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Virtual Body Swap: A New Feasible Tool to be Explored in Health and Education

Elen Collaço de Oliveira
Escola Politécnica da Universidade de São Paulo, USP
São Paulo, Brazil
elencollaco@gmail.com.br

Philippe Bertrand
BeAnotherLab
São Paulo, Brazil
digitalbertrand@gmail.com

Marte Ernesto Roel Lesur
BeAnotherLab and Universidad Iberoamericana
Ciudad de México, México
marteroel@gmail.com

Priscila Palomo
Universitat de Valencia
Valencia, Spain
pripalomo@gmail.com

Marcelo Demarzo
Universidade Federal de São Paulo and 'Mente Aberta" - Brazilian Center for Mindfulness and Health Promotion
São Paulo, Brazil
marcelodemarzo@gmail.com

Ausias Cebolla
Universitat Jaume I and Ciber Fisiopatologa Obesidad y Nutricin (CB06/03 Instituto Salud Carlos III, España)
Valencia, Spain
acebolla@uji.es

Rosa Baños
Universitat de Valencia and Ciber Fisiopatologa Obesidad y Nutricin (CB06/03 Instituto Salud Carlos III, España)
Valencia, Spain
banos@uv.es

Romero Tori
Escola Politécnica da Universidade de São Paulo, USP and Centro Universitário SENAC
São Paulo, Brazil
tori@acm.org

***Abstract*—Virtual reality has been widely explored to immerse users in environments other than those considered to be their surrounding realities. We discuss the possibility of immersion not in another environment but in another person's body. The power of body swap illusion opens up a great deal of possibilities and applications in several areas, such as neuroscience, psychology, and education. For this experiment, we used a low budget system that reproduces a person's head movements as if one's own head were in another body viewed through a head mounted display (HMD) while having body agency, i.e., controlling the movements of another real body as if it was a "real avatar". In this pilot study we describe the tool in details and discuss its feasibility and preliminary results based on the analysis of the participants' perceptions collected through validated questionnaires and in-depth interviews. We observed that the system does promote higher levels of realism and involvement ("presence") compared with an immersion experience without body agency. Moreover, spontaneous declarations by the participants also showed how impactful this experience may be. Future applications of the tool are discussed.**

***Keywords*-Body swap illusion, body agency, embodiment system, presence, virtual environment, virtual reality.**

I. Introduction

Since the publication of the paper "The Ultimate Display" [1], research protocols and developments in the field of virtual reality have sought to make users feel immersed in environments other than those they consider to be the reality of their surroundings. Augmented reality, in turn, combines real and virtual objects in a physical environment. Between these two extremes, as stated in the Milgram's reality virtuality continuum [2], there is a profusion of blending possibilities between real and virtual, going from teleportation to avatars, including extensions or changes in one's own body. One of these possibilities, however, has not been widely explored so far: producing the effect of the illusion of a full body using another real body inside the virtual reality environment, instead of an avatar, a mannequin or a game character.

Our body is the means for interacting with the world and with others and the basis of our (self-) consciousness [3]. Bodily illusions have allowed researchers to induce healthy subjects to experience having a rubber arm, for example. By altering the visual, tactile and proprioceptive environment of test-subjects, these interventions have shown behavioral and neural evidences of alterations in the perception of one's own body (anxiety responses, ownership of the artificial body, misperception of one's physical location) ([4], [5], [6]). By combining paradigms of body ownership illusions and Virtual Reality, researchers such as Mel Slater [7] and Henrik Ehrsson [8] have conducted experiments that allow subjects to experience having the body of a plastic mannequin [9], a digital avatar [6] and even a Barbie Doll [10], altering their perception of body, self-location and dimensions. The technology also allows using realistic first-person image avatars and visual-motor agency, in which users' position and movements are captured by high-speed cameras to control the avatar, allowing them to interact through the body. These systems are becoming more accessible, but still require costly equipment to process realistic images controlled by motion capture with no latency [11].

Many possibilities stem from the concept of body swapping. The relationship between individuals and their own bodies has implications on their ego and own personality. Feeling to be in another person's skin and controlling another body's movement, can facilitate the development of empathy, playing with one's ego and emotions. Such experiments could, for example, be used as a theme for discussion and behavioral changes related to issues such as racism, altruism, inclusion and anorexia, among others. In education there are also some interesting applications to be explored, such as swapping teacher's and students' bodies, or even between colleagues, during training activities, or as a way to anchor discussions on empathy, racism, bullying, social divide and so on [12].

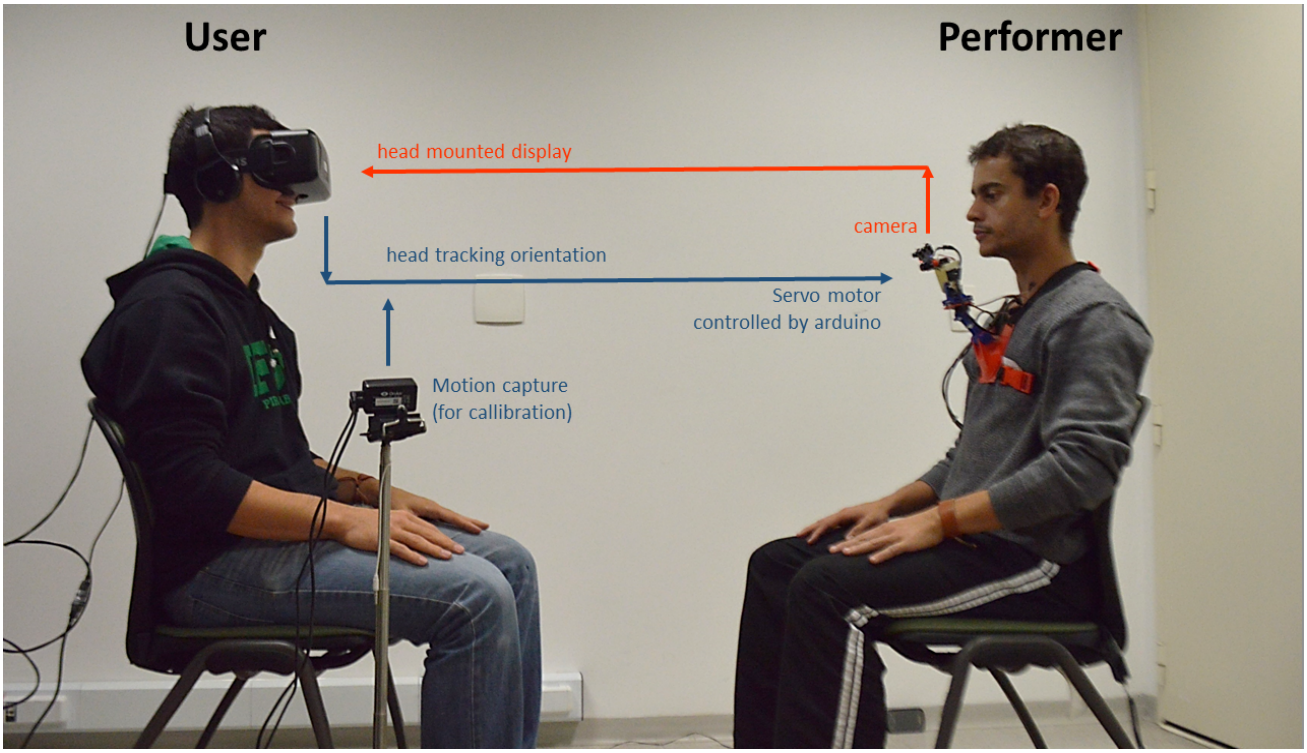

Figure 1. The Machine to Be Another (TMBA) system, by BeAnotherLab.

Several experiments have shown the possibility of changes or replacement of the human body [13], [14], [6]. In other words, the subject has the feeling of being in a different body [15]. It has also been shown that human beings have no difficulty in accepting virtual changes in their bodies, and even the possibility of experiencing an invisible body [16]. Moreover, Petkova et. al. (2008) [9] reported that it is possible to induce illusions of owning an entire body other than one's own. However, the system proposed by Petkova et. al. have some limitations, such as no head agency and limited gesture possibilities.

Although previous experiments have been made in making a person feel like being in another body, no formal experiment had been carried out so far involving swapping real person bodies with total agency and using low cost equipment. Given the potential to be explored in such way and possibilities of application possibilities in education, health and social areas, we decided to develop a pilot study on body swapping. One of the aspects studied in this protocol, and discussed herein, was the involvement of the participant and impact felt by experiencing this. To carry out this research we used the system The Machine to Be Another (TMBA) [17] from the independent interdisciplinary group BeAnotherLab (Figure 1). This system works using a head-mounted display that shows the perspective of another person (performer) mimicking the movements of the participant, while listening to audio narratives, and receiving tactile stimulus to induce body swap illusion (Figure 1). On the other hand, the performer holds a first person camera mounted such that it represents his or her point of view. The camera orientation is controlled by servos, according to the head orientation sent by a sensor on the participant's head. The participants were also asked to take part in another experiment in which they experienced a virtual tour in a first person immersive world, wearing the same kind of head-mounted display, thus having head agency, but no body agency or vision of their bodies. We used a presence questionnaire to measure the body swap illusion impact on the participant perception, as detailed below, in the methods section.

II. Presence

In virtual reality individuals often experience a feeling of being in the world outside their physical bodies generated by technology, a feeling defined as "presence". In this context "presence" is described as a state of consciousness; the sensation of "being there" in a virtual environment [18]. In recent decades, this concept has been the subject of many research fields, including computer science, medicine, psychology, military, entertainment, art, cognitive science, philosophy, and ethics [19].

Many approaches to evaluate presence can be found in the literature. These approaches can be clustered into two main categories: objective and subjective approaches. Objective approaches use physiological measure to quantify presence, such as changes in skin conductance, blood pressure, heart rate, muscle tension, respiration, ocular responses as well as neurologic measures (e.g.: fmri, ecg) and behavior [19]. Subjective approaches, in turn, use survey methods for capturing subject opinions. Presence questionnaires are the most common method to measure subjective presence. Typically, participants are asked to carry out a task in a virtual environment and then answer

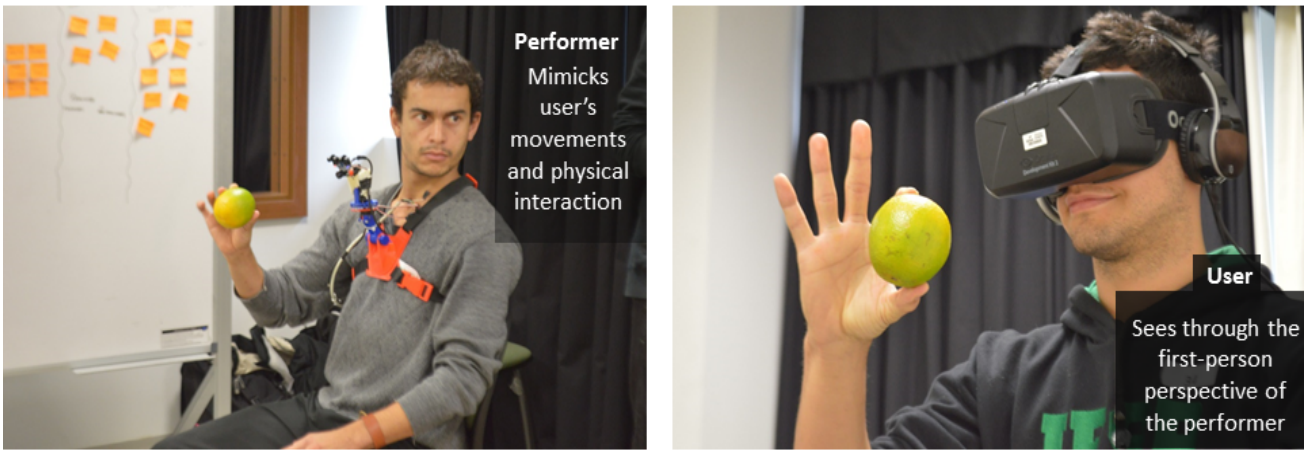

Figure 2. TMBA System - low budget approach to induce body swap illusion.

a questionnaire. The questionnaire items are measured on a Likert scale between two extremes. For example, 1 means "no presence" and 7 means "complete presence" [20]. There have been several different questionnaires developed over the years, and some researches have used a combination of objective and subjective approaches in order to quantify presence [19].

III. The Machine to Be Another: The System

The interdisciplinary research group BeAnotherLab integrated several mechanisms to create a low budget body swapping system called The Machine to Be Another (TMBA) [17]. This Creative Commons NonCommercial-Share-Alike system that uses multi-sensory stimuli (visual, tactile, proprioceptive and audio) to induce body swap illusion. By a head-mounted display, the participant sees the perspective of another person (performer) that mimicks his/her movements (Figure 2). The performer's first-person perspective is captured by a camera controlled by user's head movements, revealing torso, legs and arms of the performer's body. While interacting with the physical space, participants also perceive realistic tactile stimuli. An audio system plays a personal narrative recorded by the performer.

The present experiment uses this system - which combines hardware, software, protocols of interaction - to analyze presence, as described in the next sections:

A. Hardware

The hardware is divided in three parts: the user's, the performer's, and that of the control system.. The user's set includes a commercial Head Mounted Display (HMD), namely an OCULUS RIFT DK2 for the present study; an infrared limited motion capture camera available with the HMD and a set of stereo headphones. The performer's set, on the other hand, includes a camera orientation controller that consists of a webcam mount attached to 2 mini servo engines for controlling the pitch and yaw of the webcam; a wide angle 180-degree webcam; a vest to hold the camera on the performer's chest; it also includes an arduino which controls the movement of the servo engines. Lastly, the control set consists of a computer using Windows 8.1. For the present study the specifications were as follows: Camera orientation controller: webcam mount attached to 2 mini servo engines for controlling the pitch and yaw. USB, stereo audio, and HDMI couplers were included as part of the setup to extend the reach of the system.

The connections are presented in Figure 3 as follows (note that the software is described more extensively in the following section): The HMD orientation data was sent via USB to the computer; this data was received by a software built using Open Frameworks version 0.7.4. It was later sent to a software built with PureData extended (PD), which, in turn, controlled the servo motors by sending data through a USB cable to an arduino board positioned on the performer's chest. On the other hand, the camera, which was mounted on the servomotors, sent video to our Open Frameworks software via USB. Finally, the computer sent stereo audio through a stereo audio cable through its built in audio interface.

B. Software

The TMBA software used for the current study was built using the OpenFrameworks (OFx) version 0.7.4. The OFx software received the orientation data to be sent via OSC (Open Sound Control) messages to a software built on PD extended for controlling the servo motors using an Arduino UNO electronic platform. Both were run in the same computer using Windows 8.1 (described before). The system is built to send the orientation input from the HMD worn by the user to the servomotor controlled camera worn by the performer; it also displays the image of that camera in the HMD. The software allows for a digital zoom of the camera input as well as its rotation. It runs the camera at 60fps and has a digital dimmer to turn on and off the

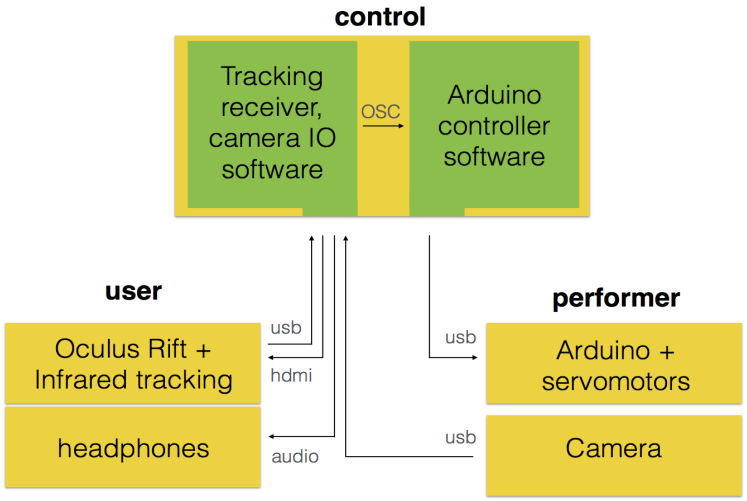

Figure 3. Diagram representing the system consisting of three sets, the user's, the performer's and that of the control. The direction of the arrows shows the direction of the signals.

video shown on the HMD. As the camera is monoscopic, the software replicates the image in each of the lenses of the HMD. The OFx software is also able to trigger audio files containing instructions and personal narratives of the performers by pressing the computer number keys.

C. Protocols of Interaction

Participants must be sitting down and wearing an HMD as well as headphones. Audio instructions are given to the participants in order to explore the environment, to move and to interact. Two assistants control the timing of the experiment and provide the synchronous tactile stimulation. A third assistant, or performer, is present during the procedure and is trained to carefully follow the participants movements while wearing the servo motor control camera in the position corresponding to its point of view. The current experimental procedure divides the combination of multisensory stimuli in 4 different sections (described in the Methods section of this paper).

IV. Methods

The design of the present study was within-groups comparing presence post-test questionnaire in two differents procedures: TMBA (The Machine to be Another) procedure and SL (Second Life) procedure. The experiment aimed to evaluate the perception of presence and the impact of feeling in another person's body. As in the case of Ivan Sutherland's equipment "Sword of Damocles" [1], the intention was to provide the immersion of a person in another virtual environment, captured from the real world through a video camera. In this experiment, for a person to feel in another's body (immersion in another reality), a head-mounted display (HMD) and a camera was used, with movements controlled by the participant's head, in order to give him/her a vision of the performer's body, mimicking the participant's movements. From a technical point of view, there would be no conceptual difference if the actual person (performer) was replaced by an avatar. In both cases, the participants of the experiment would experience leaving their reality and immersing themselves virtually into another one, i.e., the virtual body (an avatar). Yet, as the objective of the project TMBA is to deal with social, cultural and educational issues, it is important for participants to actually feel the body of a real person. For the purpose of this particular experiment, it would be possible to simulate a real person by a virtual avatar, since it was realistically rendered, going beyond the "uncanny valley" barrier [21]. This high investment, however, would not be justified, as previously exposed.

In a full body swap illusion, we should be able to see another body and to experience the feeling of being in full control of its actions as if it were our own body (body agency). The virtual environment, in turn, head and body agency, has demonstrated a high impact on immersion experience [6], [22]. Since the focus of this experiment is to evaluate the impact of another person's body vision, a control experiment was conducted, in which participants did not see their body or have the agency about it, but had head agency using the same HMD. In the control experiment, participants take a walk in a virtual environment and can freely move their head, but without seeing their body or having control over the walking path.

The aim of Experiment 1 was to demonstrate that it is possible to induce the illusion of immersion in another person's body and to evaluate the subjective impact of that experience. This experiment consisted of seeing another person's body from the first person's perspective while having head and body agency. Experiment 2 aimed to examine the effects of body image and body agency. To address this research question, we developed a virtual tour in a 3D Virtual World environment (using Second Life as the infrastructure) whereby participants could freely move their heads (head agency), while immersed into the

Figure 4. Experimental setup to induce body swap illusion.

virtual world, but without seeing their virtual bodies or having body agency. The same group of participants were submitted to both experiment 1 and 2, in this order, and answered the same questionnaire (with subtle adaptation in questions to adapt them to the context).

A. *Participants*

From sixteen participants, we considered thirteen (five females and eight males, age M=22.26, SD=3.78) for having completed all the necessary steps from this experiment and for having consistently answered the questionnaire. They were recruited among students at Centro Universitário SENAC by an advertising poster campaign sent by e-mail to various courses on the campus. The study was approved by the Ethical Committee of Plataforma Brasil, the methods were carried out in accordance with the approved guidelines, and all participants gave their digital consent. There were some criteria for exclusion: being under 18, being pregnant, previous heart disease, labyrinthitis and nausea in virtual reality immersion.

B. *Experimental setup and the body swap illusion*

The participants were asked to sit on a chair with their hands on their knees. They were then fitted with a set of head mounted display (HMD) and headphones. During this process, the staff performed the necessary calibrations and the participants saw a black screen. The headphones allowed us to give instructions to the participants, and also

Table I
QUESTIONNAIRE ITEMS

Questions	Body Agency	No Body Agency
1	I had a sense of acting in the other person's body, rather than operate something from outside.	I had a sense of acting in the other body, rather than operate something from outside.
2	I was not aware of my own body.	I was not aware of my own body.
3	I was completely captivated by the body swapping.	I was completely captivated by the virtual tour.
4	How real did the body swap seem to you?	How real did the virtual tour seem to you?

neutral and constant music played all along the process to help the participants to concentrate on the experiment. The experiment was designed to follow the conditions below (Figure 4). Between each condition, the screen was turned off and on again.

1. Exploration: Participants were asked to look at their hands and move slowly. Thus, the participants saw the performer's body in visuomotor synchronicity, where they expected to see their own body. This condition lasted for 2 minutes.

2. Explore touch: For 2 minutes, both participant and performer could interact with two assistants moving in a synchronous choreography. Simultaneously, assistants first touched the palm of the hands of both participant and user in the same location, and later stroke their hands with a brush synchronously.

3. Narrative with object: Assistants held an orange simultaneously to the participant and to the performer. The participant was asked to freely manipulate the orange. Once the participant handled the object, he or she started listening to the performer's personal narrative for three minutes.

4. Face to face and shake hands: While the display was off, the performer positioned him/herself directly in front of the participant. The display was turned on again and the participants faced themselves. The participants were asked to shake hands with the person in front of them for 3 minutes. Finally, participants heard instructions that the experiment had ended and the screen turned black. The participants were asked to remove the HDM and were guided by an assistant to another room where interview was conducted immediately, to record their impressions about the experiment. After that, the participants answered the online questionnaire.

C. Presence questionnaire and qualitative method

Interviews were conducted immediately after the experiment and participants were invited to complete a 7-item presence questionnaire. In the interviews, each participant answered the same questions, such as "Describe your experiment.", "Do you know the person you experienced the body swap with?", "Do you feel close to the other person now?".

Presence Questions were taken from the Igroup Presence Questionnaire (IPQ) [23], translated into Portuguese. The questions were adapted to our particular virtual reality scene (Table I). From the presence questionnaire, we discarded the questions explicitly related to the virtual environment. Note that we are particularly interested in analyzing the misperception that a mediated experience is not created by technology, called by Lombard and Ditton (1997) [19] an "illusion of non mediation". The questions were measured on a 7-point Likert scale from -3 ("I completely disagree") to 3 ("I completely agree"), with 0 corresponding to "I neither agree nor disagree".

D. Statistical data analyses

Statistical analyses were carried out using the software package SPSS 22.0 (IBM) for Windows. In order to compare the efficacy of the presence induction a repeated-measures ANOVA was performed between the TMBA procedure (body agency) and the SL procedure (no body agency) total means.

V. RESULTS

Statistical evidence showed differences between the TMBA procedure (body agency) and SL procedure (no body agency) [F (1,12)= 14.16, P=.003, N =.54]. The TMBA procedure promoted high levels of presence (M= 1.80, SD= .62) compared with the SL procedure (M= .21, SD= 1.37). According to ANOVA, the body agency procedure results showed to be able to induce presence perception stronger than the no body agency procedure. (Figure 5).

Moreover, results from the TMBA procedure showed more acceptable standard deviations than the SL procedure (Figure 6). The high values of standard deviation related to the SL procedure can be explained by several factors, such as fatigue of the participants, misinterpretation of the questions or even the diversity in the expectations of the participants that arouse after they experienced the body swap illusion.

From the post-experimental interviews about the TMBA procedure, our observations suggested that the system does promote a vivid illusion that the participant's body was the performer's own body. The participants voluntarily reported manifestations such as: "It was very interesting to experience a body different from my own body!", "I felt like the other person's body was my own body and it moves just like I do!" or "I was another person!". It is important to point out that the participants were asked to answer if they knew the other person (the performer) and if they felt to be closer to that person. We observed that most participants declared that they had not met that person before and then they felt closer to him or her; some participants declared: "I feel closer to the other person's body", "I would like to be her friend!", "I felt closer to the other person especially in the narrative step, sometimes it

seems that it was me talking". It is also noteworthy that, several participants spontaneously mentioned that the last step from Experiment 1 was the most remarkable: "It felt confusing to be me and, at the same time not to be me!", "Wow, who is me right now?!", "I'm shaking hands with myself!".

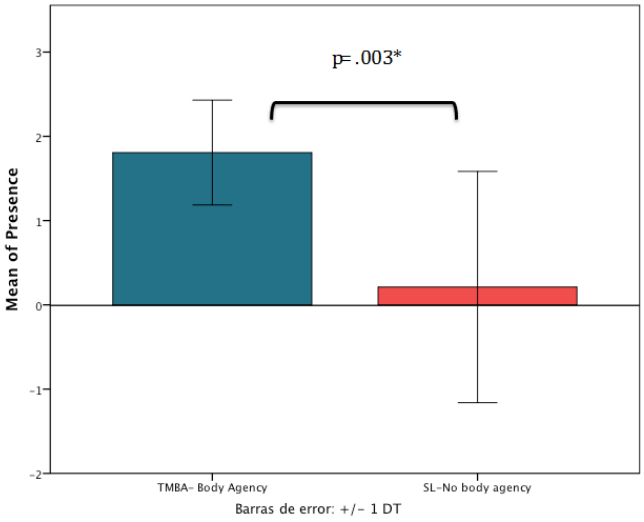

Figure 5. The results showed that the participants rated the presence questionnaire significantly higher in the body agency condition than in the no body agency condition.

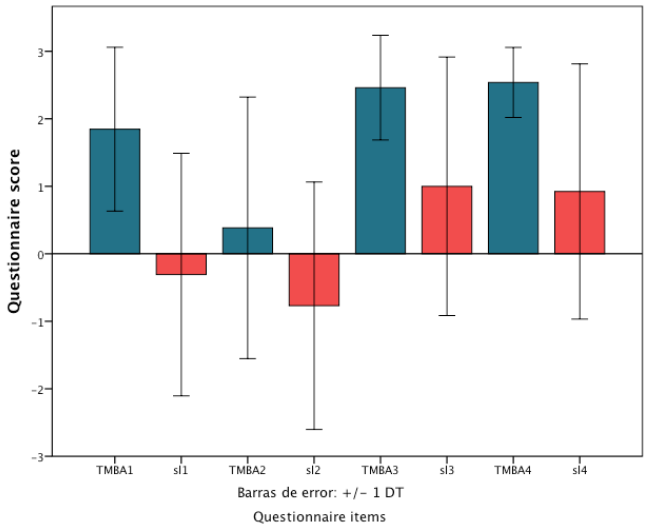

Figure 6. Questionnaire responses in two conditions: (TMBA) body agency condition using the system The Machine to Be Another. (SL) no body agency condition using the Second Life environment. Participants indicated their resposnses on a 7-Likert scale from "I completely disagree" (-3) to "I completely agree" (+3). The bars represent the mean values and the error bars indicate standard erros.

It is important to point out that when a virtual environment computer-generated is delivered through a HMD, the participants cannot generally see their own real bodies or even their entire avatar's body. Several studies, such as [24], [25], [26], can be found in the literature considering the relationship between the participant and their virtual body (avatar), and its influence on presence perception. In fact, agency and body ownership illusion have been studied and have their own metrics that, while related to presence, are different, for example, the Rubber Hand [27], [28], [29], [30], the Full Body [31], [12], [9], the Invisible Body [16] and the Enfacement Illusion [32], [33], [34]. However, from a point of view that disregards emotional and affective aspects, there would be no conceptual difference if a virtual body was replaced by a real-person's body (performer). Thus, until now, it was not known whether this could be generalized to another real entire body with body agency.

VI. Conclusion and Considerations for Further Studies

Our pilot experiment demonstrated the viability of a low cost apparatus to produce a high sense of being in another person's body. We also observed that the body agency condition does promote high levels of emotional involvement with the experience of controlling another body, having a real person as our avatar. This effect is so prominent that, during the experiment, the participant can face his or her own real body without noticing of the technological mediation and thus "shaking hands with themselves" without losing the willing suspension of disbelief.

In the near future we will be working in develop better localization of standard questionnaires, accepted by international community of researchers into "presence" as the best way to evaluate the perception of presence, in order to adapt their questions to Portuguese language and to Brazilian culture. In new researches we might also consider increasing the number of participants and reducing the time spent by each during the experiment. Nevertheless, our findings evidenced the impact and involvement of the participants during the body swap experience and a lower impact without body agency experience.

Additionally, we are already working to improve the hardware part of the system, by replacing the moving mechanical part of the system with two 180 degrees cameras graphics processing software.

Some works on body ownership illusion present studies on using traditional rubber hand illusion, invisible body, full mannequin's body and an entire real body illusion without body agency. Our contribution to this field was to show an effective and low cost way to induce body swap illusion with body agency. After this experiment we can start to explore different interesting possibilities and applications in several areas, such as neuroscience, psychology, education and social science.

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