

DYNAMIC VIRTUAL ENVIRONMENTS FOR THERAPY

A Paper on the Potentials of BioVirtual Immersive Environments

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Abstract

This paper explores how it is possible to create a BioVirtual Immersive Environment¹(B-VIE,) for a multidisciplinary platform-tool focused on helping induce immersion in virtual reality(VR), while analyzing environmental and biometric data, aimed to be used in psychotherapy, meditation, research, and more. This B-VIE could be used for an in-development case study I am conducting, which measures immersion through guided audiovisual hypnosis and virtual reality experience to help with stress levels². Furthermore, this paper covers topics about the brain's physiological responses with and without VR, as well as the current sociology of mental health, and the technologies used to build the first B-VIE. The B-VIE is intended to showcase a dynamic virtual environment enabling its usage for the case-study, as well as creating a sandbox for more unique and interdisciplinary testing environments or experiences. These B-VIEs would then be based on the engine's ability to analyze and discretize the biometric data, while accurately simulating the sense of hearing and seeing, and the environment and its physics. This would enable the usage of the state, reward pairs for the data flow in machine learning algorithms, and a basic artificial intelligence interface, for a self-focused data-driven B-VIE experience.

Introduction

We often forget about how much our physical responses and autonomous system affect our mood. On one hand, shifts in mood can be caused by chemical imbalances, hormonal

¹ Referred to as VIEE for the rest of the paper

² *HVR: Immersive Odyssey* working title of case study

changes or other effects of the body. While on the other hand, as stated in a paper comparing negative mood and self-focus, "Accordingly, negative affect only promotes symptom experience when people simultaneously focus their attention on the self. One correlational study and 4 experiments supported this prediction: Only negative mood combined with self-focus facilitated the experience..."(Gendolla, Abele, Andrei, Spurk, Richter, 2005). Needless to say, not all who suffer anxiety or depression associate a negative physical symptom as a trigger to their mental illness. Yet it's important to note that perhaps the other way around works as well. Guiding a user through a practice of self-focus, tranquility, and peace of mind, furthermore creating a long-term interactive technology for patients, players, researchers, and enthusiasts alike, and as such the paper is divided into three subsections and a conclusion:

1. The "Sociology" section, which analyzes the mental health today, and the significance of B-VIE.
2. The "Body and Mind" covering findings of interactions between what we consciously perceive (usually by sight or sound), and what our body actually perceives. An example of such interaction can be felt when you feel vertigo when crossing a high altitude cross-bridge in VR. Despite us consciously knowing we are not there physically, our sight plays a heavy role in communicating the response of fear in our bodies.
3. The "Technology" section goes over the technologies used, and the overall future direction of the research.

Sociology

This year, 2019, the WHO (World Health Organization) officially declared burn-out as a true recognizable medical condition. They state that the three identifying characteristics were: feelings of energy depletion or exhaustion, increased mental distance from one's job, or feeling of negativism or cynicism related to one's job, and reduced professional efficacy (Werber 2019.) Although described within the context of a work-place, these traits hold true with students, many of which have experienced these signs of anxiety, burn-out, and depression. Furthermore, it has also been stated that,

"Over the past half century or so, in the United States and in some other developed nations, opportunities for children to play, especially to play outdoors with other children, have continually declined. Over this same period, measures of psychopathology in children and adolescents—including indices of anxiety, depression, feelings of helplessness, and narcissism—have continually increased." (Gray, p. 443, 2011.)

What is key to note about these comparisons is that such afflictions of burn-out, depression, and anxiety are problems mostly faced during environments of high stress. Such as with students, who have to perform against their peers. Or beyond an academic environment where these mental illnesses can be symptomatic of underlying abuse and could result in someone's broken defense mechanism³. In such situations, the B-VIEs would ideally be allowed for such patients to feel comfortable regaining their composure via audiovisual stimuli in a familiar and adapting environment. This B-VIE would have the ability to be accessed by the therapist, allowing for the

³ Our brain's way of dealing with trauma, such as distracting yourself, picking up a new hobby, etc.

manipulation of the environment or to speak to the patient through a microphone (taking advantage of the spatialized sound in VR.) I believe this adds a new dimension to therapy where patients would be guided through self-focus exercises to desensitize fears and build confidence in dealing with their mental illness and their root symptoms.

Yet many patients suffering from mental illness who do find professional help are required to build a relationship with their therapist in a set-limit of time, and often with long intervals of waiting in-between sessions. This often attributed to missed red flags by the therapist.

In these situations, a B-VIE could offer a way to allow patients to relax before and during their sessions, as a way to help lighten the burden of communicating. These B-VIEs would then be given to the user and be able to render it at home, as a form of relaxation when the therapist is not available.

These B-VIEs would be a way to help negative feelings of misunderstanding and ostracization that comes with mental illness, by using generated self-focus environments based on audio cues made or chosen by the user or therapist. When considering these feelings of isolation, it is important to note that they feed into extreme negative behaviors, and often exemplified with easy to spot red-flags,

"Case studies were conducted of 15 school shootings between 1995 and 2001 to examine the possible role of social rejection in school violence. Acute or chronic rejection—in the form of ostracism, bullying, and/or romantic rejection—was present in all but two of the incidents. In addition, the shooters tended to be characterized by one or more of three other risk factors—an interest in firearms or bombs, a fascination with death or Satanism,

or psychological problems involving depression, impulse control, or sadistic tendencies."

(Leary, Kowalski, Smith, and Phillips, 2003.)

How can we avoid someone from reaching this point? How can we ensure that adequate help is being given, to those suffering depression, panic attacks, psychotic break?

The point of the B-VIEs is to enable the creation of environments that will allow the patient to calm down, and once the system perceives the user has reached a state of immersion and tranquility, they are seamlessly placed in a self-guided mindful experience on self-focus. Therefore by introducing these experiences, the B-VIE presents itself as a possible alternative and outlet for those suffering mental illness, and a subtle way to learn techniques that will help with dealing with mental illness symptoms. As well as being a platform of self-expression for those suffering a mental illness, as a way to demonstrate to loved ones, what sort of scenario, sound cues, or situations give the user peace-of-mind.

Brain and Body

Based on the assumption that humans are mostly visual creatures, and although I assume that although we get a barrage of sensory input from our other senses, our vision is what we primordially consciously react to. It is what we use to scan our surroundings to enable us to make appropriate decisions. Yet with our vision also comes then unconscious learned anticipation for an incoming stimulus. This anticipation is what I believe plays a role in heightening or lowering the response, or reaction to said stimulus.

An example of this can be seen in the levels of pain reported by burn victims in treatment. Those patients who were under the VR simulation while being treated reported average lower levels of pain (Hoffman et.al, 2011). In this case we see a heightening of pain when we think something is going to be more painful. Another similar experience is with needles, such as when people get their blood drawn, these patients sometimes report feeling faint after watching the whole process. It's also been shown in a scenario where patients were put in a VR headset pre and post needle insertion for blood donations, and reported, "Specifically, Calmness and Happy increased from prepost while Tension and Fatigue decreased significantly from prepost." (Tarrant, Abrams, and Jackson 2019.) These findings further the possibility of using VR as a form of pain therapy for post surgery patients, as well as a distraction from anxiety attacks, and psychotic breaks. We find that both of these examples get rid of that heightening of response, specifically pain stimulus. This doesn't mean that patient won't feel any pain if they go into VR, but instead it could be offered as a way to make a patient less aware and more comfortable during an intrusive medical procedure.

Furthermore, another form of using VR and dealing with anticipation, is by lowering that anticipation for certain events, in other words desensitizing. A form of exposure-therapy in which a patient is slowly accommodated to the stimulus or environment that induces anxiety. These environments are created as a way to constantly expose a patient to the stimulus or environment, until the negative response is inhibited. This particular philosophy, bodes well with VR and with the design of B-VIE, because the point is to create a virtual environment that is meant to induce a sense of safety for the user. Many times environments may represent places or scenarios that are not easily replicable in real life. Such example of this is during the treatment of

Vietnam veterans suffering PTSD, "The patient was exposed to two virtual environments, a virtual Huey helicopter flying over a virtual Vietnam and a clearing surrounded by jungle. The patient experienced a 34% decrease on clinician-rated PTSD and a 45% decrease on self-rated PTSD. Treatment gains were maintained at 6-month follow-up."(Rothbaum et.al, 2005.)

These examples demonstrates the brain's ability to analyze incoming stimulus differently based on what senses are being affected. Although we don't consciously realize it, the brains intricacies handles these senses through an array of neural pathways which then influences our reactions and behaviors. Yet, we are able to see hiccups in the brains analysis of behaviors when looking deeper into different physiological phenomena such as split brain patients, who undergo a procedure that surgically cuts the corpus callosum, which serves as a highway between the two hemispheres of the brain⁴,

"For example, it could be seen that in moving about and responding to sensory stimuli the patients favored the right side of the body, which is controlled by the dominant left half of the brain. For a considerable period after the operation the left side of the body rarely showed spontaneous activity, and the patient generally did not respond to stimulation of that side: when he brushed against something with his left side he did not notice that he had done so, and when an object was placed in his left hand he generally denied its presence." (Gazzaniga, 1967.)

Or also amputees who experience phantom limb, which is when they still feel pain or sensory input from a nonexistent part of the body. Although it can't be ignored that phantom limbs also occur to those who were born without it, which as noted by Melzack, "suggesting that the neural

⁴ This is to treat very severe cases of epilepsy and seizures

network, or 'neuromatrix', that subserves body sensation has a genetically determined substrate that is modified by sensory experience" (1990.)

Although limited to certain bodily amputations, treatment for arm and lower body amputations have been treated with moderate success using mirror therapy. The mirrors are set up in such a way that they create the illusion of the other limb being there in order to reduce phantom limb pain (referred to as PLP in the citation),

"When persons with PLP are asked to place their healthy limb in front of a mirror such that its reflection visually replaces the missing limb, this can result in pain alleviation in some patients. " (Bekrater-Bodmann, Diers & Flor, 2013)

The paper attributed its success in improving the phantom limb pain based on reduced activity in the inferior parietal cortex, and concluded that "Experienced body appearance seems to be an important predictor of mirror treatment effectiveness" (Bekrater-Bodmann et.al, 2013.)

This complex interplay between our physical state, and our mood is a current topic of research that still needs to be explored further. Yet, based on the previous examples, the B-VIEs would have to focus on these perceptual nichese of our brains.

By developing more unique B-VIEs would allow for a wider range of research test spaces ranging from psychoacoustics to visual illusions as a way to influence B-VIEs for therapy or for unique user experiences.

Furthermore, I explore the realistic possibilities to create an engine that is able to create these dynamic B-VIE with a priority in audiovisual design, while creating the dataflow for analyzing environmental and biometric data which can be used to train a machine learning model. By using these generated B-VIEs in future cases studies, to demonstrate the need to focus

on an audiovisual-design-first model to make better usage of our brains inherent perceptual illusions.

Technology

Current

The base technology for VR, exists at a consumer level allowing for a valid platform for B-VIEs to render on. Such technologies can vary with the HTC Vive, Oculus, and other uprising VR competition. The B-VIE currently renders on the Oculus, while using the *Unreal Engine 4*(UE4,) which has been chosen for developing the first version of the B-VIE.

UE4 was chosen because of the ease in which I was able to render realistic looking grass swaying, with full control of the wind and lighting strength and placement. Furthermore UE4 offers an in-house ambien audio system, with many features that can be used to build the B-VIE's sound system. The integration of sounds in the environment will rely on the psychoacoustics of low and high frequency based on Rayleigh Duplex Theory , which takes into consideration how each ear perceives sound differently based on intensity or time difference, and location in space(1907). This would form part of the cluster of data a machine learning algorithm can use to personalize the B-VIE for a user, discussed further in the Future section.

The B-VIE would also allow for a second user to be able to communicate with the user in VR with an out-of-game microphone connected to the VR headset's headphones. The microphone setup would require to have a dummy head recording device (setting two microphones about the same distance between both ears), or alternatively use a simulated

dummy head recording algorithm (Liitola, 2006) which we would allow for a physical simulation of how we perceive sound.

Furthermore, the B-VIE's physical terrain is built using a 2D plane in a third-party software called *World-Machine*. This program contains handy ways of creating various different terrains that can be easily imported into a game engine. For now the 3D environment consists of a hilly plane populated with grass and flowers as seen in Figure 1. By doing so, it confirms the ability to be able to manipulate terrain within a B-VIE's engine. Furthermore, more research should be put into figuring out the methods of manipulating a plane in 3D-space. Such methods would allow an artificial intelligence agent the agency to change the terrain subtly as part of the changes induced by a users biometric response.

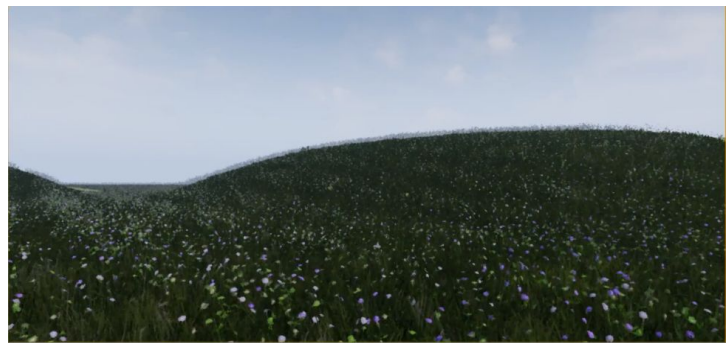


Figure 1: UE4 Grassland landscape

Future

To create a more robust B-VIE, biometric input is necessary, while obtaining physiological data without breaking a patients immersion. These B-VIEs would allow for integration of external tools that measure biometric data such as EEGs, heart rate sensors, sweat detection, and more. These physical responses would be discretized by the B-VIE, and allow for an ease of quantification of the physiological experience based on what we train the model to perceive as the users state of tranquility.

There also have been multiple studies that have measured the EEGs of users in virtual environments showing how,

"VR intervention uniquely resulted in shifting proportional power from higher Beta frequencies into lower Beta frequencies, and significantly reduced broadband Beta activity in the anterior cingulate cortex. These effects are consistent with a physiological reduction of anxiety." (Tarrant, Viczko, and Cope, 2018.)

and the exploration of a brain-computer interface with VR by measuring positive changes in a patient's mood, based on a consumer-grade neurofeedback system called Muse as stated by Tarrant & Cope, "Four firefighters served as subject and completed pre-post mood rating scales as well as 19-channel EEG recordings. An examination of sLORETA frontal lobe ROIs demonstrated a postintervention gamma asymmetry shift to the left in three of the four subjects. In addition, subjects generally reported changes in mood consistent with the frontal asymmetry changes. Overall, these results provide initial support for the idea that a consumer-grade brain-computer interface(BCI)/VR intervention can potentially have therapeutic utility and deserve further study." (2018.) These two cases worked under Jeff Tarrant, goes to show the growing interest in the effects of VR to our physiology, and consequently render positive results in mental illness treatment.

Furthermore the B-VIE would be used to train an artificial intelligence using a machine learning framework that uses these environments and biometric data to gauge rewards and actions meant to reduce symptoms of anxiety in patients. This would allow a B-VIE to be able to test the degree of interaction and helpfulness of an artificial intelligence agent, who's goal is to help guide patients through their negative experiences and symptoms.

Results

Currently, the UE4 environment is being built, and I remain optimistic about the prospects showed by scholar Jeff Tarrant with his three case studies on using biometrics and VR to demonstrate quantified reductions of anxiety and depression in patients, as well as promising surveys of users in the "Ice World" case studies from Hoffman 2011 studies, and the many other exposure therapies being tested with virtual reality.

By examining these results, it allows for the setup of a BioVirtual Immersive Environmental Engine (B-VIEE), that would be used as a tool to generate these data-drive B-VIEs with ease. The B-VIE would be made with a simplified flow of biometric, and environmental data between the user and VR, in order to create a robust and unique B-VIEs that combines the previous findings into a cohesive experience for usage and adoption by patients suffering mental illness, researches, and enthusiasts a-like.

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