The Influence of an Immersive Multisensory Virtual Reality System with Integrated Thermal and Scent Devices on Individuals' Emotional Responses in an Evacuation Experiment

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Abstract –

Virtual reality (VR) technology has proven to be a valuable tool for exploring human behaviors during construction disasters. Enhancing VR systems with multisensory devices can amplify participants' immersive experiences and emotional response to emergency events. The potential of thermal and scent feedback to intensify negative emotions and immersion in virtual disaster scenarios remains unconfirmed. Addressing this gap, this study developed an immersive VR system equipped with thermal feedback and scent feedback mechanisms, embedded within a multisensory human-computer interface, to investigate their influence on participants' negative emotional response and sense of presence. Findings indicated that thermal feedback devices by allowing participants to detect notable changes in ambient temperature, markedly augmented negative emotional states, cardiac responses, and skin conductance reactions. Meanwhile, although participants could identify noxious smells emitted by the scent player, and while the scent player did evoke negative emotions, this impact was not significantly stronger than the absence of scent feedback. This research underscores the importance and efficacy of incorporating thermal feedback in virtual disaster environments, and advances the utility of VR as a more potent investigatory tool in the realm of individual behavior during building emergencies.

Keywords –

Virtual reality (VR); Evacuation behavior; Fire emergency; Thermal device; Scent player

1 Introduction

Virtual reality (VR) technology is increasingly being utilized in the field of construction, particularly for addressing challenges involving hazardous environments that cannot be easily experimented with in the real world. Acquiring accurate behavioral data during such disasters poses a unique challenge due to the difficulty in replicating real-world evacuation scenarios. VR technology offers a solution [1,2], with its high ecological validity, the ability for precise experimental design and control over key variables, ease of behavioral data collection, assurance of participant safety, and cost-effectiveness [3]. As an illustration, Bourhim and Cherkaoui [4] employed the Unity3D game engine and the HTC Vive head-mounted display (HMD) to create a virtual representation of a fire evacuation scene in a high-rise building. By comparing the results from this VR simulation to actual fire incident data, the efficacy of VR as a research tool for fire emergencies was underscored. To further enhance the validity and impact of VR in the construction domain, scholars are devising VR systems with multi-sensory interaction models.

Immersive multi-sensory VR devices have the potential to significantly influence users' sense of presence and emotional responses. Compared to conventional desktop display devices [5], these immersive VR systems have been shown to elicit presence and emotional responses more akin to real-world experiences [6]. The depth of sensory engagement in a virtual environment (VE) directly influences how realistically human behavior is replicated in simulations used for construction industry training and safety drills [7]. Essentially, the more deeply and extensively an individual's senses are immersed in the VE, the more realistic their experiences become [5]. A literature review on multisensory interaction reveals that a staggering 84.8% of studies reported positive outcomes from multi-sensory VR systems [8]. For instance, spatial audio, when compared to non-spatial versions, has a pronounced effect on emotional responses within immersive virtual environments (IVE) [9]. Both visual and auditory immersion have been found to influence the sense of presence, and in some contexts, the emotional responses as well [10]. In the context of architectural fires, flames, smoke, and sounds such as fire alarms were identified as the primary factors influencing how people perceive fire emergency scene, and these elements can be effectively modeled using current VR technologies [11]. How the visual feedback of flames and smoke affects human emotional responses has been widely explored [11,12]. However, the tactile feedback of flames and the olfactory feedback of smoke still need to be further studied.

Multisensory stimuli, particularly tactile feedback, can significantly enhance the VR experience when accurately delivered [13]. Thermal devices, a subtype of tactile devices, produce sensory impressions by generating airflows that interact with human skin [14]. A VR system was developed in [15] that incorporated a thermal source device, linking temperature sensors to the user's HMD and proximity sensors to a heating element. This system increases the heater's temperature as the user approaches, detected by the proximity sensor, and reduces it when the user moves away. The effect of this device on individual responses has not been investigated [15]. While introducing a thermal source in VR scenarios can amplify the participants' VR experience and boost their sense of presence, there were instances where participants reported not sensing the thermal cues [2]. Studies on the efficiency of such training tools indicate that multisensory VR systems might not hold a clear edge over traditional VR platforms that merge visual and auditory feedback [16]. In the context of architectural fires, the fire's temperature plays a pivotal role in shaping individual evacuation behaviors. Yet, the influence of immersive virtual reality systems integrated with thermal feedback within a multisensory human-computer interface on emotional responses of people evacuating from virtual building fires is still to be explored.

In addition, the effect of smell VR devices on participants in building fire simulations has not received sufficient attention. In certain standard settings, exposure to agreeable odors can influence individuals' feelings of presence and emotional reactions [17]. For example, altering ambient temperature and introducing odors at specific moments in a 360° immersive film within a virtual space can amplify viewers' immersion. Conversely, the absence of these supplemental stimuli can diminish the authenticity of their experience [18]. When olfactory cues are introduced in VE, participants tend to show an increased desire for the presented virtual food, and their ability to interact with this virtual sustenance intensifies this effect [19]. Furthermore, the integration of olfactory tools can improve participants' task performance in VR settings [17]. Nonetheless, within the framework of architectural disaster simulations, especially real-life building fires, the dominant smells are often off-putting. The ramifications of immersive VR systems that combine off-putting smell devices within a multisensory human-computer interplay remain uncharted.

This study delves into the effects of immersive virtual reality (IVR) systems with thermal feedback and smell devices on individuals' emotional responses. Our goal is to ascertain whether these multisensory devices influence an individual's sense of presence and emotional reactions in simulated building fire scenarios. Subsequent sections of this article will detail our research methodology, present the results, and provide a discussion and conclusion based on our findings.

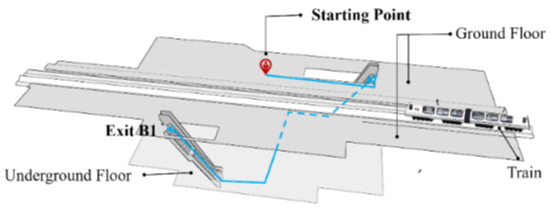
2 Methods

2.1 Experimental Design

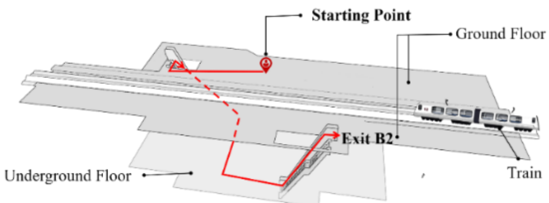
To explore the influence of an IVR system with thermal feedback and scent player on human emotional response and sense of presence, a two-factor mixed experiment is designed. Thermal feedback serves as a factor for repeated measurement, while scent feedback is a factor for non-repeated measurement. Participants' sense of presence is assessed using the Presence Questionnaire (PQ) [20] and their emotional response is measured by the Positive Affect and Negative Affect Scale (PANAS) [21]. Additionally, the electrodermal activity (EDA) [22] signals and electrocardiogram (ECG) signals [23], commonly used as markers of autonomic arousal during mental stress, are employed as objective measures of emotional response.

2.2 Experimental Environment

The experimental virtual environment was modeled based on a subway station in Beijing, including both its underground and ground floors. By strategically placing obstacles within the environment, we crafted two evacuation scenarios. As shown in Figure 1, both scenarios share architectural similarities and feature evacuation routes of identical lengths. The fire originates from a train approaching the station. Upon receiving a station-wide announcement, participants waiting for the train are instructed to evacuate immediately to designated exits within the station. Simultaneously, devices simulating temperature and smell effects dynamically adjust their intensity based on participants' proximity to the fire source. The starting point for participant evacuation is situated on the ground floor. Each scenario includes only one safe exit: participants in Scenario 1 must navigate to Exit B1, while those in Scenario 2 must proceed to Exit B2. Successfully reaching any of these exits from their respective starting positions is considered a successful evacuation.



(a). Scenario 1



(b). Scenario 2

Figure 1. Virtual experimental scenes.

2.3 Experimental Equipment

A VR fire evacuation behavior experimental system based on multisensory human-computer interaction has been developed using the Unity3d engine. This VR system facilitates a multisensory interaction experience, incorporating visual, auditory, tactile, thermal, and olfactory sensations within an engaging IVE. The initial construction and rendering of the scene, including the firework models, were conducted using Revit software to create the fundamental structures. Subsequently, 3ds Max software was utilized to enhance the models through rendering before importing them into Unity3D software for the assembly of the scene prototype. To simulate the properties of virtual flames, such as their temperature and rate of spread, we used PyroSim and FDS, applying the resultant data directly to the flame models within Unity3D. In addition to the visual elements, the IVE was enriched with a diverse array of sound effects, ranging from evacuation broadcasts to the sounds of flames crackling. The use of VR HMD culminates in a deeply immersive experience for the participants, enhancing the realism and impact of the fire evacuation simulation.

To enhance the realism of the evacuation experiment, the system incorporates interactive devices that simulate the high temperatures and smells produced at a fire scene. The purpose of the scent player is to mimic the irritating smells emitted at a fire scene. This is achieved through the use of a scent player (Figure 2) manufactured by the ScentrealmM Company [24]. The player is filled with non-toxic, side-effect-free scented materials available for selection, including smells such as burning plastic and burning paper. Depending on the participant's distance from the fire source in the virtual scene, the player can adjust the frequency of the scent released to simulate the irritating smell at a fire scene. The customized thermal interaction device consists of a heater and a lifting and rotating platform (Figure 3). The device controls the temperature changes in the participant's surrounding environment by adjusting the heater's settings and the deflection angle directly facing the participant. The lifting device can be adjusted according to the participant's height to optimize their experience. Real-time data transmission and feedback between the device and the scene are possible. In the virtual scene, as the participant approaches the fire source, the temperature interaction device automatically adjusts its settings and deflection angle based on the distance between the participant and the fire source, allowing the participant to feel varying degrees of warmth. As the distance between the participant and the fire source increases, the sensation of warmth noticeably decreases until it disappears. Before the experiment commenced, participants were positioned facing the thermal device at a distance of 0.9 meters.

Figure 2. Off-the-shelf scent player.

Figure 3. Customized thermal device.

2.4 Participants

A total of 36 participants, all of whom were Tsinghua University students, were recruited for this study. They had an average age of 21.34 years (S.D. = 3.531) and an equal gender distribution, with a 1:1 ratio of males to females. The participants were allocated into two distinct groups: both groups wore the device, and one utilized the scent player consistently throughout the entire session, while the others wore the scent player without it being activated. Every participant was subjected to both thermal-interactive and non-thermal-interactive evacuation scenarios, and whether they first engaged in the thermal-interactive or the non-thermal-interactive scenario was fully randomized. All individuals involved possessed normal visual capabilities and were free from any medical conditions that might deem them unfit for participation in VR-based experiments. Upon completion of the experiment, each participant was rewarded with a compensation of 60 RMB.

2.5 Experiment Process

This experiment proceeded in seven succinct steps: 1) Participants arrived at the lab, settled at a computer, and after a brief break, received and signed an informed consent form outlining the study's aims and data collection methods, along with a reassurance of their right to withdraw at any point without compensation. 2) Participants were briefed on the experiment, equipped with EDA and ECG BIOPAC devices, instructed on their use, and advised to minimize movement to reduce data artifacts. A one-minute pause allowed for the collection of baseline physiological data. 3) A pre-test questionnaire was conducted to gather demographic data, emotional states via the PANAS scale, simulator sickness via the simulator sickness questionnaire (SSQ) [25], wayfinding anxiety via Lawton's spatial anxiety scale (LSAS) [26], and sense of direction via the Santa Barbara sense of direction scale (SBSOD) [27]. 4) Participants proceeded to a training task, wearing VR helmets and practicing movement in a virtual empty room until they felt fully familiar with the controls. 5) Post-training, participants took a break, reviewed the instructions of the main experimental task detailing a virtual metro station scenario, and were informed that no questions would be answered once the main task began. They then re-entered the IVE to perform the main task, concluding this phase upon successful task completion. 6) Helmets off, participants completed a post-test questionnaire including the PANAS, SSQ, PQ, and questions to the utility of the thermal and smell devices. 7) Participants completed a second task by repeating step 5, followed by once again filling out the comprehensive post-test questionnaire from step 6.

3 Results

Data analysis was carried out using SPSS [28], with significance levels set at 0.1 for marginal, 0.05 for standard, and 0.01 for high significance. A normality assessment preceded all tests. The independent sample t-test evaluated mean differences between two groups for data following a normal distribution [29]. Conversely, for skewed data distributions, the Wilcoxon signed-rank test and the Mann-Whitney U test were employed for paired and independent samples, respectively [30]. No significant differences were observed between the two groups in terms of age, gender, educational background, wayfinding anxiety, or sense of direction, with all p-values exceeding 0.1.

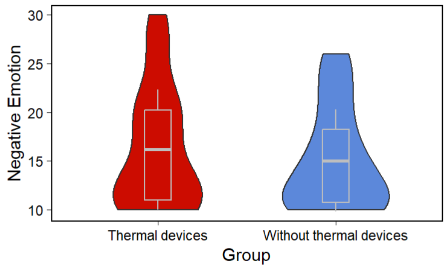
3.1 The Effect of Thermal Device

The results showed that thermal feedback did not significantly influence participants' sense of presence ($Z = 0.291$, $p > 0.1$). Regarding emotional response, no notable difference was observed in participants' positive emotions ($Z = 0.26$, $p > 0.1$). However, participants exposed to VR scenes with thermal feedback reported higher levels of negative emotion (Mean = 16.19, SD = 6.150) compared to those without the feedback (Mean = 15.06, SD = 5.226), with this increase being statistically significant ($Z = -2.948$, $p = 0.003 < 0.01$), as depicted in Figure 4(a).

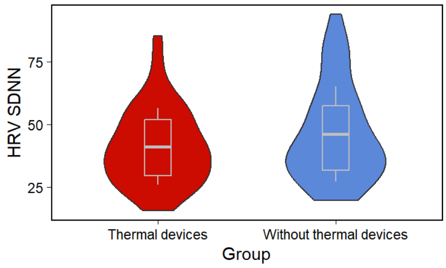
For physiological indicators, heart rate variability (HRV), specifically the standard deviation of NN intervals (SDNN), served as an ECG measure of emotional response, where a higher HRV SDNN indicates a more relaxed state [23]. Participants without thermal feedback exhibited a higher HRV SDNN (Mean = 41.13, SD = 15.275) compared to those with thermal feedback (Mean = 46.05, SD = 18.966), approaching marginal significance ($Z = -1.665$, $p = 0.096 < 0.1$), as illustrated in Figure 4(b).

Electrodermal activity (EDA), measured by the Tonic Standard Deviation (Tonic SD) [22], reflects emotional arousal, with lower EDA Tonic SD indicating a calmer state. Participants receiving thermal feedback exhibited a higher EDA Tonic SD (Mean = 41.13, SD = 15.275) compared to those without feedback (Mean = 46.05, SD = 18.966), with the difference being statistically significant ($Z = -1.665$, $p = 0.025 < 0.05$), as illustrated in Figure 4(c).

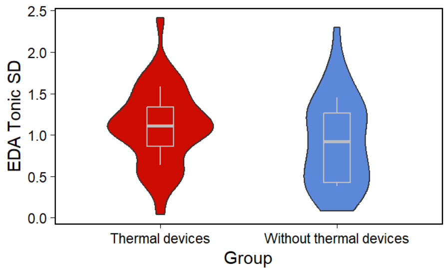
Regarding the perceived effectiveness of the thermal device (as shown in Table 1), significant differences were noted between the two groups regarding the sensation of temperature increase (measured by question 1 (Q1): $Z = -4.576$, $p = 0.000 < 0.01$) and the ability of the thermal device to alter temperature (measured by question 2 (Q2): $Z = -4.628$, $p = 0.000 < 0.01$).



(a). The effect of thermal feedback on participants' negative emotion



(b). The effect of thermal feedback on participants' HRV SDNN



(c). The effect of thermal feedback on participants' EDA Tonic SD

Figure 4. The effect of thermal devices on human performance.

Table 1. The perceived effectiveness of the thermal device.

Group	Mean	SD	Z	Sig.
Q1 (Thermal devices)	4.00	1.31	-4.576	0.000
Q1 (Without thermal devices)	2.06	1.12		
Q2 (Thermal devices)	3.25	1.23	-4.628	0.000
Q2 (Without thermal devices)	1.94	1.04		

3.2 The Effect of Scent Player

No substantial differences were observed between the two groups (with versus without a scent player) in terms of participants' sense of presence, negative and positive emotions, HRV SDNN, and EDA Tonic SD (all $p > 0.1$). However, a notable difference was found in the SSQ scores ($Z = -1.840$, $p = 0.066 < 0.1$), as depicted in Figure 5.

In terms of the effectiveness of the scent player (as shown in Table 1), the two groups exhibited significant difference in the sense of smell of paper burning (measured by question 3 (Q3): $Z = -2.349$, $p = 0.019 < 0.05$) and whether the device could produce the smell (measured by question 4 (Q4): $Z = -4.628$, $p = 0.018 < 0.05$).

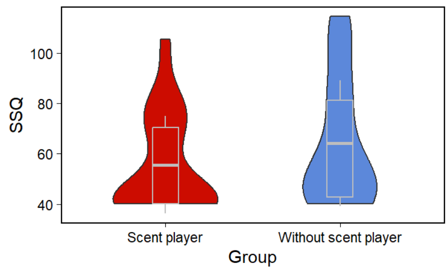


Figure 5. The effect of scent player on SSQ.

Table 2. The perceived effectiveness of the scent player.

Group	Mean	SD	Z	Sig.
Q3 (Scent player)	2.61	1.59	-2.349	0.019
Q3 (Without scent player)	1.78	1.02		
Q4 (Scent player)	2.53	1.75	-2.368	0.018
Q4 (Without scent player)	1.44	1.00		

4 Discussion and Conclusion

This study investigates the effects that a VR fire scenario, furnished with both a thermal device and a scent player, has on participants' sense of presence, emotional reactions, and perceptions of usefulness. The findings demonstrate that the thermal device significantly affected participants' negative emotional states, ECG, EDA, and directly influences their perceived effectiveness assessment of thermal devices. This highlights the ability of enhanced thermal sensations in a VR fire emergency scenario to significantly amplify participants' emotional responses. This finding is in line with previous research that showed a positive effect of thermal sensations on human emotional responses in standard virtual built environments [15]. Being the largest perceptive organ in the human body, the skin's sensitivity to temperature variations plays a crucial role in shaping an individual's environmental perceptions [31]. Incorporating a heat source device within the virtual realm thus proves to be a potent trigger for negative emotional reactions.

Conversely, despite participants' ability to detect the release of potent scents from the scent disperser, this detection did not lead to changes in their sense of immersion, emotional responses, nor affected their perceived effectiveness of the scent player. Similar findings have also been echoed in several previous studies, highlighting that smell cues do not exert a substantial influence on the sense of presence [32], given that olfactory congruence with tactile and visual inputs does not sway the participants' immersive experience [33]. Both our study and preceding research grapple with the challenge of striking a balance between the efficacy of stimuli and ethical considerations. An excessively strong scent may elicit intense physiological responses, whereas a milder scent may fall short in bolstering the VR system's ecological validity. Identifying an optimal scent concentration presents itself as a potential avenue for future inquiry. Nevertheless, this research substantiates the efficacy and imperative of integrating temperature feedback within a virtual disaster setting, thereby contributing another layer of validation to the utility of virtual reality technology as a tool for studying human behavior in the context of architectural calamities. Lastly, it is also noteworthy that participants' past experiences in real-life fire emergencies may affect how they would react to thermal and scent stimuli in virtual experiments, and this factor could be further explored in future research.

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References

[1] Xia X. and Li N. and González V.A. Exploring the influence of emergency broadcasts on human evacuation behavior during building emergencies using virtual reality technology. *Journal of Computing in Civil Engineering*, 35(2):04020065, 2021.

[2] Blomander A., Investigating the use of radiative heat panels to enhance perceived threat of fire in vr, LUTVDG/TVBB, 2020.

[3] Li N. and Du J. and González V.A. and Chen J. Methodology for extended reality–enabled experimental research in construction engineering and management. *Journal of Construction Engineering and Management*, 148(10):04022106, 2022.

[4] Bourhim E.L.M. and Cherkaoui A. Efficacy of virtual reality for studying people's pre-evacuation behavior under fire. *International Journal of Human-Computer Studies*, 142:102484, 2020.

[5] Alam T.A. and Dibben N., A comparison of presence and emotion between immersive virtual reality and desktop displays for musical multimedia. In *Future Directions of Music Cognition 2021 Virtual Conference Proceedings*, Ohio State University Libraries, Ohio State, Amercia, 2021.

[6] Chirico A. and Gaggioli A. When virtual feels real: Comparing emotional responses and presence in virtual and natural environments. *Cyberpsychology, Behavior and Social Networking*, 22(3):220-226, 2019.

[7] Shaw E. and Roper T. and Nilsson T. and Lawson G. and Cobb S.V.G. and Miller D., The heat is on. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems,* pages 1-13, 2019.

[8] Melo M. and Goncalves G. and Monteiro P. and Coelho H. and Vasconcelos-Raposo J. and Bessa M. Do multisensory stimuli benefit the virtual reality experience? A systematic review. *IEEE Transactions on Visualization and Computer Graphics*, 28(2):1428-1442, 2022.

[9] Warp R. and Zhu M. and Kiprijanovska I. and Wiesler J. and Stafford S. and Mavridou I., Moved by sound: How head-tracked spatial audio affects autonomic emotional state and immersion-driven auditory orienting response in vr environments. In *Audio Engineering Society Convention 152*, Audio Engineering Society, 2022.

[10] Pietra A. and Vazquez Rull M. and Etzi R. and Gallace A. and Scurati G.W. and Ferrise F. and Bordegoni M. Promoting eco-driving behavior through multisensory stimulation: A preliminary study on the use of visual and haptic feedback in a virtual reality driving simulator. *Virtual Reality*, 25(4):945-959, 2021.

[11] Zou H. and Li N. and Cao L. Emotional response–based approach for assessing the sense of presence of subjects in virtual building evacuation studies. *Journal of Computing in Civil Engineering*, 31(5):04017028, 2017.

[12] Perroud B. and Régnier S. and Kemeny A. and Mérienne F. Model of realism score for immersive vr systems. *Transportation Research Part F: Traffic Psychology and Behaviour*, 61:238-251, 2019.

[13] Nilsson N.C. and Serafin S. and Steinicke F. and Nordahl R. Natural walking in virtual reality. *Computers in Entertainment*, 16(2):1-22, 2018.

[14] Da Silveira A.C. and Rodrigues E.C. and Saleme E.B. and Covaci A. and Ghinea G. and Santos C.A.S. Thermal and wind devices for multisensory human-computer interaction: An overview. *Multimedia Tools and Applications*, 82(22):34485-34512, 2023.

[15] Valente L. and Feijó B. and Ribeiro A. and Clua E. Pervasive virtuality in digital entertainment applications and its quality requirements. *Entertainment Computing*, 26:139-152, 2018.

[16] Lawson G. and Shaw E. and Roper T. and Nilsson T. and Bajorunaite L. and Batool A. Immersive virtual worlds: Multi-sensory virtual environments for health and safety training. *arXiv preprint arXiv:1910.04697* 2019.

[17] Andonova V. and Reinoso-Carvalho F. and Jimenez Ramirez M.A. and Carrasquilla D. Does multisensory stimulation with virtual reality (vr) and smell improve learning? An educational experience in recall and creativity. *Frontiers in Psychology*, 14:1176697, 2023.

[18] Jones S. and Dawkins S., The sensorama revisited: Evaluating the application of multi-sensory input on the sense of presence in 360-degree immersive film in virtual reality, *Augmented reality and virtual reality,* 183-197, 2018.

[19] Tuanquin N.M.B. and Hoermann S. and Petersen C.J. and Lindeman R.W., The effects of olfactory stimulation and active participation on food cravings in virtual reality. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pages 709-710, IEEE, 2018.

[20] Witmer B.G. and Jerome C.J. and Singer M.J. The factor structure of the presence questionnaire. *Presence: Teleoperators & Virtual Environments*, 14(3):289–312, 2005.

[21] Qiu L. and Zheng X. and Wang Y. Revision of the positive affect and negative affect scale. *Chinese Journal of Applied Psychology*, 14(3):249–254, 2008.

[22] Mansi S.A. and Pigliautile I. and Arnesano M. and Pisello A.L. A novel methodology for human thermal comfort decoding via physiological signals measurement and analysis. *Building and Environment*, 222:109385, 2022.

[23] Pereira T. and Almeida P.R. and Cunha J.P.S. and Aguiar A. Heart rate variability metrics for fine-grained stress level assessment. *Computer Methods and Programs in Biomedicine*, 148:71-80, 2017.

[24] Scentrealm. On-line: https://www.qiweiwangguo.com/, Accessed: 17/08/2023.

[25] Kennedy R.S. and Lane N.E. and Berbaum K.S. and Lilienthal M.G. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The International Journal of Aviation Psychology*, 3(3):203-220, 1993.

[26] Lawton C.A. and Kallai J. Gender differences in wayfinding strat egies and anxiety about wayfinding: A cross-cultural comparison. *Sex roles*, 30(11-12):765-779, 1994.

[27] Hegarty M. and Richardson A.E. and Montello D.R. and Lovelace K. and Subbiah I. Development of a self-report measure of environmental spatial ability. *Intelligence,* 30(5):425-447, 2002.

[28] IBM, The ibm spss® software. On-line: https://www.ibm.com/analytics/spss-statistics, Accessed: 17/08/2023.

[29] Winter J.C.F.d. Using the students t-test with extremely small sample sizes. *Practical Assessment, Research, and Evaluation*, 18(10):1-12, 2013.

[30] Hoeffding W. A non-parametric test of independence. *The Collected Works of Wassily Hoeffding*, XIX(4):214-226, 1994.

[31] Zimmerman A. and Bai L. and Ginty D.D. The gentle touch receptors of mammalian skin. *Science*, 346(6212):950-954, 2014.

[32] Murray N. and Lee B. and Qiao Y. and Muntean G.-M. Olfaction-enhanced multimedia: A survey of application domains, displays, and research challenges. *ACM Computing Surveys (CSUR)*, 48:1-34, 2016.

[33] Baus O. and Bouchard S. and Nolet K. Exposure to a pleasant odour may increase the sense of reality, but not the sense of presence or realism. *Behaviour & Information Technology*, 38(12):1369-1378, 2019.