipment and the procedures followed. Section 4 and 5 presents the relevant results and detailed discussion, respectively. Finally, Section 6 summarizes the primary findings from this work and draws conclusions.

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2. Background

Body position is influenced by the somesthetic stimuli: the sensory input received from different parts of the body. Based on these stimuli, the individual is able to have an adequate perception of body orientation in space. For programmers, these multiple inputs represent problems that require particular attention. What aspects do programmers need to take into consideration when developing VR systems? For instance, when programmers are asked to recreate a bicycle ride course, the challenge is to take into consideration the multiple sensory inputs that need to be coherently processed. Thus, the question is: "What aspects should be prioritized when developing a bicycle ride system?".

To answer this question, we focused our attention on the sensory integration of visual and auditory vestibular stimulation. One VR environment, riding a bicycle downhill, where the participants can interact with a bicycle in two different body positions (standing or sitting) was created. These two body positions elicit different stimulation to and from the vestibular system, allowing us to study its impact on the sense of presence and on the Reflexive Motor Acts (RMAs). RMAS are involuntary muscle responses to particular stimuli or in other words less consciously controlled reactions. By Presence, we refer to the behavioural response to immersion [4] being that the two body positions represent two levels of immersion in which one of them represents a closer match to reality. This rationalist approach, of describing presence as a function of our experience of a given media, is called media presence [5]. Another vision, that can coexist with the rationalist, is the psychological or ecological approach that defines presence "as a neuropsychological phenomenon, evolved from the interplay of our biological and cultural inheritance, whose goal is the control of the human activity" [5] - this is also known as inner presence. However, only the rationalist approach in considered in this work.

Humans are designed to maintain spatial orientation on the ground. However, the literature has consistently demonstrated that males and females are different in this domain Sholl et al. [6]. Liu et al. [7], demonstrated with a sample size of 634 individuals who voluntarily participated in virtual environment experiment that males and females differ in several spatial domains. Although, similar studies addressing these gender differences date back to the decade of the 50's and has been consistent in demonstrating differences between genders, it is important to reconsider these gender differences as cultural changes combined with technological advances might have reduced the above-mentioned differences between each gender.

Body position as a system involves several feedback loops and is highly dependent on a well-integrated multisensory system of control that integrates vision, vestibular, and somatosensory information. According to Lacquaniti et al. [8], the literature has focused on chain reflexes from different peripheral sensors, since they are the basic elements of postural mechanisms, namely, stretch reflexes, head and neck reflexes and righting reflexes.

Riding a bicycle is a complex motor behaviour since it involves the forceful physical interaction with a machine requiring the dynamic integration of visual, vestibular, and somatosensory information [6]. This complexity might be increased when subjects are asked to perform a motor activity integrated into a VE experiment, namely, riding a bicycle compared to running the same track while standing but maintaining the control over the bicycle handlebar (see Fig. 1).

The vestibular system seems to be particularly sensitive to conflicting information input from the multiple senses involved when riding a bicycle in a virtual environment. According to St George and Fitzpatrick [9], , the sensory integration of signals for orientation can be studied in human beings, exposing them to locomotor activities that involve sensory conflict. Sensory conflict can be created in a laboratory context through the presentation of different and inconsistent sensory input [10]. Changes in head position lead to changes in vestibular system interpretation regarding orientations and balance responses. In normal situations, it is expected that head movements should be followed by a change in specific motor responses. For example, when riding a bicycle, if one wants to turn, the head movement will lead to body adjustment responses known as balance reflexes. Shumway-Cook and Woollacott [11] define balance as the ability to maintain the body's centre of mass over its base of support. A properly functioning balance system allows humans, while moving, to identify their orientation based on gravity perception and, consequently, to determine direction and speed of movement. In turn, these adjustments automatically lead to postural adjustments to maintain the body position (posture) and stability in various activities and situations.

Studies have shown that balance control in a standing position is a complex sensorimotor action based on automatic and reflexive spinal programs under the influence of several distinct and separate supra-spinal centres in the brainstem, cerebellum and cortex [12]. Based on this level of complexity, VR creative programs need to be aware of the sensory input details to be taken into consideration in order to achieve the intended levels of credibility and presence.

Kim et al. [13] define the believability as a measure of the level of realism in the interactive virtual environment and proposed that believability needs to be understood according to three dimensions as they relate to the VE (presentation, interaction, and immersion). In regard to presentation, they argue that the believability of the virtual environment can be increased if the virtual world is presented as being as real as real world. In terms of interactivity, they posit that the level of interaction is increased if the behaviour responds to the actions of users in a life-like way. In addition, finally, immersion occurs when the user can believe that the experience in the virtual world is a real experience if he or she is totally immersed (sensory immersion and perceptual immersion) in the VE.

Slater and Usoh [4] also refer to the credibility/believability of the virtual environment, stating that when a virtual world does not accurately represent the laws of physics, a user feels less present and consequently considers the experience as lacking credibility. Lombard and Ditton [14] associate credibility with perceived realism; Slater [15] proposes two constructs to evaluate the user experience in a virtual environment Place Illusion and Plausibility Illusion. The former is a construct to measure "the type of presence that refers to the sense of "being there" and the later measures the "illusion that what is apparently happening is really happening". One can say that the "plausibility illusion" is associated with credibility that what is being viewed is actually occurring (i.e., it is real). These authors further theorized that if a high level of Plausibility Illusion is combined with a high Place Ilusion, participants will respond realistically to the presented scenarios. Skarbez et al. [16] investigated which factors positively contributed to coherence and consequently to Plausibility Illusion and reported that of the four factors he studied "having an accurate and well-behaved representation of oneself in the virtual environment is the most important contributing factor to Psi". Bouvier [17] argues that it is credibility, not realism, that is central to achieving high levels of presence, and the experience should be credible enough to delude the user's perception. Fuchs et al. [18] refer to coherence as a structural factor of immersion that exists at two levels: *a*) "temporally synchronising and ensuring a spatial coherence between the different sensory stimulations" and *b*) "the second level includes the first level and concerns the response time of the system". Based on the previous discussion here presented, we believe that coherence, credibility and believability should be considered synonyms and should be defined as being one dimension of immersion. Thus, credibility

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