Multisensory Virtual Environment for Fire Evacuation Training

Tommy Nilsson
University of Nottingham, UK
tommy.nilsson@nottingham.ac.uk

Tessa Roper
University of Nottingham, UK
t.roper@nottingham.ac.uk

Emily Shaw
University of Nottingham, UK
emily.shaw1@nottingham.ac.uk

Glyn Lawson
University of Nottingham, UK
glyn.lawson@nottingham.ac.uk

Sue V.G. Cobb
University of Nottingham, UK
Sue.Cobb@nottingham.ac.uk

Hsieh Meng-Ko
University of Nottingham, UK
mengko6323@gmail.com

Daniel Miller
University of Nottingham, UK
daniel.miller@nottingham.ac.uk

James Khan
University of Nottingham, UK
james.khan@nottingham.ac.uk

ABSTRACT

Growing organizational safety awareness is propelling the interest in development of novel solutions for fire training. Significant effort in this area has previously gone into designing various immersive virtual reality (VR) systems in hopes of enabling trainees to safely explore and experience the consequences of their actions in scenarios that would be too hazardous in the real life. Yet, the fact that VR generally lacks the sensory feedback of a real life fire situation has been found to impede a sense of

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).

CHI'19 Extended Abstracts, May 4–9, 2019, Glasgow, Scotland Uk

© 2019 Copyright held by the owner/author(s).

ACM ISBN 978-1-4503-5971-9/19/05.
https://doi.org/10.1145/3290607.3313283

Figure 1: The Vive head-mounted display and controllers

Figure 2: Scent diffuser

realism and validity of such experiences. As part of our efforts to mitigate this issue, we now present a new prototype fire evacuation simulator designed to deliver not just audiovisual feedback, but likewise real-time heat and scent stimulation. By engaging prospective users through such a hands-on experience, we hope to inspire and provoke other researchers into exploring the potential offered by novel technology in improving fire safety training methods.

CCS CONCEPTS

• **Information interfaces and presentation (e.g., HCI) → Miscellaneous**.

KEYWORDS

Virtual Environments; VR; multimodality; thermal interfaces; olfactory interfaces.

ACM Reference Format:
Tommy Nilsson, Tessa Roper, Emily Shaw, Glyn Lawson, Sue V.G. Cobb, Hsieh Meng-Ko, Daniel Miller, and James Khan. 2019. Multisensory Virtual Environment for Fire Evacuation Training. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts (CHI'19 Extended Abstracts), May 4–9, 2019, Glasgow, Scotland Uk*. ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3290607.3313283

INTRODUCTION

During the financial year 2017/18, England alone recorded over 167,000 fire-related incidents, leaving 334 individuals dead and 3000 injured while imposing massive costs on the economy [3]. In combination with high profile incidents, such as the Grenfell Tower fire, it is no surprise that the awareness and interest in fire safety solutions is on the rise [5].

Recent advances in VR technology have led some researchers to postulate that it could well become the tool of choice for simulating scenarios that would be too dangerous to reenact in the real world [2]. Indeed, the application of VR is already showing promising results in conveying a range of hazardous situations, including emergency evacuations [4].

Research has however also uncovered important limitations, potentially undermining the credibility of VR-based training platforms. Chiefly, trainees have frequently been found prone to illogical behaviour, such as opening doors with smoke coming from underneath them, which has been suggested to result from the absence of sensory elements that would be present in a real fire situation, such as heat or smoke scent [7]. Such findings have brought Chalmers and Ferko [1] to the conclusion that in order to achieve valid user behaviour, it will be necessary to go beyond traditional audiovisual experiences and deliver an appropriate level of stimulation for all senses.

Following this call, we have developed an experimental multimodal VE simulating a fire evacuation. We sought to maximize realism by complementing an audio-visual VR experience with thermal and olfactory (scent) stimulation. Our initial findings suggest that the addition of these modalities affects

users in a number of potentially important ways, such as by increasing the perceived time pressure and reducing 'gaming' attitudes [6].

This installation grants us the opportunity to publicly exhibit our VR system, making it available to members of the broader academic community to experience and scrutinize.

SYSTEM DESIGN

Our prototype VE is powered by the Unity game engine, with all visual content being displayed through a HTC Vive head-mounted display. Vive controllers are also used for navigation and interaction within the VE (see figure 1). Olfactory feedback is provided by a fragrance diffuser (SensoryScent 200) to simulate smoke scent (see figure 2). Thermal simulation is provided by three 2KW infrared heaters. Finally, sound is presented through standard noise isolating stereo headphones to ensure immersion and to prevent possible confounds of hearing the activation of diffusers and heaters prior to feeling smell and heat.

The diffuser and heaters are both wired into an Arduino microcontroller, assuring that they are in tune with events in the VE. Synchronization and control of heat are improved by the addition of metal fins that open and close, meaning that changes in heat are experienced by the user in real time, without the delay of heaters warming up or cooling down (see figure 3).

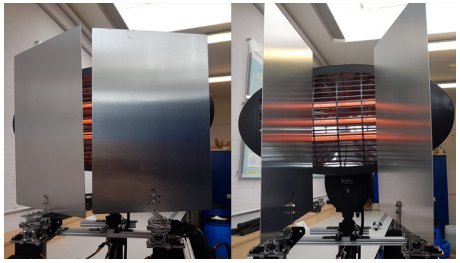

Figure 3: Control of heat from IR heaters: fins closed by default (left) and opening to direct heat toward user (right)

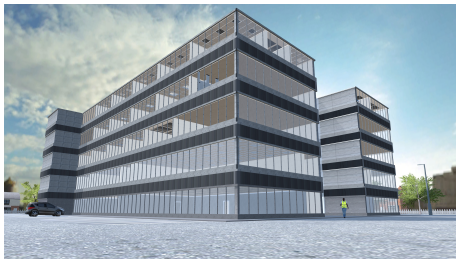

Figure 4: Office building exterior

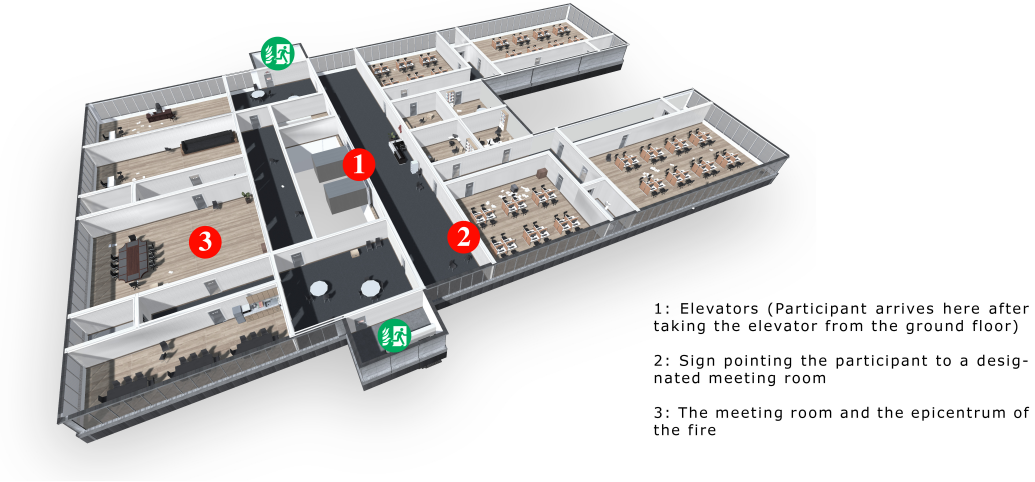

Figure 5: The fire evacuation experience

Figure 6: Fire errupting in one of the rooms

Figure 7: Smoke-filled corridor

THE INSTALLATION

In the course of our installation, participants will be invited to experience a simulated virtual fire evacuation. Specifically, they will be placed on the ground floor of a large office building (see figure 4) and asked to follow signs leading via an elevator to a meeting room at the upper floor. This initial task sequence serves the purpose of familiarizing participants with the VE, giving them a known entry (and a potential escape) route. Once arriving at the designated meeting room, a fire alarm will be triggered, followed by actual fires appearing in close vicinity of the participant (see figure 6). At this point, the participant will be prompted to evacuate the building. A range of factors, such as corridors being gradually filled with smoke (figure 7) or elevators being put out of order, will contribute towards the challenging nature of this task, while also demonstrating the capabilities of our multimodal system.

FUTURE STEPS

While relying on training requirements specified by industry partners as a starting point, we have developed our prototype system iteratively through continuous user feedback, including 43 user study sessions in total to date [6]. We feel confident that the potential benefits of multimodality are relevant beyond the context of fire safety training. Through future work we thus hope to help inform the design of interfaces both novel and existing settings.

ACKNOWLEDGMENTS

This work was funded by the Institution of Occupational Safety and Health (IOSH) through its research fund. We gratefully acknowledge Dr Tony Glover of DRT Software for his work on the VE.

REFERENCES

[1] Alan Chalmers and Andrej Ferko. 2008. Levels of realism: From virtual reality to real virtuality. In *Proceedings of the 24th Spring Conference on Computer Graphics*. ACM, 19–25.

[2] Peter A Hancock, Dennis A Vincenzi, John A Wise, and Mustapha Mouloua. 2008. *Human factors in simulation and training*. CRC Press.

[3] Marketwatch 2018. *Fire and rescue incident statistics: England, year ending March 2018*. Marketwatch.

[4] Antônio Carlos A Mól, Carlos Alexandre F Jorge, Pedro M Couto, Silas C Augusto, Gerson G Cunha, and Luiz Landau. 2009. Virtual environments simulation for dose assessment in nuclear plants. *Progress in Nuclear Energy* 51, 2 (2009), 382–387.

[5] National Statistics, UK 2018. *3. Global Fire Safety Systems and Equipment Market (2017-2023): Forecast By Types, Verticals, Regions and Competitive Landscape - Research and Markets*. National Statistics, UK.

[6] Emily Shaw, Tessa Roper, Tommy Nilsson, Glyn Lawson, Sue V.G. Cobb, and Daniel Miller. 2019. The Heat is On: Exploring User Behaviour in a Multisensory Virtual Environment for Fire Evacuation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM.

[7] Stan W. Smith. 2010. An experiment in bibliographic mark-up: Parsing metadata for XML export. In *Proceedings of the 3rd. annual workshop on Librarians and Computers (LAC '10)*, Reginald N. Smythe and Alexander Noble (Eds.), Vol. 3. Paparazzi Press, Milan Italy, 422–431. https://doi.org/99.9999/woot07-S422