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MuseVR: EEG and Virtual Reality for Self-Therapy

Abstract

We designed an interactive virtual reality (VR) experience aimed at improving user mental state. This project, museVR, could potentially be a viable and accessible method of self-therapy. We incorporate electroencephalogram (EEG) technology with VR to create museVR. Users are placed into a virtual nature environment, and interact within it by performing a concentration task. To evaluate the effectiveness of museVR, we performed a pilot study involving 7 participants and compared museVR with a proven therapy exercise. Our pilot study indicates there is potential with museVR for individuals seeking a self-therapy tool. The results of museVR were very similar to our control exercise, diaphragmatic breathing. The pilot study consisted of a pre-survey and post-survey both incorporating the PANAS scale

Introduction

We designed our application, museVR, as an accessible self-therapy tool. MuseVR takes advantage of EEG and VR technology to create an immersive and interactive experience. In museVR, users will perform mind-training exercises. Our hope is that users will experience a positive effect on their mental state after using museVR.

As of now, there are few applications or projects that make use of both EEG and VR technology with the sole purpose of positive mental effect. There is a lack of research on incorporating these two technologies for self-therapy. With museVR, we hope to show the viability of an approach to self-therapy with EEG and VR technology.

Electroencephalogram (EEG)

EEG is a noninvasive method of monitoring or recording brain electrical activity. Electrodes are placed around a participant's scalp. Voltage fluctuations can be recorded and analyzed. A modern EEG device can measure voltages at a very high sampling rate.

The frequency ranges are typically divided into several ranges for further interpretation. We will be using the Muse 2 headset as our EEG device. Various brainwave frequency ranges can be associated with certain brain activities [5].

TABLE I
BRAINWAVE FREQUENCY BANDS VERSUS BRAIN ACTIVITIES

Band	Frequency [Hz]	Activities
Delta, δ	0.1 ~ 3	Deep sleep, awaken, attention
Theta, θ	4 ~ 7	Drowsiness, idling
Alpha, α	8 ~ 12	Relaxed
SMR	12 ~ 15	Concentration without movement
Beta, β	15 ~ 20	Active thinking, focus
High beta	20 ~ 35	Stiff, anxious, stress

SMR denotes sensory motor rhythm

Brainwave frequencies and their associations [5].

Related Work

The use of EEG in interactive experiences is not mainstream, but it has been utilized before in various ways. In designing museVR, we analyzed several projects that have been created by others.

RelaWorld

RelaWorld is a "neuroadaptive virtual reality meditation system that combines virtual reality with neurofeedback to provide a tool that is easy for novices to use yet provides added value even for experienced meditators [3]." RelaWorld features both focusing and relaxation (meditation) exercises. One example of an exercise involved the participant meditating in order to raise themselves in the air within the VR environment. The study performed on RelaWorld showed how users felt an improved sense of mindfulness and wellbeing after using the application. Users had reported deeper relaxation, feeling of presence, and a deeper level of meditation compared to traditional forms of meditation. RelaWorld shows great potential in this space within self-therapy. We found certain drawbacks within the implementation of RelaWorld. RelaWorld is very inaccessible to most individuals as there is little real-world possibility of using it within a home setting. The EEG headset that participants used allowed them to capture higher resolution and more accurate data, but it is difficult for a user to equip on their own. Their EEG headset is also difficult to obtain, and the cost of the professional device may be out of reach for a mainstream audience.

PsychicVR

PsychicVR [2] is the closest project to what our project, museVR, was designed to be. The team behind PsychicVR also chose to use the Muse headset with a VR headset. Players in their application performed 'magic' by concentrating or relaxing. Players essentially perform mind exercises to interact with their virtual environment. It's creators claim that their system ‘increases mindfulness and helps achieve higher levels of concentration,’ which is similar to the results from RelaWorld. However, we want to measure overall positive and negative effect on the user's mental state.

My Virtual Dream

My Virtual Dream is another interactive project that uses EEG technology [4]. However, this project is not specifically focused on mindfulness. My Virtual Dream is an immersive collaborative art installation where participants wear Muse headsets. All of their data is used to generate art. We were interested in this project because they also used the Muse headset. To determine a participant’s mental state, they had incorporated a one minute ‘training’ phase. For museVR, we were inspired to also incorporate this idea of a training phase to ensure improved accuracy.

Meditation Chamber

An example of a successful therapy tool making use of VR would be the Meditation Chamber [9]. This tool uses other biofeedback technology to relay information to the user in real-time. They use biofeedback to sense the lowering of stress levels and then inform the user of it. Meditation Chamber is interesting to study because it was targeted at users who had no experience with meditation. We want museVR to also be approachable and usable for users who have no experience with forms of self-therapy. The Meditation Chamber succeeded in also proving that mainstream success could be possible for such technology. Though it is still only used in clinics, we believe museVR has the potential to be used in a larger capacity.

MuseVR

User Experience

The user experience we designed was heavily influenced by PsychicVR and RelaWorld, as they both reported positive results from their participants. When starting museVR, users are placed into a forest where they are surrounded by dense fog. Their only method of interaction is with their mind. They are also able to turn their head and observe their surroundings. Before beginning the exercise, the user goes through a ‘training’ phase where they try to clear their mind. The training phase is in progress when the soft piano music can be heard.

Once the piano music is over, the training phase is completed. The user will immediately begin their concentration exercise. In this exercise, the user is asked to go into a concentrated state. While the user is in this state, the fog will begin to retreat. The forest environment including the streams and distant trees will begin to become more visible to the user. By the end of the exercise, the fog should be cleared.

Design Considerations

Our design for museVR was based around accessibility and the promotion of a better mental state. This influenced the design of the user experience, virtual environment, and system hardware. We wanted to show this type of self-therapy tool can be created for a more mainstream use. Our design would also be influenced by past research in improving well-being.

For our virtual environment, we decided to use a forest setting. Nature environments may promote positive well-being [1] in the people who experience them. For this, we used a pre-built environment available on Unity. This virtual world features dense trees and vegetation. A stream runs through the forest. The user is situated by the stream.

We hope this forest environment can help users in improving their mental state and concentrate within their mental exercise. This nature scene should help users reach a more relaxed mental state.

The hardware we chose to implement this project is obtainable and relatively low-cost. We decided to use the Muse 2 headset for several reasons. Compared to other research-grade EEG technology, the Muse headset is very affordable. It is also very easy to purchase online. However, obtainability was not the only factor in accessibility. The Muse headset is approachable by a wide range of users. There is a minimal learning curve. This headset is essentially a ‘plug-and-play’ device that requires no setup. Many research-grade EEG headsets are complex to wear due to being tailored towards professional clinicians. The Muse headset can be equipped by the users themselves, who can easily slip it around their forehead and behind their ears. There are no adhesive gels or complications when applying the headset’s electrodes like on some other EEG devices.

The Muse headset’s physical design is also very important to our application. Due to its compact form, it can be worn with many virtual reality headsets. The Muse is compatible with a wide range of headsets, and this helps with the wide accessibility of museVR.

The VR headset we used for our testing was an older entry level unit. We assumed this would be more obtainable for most potential users, so we decided to evaluate museVR with this low-end unit.

Original Goals and Final Result

Our original goal was to create an application with several different mind-training exercises available. The initial exercise would be for users to clear the fog through a concentration exercise. After completing this first exercise, there could be more exercises following it. We wanted to use realistic nature sounds such as bird chirps to enhance the interactive game experience.

One idea we would have liked to implement would have been adding a relaxation exercise after the users clears the fog. This further relaxation would silence the bird chirping. Other implementation options for concentration or relaxation exercises could include control over rainfall or other environmental stimuli.

In the end, we only implemented the fog effect concentration exercise. There were many obstacles that hindered our ability to implement more exercises. Currently the user clears the fog by going into a concentrated or focused state of mind.

We were able to perform the pilot testing that we had wanted, however we were unable to recruit as many participants as we initially expected. Instead of having 10 participants for our study, we were only able to recruit 7. As a result, our study group was not very diverse.

Current Issues

There are several issues that are worth noting with the current state of the application and also our pilot study. The comfort of using our system is an issue that must be improved. While the Muse headset and VR headset can both be worn together, the combination is not very comfortable. The Muse also tends to make poor contact without a headband holding it securely in place. One solution for this would be to find a more suitable VR headset that can better accommodate the Muse. The accuracy of our concentration algorithm was also an issue at times. Thus, the application may have shortcomings in its detection of users concentrating.

Our pilot study shows good results, but the small size resulted in a narrow demographic. In the future, We would like to include a wider range of participants. It may also be interesting to involve participants who are not neurotypical, as we do not know the potential issues that may arise.

Challenges

While developing museVR, we ran into several major challenges. Our EEG device, the Muse 2, was no longer supported by InteraXon. The developer and producer of the device stopped providing manufacturer support. All the software that had previously existed was removed from the developer site. Because of this, we no longer had a reliable program to pair the Muse 2 headset to a computer and receive the OSC data from the device. In the previous developer programs, there was data processing provided to make analyzing the data much easier. To work around this, we manually parsed the OSC stream containing all the signals from each sensor on the Muse.

There was also no clear solution to determine a user’s mental state. We could not implement a method to identify a state of relaxation. Past research showed there were several methods of classifying mental states, but they were only ideas, and not concrete formulas. For our use case, we required a method of determining mental state in real-time. One potential approach was using a machine learning classifier. Unfortunately, we lacked the data to create such a classifier. As a result, we settled on creating a formula based on research that suggested the use of beta and theta waves to determine state of concentration [6][7].

nature environment with no fog

Implementation

Tools

MuseVR is implemented with the Muse 2 headset by InteraXon, an entry-level Acer VR headset, and Unity. It currently only runs on a Windows PC. The Muse headset is shown to have potential for some research uses [10]. Unlike other EEG headsets used for research, it is considerably cheaper than others. Data from the Muse can be retrieved over Bluetooth using the OSC streaming protocol. This was how we retrieved the data stream through Unity.

The VR headset is an entry-level device. Still, the headset features standard features such as head movement. It also works comfortably with the Muse headset.

Unity was used to both retrieve Muse data and create our virtual environment. We used a premium Unity pre-built forest environment. Using Unity allowed us to create an interactive world for users that works well with VR.

Execution

To create our application, we worked with our pre-made forest virtual world. We used the fog effect, as it was straightforward to adjust. Our fog illusion was created by simply placing fog directly on the user. We wrote scripts that would handle the real-time data stream from the Muse headset.

Determining the user state of mind was the most challenging part of this project. Following the suggestion of previous work, we decided to use only the front Muse sensors: AF7 and AF8. These sensors would provide better data for determining user concentration [7]. Our concentration function was a function of beta / theta [7]. We used this function to determine an average index value during the training phase. After training, we classified concentration as the current index value being 130 percent greater than the average during training.

Evaluation

Methodology

Our pilot study involved 7 participants. They were all college students ranging from 19 - 24 years old. We separated them into two groups: one using museVR, and a control group that performed breathing exercises. The breathing group had 3 participants while the museVR group had 4. We wanted to compare our application with an existing form of self-therapy. We decided on having one group perform diaphragmatic breathing exercises because it has been shown to relieve stress and promote well-being [11] [12].

Certain variables were kept consistent across both groups. Our study was only performed during the daytime, and both were performed within a private space. Participants were given a pre-survey and a post-survey to measure a change in mental state. MuseVR users were also given a short informal interview after using the application.

Our pre-survey and post-survey both included a PANAS scale. PANAS was chosen because it is a proven, reliable, and consistent tool for measuring positive and negative effect in a given moment [8]. In the post-survey, we also asked users for feedback and included a scale to rate their experience. Participants for the deep-breathing diaphragmatic exercise were given 5 minutes to perform the exercise. Participants for museVR performed their exercise until the task was completed.

Results

The results from our pilot study were positive for museVR. Our application performed similarly to the diaphragmatic breathing exercise. For both groups, participants' moods generally improved immediately after their tasks. Generally, they all seemed to enjoy their tasks.

Positive affect was generally increased in the post-survey for both exercises. In all participants, negative mood remained about the same. No participants reported an increase in negative affect. For museVR, 3 out of 4 participants reported higher positive affect after use. Half of our museVR participants also have never used any form of virtual reality device before.

Feedback for museVR

The feedback obtained from our short interview was largely positive. Most users noted that our concentration algorithm worked well. During their exercise, the users liked concentrating on their environment. One user noted that they were confused about their surroundings initially due to the amount of fog.

Future Improvements

There are many ways museVR can be improved from its current state. We would like to improve on the immersive nature of the experience. The training phase could be modified to enhance the overall experience of the user. Similar to the related work mentioned earlier, we could have incorporated more mind exercises as well.

To improve the immersive nature of the experience, we could choose to include more methods of interaction. Currently, a user can only interact by moving their head around or using their mind. Potentially, we could add additional controls for players which would allow increased navigation and exploration of their forest environment. This could greatly enhance the immersiveness and interactivity of our application.

An issue we noted with the training phase was users,at times, did not realize when it ended. Users may not notice the piano music indicating the training phase has ended. Perhaps we could place players in a separate virtual space during the training phase. We could also use other clear indicators such as louder music.

We want to add an exercise for relaxation. The exercise can be similar to the concentration exercise in that the user changes the environment through the exercise. We would like to incorporate nature sounds such as bird chirps or rainfall as potential variables that can be altered with relaxation.

Conclusion

The results from our pilot study show promise for the mainstream application of technology like our project, museVR. We have created an accessible form of self-therapy incorporating EEG and VR technology. The hardware used in our application is obtainable for most people. Our study shows similar mental effects compared to a current self-therapy exercise in use today. As EEG and VR devices continue to improve and become more accessible, this form of self-therapy may become more appealing.

MuseVR provides a novel approach to self-therapy as even individuals who have never experienced VR technology can still have positive mental effects through use of our application.

Our next steps for museVR would be to implement a larger-scale study which would validate the results of our pilot study.

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