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CiAUD Centro de Investigação em Arquitetura, Urbanismo e Design

FCT Fundação para a Ciência e a Tecnologia

Effects of Virtual Reality Locomotion Systems over Space Perception

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Keywords
Virtual Reality, Locomotion-in-place, space perception

Partner Institutions
Interactive Technologies Institute (ITI/LARSyS)

Expected Future Partner Institutions
ITI/LARSyS

OBJECTIVES

The main objective of this project is to contribute to the validation of virtual reality as a tool to study human behaviour in the area of ergonomics and interaction design, namely concerning the investigation of the effects of VR locomotion systems over space perception.

Specific Objectives:

1. Compare perception of distances (egocentric depth perception) in real situation with three VR locomotion systems (locomotion-in-place, simulated gait and natural gait.)

2. Compare perception of passability (available space to pass through a space) in real situation with three VR locomotion systems (locomotion-in-place, simulated gait and natural gait.)

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ABSTRACT + IMAGES

Virtual Reality technology nowadays provides high levels of immersion and presence, but VR is not the same thing as reality. Thus, it is mandatory to research what are its differences to reality, especially when VR is used to draw conclusions about the impact of ergonomics design in human behavior. It should be noted that one of the frequent criticisms of reviewers who analyze studies carried out in VR concerns the validity of transposing the results obtained in VR to Reality.

An obvious difference is that the space of the metaverse is virtually infinite whereas the physical space of reality where we use our HMD is restricted (Figure 1). Indeed, many of studies that use VR carried out at ergoUX Lab (Rebelo et al, 2021), model large spaces such as offices, hotels (Figures 1, 2 and 3), factories or airports, where participants are required to traverse in an immersive virtual environment. However, the space in VR lab has restricted dimensions, thus, locomotion within the virtual space must be simulated in some way, as the real gait would lead the participant to hit the walls of the lab. To move we have several alternatives such as the locomotion-in-place, the teleport to points within the virtual space or even the simulated gait using a joystick (Galrão, Rebelo & Noriega, 2020) .

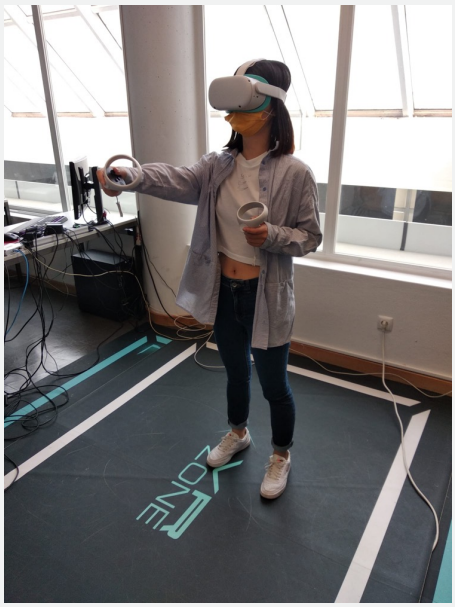

Figure 1. Participant in VR in "restricted" physical space (Image from ergoUX Lab).

In semi-immersive virtual environments such as desktops, the **simulated gait** used in many FPS (First Person Shooter) games is the best solution, however in VR this simulated gait, which is accompanied by a vection, can cause simulator sickness as there is a perceptual conflict between the self-motion visual cues and information from the vestibular system. That is, when the user is still, does not give vestibular movement cues to the brain consistent with vection. In previous studies carried out in the ergoUX Lab (Galrão, Rebelo & Noriega, 2020), it was shown that the best way to solve locomotion problems was to opt for a **locomotion-in-place** that allows participants to move in "small jumps" using command buttons. Thus, there is a displacement that is not as exaggerated as that of teleport and at the same time, vection is inhibited, thus avoiding perceptual conflicts arising from contradictory information between the visual and vestibular system. This mode of locomotion has been sufficient for the studies carried out, but questions arise whether this locomotion-in-place will not cause perceptual and action errors in studies with different objectives, namely in those which perceptual judgments depend on the information from self motion. Previous studies using VR showed that the information acquired by the integration of visual and vestibular cues from natural gait, allows accurate perception and action in judgement of **passability (available space to pass through a space)** (Bhargava et al. 2020) and the judgment of **distances** evaluated through **egocentric depth perception** are only slightly underestimated (Jones et al. 2008).

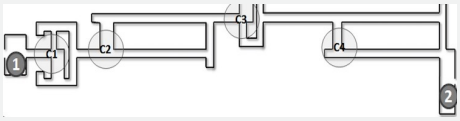

Figure 2. Plant of a hotel section used in a virtual reality study (Rebelo et al 2020) where is possible to see that the limits of space are not restricted to a physical space.

However, till the current date, we did not found studies that evaluated the effects of locomotion-in-place over the judgment of passability or egocentric depth perception. Thus, this is the study's main objective, investigate the effects of locomotion-in-place over space perception in VR. For this, methods used by Bhargava et al (2020) and Jones et al. (2008) will be adapted by adding an experimental condition with locomotion-in-place

We will have two tasks, one related with the perception of egocentric depth perception and another with perception of passability. For both tasks we will have a baseline condition in real situation and three conditions for each one of VR locomotion systems (locomotion-in-place, simulated gait and natural gait). We will analyze objective results concerning precision in perceptual judgments of passability and egocentric depth perception as well as subjective measures related with presence.

The results obtained will allow to add more information related with the differences between VR and reality, which has implications for studies in ergonomics and design that use virtual reality to study human behavior. The exploration of the methodologies used in this embryo-project is a first step towards a project of greater dimension and complexity, whose objective is to outline guidelines for designers of immersive virtual environments. Specifically, if we know that, for example, there is an underestimation of distance or dimensions, we want to be able to specify what distortion is necessary in the modeled space, so that the perception and respective action does not suffer from this underestimation, thus allowing accurate predictions of human behavior using VR as tool. That will be the objective of a larger project to be submitted to FCT (Fundation for Science and Technology – Portuguese organization responsible for science funding).

Figure 3. View from point 1 one of corridor C1 of figure 2 hotel section.

Figure 4. View inside the point 2 of figure 2 hotel section, the lift room.

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SCIENTIFIC RELEVANCE FOR THE DISCIPLINE

Ergonomic science as other sciences depend on the reliability of used methods. As there are a lot of ergonomic studies that can't be made due to economic restrictions, safety or ethical reasons, virtual reality is a tool that can be integrated in the ergonomic methodologies that make possible develop studies that before could not be made because of the forementioned reasons. For instance, in the ergoUX lab, many studies has ben made concerning compliance with security warnings or egress signs, in large buildings, demanding from the participants to walk or run inside the buildings, and find an egress route or to read a warning in stressful conditions. The perception of affordances is related with action, as Gibson argued (2014), "We must perceive in order to move, but we must also move in order to perceive", thus the clear understanding of the mechanism used to locomotion in virtual reality spaces and its precision, it is crucial to validate results about human behavior using VR. The insights obtained with this project and the results from affordances perception and action in virtual reality is one more step in order to increase the validity of virtual reality as a tool to ergonomic studies.

EXPECTED ECONOMIC AND SOCIAL IMPACT

With the massification of virtual reality and the expected economic growing of virtual reality hardware and applications, all the research that can improve ergonomics, usability and user experience of virtual reality and metaverse experiences can have an impact in the economic grow and in the users. Society digitalization, for work and leisure reasons, is a reality, mainly after covid19 pandemics. Using metaverse, for work or leisure, it is a real possibility with a lot of researchers, companies and developers working in VR applications for collaborative work, or creating experiences where people can relax, having fun times, and of course making research. The use of metaverse can have a positive outcome concerning the reductions of ecological footprint when it allow user not to commute between places. This research outcomes, as other researches, can be a drop in the ocean of knowledge increasing the positive impact of VR technology on society. However, as all the technologies have two sides, we must be aware of the dark side associated with the abuse of technology use, mainly if we think that virtual reality can be very immersive and addictive, and of course can lead to alienation of users from reality.

RESEARCH PLAN AND TASKS

This project is centered in the validation of virtual reality as a tool to be used in ergonomic and design studies. Namely on the implications of VR locomotion systems in the perception of space.

RESEARCH PLAN

The research plan have one year duration and it is divided in 8 tasks:

1. Planning
2. Creation of baseline scenario for real-world evaluation
3. Development of virtual reality scenarios (training and test)
4. Usability testing of the three VR locomotion systems
5. Pre-testing of the real and virtual scenarios
6. Final tests in real situation and virtual reality
7. Data analysis
8. Dissemination

Tasks	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
1. Planning												
2. Baseline Scenario												
3. VR Scenarios												
4. USI Testing												
5. Pre-testing												
6. Final Tests												
7. Data analysis												
8. Dissemination												

Table 1: Project chronogram

TASKS

1. Planning.

All project researchers will be present in the planning stage. We will have two more intense initial months where issues of recruitment of a graduate scholarship holder for the project will be managed. Previous studies will be reviewed in order to accurately plan the following phases. Halfway through the project, we will have another meeting with all project researchers, to discuss the results of the pre-tests and make a final decision on the final tests. The last meeting will be preparatory for the closing of the project closure and the distribution of tasks for the seminar and workshop to be held at the end of the project, which aims to bring together the local community (Portugal) of professionals and academics who use VR.

2. Creation of baseline scenario for real-world evaluation

This project has as its global objective the comparison of VR with reality, in this sense an evaluation of space evaluation tasks related to distance perception (egocentric depth perception) and perception of passability (available space to pass through a space) will be carried out in a real situation. For the assessment of distance perception, the construction of a physical obstacle is simple, but for the assessment of passibility, the need for something more elaborate is foreseen, such as the device used by Bhargava et al (2020), which can be seen in figure 1. It should be noted that the faculty of architecture has workshops where these simple physical devices can be manufactured. Paulo Noriega, Ernesto Filgueiras and the student fellow will be responsible for this task.

3. Development of virtual reality scenarios (training and test)

In this stage it is necessary to develop the scenarios for VR training and the final evaluation scenarios. These scenarios will be developed in Unity3D. The training setting is where participants get used to VR. Only after this habituation to VR can we move on to the tests. Many participants have never experienced VR, so it takes time to learn to navigate within the metaverse and know how to use the commands. These training scenarios involve simple tasks like going from point A to B or picking up an object. The test scenario will be constituted by a space in which the subjects have to move to a certain place and a scenario that replicates the real scenario for the assessment of passability (Fig 1 b). For distance assessment, we will in principle use a typical depth assessment task in these studies which consists of asking participants to assess the distance to point x and then walk to that point with their eyes closed. Thus, the error in this estimation is evaluated. For passability, for each opening measure chosen, the participant decides whether he can pass through that opening. All researchers will be in this task.

4. Usability testing of the three VR locomotion systems.

Due to constant upgrades of unity 3D, sometimes the functionalities previously developed no longer work, so it is mandatory to check the usability and functionality of the three locomotion systems used in this investigation, in order to control stange variables related with technical issues. Paulo Noriega and Student will be in this task.

5. Pre-testing of the real and virtual scenarios

At this stage we will make test the scenarios, experimental procedures and check objective and subjective used measures, and collect some data with a reduced sample. Paulo Noriega, Elisângela Vilar and Student will be in this task

6. Final tests in real situation and virtual reality.

Final tests will be made mainly by the student fellow, supervised by Researchers Paulo Noriega, Elisângela Vilar and Ernesto Filgueiras.

7. Data analysis

We will collect data from experiments and treat data using SPSS. After data analysis by Paulo Noriega and Student we will have planing meeting with all researchers to analyze and discuss results

8 Dissemination.

A paper for an international conference will be submitted at half of the project, with results of the pretests. All researchers will support in ergoUX Event seminar and workshop related with Virtual Reality Methodologies, as well in a paper production.

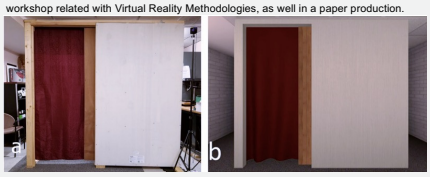

Figure 1. Real-world (a) made of wood with a sliding door and VR Replica (b) used by Bhargava et al (2020)

EXPECTED SCIENTIFIC RESULTS

Develop the knowledge about methodologies to compare VR with reality, namely in the effect of VR locomotion systems over space perception, it is an original thematic that will allow to have positive results concerning dissemination and academic thesis. Thus, with the research achieved inside this embryo-project it is expected the publication of an international conference paper, a paper in a scientific journal and the realization of a master thesis. Because we have in Portugal a significant number of researchers using VR in several areas, this project will inspire, in a local scientific event related with Ergonomics, Design and User Experience (ergoUX Event), a special seminar and workshop about methodologies used in Virtual Reality to approach the professional and academic Portuguese community working with VR.

BUDGET: € 7.447,88

a) Human Resources:

A 6-month research grant for a graduate (6*857.98=€5147.88)

b) Acquisition of other goods and services:

Materials (wood, fabrics for curtains, glue, etc.) and labor for the construction of the experimental setting for the baseline study to be carried out in a real situation. (€1700)

Payment of services to voluntary participants in the experiments (€600)