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Safe Buildings

CiAUD Centro de Investigação em Arquitetura, Urbanismo e Design

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

Using Virtual Reality to develop safety information for smart buildings

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Smart buildings, Virtual Reality, User-Centered Design, Human compliance, Safety information

Partner Institutions
ITI/LARSys

Expected Future Partner Institutions
MIT - USA

OBJECTIVES

The main objective of this project is to propose a warning for smart buildings to evacuate people in an emergency situation in the moment of decision making to leave the site.

The specific objectives are:

Development of a virtual environment of a budling to be used in virtual reality.

Create a narrative composed by two tasks with low and high levels of participant engagement.

Develop a new technological based solution for a new warning, to be integrated in the developed virtual environment with the two participant tasks.

BIBLIOGRAPHIC REFERENCES

ABSTRACT + IMAGES

During an emergency situation, into complex buildings, evacuation time is a key factor to save lives, in this context, project effective buildings and safety systems, that reduce this time is a challenge for architects and designers. In this scenario, Human behavior is one of the most critical determinants in the occupant safety in indoor or outdoor environments, such as fires, terrorist attacks and earthquakes [1]. In those critical situations, the crucial aspect of a building safety is to provide for their occupant's possibilities of exit, giving then a safe escape. Studies of Human behavior in buildings date from '50s motivated by an increase of natural disasters [2]. In 2001 the attack to World Trade Center, boosted the research in this area, with a particular focus on the protection of humans in buildings against terrorism-related risks [3]. Prior studies categorize the Human behavior during emergency events in two moments:

(1) pre-movement behavior, related with the process that begins when an alarm is triggered and ends when the occupant starts his/her travel to a safe place [4,5] and

(2) movement process, that starts when the occupant travel to an exit and ends when the occupant leaves the building or find a safe place [6].

During those moments can occur interaction behaviors with others [7,8] and interaction behaviors with the environment and emergency hazards [9,10]. Evacuation time was considered only the basic measure to evaluate fire protection systems [11], normally, no basis in behavioral literature is used during the project of a building or in alarm and signage development process. However, there is a diversity of factors that could impact in human behavior during evacuation situations. In this situation, the foremost important factors are the building attributes.

In previous projects [12,13], our research team used virtual reality to prove that evacuating people from complex buildings in an emergency situation can lead to the death of the occupants. This occurs because the mandatory safety information that must be placed on buildings, which complies with ISO 7010, to guide people to the exit, does not help them in a stressful emergency situation.

Given the need to protect people's lives, our team used virtual reality to successfully develop directional information for buildings to guide people in an emergency situation. There are, however, unresolved problems that our team proposes to research and unravel new solutions.

The period of time it takes people to make a decision to leave their place and head for the safe exit is long. This situation is reported in several studies [4], for example, in the attack of the twin towers in New York, many people did not immediately leave their workplaces to go to the emergency exits and ended up death. The ISO 8201 and 7010 Standards that regulate solutions for evacuating people now deserve our attention. Few studies [14,15] have explored the possibility of using other strategies, particularly those based on technology that can be more effective, making people more prone and quicker to act, thus avoiding people's death.

In this context, there is an increasing need for studies that explore the development of solutions, which can be later translated into International Standards and successfully implemented with technological solutions in the international market.

In previous studies [16,17], our research group has shown that virtual reality can be used effectively to create virtual environments, where the behavior of people in an emergency situation is very similar to that of a real situation. In this context, the methodological approach in this study will involve the use of virtual reality for the development and evaluation of the proposed solutions.

This project has already been submitted to the Portuguese Foundation for Science and Technology (project reference: PTDC/ART-DAQ/3082/2021).

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SCIENTIFIC RELEVANCE FOR THE DISCIPLINE

In this project proposal we continue to use virtual reality as a tool to evaluate Human compliance with safety information. In previous studies we prove that virtual reality as a good tool to evaluate the Human compliance with warnings, in a wayfinding exit situation, in this project, we will explore the pre-movement situation, the decision to leave from a space after received a warning in an emergency situation. The exploration of virtual reality in this context will open a new research area, that will allow different studies to improve Human safety in critical situation, an important aspect for Ergonomics and Human Factors.

EXPECTED ECONOMIC AND SOCIAL IMPACT

This project is in line with the Goal 11, 'Make cities and human settlements inclusive, safe, resilient and sustainable' of the 2030 Agenda from United Nations. Developing new technological based solutions do improve safety conditions, in smart budlings, particularly for critical situations.

The results of this research project, particularly a new generation of alarms and signature systems could be used in a near future smart buildings and smart cities. The results from the behavior compliance with safety information (alarms and directional signals) will provide indicators for the future the new ISO Standard. A deeper knowledge of Human behavior and critical events caused by emergency situations, will feed future models of evacuation simulation.

RESEARCH PLAN AND TASKS

Introduction

Our experimental approach to develop this project, uses immersive Virtual Reality (VR) as an interaction environment to evaluate the efficiency of the proposed emergency information system. This methodology allows a better control of the variables and a higher ecological validity. With immersive VR, participants tend to experience high levels of immersion and Presence, that indicates their behavioral response is similar to a real-life situation.

To achieve our main objective, three studies will be developed:
Study 1 – Development of the VR environment, narratives and integration of the technological based solutions.
Study 2 - Develop a new generation of technological based solution to improve the premovement phase egress.
Study 3 - Evaluate the technological based solution in VR.

Study 1 – Development of the VR environments, narratives and user scenarios and integration of the technological based solutions.

For this project we will adapt a previous developed budling composed by an entrance hall, meeting rooms and services, where the participants will be involved in a narrative and tasks. The geometrical model will be imported to UNITY3D to integrate new textures for the walls, floor, ceilings and decoration. Next, we will also introduce the lights, environment sounds and furniture.

The final step will be the introduction in the virtual environment a first person as an avatar of the participant and a virtual autonomous agent for the receptionist in the budling. We will use our own developed UNITY3D scripts to create the participant interactions and log all her behavior inside the building. The narrative as the objective to put the participant in action inside the developed virtual environment. In this project we will have two narratives, for two experimental conditions: one related with high engaged task and another with low engaged task. Methods: This development will be done during project team meetings in brainstorming meeting.
Main outputs: The virtual reality with the following dimensions; the smart building characteristics (dimensions, compartmentalization, textures, lights, sounds and object animations); the critical (emergency) situation to be simulated inside the building (a fire, for example); the participant tasks and the participant avatar interactions; the need to engage the participants in the virtual environment.
Study duration: 5 months

Study 2 - Develop a new generation of technological based solution to improve the pre-movement phase egress.

The level of efficiency of the exist solutions, proposed by the ISO Norms 8201, for alarms in the first pre-movement phase, particularly, in a critical situation are low.
In this study we will develop, at least, two new proposals of technological based solutions to be used in pre-movement phase. As main requirements, the solutions will be developed for smartphone, were will integrate different levels of: sound; text; images; animations; vibrations and personalized information.
Methods: This development will be done during project team meetings in brainstorming meeting.
Main outputs: Two proposal of technological based solutions to be used in premovement phase.
Study duration: 3 months

Study 3 - Evaluate the technological based solution in VR.

We will evaluate two technological based solutions for the pre-movement egress situation.
Methods: For each solution, we will have a sample of 30 participants, in a total of 60 participants. The experiment will be divided into 4 major phases: 1) introduction to the study; 2) training session; 3) experimental session; and 4) post-hoc questionnaire session. The whole procedure takes approximately 30 min in total.
(a) Introduction to the study phase: At the beginning, the participants are informed that they participate voluntarily in this experiment, being informed of possible side effects of VR, particularly nausea. They are also informed that they can give up the experience at any time, without any problem.
(b) Training session: In the first experimental session, a training period in which the participants practice using the system's equipment/ device, as well as learn how to interact inside the VE;
(c) Experimental session: at beginning, the defined narrative created in the WP 2 will be presented to participant to give him an objective to do inside VE. Next, the participants will interact with the head mounted display and VR commands to navigate inside the VE building, receive the information until a critical situation occurs (for example, a fire in the building).
(d) Post-hoc/ follow-up questionnaire session: at the end of the experimental session, the participants had another 5min break and then filled out two questionnaires, namely the: 1) Simulator Sickness Questionnaire, to assess if there was any symptom of cybersickness and 2) Presence questionnaire, to assess the level of immersion and interaction in VR.
Study duration: 4 months

Task Management and Coordination

This task consists of the project management and coordination and of the elaboration and implementation of the data management plan. In addition, aims to promote the exploitation of the results.

Project Management
This task runs throughout the entire project and consists in the management of the project resources (human, equipment, and financial resources) and coordination of the team and research members, such as to promote an effective use of those resources and time. Therefore, the global management structure will be implemented to facilitate the flow of information between the principal investigator and the local research members.

Data Management
This task will provide an analysis of the main elements of the data management policy that will be used with regard to all the data generated in the project and will be preserved and shared in an open repository (figshare, arXiv, and engrxiv). The data that will be freely available and will follow European Commission on Open Science Policy Platform Recommendations (https://bit.ly/2H4b4Yz).

Coordination
This project will have Francisco Rebelo as principal investigator who will be responsible for the coordination of the project activities. The project will be developed in the ergoUX ergonomics and user experience laboratory, at Faculty of Architecture, where most of the researchers belong. In this context, there will be weekly meetings to monitor and discuss the evolution of the project very closely.

EXPECTED SCIENTIFIC RESULTS

At the end of this project, we expect to have developed a system for smart buildings to improve the evacuation people in an emergency situation.

The expected outputs for the proposed project are:
- The development of a virtual reality simulator and a narrative, to be used in this project.
- The development of a new solution to improve the Human compliance with a proposed technological based alarm.
- The publication of two papers indexed in ISI or SCOPUS.

BUDGET: € 7.469,00

To develop our project objectives, we will need the following equipment:
Head-mounted Display HTC VIVE Pro Eye, necessary to run a complex virtual environment scenario to get data of behavior compliance.
Price – 1800 €
3 Body Trackers and VIVE Facial tracker, necessary to track the body movement information inside the virtual environments.
Price: 559 €
Workstation for VR – (AMD 5800X/32GB/500GB SSD+2TB/RTX 3080)
This workstation will be used to develop the virtual environments.
Price: 3100€
Portable VR (Intel Core i7/16GB/1TB SSD/RTX2080)
This computer will be used to get data outside of the laboratory setup.
Price: 2000 €