The Effects of a Stressful Physical Environment During Virtual Reality Height Exposure

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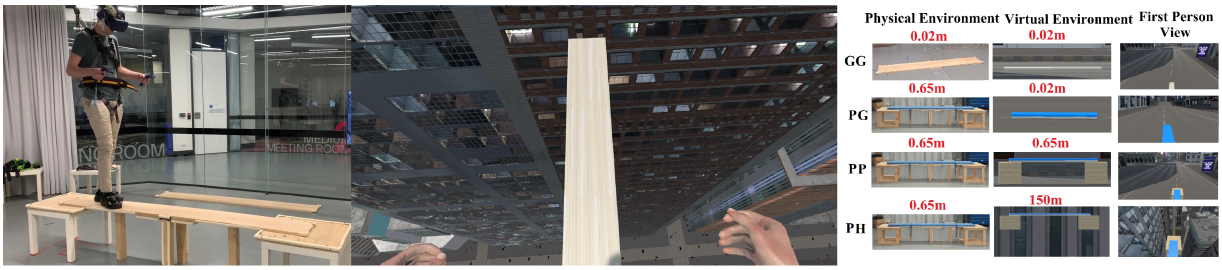

Figure 1: Elevated Physical Platform, the First Person view of the Virtual Environment, and the experimental conditions.

Abstract

Virtual reality height exposure is a reliable method of inducing stress with low variance across age and demographics. As the virtual environment's quality of rendering fidelity increases dramatically, it leads to the neglect or simplification of the physical environment. This paper presents an experiment that explored the effects of an elevated physical platform with a virtually heightened environment to induce stress. Fifteen participants experienced four different conditions of varying physical and virtual heights. Participants reported significantly higher stress level when physically elevated regardless of the virtual height, which suggests that the inherent elevation will induce more stress within participants.

Index Terms: Human-centered computing—Virtual Reality—Height Exposure—Passive Haptic Feedback;

1 Introduction

Physiological stress is a universal survival mechanism directly related to a human's natural fight, flight, or freeze response. The ability to manage stress is essential to maintaining healthy mental health. Height exposure is a reliable method of inducing physiological stress which aids in improving stress management [6].

The introduction and improvement of Virtual Reality (VR) technology provide controlled exposure to heights safely, and cost-effectively [1]. Many height-related VR studies [7, 9, 10] have accepted and adopted passive haptic feedback to enhance the correspondence between the real-world environment and the VE. The typical passive haptic feedback platforms are the stable and low elevation, with the visual display as the source of the stressful stimuli.

This paper presents an experiment investigating the impact of physically elevating walking platform on a person's physiological stress when experiencing different VR height exposure levels. Fifteen participants (4 females and 11 males) were recruited, and each experienced four different conditions of varying physical and virtual heights. As shown in Figure Fig. 1, these four conditions are *GG*: both the physical (G) and virtual environment (G) are on the ground level (0.02m). *PG*: physically elevated (P, 0.65m) while on the ground level in the VE (G, 0.02m). *PP*: both the physical (P) and virtual environment (P) is on the elevated level (0.65m). Finally, *PH*: physically elevated (P, 0.65m) while at extreme heights in the VE (H, 150m). The main contribution is introducing a novel experimental setup with a physically elevated platform providing further insight into how physical height and virtual height affect the user's physiological stress level.

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2 Related Works

This paper's experimental design is motivated by past works done in the areas of physiological stress and VR exposure therapy studies. Early studies such as Hodges et al. [5] established the efficacy of using VR to simulate a heightened environment for acrophobia exposure and inducing stress. Later studies [9, 10] began to emphasise the importance of immersion and presence through the introduction of passive haptic feedback. Based on these past contributions, we believe an effective height exposure-based virtual environment should: 1) provide a high-quality visual rendering [3] and auditory stimuli [4], 2) provide a physical sense of elevation in the real world [9], and 3) have strong correspondence to the surrounding physical environment [11].

3 Methodology

3.1 Physical Space

We constructed an elevated physical platform to provide the physical height to this experiment. Participant safety was ensured through protective foam and a rail fall arrest system to protect the participants from fall-related injuries (no participant fell off during the experiment). Based on the height of the rail, safety line, and harness system, the platform was set to 0.65 metres in height. Based on the design of the Loreto et al. [7] study, an instability factor was included to influence the participant's sense of realism and anxiety. Both the elevated (0.65m height) and ground (0.02m height) platform had the same walk space dimensions of 2.4m long and 0.3m wide.

3.2 Virtual Space

The dimensions, orientation, and position of the physical plank was measured through the Optitrack motion capture system and mapped in virtual space. The visual display was rendered through the HTC

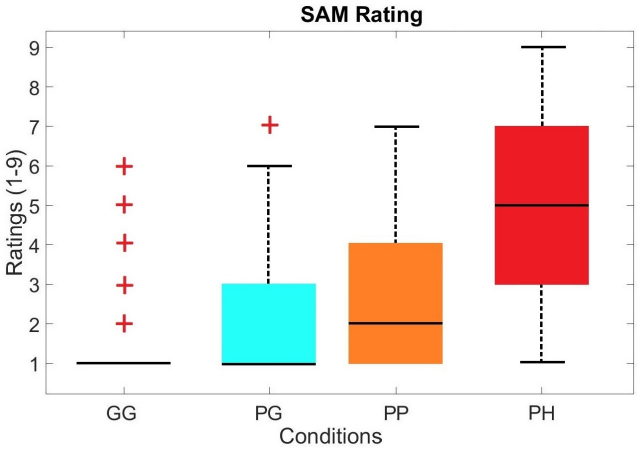

Figure 2: A Box plot of the Average SAM Rating, + indicate the outlier values.

Vive Pro VR HMD and used a VR-optimised PC to ensure a high-quality VE. A virtual avatar was the participant's medium for virtual embodiment. The avatar used inverse kinematics and a six-point body tracking system with HTC Vive trackers.

3.3 Protocol

This experiment tested four conditions; each condition consisted of a combination of the physical (ground and elevated platform) and virtual (ground, elevated platform, and extreme height) independent variables. Every participant experienced the four conditions in a randomised sequence. Each condition of the experiment consisted of 5 trials. One trial involves a return trip on the platform. The participants had 3 minutes resting periods between each condition; they may extend this time based on need.

3.4 Self Assessment Manikin

At the end of each trial (5 trials per condition), the participant provided a verbal Self-Assessment Manikin (SAM) rating (1-9) on their current arousal level [8]. A One-Way ANOVA test was applied to determine the statistical significance between the four conditions in a pairwise manner with the significance level ((α) of 0.05 determining statistical significance.

4 Results and Discussion

4.1 Self-Assessment Manikin

Fig. 2 shows a box plot of the SAM results across the 15 participants. *PH* is significantly different ($F(1,148)>40$, $p<0.001$, and partial $\eta^2>0.25$) to all the other conditions (*PP*, *PG*, and *GG*). There is also a significant difference when comparing *GG* to *PG* ($F(1,148)=10.49$, $p=0.0015$, and partial $\eta^2=0.07$) and *PP* ($F(1,148)=23.28$, $p<0.001$, and partial $\eta^2=0.14$). Based on the average value and significance, the trend of the SAM ratings is $PH>PP=PG>GG$.

4.2 Discussion

The *PH* condition results were consistent with previous studies [9, 10] with the highest SAM rating indicating a high threat level. The assessment of the efficacy of the physical elevation is through the comparison of the conditions *GG*, *PG*, and *PP*, which had different physical elevation and similar levels of virtual elevation. There was a significant difference in the SAM ratings between *GG* to *PG* and *PP* conditions which suggests that the elevated platform is inherently threatening regardless of the virtual height. This finding is unique because, from a tactile sensory perspective, the participants should be unable to differentiate the elevation between the two platforms when using VR.

A possible explanation could be that the platform's instability and the tactile surface are causing stress from the imbalance, causing fear of falling off the elevated platform. The evaluation of this is difficult due to the safety harness, which may provide a sense of safety [2].

A plausible explanation for this phenomenon could be a presupposition of height affecting the person's perception of height. The implication is that prior knowledge of environmental height will affect the perceived height and fear response experienced. Even though, the participant does not directly see the elevated platform when in VR, the presupposed knowledge of the platform's height from visually seeing the platform before wearing the VR, and memory of physically stepping up onto an elevated surface is enough to induce a sense of height.

5 Conclusion

This paper has proposed a novel experiment set up that investigated the efficacy of physical and virtual elevation on a person's stress levels. The overall results showed that the physical elevation causes a significantly higher SAM rating, indicating that the elevating of one's physical environment indeed induces stress. Further investigation into the effects of a more diverse range of physical and virtual heights will improve our ability to differentiate different stress levels.

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