The Effects of Virtual Reality Environments on Physiological Stress: A Platform Comparison Between Room-Scale Displays and Desktop Computers

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Table of Contents

Abstract

In the past, existing studies have proven the effectiveness of forest therapy as an option for stress reduction, but what happens when an individual is seeking stress relief but the outdoors is unavailable due to unpredictable weather or even a lack of accessibility? The purpose of this research project is to observe the effects of guided scenic meditation in a virtual reality environment on physiological stress. Additionally, it intends to perform a platform comparison by deploying the same meditative experience and testing its effectiveness using a room-scale display and a desktop computer, as the latter ($400 - $1000) is far more affordable and widely available relative to the former ($1 million+). Using both platforms, ten participants were asked to engage with a Unity-built meditative application that simulates the sights, sounds, and smells of a forest environment. Based on the data collected, the participants experienced a decrease in both heart rate and blood pressure, demonstrating the effectiveness of the simulation in reducing physiological stress. Similarly, according to the participants, their subjectively perceived stress levels decreased, resulting in a far more relaxed state than before. The results showcase that a virtual simulation of an environment actively contributes to stress reduction and can be used in cases when the outdoors is unavailable. The platform comparison demonstrates that the product of the research — a guided scenic meditation application that simulates a forest — is accessible and does not require a million-dollar room-scale display in order to be effective in reducing stress.

Introduction

As summarized by Hong, et al., forest therapy is an effective option for stress reduction; it has been reported that walking in forest environments as opposed to urban environments significantly increases the activity of the parasympathetic nervous system and significantly decreases the activity of the sympathetic nervous system. Similarly, simply viewing forest landscapes increases the In (HF) substance and decreases the mean heart rate. While visual stimuli are undoubtedly effective, it should be noted that they are not the only sensory contributors to stress reduction; it can also be the result of auditory and olfactory stimuli. Hong, et al. reported that, after being under stress, listening to natural sounds, such as chirping birds, as opposed to loud noises, such as honking cars, also improves the sympathetic nervous system. Additionally, inhaling scents such as wood while working or studying increases the level of bodily arousal and improves psychological stability [3].

Presenting an alternative to the outdoors, the purpose of this research project is to simulate the sights, sounds, and smells of a forest environment in virtual reality in order to observe and assess its effectiveness in reducing stress objectively and subjectively. To do so, a guided scenic meditation application simulating a forest environment was developed in the cross-platform game engine Unity. In addition to observing the effectiveness of the application in virtual reality, the project intends to perform a platform comparison between room-scale displays and desktop computers to ensure that the product of the research is accessible, as a desktop computer, which costs between $400 to $1000, is far more affordable and widely available than a million-dollar room-scale display. The first objective is similar to the work of Kamińska, et al. except that, rather than using a head-mounted display like the HTC Vive, the research project will test the effectiveness of a room-scale display in simulating a forest environment and reducing physiological stress [4].

The room-scale display in question is the CAVE2 Hybrid Reality Environment located at the University of Illinois Chicago's Electronic Visualization Laboratory. The surround-screen immersive system blurs the line between virtual environments and high resolution tiled display walls, enabling users to simultaneously view both 2D and 3D information for greater flexibility with mixed media applications. This project utilizes the CAVE2's Fully Immersive mode that dedicates the entire display to one simulation which, in this case, is the guided scenic meditation application of a three-dimensional forest model created using Unity [2].

Fig. 1. The CAVE2 Hybrid Reality Environment as photographed by Lance Long.

As demonstrated by existing studies, an indoor simulation of a forest environment, as opposed to a real outdoor forest environment, can also contribute to the reduction of physiological stress. Therefore, in cases when the outdoors are unavailable due to unpredictable weather or even a lack of accessibility, an indoor simulation that uses the sights, sounds, and smells of a forest environment can serve as an alternative option. This project proposes a guided scenic meditation application that utilizes all three for a stress-reducing virtual reality experience. The use of a virtual reality environment intends to increase the immersion of the user and, as hypothesized, decrease their levels of stress.

Methods

Application Development

In order to test the effectiveness of a forest simulation on physiological stress, the first task was to create an application for use in a virtual reality environment, specifically the CAVE2. The forest model of the initial application, developed in Unity, was completed to fulfill the requirements of the course CS 398 titled "Undergraduate Research/Design" at the University of Illinois Chicago. At the time, there was no prior experience working with the game engine, so modeling the forest proved to be a steep learning curve. Briefly put, the process involved sculpting a terrain, painting a trail, scaling models, and importing assets, the result of which was a lush and vibrant stretch of land decorated with tall conifer trees, swaying grass blades, colorful flowers, and large stones.

Fig. 2. The forest model developed in Unity.

Because "research has shown that viewing natural scenes can lower heart rate and restore focus, both of which are important for combatting physical and mental health disorders," enhancing the visuals of the forest model was a priority [7]. With the visuals completed, the next task was to script the application as a guided scenic meditation using the programming language C#. With the knowledge that the application would eventually be used by future participants in a series of user studies, a simple user interface was created in the form of a start menu. It informs the user how to begin the guided scenic meditation depending on their designated platform. If using the CAVE2, the user must press the L1 button. If using the desktop, the user must press the left mouse button.

Fig. 3. The start menu that appears when the application is first launched.

Regarding functionality, the shots of the guided scenic meditation were achieved by primarily scripting the in-game camera which is attached to the player controller. Its position, rotation, and speed were altered depending on the context provided by the two accompanying voice-overs. As credited in Figure 3, the voice-over for the first part of the guided scenic meditation originates from “Guided Imagery Meditation: Forest CHOC” and has been provided by the accredited hospital Children’s Health of Orange County [1]. The voice over for the second part originates from “Guided Imagery - Walk Through Forest” as provided by the meditation channel Mindfully [5]. Because research studies have found that “listening to clips of multiple bird species singing in an urban area had a stronger positive effect on people’s perception of the space [around them]”, it is made clear that visuals are not the only sensory contributors to stress reduction [7]. Therefore, to enhance the forest simulation, a looping audio clip of chirping birds was added. In addition, because “smells might have a much more profound effect on reducing stress compared with sights and sounds", a coniferous scent diffuser was placed in front of all participants to simulate the smell of a forest [7].

With the forest model and guided scenic meditation application in a completed state, the next course of action was to deploy the project to the CAVE2. In order to do so, the project needed to be configured and built for the room-scale display. This was achieved using the CAVE2/Unity simulator developed by Dr. Arthur Nishimoto as well as his guide that is aptly-titled *Guide for running Unity in CAVE2* [6]. When initially developed, the project was created using the Unity version 2018.4.14f1. To ensure that it was compatible with the CAVE2 and its Unity simulator, the project was upgraded to 2019.2.11f1, the latest Unity version that is supported.

Fig. 4. The guided scenic meditation application deployed to the CAVE2, pictured on the left, and the desktop, pictured on the right.

IRB Approval and User Studies

After successfully testing the finalized application on both platforms, the next step was to prepare for user studies with human subjects. Due to their involvement, it was vital that the study first be approved by the Institutional Review Board (IRB). After the completion of the CITI Training courses "IPS For Researchers" and "Group 2. HSP, Social / Behavioral Research Investigators and Key Personnel" as well as the submission of a protocol, recruitment form, informed consent form, and additional documents, the study was successfully approved by the IRB on January 5th of 2023 (STUDY2022-1377).

The study consisted of two hour-long sessions hosted a week apart from one another that asked ten participants — all of whom were university students that were 18 years or older — to engage with the same Unity-built, meditative application using two different platforms for comparison: the CAVE2 and a desktop computer. At the start, the platform designation was randomized. Before and after each session, the participants were asked to complete a subjectively perceived stress evaluation survey using Likert scales. In a similar fashion, the heart rate and blood pressure of the participants was recorded before and after each session using a lab-owned, general use Fitbit bracelet and a standard OMRON HEM-FL31 blood pressure monitor respectively. At the end, the participants were given the opportunity to provide suggestions for the study and application. The same procedures were performed for both sessions.

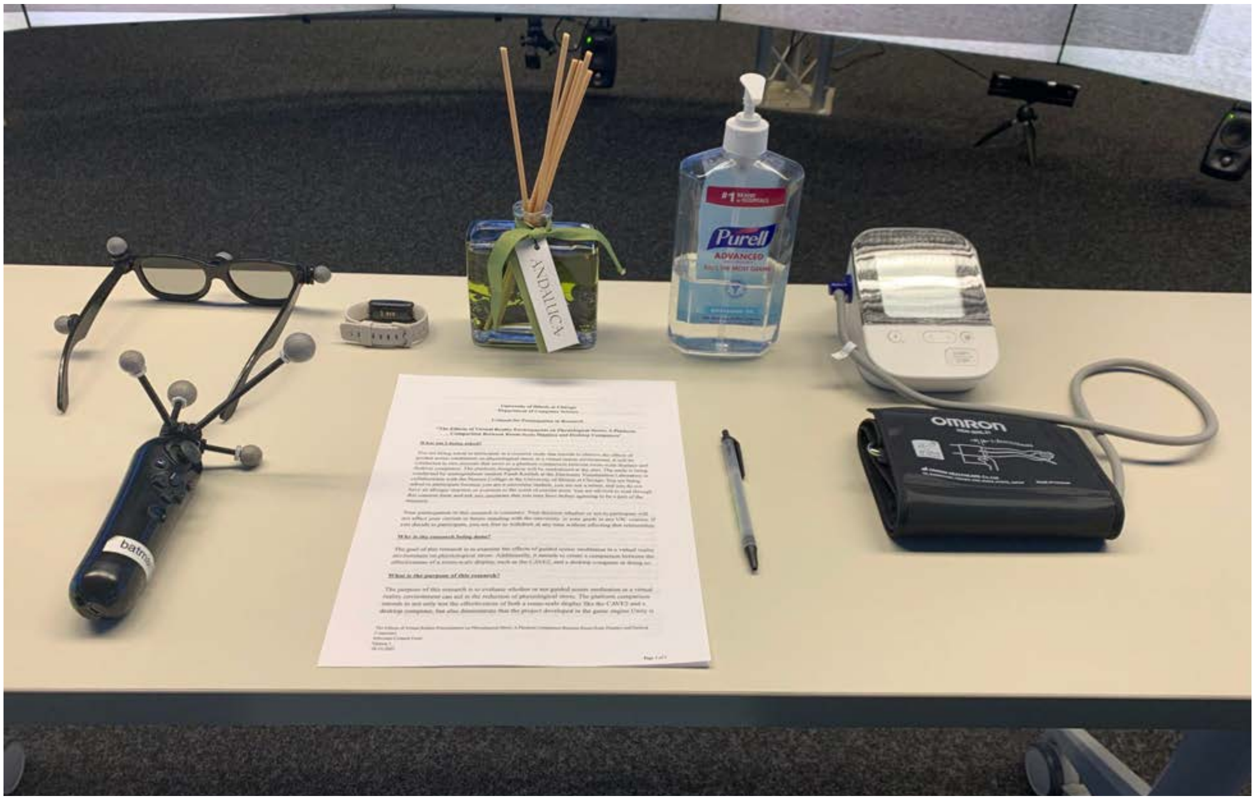
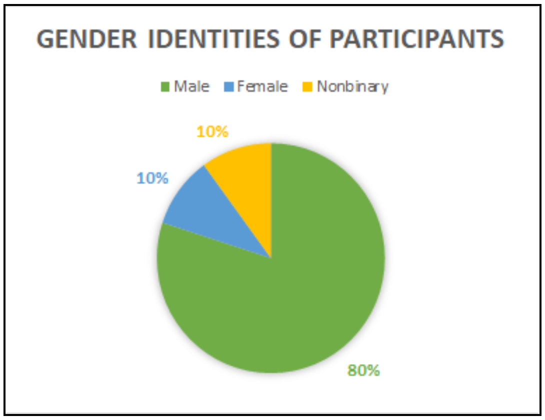


Fig. 5. The placement of all the materials needed for the user studies with CAVE2 designation.

Results

Participant Demographics

The twenty hour-long user study sessions were conducted over three weeks at the Electronic Visualization Laboratory located at the University of Illinois Chicago with a total of ten participants. Among the participants, eight identified as male, one identified as female, and one identified as nonbinary. The ages of the participants ranged from 18 years old to 36 years old.



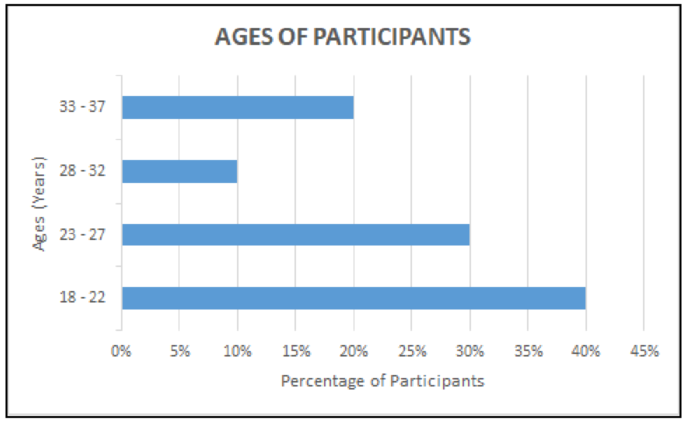


Fig. 6. The gender identities and ages of the participants on the left and right respectively.

Objective Data

Before and after engaging with the guided scenic meditation application using both platforms, the heart rates of the participants were collected and recorded. As shown in Figure 7, all ten participants experienced a decrease in heart rate after engaging with the application using the CAVE2. While a similar trend can be observed for the desktop in Figure 8, the CAVE2 proved to be more effective in reducing the heart rate of the participants. 80% of the participants' heart rates decreased using the desktop, but Subject 4's heart rate remained the same while Subject 5's increased by one beat per minute.

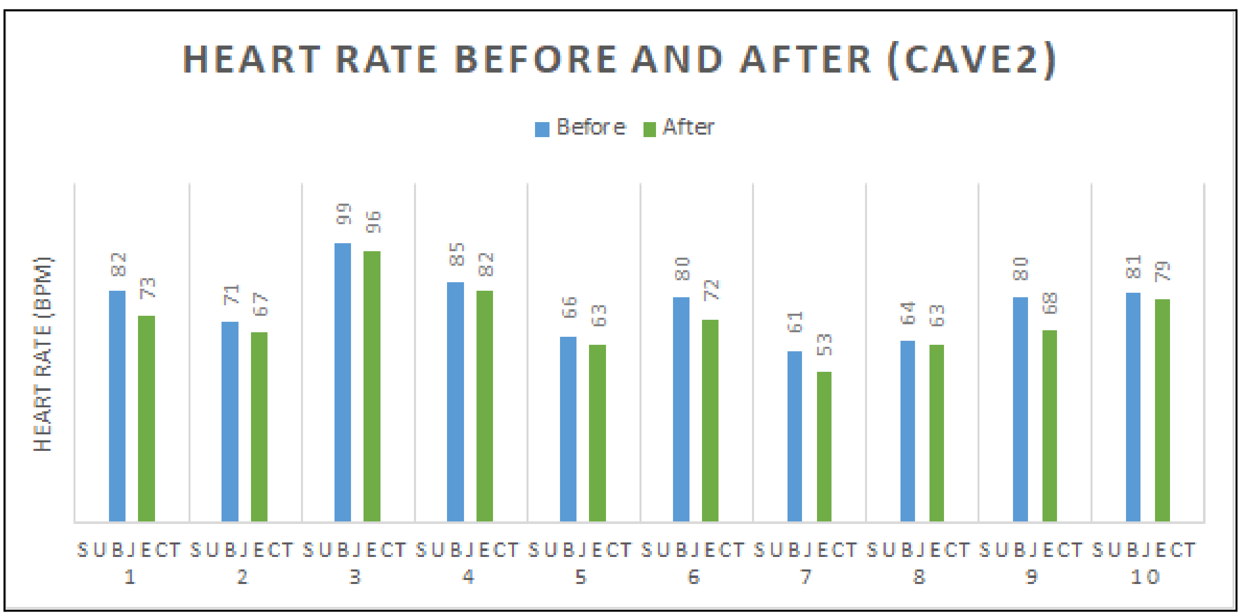


Fig. 7. The heart rates of participants before and after application engagement using the CAVE2.

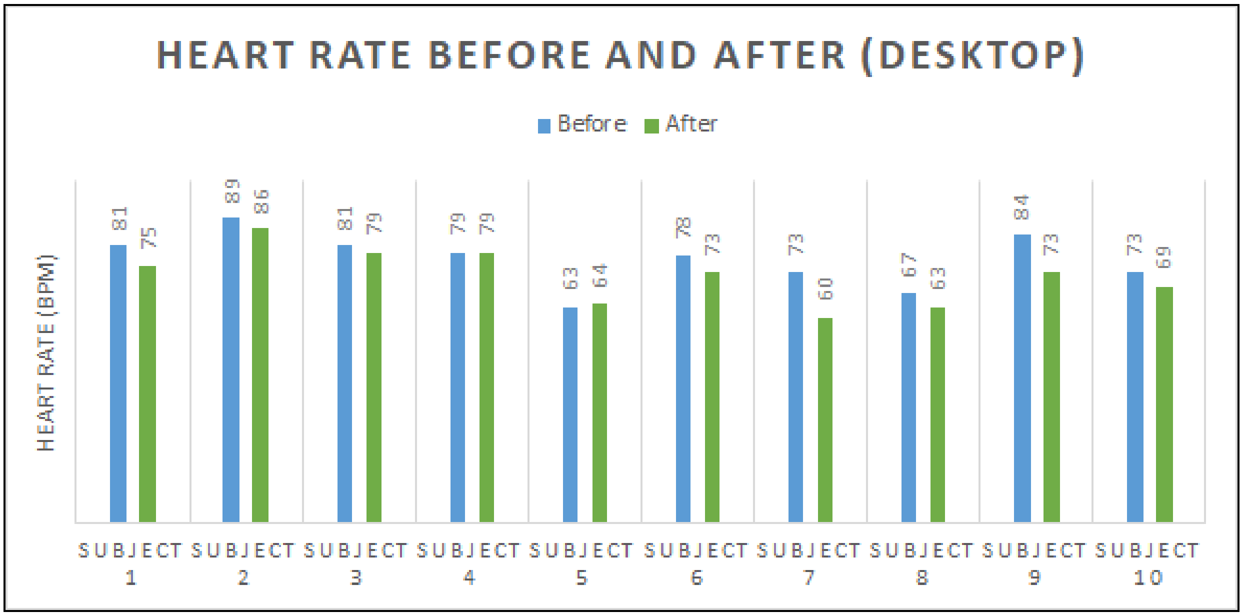


Fig. 8. The heart rates of participants before and after application engagement using the desktop.

Like the heart rate, the blood pressures of the participants were collected and recorded before and after their engagement with the guided scenic meditation application using both platforms. 70% of the participants experienced a decrease in their systolic blood pressure when using the CAVE2 while 60% experienced a decrease using the desktop.

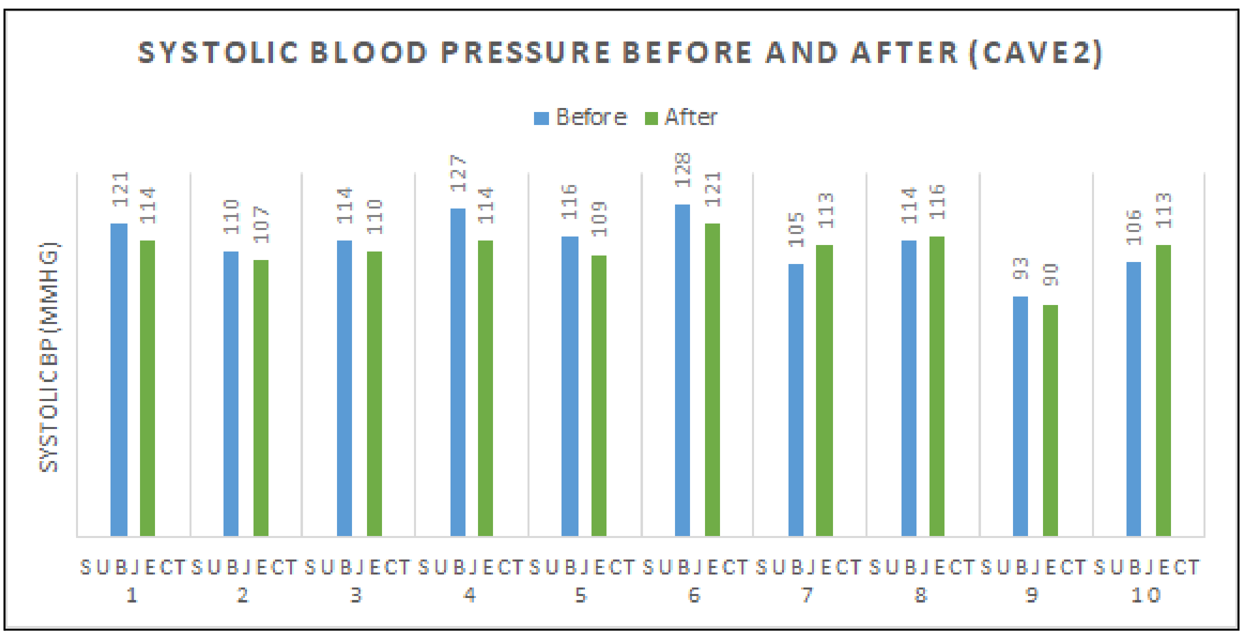


Fig. 9. The systolic blood pressures of the participants before and after application engagement using the CAVE2.

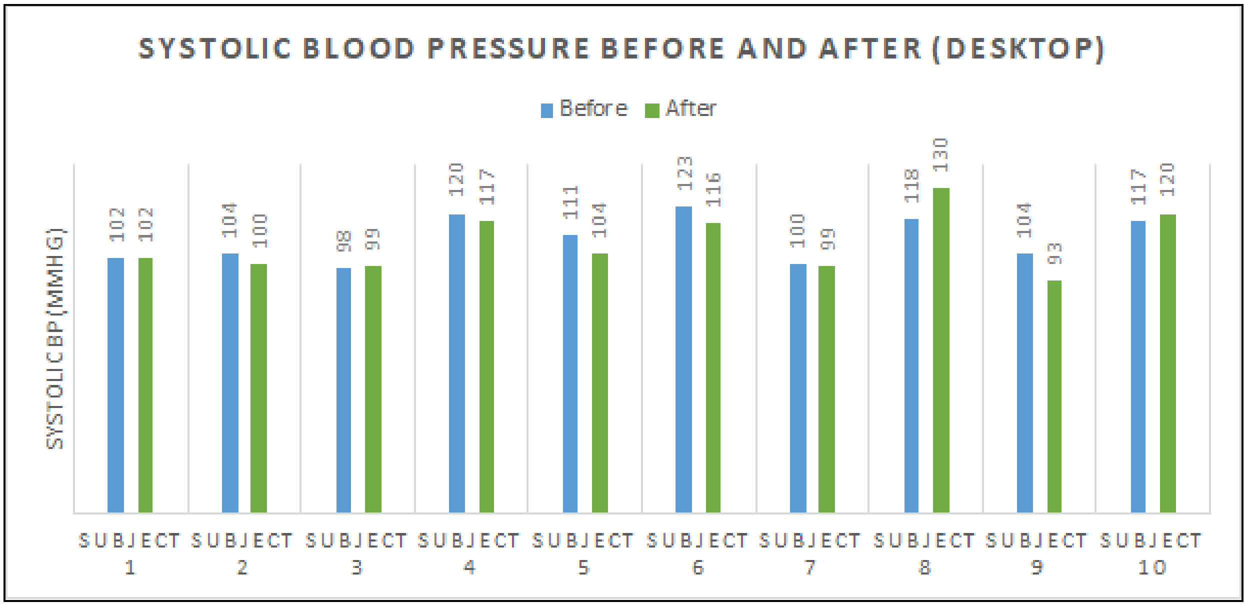


Fig. 10. The systolic blood pressures of the participants before and after application engagement using the desktop.

For diastolic blood pressure, 60% of the participants experienced a decrease after engaging with the application for the CAVE2 while 80% experienced a decrease for the desktop. Unlike heart rate and systolic blood pressure, in the case of diastolic blood pressure, the desktop outperformed the CAVE2.

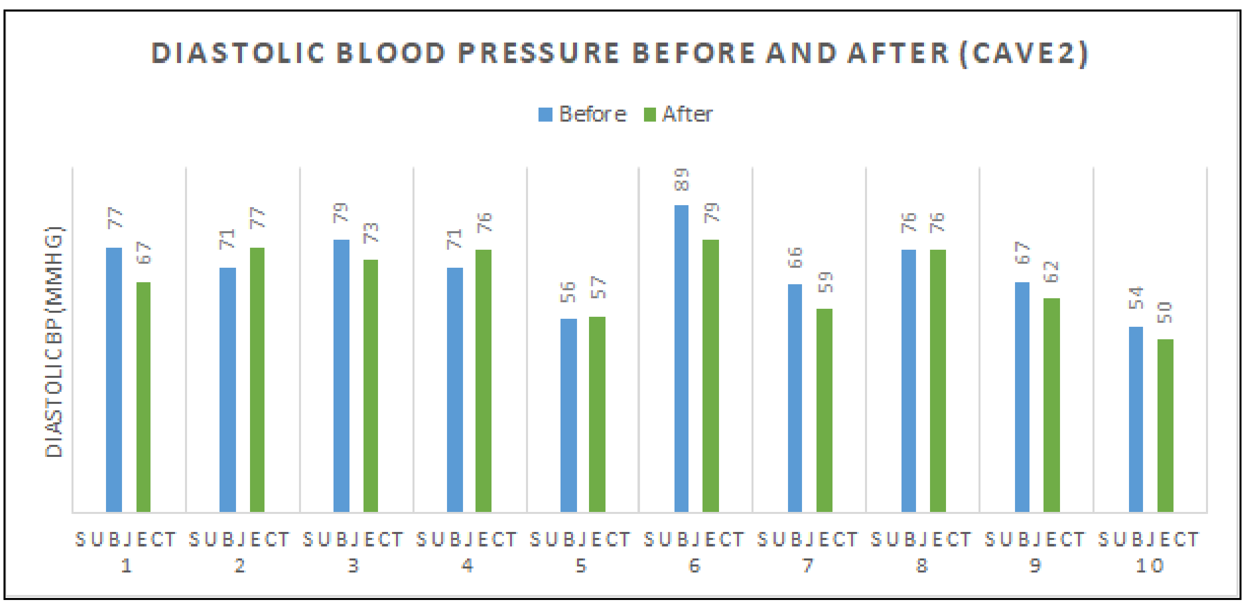


Fig. 11. The diastolic blood pressures of the participants before and after application engagement using the CAVE2.

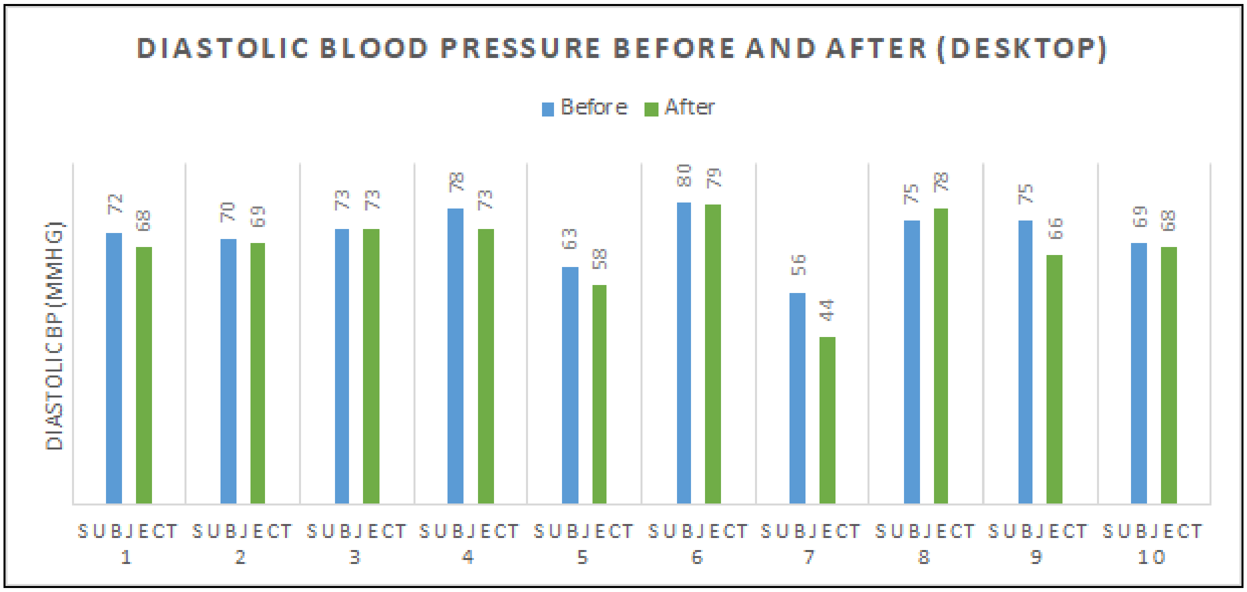


Fig. 12. The diastolic blood pressures of the participants before and after application engagement using the desktop.

Subjective Data

Before and after engaging with the guided scenic meditation application, the participants were asked to fill out a survey about their subjectively perceived moods and stress levels. Using Likert scales, they were made to select their levels of agreement or disagreement with statements such as “I feel relaxed and calm” and “I feel blue and hopeless”. According to the box and whisker plots of Figures 13 and 14, all participants experienced an improvement in their mood and stress levels after engagement regardless of platform. A similar trend is observed with the CAVE2 and the desktop.

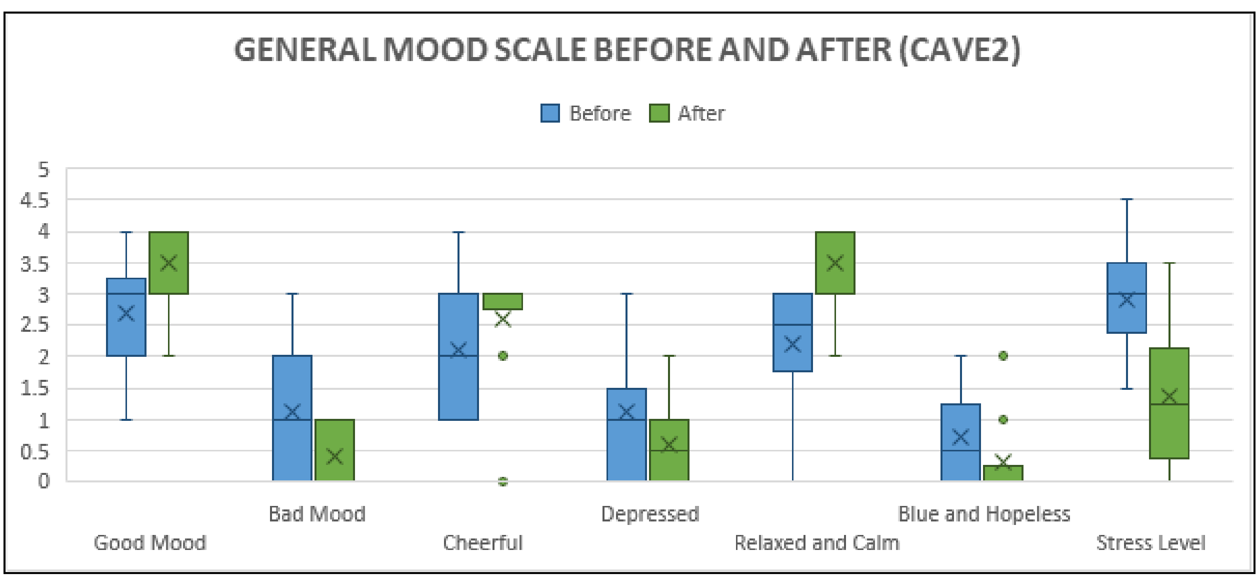


Fig. 13. A box and whisker plot showcasing the subjectively perceived moods and stress levels of the participants before and after application engagement using the CAVE2.

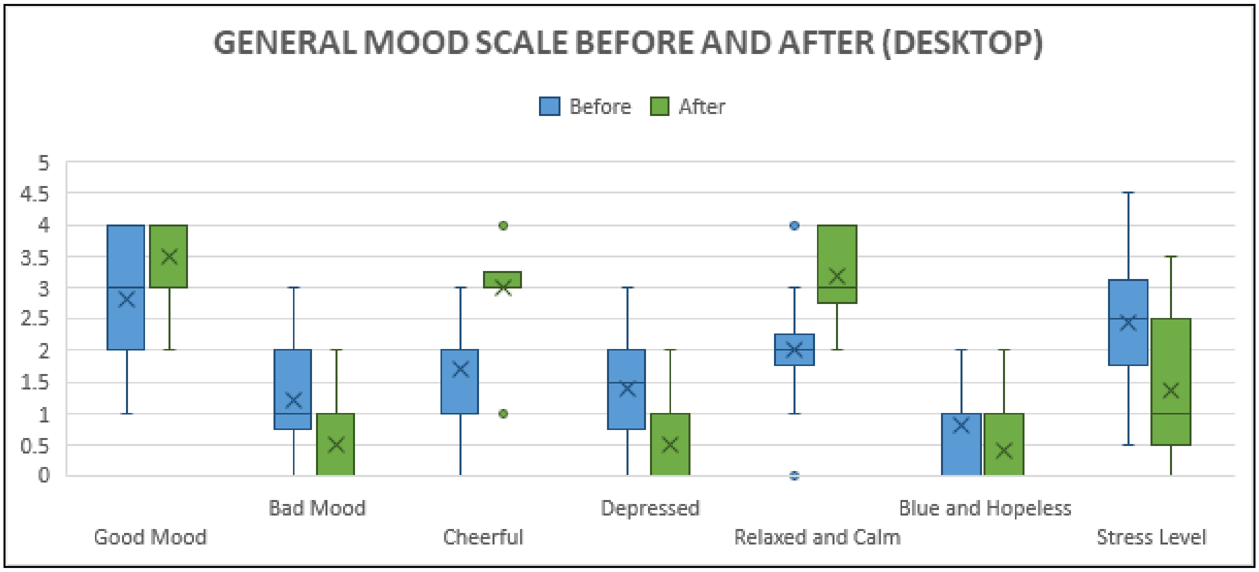
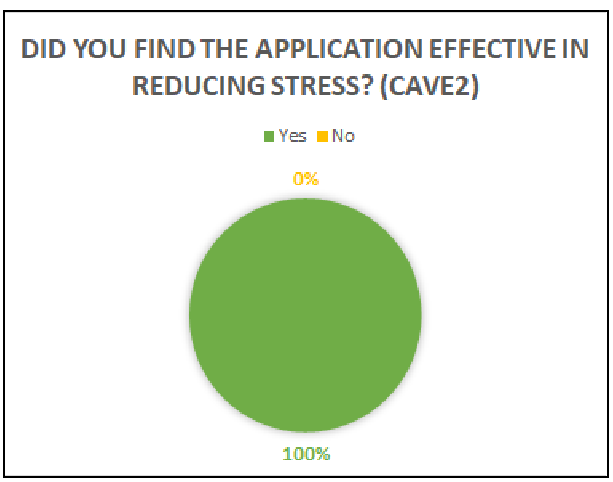


Fig. 14. A box and whisker plot showcasing the subjectively perceived moods and stress levels of the participants before and after application engagement using the desktop.

At the end of each session, the participants were given the opportunity to fill out an evaluation of the application and provide suggestions for improvement for each platform. One of the questions asked, “Did you find the application effective in reducing stress?”. As shown in Figure 15, for both the CAVE2 and the desktop, 100% of participants voted yes, confirming that, subjectively, the guided scenic meditation and forest simulation successfully reduced their stress as intended.



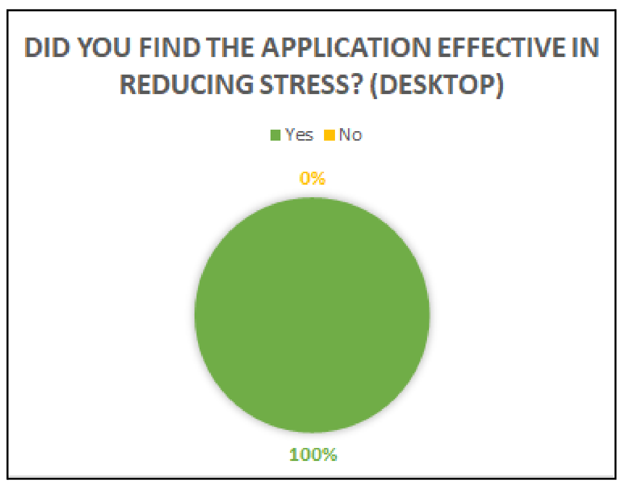


Fig. 15. A subjective evaluation of the application’s effectiveness in reducing stress for the CAVE2 and the desktop on the left and right respectively.

With the intention of assessing whether the product of the research would be used by people, another question asked, “Would you be interested in using the application in everyday life?”. For the CAVE2 version, 80% of the participants confirmed that they would. For the desktop version, on the other hand, 90% of the participants confirmed that they would, showcasing a slight preference for the latter. However, according to participant feedback, the CAVE2’s seventy-two surrounding displays created a better visual experience than the single screen of the desktop, providing greater immersion. Similarly, the desktop version was described as being distracting due to external visuals and sounds.

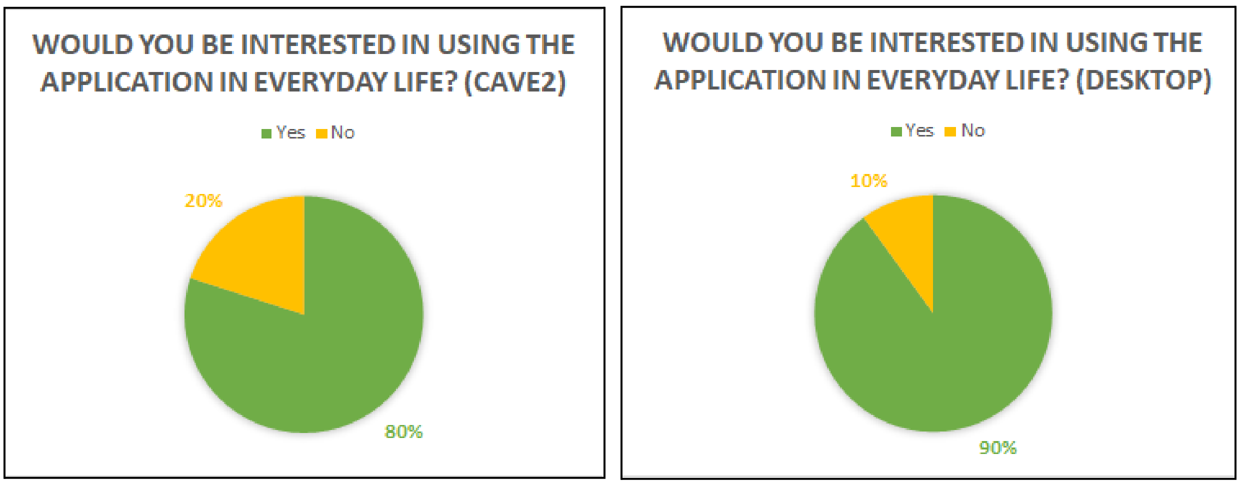


Fig. 16. Pie charts showcasing whether participants would be interested in using the application in everyday life for the CAVE2 and the desktop on the left and right respectively.

Conclusion

Based on the results, it can be concluded that the guided scenic meditation application simulating a forest environment is effective in reducing stress, especially subjectively. It is capable of reducing the heart rates and blood pressures of its users regardless of platform, as the CAVE2 and desktop exhibited similar trends. However, it should be noted that a reduction in heart rate was far more successful than a reduction in blood pressure. In addition, the application is capable of improving moods and stress levels according to the subjective data collected from the participants. Because the desktop can also reduce stress, it can be concluded that the product of the research is accessible and affordable. This also showcases that, while effective in virtual reality, it is not a requirement to achieve the aforementioned results. However, based on participant feedback, the desktop is less immersive due to potential external distractions. If more subjects were included in the research study, the results would be far more conclusive. Therefore, a future endeavor would be to perform additional user studies with more participants in order to confidently report results and make conclusions.

Fig. 17. The guided scenic meditation application running in the CAVE2 with its accompanying user study set-up.

Fig. 18. The guided scenic meditation application running on a desktop computer with its accompanying user study set-up.

Future Work

Participant Suggestions

According to the participants in the evaluation section of the survey, the application's use of visual, auditory, and olfactory stimuli successfully simulated a forest environment. However, there is more that can be done to increase immersion and create the illusion of a real forest for relaxation. The following are the observations and suggestions of the participants in regards to the use of sensory stimuli and the future of the application.

A common request among the participants was the addition of touch to the sensory stimuli being used. While engaging with the application, the user can interact with physical objects that simulate textures found in forests such as tree bark and pine cones. Some participants even suggested the placement of fake grass underneath the user's feet and a glass of water to dip their hands in. On a similar note, it was suggested that a different chair be used rather than the one present in Figures 17 and 18, as it was often described as uncomfortable.

Among the sensory stimuli being used, expansions were especially suggested for the application's use of sounds and smells. Additional sound effects that the participants believed would strengthen the simulation are rustling leaves, crunching footsteps, and blowing wind. It was also requested that the visuals match the voice-over more closely. When it comes to smells, only a single scent, that of conifer trees, is present. One participant suggested the use of flowers.

In order to increase immersion and engagement, user interaction with the application was heavily requested. Other than being able to freely move throughout the environment, the participants encouraged the inclusion of engaging activities such as locating objects and building their surroundings. Some even encouraged activities to be performed outside of the application with the voice-over serving as a guide or instructor. Such activities include stacking rocks, separating grass blades, and pushing away branches.

Finally, in order to expand the application, participants suggested the inclusion of additional environments. Rather than only being able to engage with a forest, the user would be able to choose which environmental simulation to be immersed in. Such environments include beaches, deserts, and jungles. Lastly, it was requested that the application be available on more platforms than a room-scale display and desktop computer. It is predicted by the participants that a head-mounted display would be best for immersion, as it would dispel all external distractions. Additional platforms suggested include televisions, mobile phones, and tablets, all of which are more widely available and affordable than a room-scale display.

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I would also like to thank Dr. Arthur Nishimoto who gladly assisted me in increasing my knowledge and skills when it comes to developing projects in Unity and working with the CAVE2. When I first began learning how to use Unity and the simulator he created, Dr. Nishimoto patiently demonstrated, step-by-step, how to configure and build projects for the room-scale display. Because of his contagious enthusiasm for both learning and teaching, I am now able to assist others when it comes to developing and deploying projects for the CAVE2.

I am indebted to the Electronic Visualization Laboratory, the National Science Foundation, and the Honors College for their funding and support. This research project could not have been conducted nor completed without their assistance. In addition, I am thankful to the ten students at the University of Illinois Chicago who willingly served as participants in my user studies and made the data-collection portion of the project possible.

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