Designing and developing a virtual reality simulation intended to induce a stressful reaction using Half-Life: Alyx

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Introduction

Virtual reality (VR) allows users to experience full visual feedback in a simulated environment through a head-mounted display (HMD). Examples of consumer-grade VR products include the HTC Vive and the Oculus Quest 2, which allow users to immerse themselves in a virtual environment, introducing them to life-like stimuli, thus making it possible to create a stress-inducing scenario while causing the user no actual physical harm.

Augmented feedback (AF) is a type of feedback that is provided by an external source while performing a certain task. Previous research in the field of augmented feedback has shown its effectiveness in human motor rehabilitation through tactile and visual feedback (Lieberman & Breazeal, 2007).

Research has also shown that VR has been effective in cognitive therapy using dynamic difficulty adjustment (DDA), adjusting a game's difficulty according to a user's facial electromyographic (EMG) measurements in real-time while users play (Reidy et al., 2020).

The purpose of this project was to develop a VR simulation with augmented feedback, intended to induce a stressful reaction in users and modulate their measured stress level in real-time using aspects of DDA.

Materials and Methods

The development of this project was divided into three phases. The first phase was the creation of the stress-inducing VR simulation. The second phase was verifying the effectiveness of the VR simulation at inducing stress. The third phase involved designing and developing improvements to the VR simulation based on feedback from volunteers in the verification phase.

Development was done using an HTC Vive HMD and a laptop with VR capabilities (Figure 1). The design of the stress-inducing scenario was based on the VR game Richie's Plank Experience.

To allow for the addition of an AF system, the simulation was developed using the workshop developer tools of Half-Life: Alyx (Figure 2), a popular VR game with elements of horror, which can induce stress. These tools allowed for the creation of a level using assets from the game itself, eliminating the need to create new software.

Figure 1: A subject wearing the HTC Vive VR headset. In the background, Half-Life: Alyx can be seen.

To validate the effectiveness of inducing stress, the simulation was tested by 17 high school students, using the Oculus Quest 2 HMD. Students first completed a survey asking for their general experience with VR and video games. Students were fitted with the HMD and, in random order, experienced a no-stress baseline scenario (Figure 3), a low-stress scenario on a plank above an in-game height equivalent to 280 real feet (Figure 4), and a high-stress scenario resembling the previous simulation, with the addition of several monsters that jumped toward the user in the game (Figure 5).

Materials and Methods (continued)

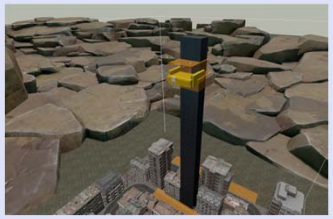


Figure 2 (above): The low-stress scenario in the Half-Life: Alyx workshop tools, the environment where the map was developed.

Following each scenario, students were asked to complete a survey about their experience and stress level on a scale of 1–10, with 10 being the most stressful rating. The survey responses were used to make changes to the scenarios and continue development, fixing issues such as graphical bugs. With an AF system in mind, map logic was added for teleporting the player to different areas of the map, intended to induce different levels of stress according to external measurements.

Figure 3 (left): The first scenario, considered "no-stress". This was the baseline scenario where the VR user was on the ground, surrounded by barriers to restrict movement. A target was placed to aim and shoot weapons that are accessible in the game.

Figure 4 (right): The second scenario, considered "low-stress". The VR user was on a plank at a high height. The design of this scenario was inspired by Richie's Plank Experience.

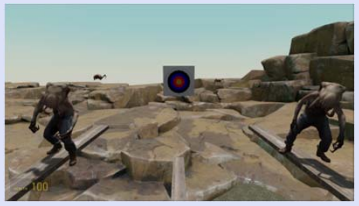
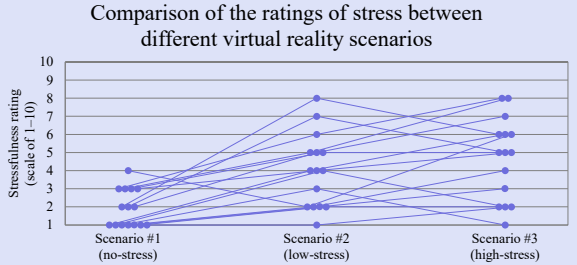


Figure 5 (left): The third and final scenario, considered "high-stress". This was similar to the low-stress simulation with the addition of monsters that jump at the user.

Results (continued)

A non-parametric Friedman test of differences was used to evaluate the effectiveness of the final VR simulation. The Friedman test among the stressfulness ratings between the three VR scenarios (Graph 1) was conducted and showed a significant difference between the no-stress, low-stress, and high-stress scenarios, $\chi^2(2) = 18.10$, $p < .001$.



Graph 1: A comparison of the stressfulness ratings between the no-stress (*Mdn* = 2.6), low-stress (*Mdn* = 4.3), and high-stress (*Mdn* = 5.0) scenarios, with $n = 15$. Two subjects from the original sample were excluded due to equipment malfunctions.

Conclusions

There was a significant increase of 1.7 and 2.4, respectively, in the median low- and high-stress ratings compared to the no-stress rating, with a small difference of 0.7 between the low- and high-stress ratings. The increase in stress ratings indicate that the purpose of developing a stress-inducing VR simulation using Half-Life: Alyx was met.

Due to time constraints, an AF system could not be developed. However, this project still served as a first step toward such a system by creating a developer-friendly environment, which was not possible through existing games such as Richie's Plank Experience.

In the future, a real-time AF system using artificial intelligence could be developed using this simulation as the VR medium. This could be used in conjunction with live electroencephalographic data, allowing users to have their stress measured and modulated while in VR.

References

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Reidy, L., Chan, D., Nduka, C., & Gunes, H. (2020). Facial electromyography-based adaptive virtual reality gaming for cognitive training. *Proceedings of the 2020 International Conference on Multimodal Interaction*. ACM Digital Library https://dl.acm.org/doi/10.1145/3382507.3418845