SIMULATED STATES OF CONSCIOUSNESS: INDUCING PSYCHEDELIC EXPERIENCES IN VIRTUAL REALITY

by

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Abstract

Virtual reality has recently been utilized in a therapeutic tool within the area of psychotherapy. VR therapy has become a significant approach to a number of psychological disorders such as anxiety, PTSD, and depression through exposure therapy and simulated environments (Park et al., 2019). However, the potential to mimic psychedelic experiences through VR simulations as a therapeutic modality has yet to be examined. Current research suggests individuals in VR simulated psychedelic experiences undergo similar effects to those using psychedelic drugs (Suzuki et al., 2017). Yet the extent to which psychedelic VR simulations can physiologically impact the brain and mind is largely unexplored. To determine whether VR simulations can mimic psychedelic drugs, a targeting of 5-HT receptor activity, within the frontal lobe, is proposed in order to hypothesize an area of activation for psychedelic simulations (Lu and Liu, 2017). This paper will examine drug mechanisms of psychedelics, the theoretical application of VR-based psychedelic therapy, and postulate a method to measure the effectiveness of psychedelic simulations with respect to psychopathology.
Keywords: virtual reality, psychedelics, psychedelic therapy, simulation, psychotherapy, serotonin, consciousness, altered states, cognitive neuroscience, neuropsychopharmacology.

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For Timothy Leary

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Preface

Our perception of reality is often impacted by external and internal factors, however, this reality as processed by the mind is inherently malleable. The brain itself has plasticity, and our perceptions of reality can be shifted, resulting in altered states of consciousness. The ways in which we alter our conscious states are numerous; dreams, meditation, creative acts, or drugs. Virtual reality experiences also impact the brain, allowing us to believe we are experiencing something "real". Regardless of the method, our perception and experience of reality is subject to change.

This thesis began with the following questions: What does it mean to experience "reality"? If our perception can change and our brains can be tricked into processing simulations as experiences, what exactly is *real?*

Mirage (2020), Harman Brar

Introduction

Psychedelic drugs have long been used for spiritual, recreational, and therapeutic purposes. With a rich and troubled history, psychedelic drugs have been an area of interest for scientific research. Specifically, psychedelics have been examined for their potential therapeutic qualities and application in psychotherapy settings. Similarly, virtual reality technology has been adapted and studied as a tool to aid in various clinical psychotherapy settings. However, despite growing interest in both VR and psychedelic therapy, the two fields have yet to merge in order to simulate a psychedelic therapeutic experience in VR. With the numerous advantages of VR-assisted therapy, and growing literature on psychedelic therapy, a proposed combination has yet to be explored for therapeutic purposes. Both psychedelics and virtual reality have potential to address a number of psychological disorders and their respective treatments.

This paper will review previous studies which indicate virtual reality psychedelic simulations can impact individuals' self-reported experiences, and address the gaps in the literature regarding the neurophysiological implications of said simulations. To establish a theoretical framework, a hypothesis will be brought forward suggesting specific neural areas of activation that can be targeted in order to simulate positive effects associated with psychedelic drugs. Furthermore, by building on current literature examining both psychedelics and VR, a simulated psychedelic experience is posited as a worthy inquiry into the potential of technology-aided therapy. The intended outcomes of this research aim to contribute to the growing interest in both psychedelic therapy and virtual reality-aided therapy within the field of psychotherapy.

Contributions

This thesis project posits a largely unanswered research question of whether VR simulated can mirror psychedelic drug effects in a therapeutic setting. To address the current gaps in the literature of both psychedelic therapy and VR therapy, a VR experience is proposed as a solution of drugless psychedelic therapy. Regardless of the outcome of this research, a number of pertinent topics will be addressed. Among them, the potential areas of activation within the frontal lobe contributing to positive effects of psychedelics, the potential for VR therapy to effectively simulate drug effects, and the possible implementation of VR therapy in a psychotherapy setting.

This thesis may benefit a number of groups of individuals for scientific purposes. The proposed research question may be of interest to neuroscientists and psychologists specializing in serotonin research and psychedelic therapy. Additionally, the potential to apply VR in a clinical setting as a tool to achieve psychedelic therapy effects would benefit practitioners, patients, and scholars interested in the growing field of psychedelic therapy research.

Background

Turn On, Tune In, Drop Out: A Brief History of Psychedelics

Psychedelic drugs have a rich history, and the word "psychedelic" is derived from the Greek word psyche ("soul" or "mind"), and delein ("to reveal", "to manifest"), and the term "psychedelic" is translated as "mind-manifesting" or "mind revealing" (Glowacki et al., 2020). The origins of psychedelic drugs predate much of the scientific literature, with a history tracing back to ancient India in the form of the psychedelic drug *Soma* (Nichols, 2016). Additionally, the psychedelic cactus plant, Peyote, has been used ritually by Native Americans dating back to 3780 BCE (Nichols, 2016). However, the most prominent scientific documentation of psychedelic drugs began in 1943, with the discovery of (5*R*, 8*R*)-(+)-lysergic acid-*N*, *N*-diethylamide (LSD) by the Swiss chemist Albert Hofmann (Carhart-Harris, 2014). However, the scientific research into psychedelic drugs and their potential use in psychotherapy swiftly ended by 1970 (Nichols, 2016). Much of the research conducted prior to 1970 indicated psychedelic-assisted therapy to be safe treatment options for a number of disorders such as chronic pain, alcoholism, and trauma (Mahr and Sweighart, 2020).

Despite the scientific interest in psychedelic drugs, an abrupt end to psychedelic research occurred due to the social and political climate at the time. At the time of the Vietnam war and "hippie movement", psychedelic drugs were popular amongst youth and famously encouraged by notable Harvard professor, Timothy Leary (Nichols, 2016). However, the fear of counterculture and "free thinking" of the youth population led to strict regulations ending in the Controlled Substance ACT (1970) which placed LSD as a Schedule I drug (Nichols, 2016). The ban on hallucinogenic drugs halted years of potential research, yet 40 years later a reemergence in psychedelic therapy research has occurred with studies pursuing the possible applications of psychedelic drugs with respect to psychopathology (Mahr and Sweighart, 2020). A cohesive timeline of psychedelic research is not without relevant cultural events of the times from 1943 to 1970, and can be viewed in Figure 13 (see Appendix B).

LSD is perhaps one of the most studied psychedelics, and scientific inquiry into its effects have led to a greater understanding of the brain and its functions. A study conducted by Woolley and Shaw (1954) indicated that LSD's effects interfered with the action of serotonin in the brain (Nichols, 2016). Thus, serotonin's role in brain function was highlighted through the effects of LSD on the brain.

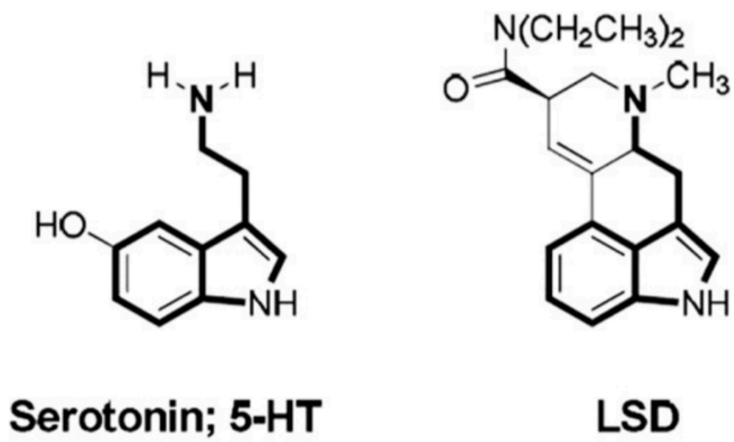

Figure 1. Structure of serotonin and LSD (Nichols, 2016)

Neuroscience of Psychedelics

Mechanism of Action and Role of Serotonin

Psychedelic drugs act on serotonin receptors in the brain, as described by numerous studies on LSD which found the drug's potent effect on the brain's serotonin systems led to elevated levels of serotonin and reduced metabolites of serotonin (Nichols, 2016). These findings indicate a higher level of serotonin due to increased production and reduced metabolization of the neurotransmitter. Additionally, studies have discovered 5-HT2A receptors to be primary targets for psychedelics (Nichols, 2016). A clinical study conducted by Kometer et al. (2012) concluded that the psychedelic drug psilocybin effectively enhances positive moods, while its activation of 5-HT2A receptors plays an important role in mood regulation ultimately suggesting the antidepressant effects of the psychedelic drug when acting on serotonin receptors. As illustrated in Figure 2, many psychedelic drugs are similar in chemical structure to serotonin as they are serotonin receptor agonists. The significance of serotonin in mood regulation and psychedelics will be further discussed in this paper.

Figure 2. Chemical structure of mescaline, psilocybin, and DMT (Nichols, 2016)

5-HT2A receptors play an import role in mood regulation and associated effects of psychedelic drugs. A study conducted by Kometer et al. (2017) suggested that the binding of psilocybin to 5-HT2A receptors was responsible for the visual hallucinations that result from psychedelic drug properties. This is due to the fact that activating 5-HT2A receptors with psilocybin may modulate the visual cortex leading to altered excitability that results in visual hallucinations forming in response to external stimuli (Kometer et al., 2017).

The serotonin system is largely complex and consists of receptor subtypes many of which are characterized by expression in the brain (Carhart-Harris and Nutt, 2017). However, when looking at psychedelic drugs and associated positive neurocognitive effects, 5-HT2A receptors are primarily focused on due to the binding of psychedelics to these receptor subtypes (Carhart-Harris and Nutt, 2017). 5-HT2A receptors are relatively dense in high-level associative cortex, specifically areas belonging to the Default Mode Network (DMN) (Carhart-Harris and Nutt, 2017). Furthermore, 5-HT2A receptors have been found to be expressed in the prefrontal cortex of both humans and monkeys (Carhart-Harris and Nutt, 2017). The up regulation and down regulation of these receptor subtypes leads to a variety of effects, many of which are outlined in the table below. Some of the prominent effects of down regulating serotonin levels are decreased mood, increased depression, increased anxiety and stress, increased impulsivity and agression, and decreased learning and cognition (Carhart-Harris and Nutt, 2017).

Serotonin and mood have been linked through the discovery of LSD in the 1950s, through the modulatory effects for the drug on mood and cognition (Carhart-Harris and Nutt, 2017). Additionally, evidence for the involvement of serotonin in depression resulted from studies illustrating an antidepressant effect with tryptophan the precursor to 5-HT (Carhart-Harris and Nutt, 2017). Serotonin has since become an important component of mood disorder treatment as seen in the use of SSRIs (Selective Serotonin Reuptake Inhibitors), which increase concentrations of 5-HT through rocking reuptake (Carhart-Harris and Nutt, 2017). Further support for serotonin's role in mood regulation arises from the low levels of plasma tryptophan observed in patients with severe depression (Carhart-Harris and Nutt, 2017). These findings further indicate the role of serotonin in mood regulation such that lower levels of serotonin are attributed to lower moods or depression.

	5-HT implicated	Post-synaptic (pst) 5-HT1AR signalling (sg) implicated	5-HT2AR signalling (sg) implicated
Impulsivity and aggression (I&A)	**5-HT ↓ → I&A ↑ +++**	**pst5-HT1ARsg↑ → I&AG↓ +++**	5-HT2ARsg↑ → I&A ↑(ST) ++ 5-HT2ARsg↑ → I&A ↓ (LT) ++
Anxiety and stress (A&S) and punishment (Pun)	**5-HT ↓ → A&S ↑ +++** **Pun ↑ → 5-HT ↑ → +++**	**pst5-HT1ARsg↑ → A&S ↓ +++**	5-HT2ARsg↑ → A&S ↑(ST) ++ 5-HT2ARsg↑ → A&S ↓(LT) ++
Learning and cognition (L&C)	5-HT ↓ → L&C ↓ ++	pst5-HT1ARsg↑ → L&C ↓ ++ pst5-HT1ARsg↑ → L&C ↑ +	5-HT2ARsg↑ → L&C ↑(ST) + 5-HT2ARsg↑ → L&C ↓(ST) ++ **5-HT2ARsg↑ → L&C ↑(LT) +++**
Depression (D) and mood*	5-HT ↓ → mood ↓ ++ 5-HT ↑ → mood ↑ ++	pst5-HT1ARsg↑ → D ↓ ++	5-HT2ARsg↑ → D ↓(LT) ++
General plasticity (gP) and regional specific plasticity (rP)	**5-HT ↑ → gP ↑ +++**	pst5-HT1ARsg↑ → GP ↑(hip) ++	5-HT2ARsg↑ → rP ↑(LT, cx) ++ 5-HT2ARsg↑ → rP ↓(LT, hip) ++ **5-HT2ARsg↑ → gP ↑(ST & LT) +++**

Figure 3. Functions associated with brain serotonin (Carhart-Harris and Nutt, 2017)

Perceptual Psychedelic Phenomena

Many perceptual effects occur as a result of a psychedelic experience. While effects vary with dose, set, setting, and individual factors many common phenomenon have been described. While some effects are physiological, others tend to be highly psychological and philosophical in nature. To accurately address these different effects, they will be categorized as "physiological" to address the effects that can be accounted for neurochemically in a relatively objective manner;

and “psychological” to describe effects that are subjective and less easily quantifiable.

Physiological Effects

We do not currently concretely understand the basis of consciousness, either scientifically or philosophically, and its neuronal correlates (NCC), let alone unconsciousness. Therefore, the effects of psychedelics are often described and analyzed through a neuropharmacological lens. Visual hallucinations and illusions are often perceived during psychedelic experiences and are markers of serotonergic hallucinogen-induced altered states of consciousness (Kometer et al., 2013). In a study conducted by Kometer and colleagues, it was found that the activation of 5-HT2A receptors by the psychedelic drug psilocybin highly modulated the neurophysiological and phenomenological visual processing (Kometer et al., 2013). Thus, the activation of 5HT2A receptors was strongly correlated with the presence of visual hallucinations.

Perceptual effects have also been identified to include intensified colour saturation, perceptual distortion, illusion, mental imagery, increased texture definition, increased light intensity, among other visual characteristics (Swanson, 2018). Additionally, the world or external environment is perceived in a higher resolution, with crisp details (Swanson, 2018). Additionally, a study conducted by Swanson (2018) outlines two types of hallucinations: elementary and complex. Elementary hallucinations often include geometric patterns in the visual field, while complex hallucinations include elaborate motifs, landscapes, humans, galaxies, et cetera. A further distinction has been made when looking at dosage; psycholytic doses (lower doses) cause sensory alterations including warping of surfaces and colour variations (Mahr and Sweigart, 2020). At psychedelic doses (higher doses), perception alterations occur such as textured surfaces and objects appearing to have animated fractals and patterns often causing the user to feel an altered sense of reality (Mahr and Sweigart, 2020). Additionally, synesthesia which refers to the merging of sensory boundaries, such as hearing colour, may be experienced (Mahr and Sweigart, 2020).

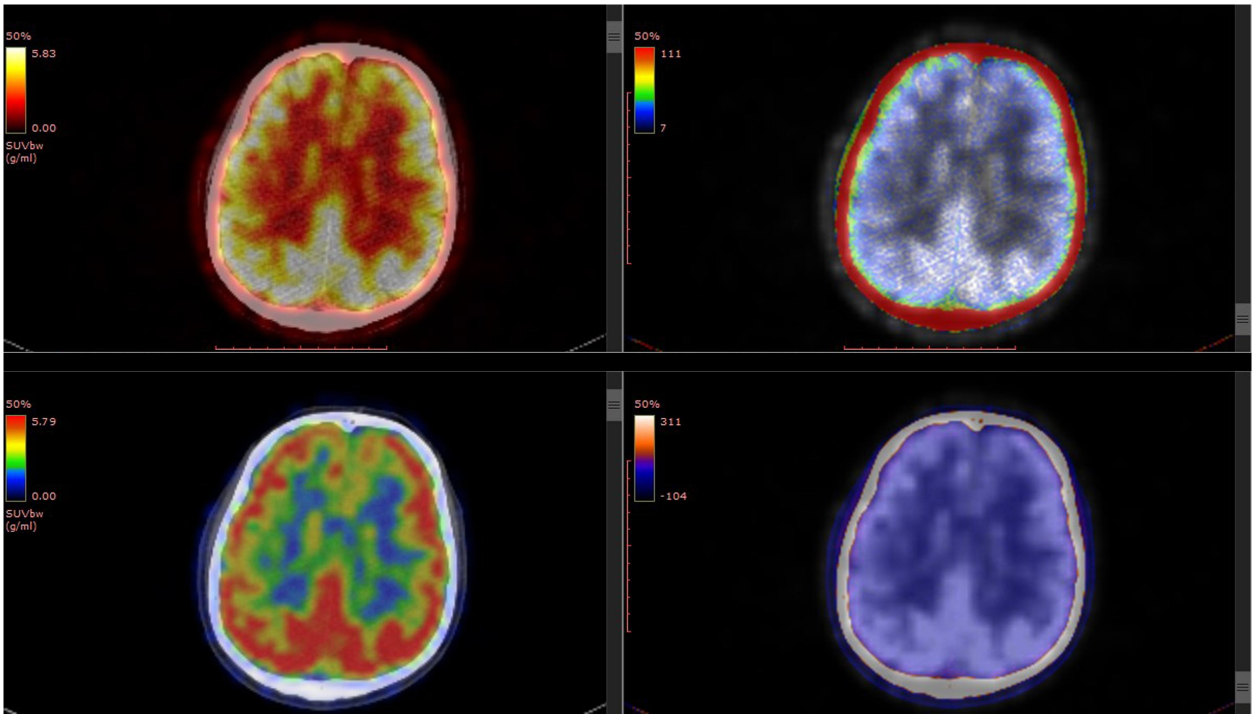

Figure 4. Brain imaging displaying psilocybin effect on frontal lobe activity

Psychological Effects

Unbound ego dissolution is a phenomena often associated with psychedelic drug experiences (Letheby and Gerrans, 2017). Letheby and Gerrans posited that the phenomena of ego dissolution was related to the notion of unbinding in the brain. Binding theory refers to the integration of information in neural networks, representation and integration of perceptual events, and the processing of perceptual information from global to executive consciousness. (Letheby and Gerrans, 2017). Binding theory attempts to explain how perception is processed and how perceptual experiences are organized and fed to higher levels within a metacognitive process (Letheby and Gerrans, 2017). With respect to psychedelic experiences, the researchers Letheby and Gerrans proposed that the phenomenon of ego dissolution can be understood through a process of unbinding where unbinding underlies self-awareness. Thus, the loss of ego and self-awareness as a result of psychedelic drug experiences may be explained through the theory of unbinding.

The phenomena of ego dissolution is a complicated and often subjective experience, with varying degrees. However, some characteristics can be described as individuals becoming less defensive, more able to view their thoughts and feelings dispassionately, and their experiences are no longer attributed to a specific entity (Letheby and Gerrans, 2017). Instead, dysfunctional emotional and behavioural habits or patterns can be observed with objective clarity, and cognitive processes tied to self-representation are weakened (Letheby and Gerrans, 2017). In a study conducted by Carhart-Harris et al. (2012), fMRI studies of psilocybin described a decreased activity in the Default Mode Network (DMN). The relevance of down regulation of DMN lies within the fact that this region of the brain is integral to self-representation including self narrative, mental time-travel, judgement, planning, goals (Letheby and Gerrans, 2017). A down regulation of the Default Mode Network leads to dissolution of narrative self including memories and ownership of thoughts (Letheby and Gerrans, 2017).

Another neurocognitive network that is implicated in self-representation and down regulated as a result of psychedelic drug actions is the Salience Network (SLN). (Letheby and Gerrans, 2017). The SLN is related to the embodied self including emotional feeling and salience and when down regulated results in a dissolution of embodied self affecting spatial location, relevance of emotional feelings (Letheby and Gerrans, 2017). The down regulation of these areas as a result of psychedelic drug action can therefore lead to unbinding of self awareness and allow for a feeling of ego dissolution.

In addition to ego dissolution, emotional and cognitive effects are also experienced through psychedelic drug use (Swanson, 2018). Emotional effects may include intensification of feelings, increased access to emotions, and a broader range of emotions throughout the drug experience (Swanson, 2018). Additionally, these emotional effects can be positive or negative depending on the environment (set and setting) of the user (Swanson, 2018). Cognitive effects are often described as non-linear thinking, and potentially reduced performance of working memory (Swanson, 2018). However, cognitive impairments are dose dependent, and low doses (microdoses) are sometimes associated with improved cognitive performance (Swanson, 2018). Other cognitive traits include increased creativity as seen through divergent thinking, unlikely language patterns, and increased attributed meaning to stimuli, among others (Swanson, 2018). Swanson (2018) also concludes that cognitive flexibility and optimism are often side effects of psychedelic drugs and long-term increases in creativity and problem solving as well as openness can occur.

Psychedelic Therapy Literature Review

Psychedelics have a relatively complicated relationship with psychology and psychiatry. Beginning in 1950, psychedelics were used to aid psychotherapy treatment of mood disorders and alcoholism; specifically, drugs such as LSD showed therapeutic promise prior to legal prohibitions that ended psychedelic research in the 1960s (Carhart-Harris and Goodwin, 2017). In Saskatchewan, hallucinogens were used as aids in psychotherapy for the treatment of alcoholism in the mid 1950s (Barber, 2018). The research and clinical trials set in Saskatchewan by Dr. Hoffer and colleagues displayed efficient results when treating alcoholism due to the pioneering use of psychedelic drugs (Barber, 2018). Despite these findings, regulations resulted in an end to psychedelic research. However, there has been renewed interest in psychedelic therapy research with brain imaging studies of psilocybin indicting positive effects for depression symptoms (Carhart-Harris and Goodwin, 2017).

Depression

When addressing antidepressant potential, psilocybin and psychedelics share similarities with antidepressants through serotonergic modulation, via 5-HT2AR agonist action (Carhart-Harris and Goodwin, 2017). However, there are important differences when comparing psychedelics to traditional antidepressants. One such difference is the side effects of antidepressants such as SSRIs, which include emotional blunting (or "flat affect") which is contrary to the emotional release associated with psychedelics (Carhart-Harris and Goodwin, 2017). Many clinical trials have been conducted in a "second wave" of psychedelic research, which can be found below (Figure 5).

Study	Population/indication and sample size	Drug and design	Main efficacy outcome
Moreno *et al* (2006)	Obsessive compulsive disorder, $n = 9$	Psilocybin: single-arm, within subjects, variable doses. Up to four doses of psilocybin	All patients showed improvements within 24 h c a treatment but no effect of dose
Grob *et al* (2011)	Anxiety and depression in end-stage cancer, $n = 12$	Psilocybin: DB-RCT, crossover, inert placebo. Single dose of psilocybin	Significant reductions in trait anxiety at 3 month and depression at 6 months
Johnson *et al* (2014)	Long-term chronic tobacco smoking, $n = 15$	Psilocybin: open-label. Up to three doses of psilocybin after four CBT sessions	80% of sample abstinent at 6 month follow-up
Gasser *et al* (2014)	Anxiety related to life-threatening disease, $n = 12$	LSD: DB-RCT, crossover, very low dose (VLD) LSD = control. Single dose of LSD	Significant decreases in state and trait anxiety *vs* VLD at 2 months and sustained for 12 months
Bogenschutz *et al* (2015)	Alcohol dependence, $n = 10$	Psilocybin: open-label. Up to two doses after seven motivational therapy sessions	Significant decrease in drinking behaviors for up t 9 months
Osorio Fde *et al* (2015) and Sanches *et al* (2016)	Major depressive disorder (MDD), $n = 6$+study extension to $n = 17$	Ayahuasca: open-label. Single dose of ayahuasca	Significant decreases in depressive symptoms fo up to 21 days

Figure 5. Recent clinical trials involving psychedelics (Carhart-Harris and Goodwin, 2017)

Addiction

A significant finding in the literature is the efficacy of psychedelics in treating long-term chronic tobacco smoking which resulted in 80% abstinence of the sample size (Carhart-Harris and Goodwin, 2017). Multiple studies have concluded that psychedelic drugs have positive effects on mood disorders, such as major depressive disorder (MDD) as seen in a study by Carhort-Harris et al. (2016) which found psilocybin to prompt significant decreases in depressive symptoms for a period of six months.

Therapeutic Aid

Psychedelics can also be examined through a Jungian therapeutic lens, wherein Jungian theory can be applied to understand the efficacy of psychedelic drugs, as posited by Mahr and Sweigart (2020). The use of Jungian theory is applicable due to the fact that psychedelic drugs have therapeutic benefits through generating clarity and insight in the user in contrast to neuronal modulation of traditional antidepressant drugs (Mahr and Sweigart, 2020). As Mahr and Sweigart infer, psychedelic drugs have benefits that result from the suppression of the Default Mode Network (DMN) which is often metaphorically considered the neural correlate of the ego. The DMN is normally active during performing of tasks and self-talk (Mahr and Sweigart, 2020). When this area is suppressed, psychedelic drugs open the ego up to activities and influences from different areas of the brain, resulting in depersonalization, feelings of boundlessness and transcendental "oneness" (Mahr and Sweigart, 2020). These findings may indicate a broadening of consciousness and openness to exploration of the mind as a result of psychedelic drugs.

Memory

In addition to serotonergic related benefits of psychedelic drugs, research has indicated other benefits related to psychotherapy when coupled with psychedelics. In a study conducted by Carhort-Harris and colleagues (2012) it was found that psilocybin enhances recollection of personal memories, thus implying its potential use in psychotherapy. Psilocybin was illustrated as a potential tool in recalling salient memories or reversing negative cognitive biases in patients (Carhart-Harris et al., 2012). The study viewed fMRI scans which displayed additional visual and sensory cortical activations in individuals under psilocybin compared to placebo groups (Carhart-Harris et al., 2012). Furthermore, vividness of memory and visual imagery were higher after psilocybin intake and a positive correlation occurred between vividness and wellbeing at follow-up (Carhart-Harris et al., 2012). These findings highlight the potential for psychedelics beyond serotoningeric receptor activation. Examining the effects of psychedelics in a holistic view can emphasize the potential for openness and subsequent healing when used therapeutically.

Potential Concerns and Negative Side-Effects of Psychedelics

Despite the positive potential of psychedelics and psychedelic therapy, there are concerns and considerations to address. While few risks have been outlined by use of psychedelics, and they are noted to be non-addictive (unlike dopaminergic opioids for example) (Nichols, 2016). There are rare instances where the drug can have adverse effects, particularly when used recreationally and with impure drug doses (Nichols, 2016).

As outlined by Nichols (2016), use of high doses of psychedelics can result in vascular problems due to the fact that the 5-HT2A receptor targeted by psychedelics is associated with vascular smooth muscle contraction, coronary artery spasms, among other vascular activity, Acute vasoconstriction due to serotonin activation is also possible as a result of psychedelic drug intake (Nichols, 2016). It was also found that psilocybin administered in a controlled setting is often reported to cause transient delayed headache, that increases in severity relative to dose (Nichols, 2016).

Another significant adverse effect of psychedelic use, specifically with LSD intake, is hallucinogen persisting perception disorder (HPPD) (Nichols, 2016). This disorder is often described as “flash backs” where the perceptual effects of hallucinogenic drugs are experienced again at a later time after the initial drug effects have worn off (Nichols, 2016). HPPD consists of afterimages, movement perception, blurring of patterns, halo effects (Nichols, 2016). However, it is apparent that HPDD was less likely to occur in controlled therapeutic settings when compared to recreational use (Nichols, 2016).

Virtual Reality Therapy Literature Review

Application of Virtual Reality in Treatment of Psychiatric Disorders

Virtual reality technology allows a user to engage in a simulated immersive experience, within a computer-generated environment. VR technology allows for immersive engagement and interaction in a simulated environment through the use of head mounted displays (HMD) and hand held controllers. With the advances in VR technology, its application has expanded into the medical health fields, particularly within the field of psychiatric treatment. Virtual reality (VR) technology has been utilized in therapeutic settings where virtual environments provide a controlled immersive experience for patients.

The benefits of VR technology include an immersive simulated environment using a human-computer interface (HCI) which allows a user to interact with virtual items (Kim and Kim, 2020). Additionally, virtual reality generates rich visual, auditory, and tactile stimuli which help users realistically feel and recall the VR experience (Kim and Kim, 2020). Furthermore, virtual reality therapy provides patients with realistic and immersive environments that can be controlled and adjusted according to patient and therapist needs. Realistic sensory stimulation can also be controlled by the therapist within a clinical setting (Maples-Keller, et al., 2017).

Virtual reality modalities have been adapted to the treatment of psychiatric disorders, with an emphasis on exposure-based therapy for anxiety disorders. (Maples-Keller, et al., 2017). The treatment of psychological disorders such as PTSD, general anxiety disorder, and phobias have utilized virtual reality therapy methods. The application of virtual reality in the treatment of psychiatric disorders is a rapidly growing area of clinical research.

Anxiety Disorders

One of the most common applications of virtual reality in mental health treatment is within exposure-based therapy for anxiety disorders. Anxiety disorder treatment studies have reported significant effectiveness and benefits when implementing virtual reality-based therapy methods (Kim and Kim, 2020). In traditional psychotherapy treatment of anxiety disorders, exposure therapy has been identified as one of the most effective treatment methods, wherein a patient is directly exposed to the feared or anxiety triggering situation (Kim and Kim, 2020). However, this direct exposure to a stimulus may exacerbate the patient's anxiety symptoms, potentially deterring them from further treatment (Kim and Kim, 2020). A virtual reality environment (VRE) that simulates the feared situation would allow both the therapist and patient to have control over the level of exposure received or experience during the therapy session. Additionally, in-vivo exposure can be costly, such as flight sessions; or difficult to recreate such as war combat settings (Maples-Keller, et al., 2017). VRE therefore allows for a cost-effective alternative and easily manipulated exposure experience. Using a simulated environment, the exposure scenario can be repeated multiple times as is the case for repeating virtual flight landing sessions (Maples-Keller et. al., 2017). Moreover, through virtual reality aided therapy, patients can maintain an anxiety-inducing exposure in a safe environment with the option to control the graded exposure levels. The perceived control and option to end the exposure to the anxiety-inducing situation can allow for patients to receive a comfortable and safe therapeutic approach to exposure therapy.

Virtual reality therapy methods also allow for bio-tracking and biofeedback through objective measures of bio-signal data (Kim and Kim, 2020). Therefore, changes in heart rate and galvanic skin reflex can be monitored and observed using wearable devices while in the VR experience (Kim and Kim, 2020). The monitoring of bio-signals in a traditional exposure therapy may seem unnatural, however, when combined with the VR headset and controls it can become part of the equipment worn by the patient. Therefore, the biofeedback becomes a natural part of the virtual reality experience and allows for accurate monitoring of vital physiological changes necessary to assess the patient's anxiety levels. The combination of virtue reality exposure therapy and physiological monitoring of bio-signals related to anxiety create an effective and convenient method of real-time tracking of anxiety symptoms while in therapy. Another advantage for VR exposure therapy is within the domain of psychiatric research. The ability to control exposure levels and stimuli affords researchers highly controlled clinical and experimental research (Maples-Keller et al., 2017). This precise control combined with objective physiological measures posits virtual reality based exposure therapy as a potentially vital component of psychiatric treatment and research with respect to anxiety disorders.

Social Anxiety Disorder (SAD)

Another form of anxiety disorder, social anxiety disorder (SAD) refers to cases where patients experience anxiety specifically in social interactions where they may be judged or evaluated by others (Maples-Keller et al., 2017). These interactions can include conversations, public speaking, interviews, and meetings with other individuals. To aid in treatment of social anxiety disorder, virtual reality environments have been developed to allow priests to interact with computer generated social environments with virtual audiences. (Maples-Keller et al., 2017). In a study conducted by Maples-Keller et al. (2017), examining generalized social anxiety disorder, it was found the VR-based cognitive behavioural therapy (CBT) was as effective ass traditional

CBT and superior to control conditions. The combination of virtual reality environments and cognitive behaviour therapy is therefore significant when treating social anxiety disorder.

Social Anxiety Disorder (SAD)

PDA is a condition associated with a rush of anxiety manifested by physiological symptoms such ass sweating, choking, heart palpitations; and cognitive symptoms such as icing thoughts. The combination of these symptoms often leads to fear and/or avoidance of specific places or situations (Maples-Keller et al., 2017). Research has indicated that virtual reality-based cognitive behavioural therapy is as effective as traditional therapy techniques. When treating PDA, exposure therapy is often implemented in order to simulate the feared or panic-inducing environment, as seen in exposure therapy for anxiety. Studies have found improved treatment response and decreased required time for treatment when patients are given virtual reality simulated exposure therapy (Maples-Keller et al., 2017). Patients with panic disorder are able to utilize the controlled and gradual exposure to the fear-inducing stimuli or environment through virtual reality therapy. This perceived control over the exposure dose and the option to exit the situation without hesitation allows patients to be comfortable during exposure. The benefits of virtual reality therapy thus positively impact holistic treatment modalities for patients with PDA.

Acute and Chronic Pain

Virtual reality simulations have also been applied to cases of acute and chronic pain. With patients suffering from acute pain, virtual reality experiences have been found to facilitate distractions from the sensations during painful procedures (Maples-Keller et al., 2017). For example, burn patients undergoing treatment reported lower levels of subjective pain when in virtual reality environments during occupational therapy sessions (Maples-Keller et al., 2017). For patients with chronic pain conditions such as fibromyalgia, engaging in virtual meditative walks to learn mindfulness-based stress reduction led to a reported decrease in subjective pain and improvement in mood (Maples-Keller et al., 2017). Virtual reality therapy can therefore include distraction techniques for cases of both acute and chronic pain.

Addiction

Virtual reality has also played a role in addiction therapy, specifically with respect to reducing conditioned reactivity. Repeated exposure to drug related cues is a method often used to reduce cue reactivity craving in an effort to prevent relapse into addiction (Maples-Keller et al., 2017). VR environments allow for simulated drug cues and therefore repeated exposure to cues such as a virtual bar, syringe, or needle and a pilot study found VR cue exposure to be effective at triggering physiological arousal, cravings, and urges to use drugs in men with opioid addiction (Maples-Keller et al., 2017). A nicotine focused study demonstrated the a VR smoking environment resulted in increased psychophysiological arousal and cravings for nicotine, and this response decreased over a four week period of VR cue exposure (Maples-Keller et al., 2017). VR based cue exposure therefore effectively facilitates decreased reactivity to addiction cues and reduces cravings normally induced by exposure to said cues. While cue exposure is another form of exposure therapy, it operates by reducing cravings through repeated exposure to addiction triggers or cues. Thus, substituting the addictive substance or environment with virtual simulation produces similar effects and can substitute dangerous environments for patients with addiction and dependence.

Autism

Autism is a developmental disorder characterized by symptoms of difficulties with social interaction, communication; as well as repetitive, compulsive, and ritualistic behaviour. Often diagnosed in childhood, autism varies widely from individual cases, and children with autism often do not interact with others (Park et al., 2019). Virtual reality approaches have been developed for autism treatment and rehabilitation. When integrated with other techniques, virtual environments can facilitate cognitive processing, social and functional skills training, and concentration training (Park et al., 2019). A training program developed at the University of Texas targeted the social skills training of children with autism (Park et al., 2019). The program utilized virtual reality environments and avatars to enable children to interact in social situations such as meetings, while tracking brain imaging and electroencephalography (EEG) monitoring of brain activity (Park et al., 2019). The children would practice exercises of reading social signals and expressing appropriate social behaviours (Park et al., 2019). When the program was completed, the activity of brain areas associated with social understanding increased when looking at patients' brain imaging results (Park et al., 2019). It can be concluded from these results the VR-based therapy simulates real world experiences and can help patients with social cues and social behaviour skills.

Post-Traumatic Stress Disorder (PTSD)

Another common application of VR therapy is in the treatment of post-traumatic stress disorder (PTSD). Patients with PTSD have a history of exposure to a traumatic event and symptoms of avoidance, negative alterations in cognition and mood, among other symptoms (Maples-Keller et al., 2017). When treating PTSD, prolonged exposure therapy has been deemed effective as it aims to target traumatic memory and related emotions and behaviours (Goncalves et al., 2012). Additionally, patients are then able to understand the impact of the traumatic experience and its context. Exposure therapy stimulates emotional engagement through imaging exposure, however, some patients find it difficult to immerse in the traumatic environment with studies indicating a drop out rate of up to 50% (Goncalves et al., 2012). An alternative method to this prolonged exposure therapy approach is the incorporation of virtual reality exposure therapy. Virtual reality exposure therapy (VRET) involves emotional engagement of patient with PTSD while being exposed to multiple sensory stimuli in the virtual environment and allows the therapist to facilitate control which bypasses symptoms of patient avoidance (Goncalves et al., 2012). Additionally, gradual exposure to related stimuli is possible based on the needs of individual patients (Goncalves et al., 2012).

There are many benefits associated with virtual reality therapy applied to PTSD including the ability to recreate settings that are difficult to access repeatedly. An example of such an environment is a combat or war setting that is difficult to recreate, and many cases of PTSD often involve war veterans. A study investigating virtual reality environments for military related PTSD with post 9/11 veterans suggested that six sessions of VRE related to improved PTSD symptoms (Maples-Keller et al., 2017). The objective measures were psychobiological measures of cortisol reactivity post-treatment and after three, six, and twelve months post treatment thus indicating clinical improvement sustained over time (Maples-Keller et al., 2017). The efficacy of virtual reality therapy can thus be found in the treatment of post traumatic stress disorder, wherein virtual environments can simulate traumatic events in a gradual, controlled, and safe manner for the patient and therapist.

Schizophrenia

Virtual reality therapy extends beyond exposure therapy, and studies have suggested successful application in treating other psychiatric disorders, such as schizophrenia. Schizophrenia is a disorder with symptoms including hallucinations, delusions, abnormal emotional/behavioural functioning (flat affect, isolation), and difficulty with cognitive processing (Maples-Keller et al., 2017). When treating schizophrenia, VR technology has been used to create social situations in which patients learn to cope with social distress elated to delusions and are bale to practice social skills (Maples-Keller et al., 2017). A number of studies have utilized virtual reality technology with social skills training (SST) for schizophrenic patients with supporting evidence of improving social skills and interactivity (Maples-Keller et al., 2017). Therefore the use of virtual reality therapy has potential to be applied to psychiatric disorders when training patients and improving social skills affected by the disorder.

Depression

Depression is often treated with a number of different treatment approaches including medication and cognitive behavioural therapy (CBT). However, VR technology has also been examined as a treatment technique for low-intensity interventions of depression. Within CBT, psychotherapeutic techniques of psychoeduction are often utilized, where a patient learns problem solving skills such as breaking large goals into smaller tasks, planning, brain storming (Lindner et al., 2019). Immersive VR therapy can thus be applied in psychoeducation, as an educational tool that allows the patient to experience what is learned (Lindner et al., 2019). Additionally, CBT encourages objectivity which can be produced in VR where a patient can interact with scene or scenario in first or second person views and then view the same situation as a third person observer making note of discrepancies (Lindner et al., 2019). Therefore, virtual reality simulations can allow patients to see their life scenarios and situations from an objective perspective in order to better develop coping mechanisms.

Additionally, virtual reality simulations can be utilized to create positive affect through the use of virtual objects and environments. Studies indicate relaxation techniques using virtual reality based natural scenes resulted in reduction of stress and improvement of mood in participants (Anderson et al., 2017). A study at the University of Barcelona indicated the VR therapy applications to depressed patients reduces severity of depression and increases reported levels of satisfaction (Park et al., 2019). Researchers also suggest the VR environments can limit distractions from the "real world" and increase awareness, presence, and thus facilitate mindfulness (Park et al., 2019). While the current literature is limited on immersive simulations inducing positive affect in patients with depression, much of the ongoing research indicates positive affect can result from immersion in natural and relaxing scenes based in virtual reality.

Limitations of Virtual Reality Therapy

Virtual reality technology has a number of advantages and affordances as previously outlined. However, there are some limitations to the technology, particularly within the treatment of psychiatric disorders. Some concerns that arise when looking at virtual reality applied to clinical settings are the technological side effects. First, VR experiences can result in discomfort and symptoms of motion sickness including eye fatigue, headaches, cause and sweating (Park et al., 2019). VR sickness differs from motion sickness as it does not require physical movement and instead results from conflicts between accommodation and mergence depth cues (Park et al., 2019). Furthermore, dry eyes may result due to overheated displays and retinal damage from blue light are both physiological concerns (Park et al., 2019). Additional research within the field of ophthalmology and optometry could generate insight into preventing or correcting for both dry eyes and retinal damage in patients engaging in virtual reality therapy treatment.

Another concern, particularly with patients exhibiting both hallucinations and delusions as symptoms of their psychiatric disorder, is the potential to become dependent on the technology. As Park et al., stated in their review of virtual reality therapy, patients may become addicted to the VR environment, similar to internet-based game addiction. For example, patients with schizophrenia often have impairment on reality testing and they may also suffer from delusions or exhibit delusional thinking in the VR environment as well. This raises a complex issue of delusions within a virtual environment. These potential risks would require necessary precautions and preliminary education for the patient and doctor when involving VR in treatment plans. Doctors would be responsible for judging whether a patient is fit to engage in virtual reality environments and a common understanding of the technology would have to exist in order for the treatment to be effectively utilizing VR simulations. To ensure this, a set of guidelines could be provided to doctors using VR treatments, possibly within the DSM.

Other possible limitations of VR simulations could be an aversion to the technology. Oftentimes individuals who are unfamiliar with the headset, controllers, and general computer interaction may not be willing to engage in treatment based on said technology. However, with common techniques and educating patients on the procedures associated with VR therapy, these obstacles can be overcome. Specifically, educating patients with onboarding techniques (how to wear the headset, how to look around in the VR environment) can ease hesitation or avoidance of perceived technology barriers.

Potential Future Applications

Virtual reality technology allows for simulated immersive experiences that can be monitored and controlled in real-time. While a significant amount of research exists examining the application of virtual reality when addressing psychiatric disorders, much of the applications are based in exposure therapy and cognitive behavioural therapy. Little to no research has examined the potential for virtual reality applied to therapeutic simulations that mirror altered states of consciousness, such as drug-induced states. An area of research worth investigating would be the simulation of psychedelic experiences, wherein a patient can immerssevely engage in a simulated experience mimicking the effects of psychedelic drugs. Psychedelic therapy has regained interest within clinical research particularly in treating PTSD and depression, and to bypass drug therapy and scheduled drugs, a psychedelic simulation could be developed while testing for biofeedback. The biofeedback results could then be compared to brain activity of participants taking a psychedelic drug. Analyzing the areas of the brain activated during a simulated psychedelic experience and comparing them to a drug control would provide insight about the possibility of simulating positive effects associated with psychedelic drug therapy. The potential for simulated psychedelic experiences may allow for self-therapy, and positive affect resulting from these simulated altered states of consciousness. While the resulting effects of a simulated psychedelic experience are wholly unknown at the current time, a potential exists to explore the impact and effect of an immersive virtual reality-based psychedelic experience and its possible therapeutic applications.

Virtual reality has a multitude of applications within the treatment of psychiatric disorders. Common applications of virtual reality environments are seen within exposure therapy for anxiety disorders, PTSD, and PDA. Additionally, virtual reality technology has been shown to be significant when simulating social interactions, skills training, and psychoeducation in schizophrenia and depression treatments. Virtual reality simulations have a number of benefits and advantages, particularly within exposure therapy when compared to traditional exposure therapy methods. VR therapy conveniently allows for multiple experiences and simulations, and is cost effective compared to real-world exposure settings. Furthermore, VR therapy makes possible scenarios that may otherwise be difficult to recreate such as combat environments with PTSD patients. In addition to the convenience of VR therapy, it has been described as an effective treatment tool due to level of control one has over their environment. This control allows both the patient and the therapist to feel safe, and provides the option to gradually experience exposure stimuli, with the dose of experience tailored to the individual patient needs.

With the multitude of benefits associated with virtual reality therapy applications, the potential exists to expand research into simulated drug therapy. As proposed in this paper, psychedelic therapy simulations may be an area of research worth pursuing in order to address a gap in the literature regarding simulated psychedelic experiences and their effects on the brain. Further research can address the potential for virtual reality therapy techniques to replace or support traditional therapeutic techniques. Further research into the impact of virtual reality simulations on the brain with respect to therapy and meditation could result in major breakthroughs within psychotherapy treatment.

Virtual Reality Simulated Psychedelic States Literature Review

Currently, there are a small number of studies that examine the potential to achieve psychedelic states in virtual reality. One study, attempted to create a shared psychedelic experience within a group setting, using a virtual reality experience called "Isness" (Glowacki et al., 2020). The study attempted to induce mystical type experiences of connectedness and transcendence within a group virtual reality environment (Glowacki et al., 2020). This experience was designed to allow users to enter a virtual reality setting where bodies ceased to exist and instead appeared to be balls of energy. Each individual in the experiment could not identify anyone else except by their energetic presence, allowing for a shared experience and attempt at purer awareness without ego distractions (Glowacki et al., 2020). While this study examined the potential to experience connectedness and ego dissolution while in a virtual reality simulation, it focused more on the "mystical" experience rather than the visual hallucinations associated with psychedelic drugs. Furthermore, the study did not collect neurofeedback, brain imaging results, or other metrics by which to compare the participants' experiences to those of drug conditions with respect to physiology. Instead, self-report measures were used through questionnaires and compared to individuals who had taken psilocybin (Glowacki et al., 2020).

This study yielded significant findings that indicated VR phenomenology could simulate conditions for mystical type experiences similar to psychedelic drugs, experiences that felt meaningful to participants. However, the limitations of the study exist in the lack of biological measures, and the study also fails to address whether the experience could be beneficial for therapeutic applications, particularly in individual settings. The research also did not propose neural areas of activation which may indicate successful simulations of psychedelic experiences through increased activity. Despite these unaddressed concepts, Glowacki and colleagues highlighted the potential of virtual reality to simulate meaningful psychedelic phenomenon which could be further extended to address whether effects achieved in simulations can be measured. Additionally, the implications of such measures could be addressed and analyzed to better understand whether simulations can be significant alternatives for psychedelic drugs when considering therapeutic applications.

Another study, which served as a point of reference for this major research project was conducted by Suzuki et al. (2017), that looked at a deep-dream virtual reality platform called the Hallucination Machine. Suzuki and colleagues attempted to simulate phenomenological aspects of altered states using natural scene videos in virtual reality and deep neural networks to achieve dynamic hallucinations. While the achieved effect was evocative of coloured patterns overlaid on top of a video of a street-scene, and featured psychedelic inspired patterns, specific hallucinatory effects were not clearly described. For example, the study did not indicate what a "biologically realistic visual hallucination" entailed and how it would be measured perceptually by the participant. The experiment also looked at whether temporal distortion could be a result of the Hallucination Machine experience (Suzuki et al., 2017).

When assessing the effectiveness of the visual hallucinations, Suzuki and colleagues relied on subject experiences of participants as reported in a self-report questionnaire. However, they did not assess the biological indicators such as neurofeedback that would generate data indicating brain activity that may be comparable to drug control groups. Despite the use of qualitative and no quantitative data for the users' perceived psychedelic experiences, the researchers found that experiences within the simulation were distinct from control videos and qualitatively similar to psilocybin experiences (Suzuki et al., 2017). When investigating the presence of temporal distortions, the participants were asked to rate their experiences based on a questionnaire and were also asked to complete temporal production task in the simulation versus control settings. The results of the study indicated that there was no temporal distortion effect present in the simulation (Suzuki et al., 2017). The aspect of the study that was of clear significance to this research project was the qualitative results collected by participants. A majority of participants indicated that the simulation experience was similar to a psilocybin experience. This finding became the basis of a major research question which addressed a topic not clearly answered in the current literature. The question of whether a virtual reality simulation effectively simulate positive cognitive effects of psychedelic drugs when isolating for visual hallucinations has yet to be answered.

Proposed Research Question and Hypothesis

To address the apparent gaps in the literature regarding the efficacy of a simulated psychedelic virtual reality experience, a psychedelic virtual reality simulation is proposed in order to answer a hypothesis and speak to a larger research question based in cognitive science. A simulated psychedelic experience is proposed to attempt to mimic and induce psychedelic visual hallucinatory effects in a virtual environment. It is then intended to experimentally test the simulation through participants and measure neurfeedback in the form of EEG and fMRI data to determine whether specific brain regions are activated in the simulation similar to a drug control.

Currently, studies do not address whether or not psychedelic simulations can impact the brain similarly to their drug counterparts. The current research indicates self-report of psychedelic simulations being similar to actual psychedelic drug experiences, however there is no concrete neurophysiological evidence to support these findings. To determine the potential of a simulation to mimic neuropharmacologically induced effects of psychedelic drugs, a number of parameters need to be addressed within the experimental design, including targeted neural areas of activation, comparative brain activity viewed through brain imaging techniques, and neurochemical measures of serotonin levels within the brain.

Research Questions

The following research questions would be addressed through implementation of a the proposed simulation and experimentation yielding empirical data.

1. Can a psychedelic virtual reality simulation mimic the psychological and physiological effects of psychedelic drugs?

2. If we isolate for visual hallucinations, can we simulate these effects and target specific brain areas of actuation to measure the physiological effects of the experience?
3. If we can trick our brains into perceiving a simulation as a true psychedelic experience physiologically, what might this suggest about the limits of perception and how can this further our understanding of the mind with respect to psychopathology?

Hypothesis

If brain activity of individuals in a psychedelic virtual reality simulation shows activation of 5-HT2A receptors, leading to increased serotonin levels and associated "positive" feelings, then it may indicate that simulated psychedelic experiences can mirror psychedelic drugs when isolating for visual hallucinatory effects on the brain.

Specifically, 5-HT2A receptors within the frontal lobe are proposed to be the areas that may be activated in a psychedelic simulation to mirror the activation that occurs under the psychedelic drug conditions. As outlined earlier, 5-HT2A receptors are serotongeric receptors activated by psychedelic drugs and studies have suggested their role in the formation of visual hallucination due to their impact on visual cortex.

It is therefore hypothesized that if we can target 5HT2A receptors in the frontal lobe through simulated hallucinations, perhaps the effects may mirror that of psychedelic drugs. This would be indicated by an increase in serotonin receptor activity and decrease in serotonin metabolites resulting in overall serotonin level increase. The goal of this research project would be to simulate the positive neurocognitive effects that result from psychedelic drugs in the absence of said drugs, with a goal of therapeutic application.

A Research Opportunity

Using virtual reality as a tool to examine brain activity in response to simulated environments may be an endeavour worth pursuing in order to understand how technology can be aided in therapeutic treatment. While virtual reality-based therapy is already a treatment option available for patients in psychotherapy, the potential for mimicking neuropharmacological effects in simulated environments is an unexplored area of research that may prove useful for settings in which drug therapy is not feasible or ideal. As previously mentioned, psychedelic drugs are largely regulated and a simulated environment may provide an alternative method of achieving the desired effects of psychedelic drugs in therapeutic settings. Thus, a research opportunity remains to be explored regarding the implementation of virtual reality to simulate the effects of a psychedelic drug within a psychotherapeutic environment. The application and further experimentation of this research project may prove to be a start in the direction of answering this unknown potential of virtual reality simulations with respect to neuropharmacology. The research project outcome is intended to further our understanding of the brain, mind, and consciousness in a therapeutic and wellness based environment.

A Bio-Technological Opportunity

Within the field of digital media, wellness and specifically therapy based wellness is an area that can benefit from the advancement of new modalities. Virtual reality is largely adapted in psychotherapy when dealing with simulated environments and exposure therapy, as discussed in the literature review. However, combining psychotherapy, psychedelic therapy, and VR technology may result in a new avenue of treatment options and open up new ways to implement digital media technology in other domains such as the health and wellness sectors. Using digital tools and expanding on the data collection through biofeedback, significant developments can be made with respect to the field of digital media. In particular, an area of digital media and technology that may benefit from the proposed research project is the health-tech and biotech industries which are involved in medical health and wellness based technological developments.

Neuroscience Applications

The possible outcome of this research project can be applied to neuroscience and psychology research in a number of ways. First, building the previous research studies reviewed in this paper, psychedelic therapy has proven to be a treatment option for otherwise treatment-resistant depression, PTSD, addiction and other mood disorders. Similarly, virtual reality-based therapy has provided insight into the effectiveness of simulated environments in therapeutic settings as previously outlined. To combine these two areas of research and explore potential neuropharmacological simulations may allow for a breadth of research possibilities. First, simulating drug effects in virtual reality could provide therapeutic applications but also help us learn more about the brain and its responsiveness to simulations, drug effects, placebos, and related topics. Combining virtual reality and neurofeedback in the form of fMRI, EEG, and common neuroimaging techniques may yield results that teach us about various brain areas, neural pathways, and actions of drugs and simulations.

The brain is highly complex and many of its mechanisms and structures are not yet understood. With the development of technology, non-invasive techniques can be used to simulate environments, target and stimulate brain areas, and comparatively analyze drug effects and simulated experiences. The invention of LSD allowed for the discovery of serotonin and its role in neuromodulation. Previous clinical studies of psychedelic drugs have unveiled new information regarding mental illnesses, neuronal activity, and receptor actions as outlined in this paper. Additionally, psychedelic and virtual reality therapy have helped examine topics that extend outside of psychotherapy; metaphysical, philosophical, and spiritual topics have also resulted from the extensive analysis of these modalities. The potential to uncover new discoveries within the brain can lead us to understand the mind, and in turn, ourselves.

MIRAGE: Psychedelic VR Experience

Overview

To test the stated hypothesis and understand the effects of a simulation on the brain, a virtual reality experience, MIRAGE, was designed. The proposed VR simulation experiment focuses on the visual hallucinations often induced by psychedelic drugs. These effects include blurred vision, tracers, increased saturation of colour, dizziness, moving patterns, and textures, among other visual hallucinatory phenomena. The user would thus enter a virtual reality environment and interact with and experience visual hallucinatory effects while immersed in the simulation.

Additionally, a psychedelically inspired interactive website was created for users to understand the inspiration and process of the experience. The website contained both an enter page featuring psychedelic artwork animations of fractals and eye imagery often associated with psychedelia, and a full site featuring demos, trailer, research, and information regarding the design and development process. The trailer of the experience showed footage of the experience set to a psychedelic sitar soundtrack by Anoushka Shankar.

The simulation was meant to be experience using Oculus Rift system, requiring only a head mounted display (HMD). The experience is an open-world environment wherein the user can interact with and be immersed in the desert space while experiencing visual hallucinations as they explore the terrain. The environment also contains realistic desert sounds of wind and animals found in the arid climate.

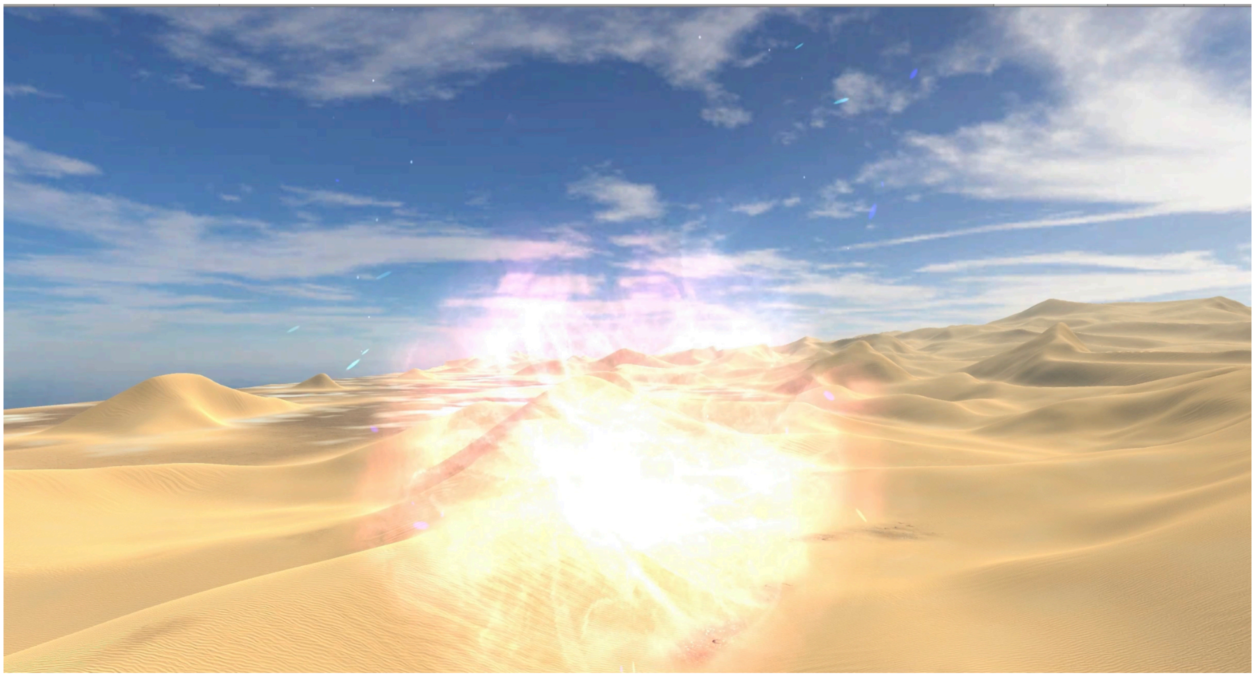

Figure 6. Early prototype still of MIRAGE

Methodology

Preliminary Research

Prior to designing and developing the VR experience, research was conducted through confidential consultation with individuals experienced with psychedelic drugs, and historical scientific documentation of psychedelic drug effects.

Although user reports were subjective accounts, they provided inspiration through the personalized descriptions provided. Users often described their experiences as out of body experiences, often feeling as if they were floating above ground from a third person perspective. Additionally, accounts of patterns moving such as textures of grass and tree bark patterns moving, vibrating, or “breathing”, and floors appearing to move like conveyor belts. It was also reported that colours became intensely saturated, and waves of blurred motion occurred.

One account described the psychedelic experience as “more real than reality”, and that the experience was spiritual such that they felt a part of something bigger than reality. An ego death was also described, where an individual felt their sense of self disappearing, and went on to state that they could switch minds with someone else and it would make little difference; they could thus abandon the concept of self, as well as detach from the people in their lives.

Other effects described included temporal distortion, where a perceived loss of time occurred. One individual described a shared psychedelic experience wherein they referred to their friend asking, "What time is it *here*?", thus suggesting that a sense of time was different in this altered state of consciousness. In addition to distorted sense of time, some accounts recalled a loss of spatial direction where the user continuously got "lost" in their environment unable to follow direction out of a room.

These user accounts were taken into consideration along with the neuropsychological effects described earlier, in order to design an experience that would stimulate the mind and simulate a psychedelic experience.

Design and Development

Originally, the concept of a psychedelic experience in virtual reality was to be set in a naturalistic environment. This is due to the user accounts that depicted individuals taking recreationally taking psychedelic drugs often outdoors in nature. Originally, an experience in a forest setting was decided upon due to the textures of the trees and grass that could be manipulated to simulate many of the effects described during a psychedelic experience such as moving textures and patterns. However, a creative approach was taken perhaps due to the impact of the COVID-19 pandemic which allowed for greater experimental design as a result of impossible experimental design. No user feedback was collected given the quarantine restrictions, and thus a more creative experience was designed in order to bring forth an immersive and interactive journey.

The design was then shifted into a desert setting with the desert serving as a metaphor for the mind; both vast and seemingly endless. Additionally, the title of the experience, “MIRAGE”, refers to an illusion or hallucination that occurs in the desert. A mirage is thus a metaphor for a psychedelic experience. The desert motif was also deliberately chosen to recall the psychedelic landscape of California in the late 1960s, as well as a reference to the psychedelic plants that thrive in the desert such as Peyote.

The design began as a surrealistic painting of a desert landscape. Intended to represent a mental landscape, the experience was designed to be explored individually, with the desert serving as a vast and empty environment upon which the user can interact. The desert terrain was imported into Unity3D from the Unity Asset Store. Many changes and manipulations were made in order to achieve aesthetic and technical effects. First, the landscape’s tone, saturation, and colour were altered to invoke a psychedelic palette. The sky was altered to a bright gradient and the sand’s saturation increased. Additionally, the experience was developed to contain multiple effects, including blurred motion, waves and patterns, moving textures, highly contrasted and saturated colours, as well as feelings of floating above the ground or out of body experiences. These effects were achieved through multiple settings within the Unity interface, inversion of colours, scripting blurs, and utilizing the first person camera effects that occur within virtual reality environments.

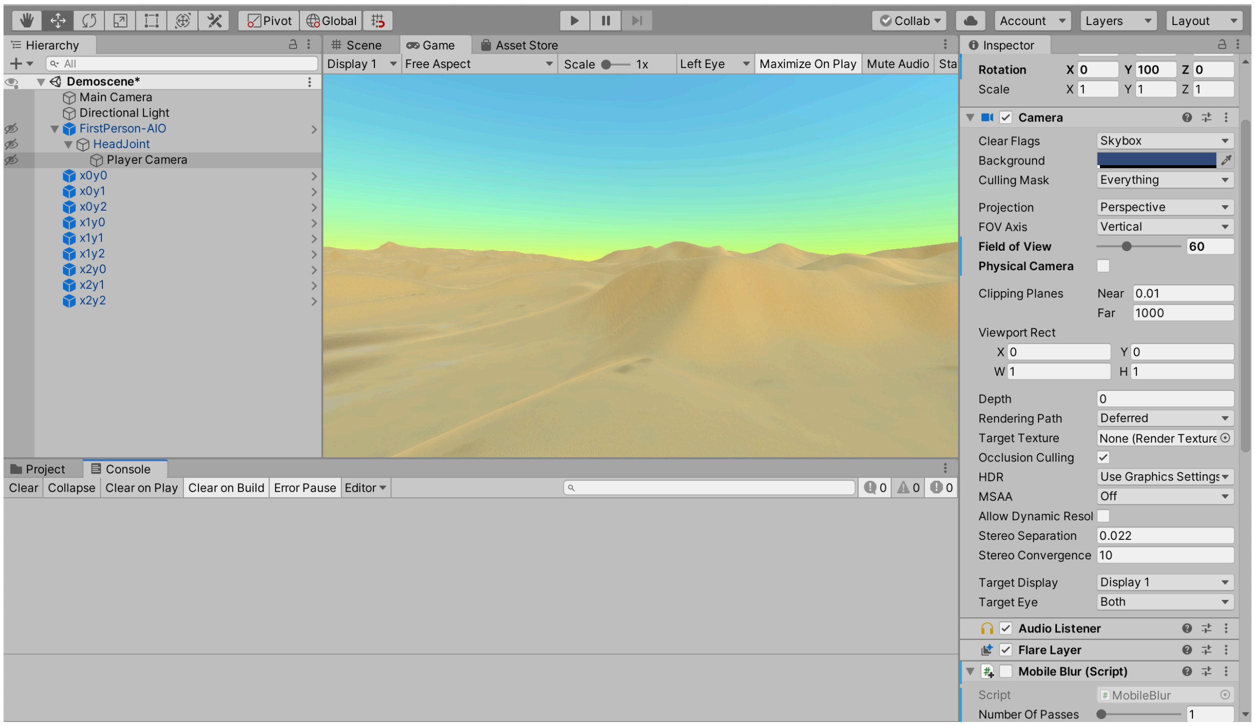

Figure 7. Workflow in Unity3D

Certain characteristics of virtual reality experiences lent themselves to the creation of this project. In particular, virtual reality experiences tend to leave some users feeling disoriented, out-of-body experiences, and generally displaced from the real world. These effects were exploited in the creation of a psychedelic experience, as users often describe similar effects when under the influence of psychedelic drugs. In particular, the first person camera was used to create a disoriented feeling of floating above the ground with a dizzy effect resulting from the abrupt motion. Additionally, blurs and distortions were applied to the camera to create motion that was blurred and unfocused to mimic the effects experienced with psychedelic drugs.

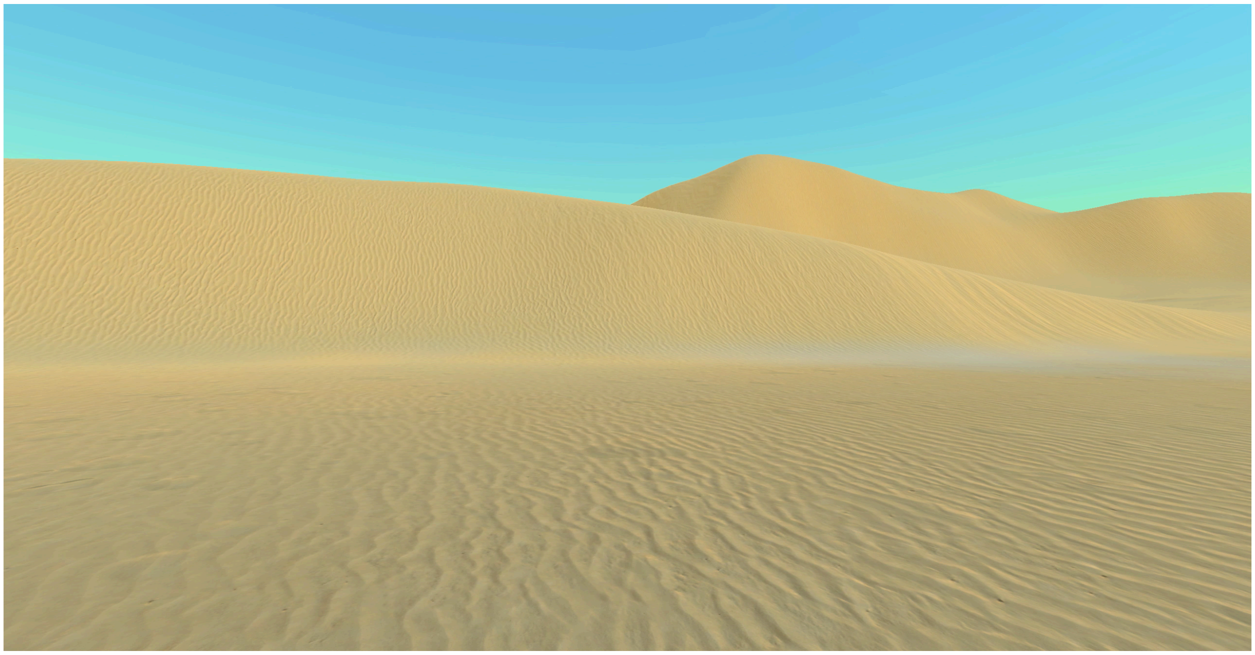

Figure 8. MIRAGE experience still, clear vision.

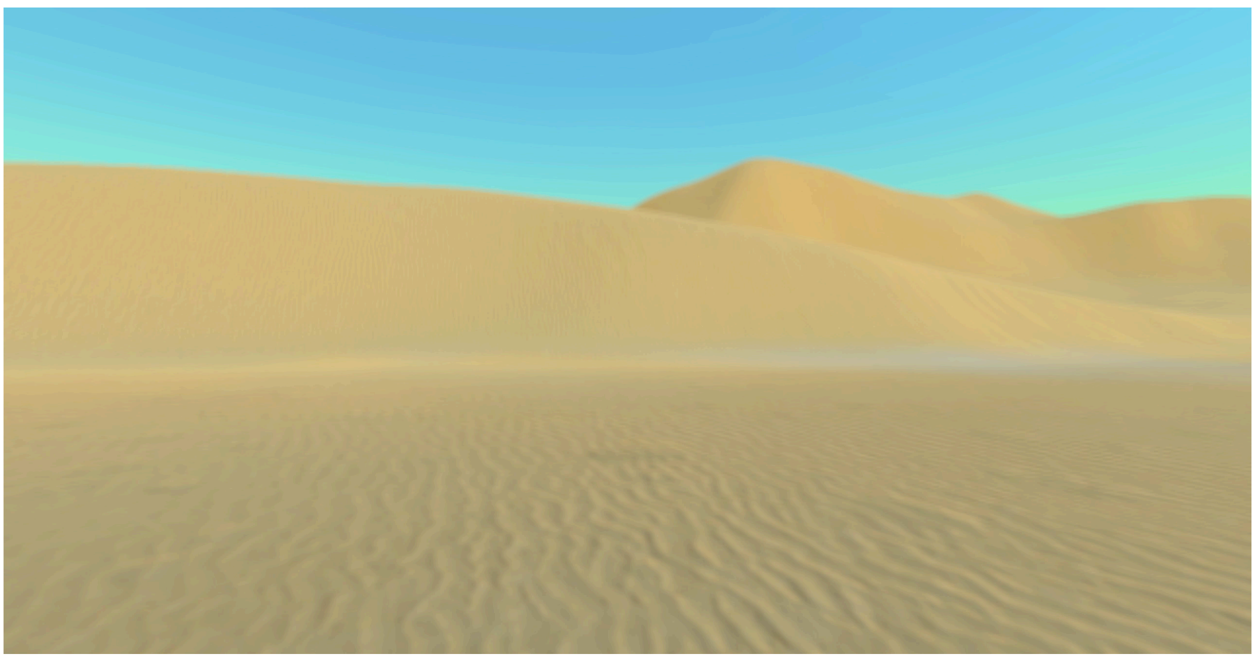

Figure 9. MIRAGE experience still, blurred vision effect.

Furthermore, effects achieved in Unity allowed for the production of realistic psychedelic experience effects such as moving textures and “breathing” objects in the environment. These effects were achieved through motion blur and inverted rays of motion to depict both colour saturation and movement of patterns and textures within the terrain. Finally, moving fractals were incorporated into the environment for artistic effect. These fractals were representative of psychedelia and imagery associated with sacred geometry prominently found in psychedelic art.

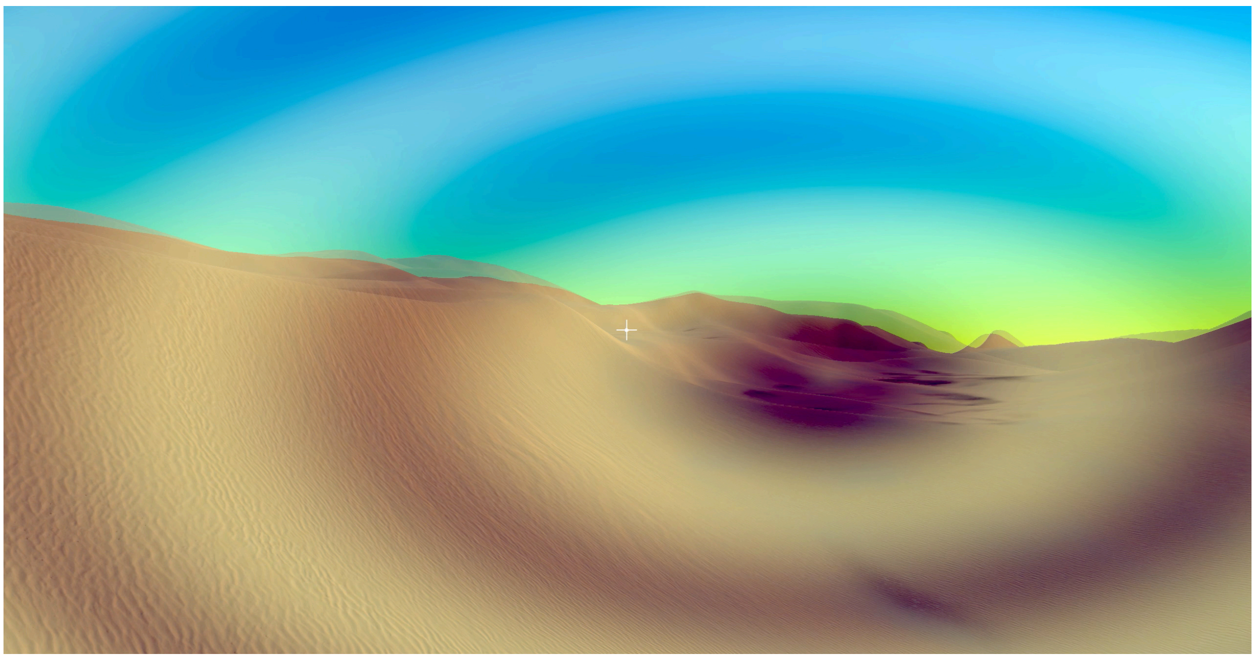

Figure 10. MIRAGE experience still, high colour saturation effect.

Other customizations were made to the desert terrain to achieve a highly colourized environment (see Figure 10). These alterations included bright gradient skylines and highly saturated and sharpened colours in the sand terrain.

Implementation

In order to implement this virtual reality experience, a user would be go through onboarding of VR equipment. Using an Oculus Rift system, a user would be required to wear a head mounted display (HMD) and be free to move around in an open space. The experience is ideally intended to be an immersive and interactive open-world exploration.

In an experimental setting, a number of considerations would be required in order to proceed with user testing. First, participants would be required to disclose of any medical (physical or psychological) conditions that may impact their experience of virtual reality simulations, and specifically simulated visual hallucinations. Once screened, individuals would then be prepared instructed on the precautions and measures needed when immersed in the simulation. For example, participants would be made aware of how to exit the simulation when necessary, how to navigate the virtual environment, and the extent to which they may interact with the experience. Furthermore, a brief overview of the experience would be disclosed to the participants in order to prepare them for the visuals they may experience.

To measure the effects of the simulation, biofeedback would be collected through the use of EEG and fMRI technology. The intention of brain imaging techniques would be to visualize the brain activity and specific areas of neural activation that may be targeted throughout the simulated experience. These results would then be compared with brain activity of participants who had taken a psychedelic drug. By comparing the two groups, we would then be able to understand any similarities and thus highlight the possible potential of a simulated experience to mimic the effects of psychedelic drugs.

Evaluation

Due to COVID-19 restrictions the project was not implemented through experiments and user testing. No lab experiments were conducted to inform the evaluation of the simulation with respect to effective impact on brain activity. Despite the limitations of lack of empirical data, a theoretical framework to assess the simulation's effects has been developed. First, by testing the hypothesis outlined earlier, we can address the key research questions posited in this paper. Should 5-HT2A receptor activity in the frontal lobe increase, then it would indicate that the simulation is affecting similar brain areas (5-HT receptor subtypes) that psychedelic drugs target and bind to. Additionally, the activation and increased serotonin levels would mirror the positive effects of psychedelics as serotonin has been linked to enhanced mood effects. Potential findings that may suggest successful simulation of a psychedelic experience include 5HT2A receptor activity, increased serotonin production and decreased production of serotonin metabolites thus indicating increased serotonin levels.

If participants indicate similar positive cognitive effects and their brain activity closely mirrors the activity resulting from psychedelic drugs then the simulated experience may be considered successful at mimicking the neuropharmacological effects of psychedelics.

The theoretical evaluation of how this experience can be used in a therapeutic setting would rely heavily on the experimental results. Should the experience allow for positive psychological effects, as indicated by participants and their fMRI/EEG results, then further investigation can be conducted into how viable this technology may be for therapeutic application.

Conclusion

Implications for Future Research

To extend this research project, further analysis and experimental data collection would be required to assess the validity of the simulation effects and impact on the neural activity of participants versus drug control groups. As indicated in previously in a theoretical evaluation of the project, acquiring neurofeedback would be instrumental in understanding the extent to which a simulation can mimic a psychedelic experience. Furthermore, additional research would aid in identifying alternative neural areas of activation with respect to psychedelic drug actions. Other receptor subtypes may be of interest such as 5-HT1AR, as well as focusing on specific brain regions such as the Default Mode Network (DMN), and Salience Network (SLN).

Future research may allow for a greater understanding of the brain and mind, when experiencing simulated situations and environments. While previous research has been compiled regarding the efficiency of simulated virtual reality environments and their effects on the brain showing similarities to real-world counterpart environments, little research has been done to quantify the effects of simulating altered states of consciousness. This project may open up a path to understanding how to we can simulate a hallucination which is already “false” perception, and how this can impact the brain’s response and mechanism of detection. The metaphysical experience in a simulation may underline key implications for neuropsychological research. This project may then lend itself to the investigation of how simulated environments impact our brains and in turn, our minds. These findings may be of use to further understand the brain, consciousness, and be applicable to psychotherapy treatments.

Limitations

Despite the potential for virtual reality psychedelic simulations to be utilized in therapeutic settings by mimicking the positive neuropharmacologically induced effects of psychedelics in the absence of drugs, some concerns and limitations exist. Of greatest concern in the unknown impact the simulations may have on users' mind. While psychedelics and virtual reality have both been studied for their strengths and weaknesses, there has yet to be a conclusive investigation into the integration and application of a psychedelic virtual reality simulation. The unknown effects, particularly long term effects, of mind-altering simulation are important to consider and proceed with caution.

Another concern resides in the potential application of this technology in a therapeutic setting. It is vital that both the practitioner and patient are comfortable with the technology, the process, and the experimental effects when utilizing the simulation in therapy. The technological onboarding and comfort and ease of user experience are important to consider when considering therapy applications.

With respect to this research project limitations exist in the lack of user testing as a result of COVID-19 restrictions. Originally, the intention to conduct experiments in order to obtain neurofeedback and data through neuroimaging techniques (EEG, fMRI) studies was imperative. However, due to unavoidable circumstances as a result of the global pandemic, experimental data was no longer obtainable. Thus the project is a theoretical framework which can be further extended to answer a number of research questions stated in this paper. The lack of experimental data is a significant limitation, however this project attempts to form the foundation for a larger research project addressing the potential of psychedelic virtual reality therapy.

The limitations of a simulated virtual reality psychedelic experience are numerous. Many effects of psychedelic experiences are difficult if not impossible to recreate in a virtual reality simulation. For example, beyond visual hallucinations there are effects that are metaphysical, bordering on “spiritual” and often highly subjective. Some users experience spiritual awakenings that feel almost religious, others claim to feel a connectedness to earth and a sense of ego dissolution. These effects go far beyond visual hallucinations that are isolated for within the MIRAGE experience. While the purpose of this project was to investigate the simulation of visual hallucinations in virtual reality and look at specific brain areas responsible for these hallucinatory effects, many other physiological effects are left unaccounted for. Simulating physiological reactions in the body through virtual reality may rove to be difficult without invasive techniques to aid in the simulation. Despite the immersion and interactivity of a virtual simulation, there are aspects of the psychedelic experience that are difficult to recreate in virtual reality. Many of these include subjective and personal experimental factors, depending on a number of factors some of which are uncontrollable, such as individual predispositions, set, and setting. Additionally, the knowledge of being in a simulation may affect the user’s perception and willingness to “surrender” to the experience when they are aware of the simulation being “unreal” relative to the “real world” experiences.

Despite these limitations, the investigation into simulating components of a psychedelic experience in order to address positive cognitive outcomes is a worthy endeavour. Isolating for visual hallucinations and addressing the impact on the brain’s serotonin production and receptor activity may help uncover new understanding of the brain and its processes as well as introduce a potential new modality in psychotherapy and related fields of study.

Summary

The aim of this research project was twofold; first, to examine the current literature on virtual reality psychedelic simulations and identify the existing gaps in existing research studies. Second, to create a simulated psychedelic experience with potential therapeutic applications. The project culminated in both a literature review and proposed hypthoesis accompanying cognitive science based research questions and a working prototype of a simulated psychedelic virtual reality experience. However, the limitations resulting from the COVID-19 pandemic have resulted in a lack of experimental data to clearly assess the project's potential when examining its effective simulation and generation of effects resulting from psychedelic drugs.

While the research allowed for a hypothesis outlining specific areas of neural activation, leading to a theoretical framework from which we can conduct studies in the future, the potential of this project has yet to be tested. However, the foundation of the project has been established both in research supporting the potential of such a simulation as well as the design and development of a virtual environment.

More research would be required to further assess the possibility of a simulated psychedelic experience and its application in regards to psychotherapy. From the basis of current research and a proposed hypothesis, the potential does indeed exist to utilize virtual reality technology in order to stimulate and understand the mind.

Appendix A

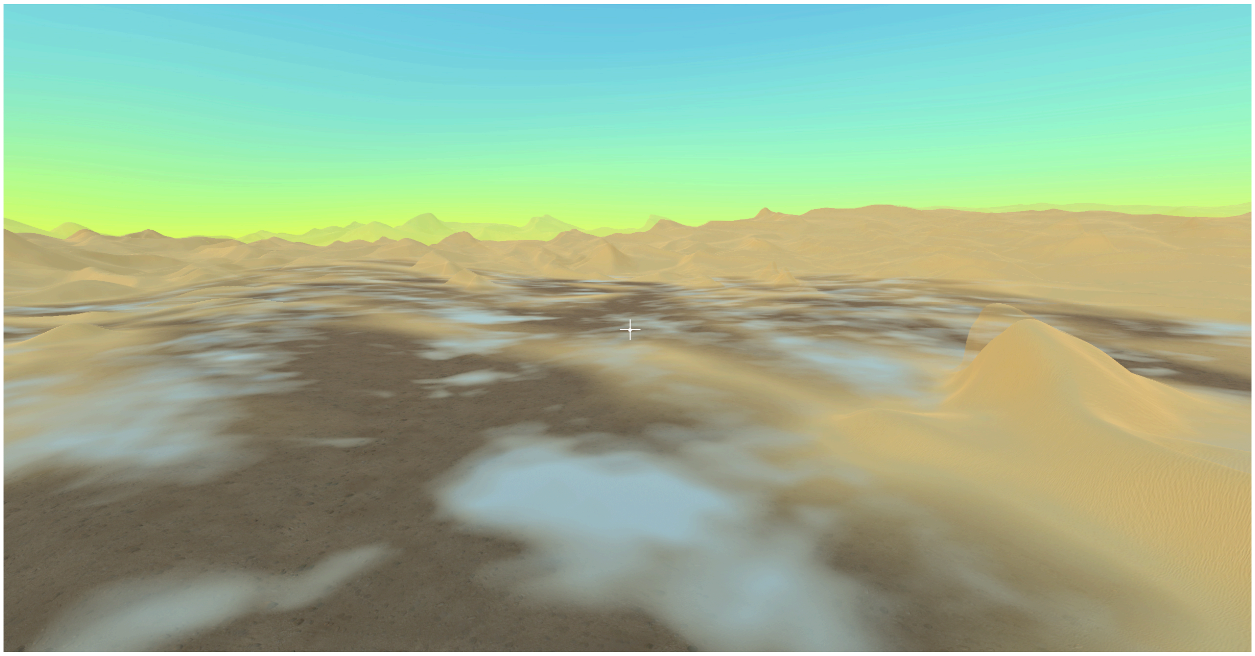

Figure 11. MIRAGE still depicting blurred motion

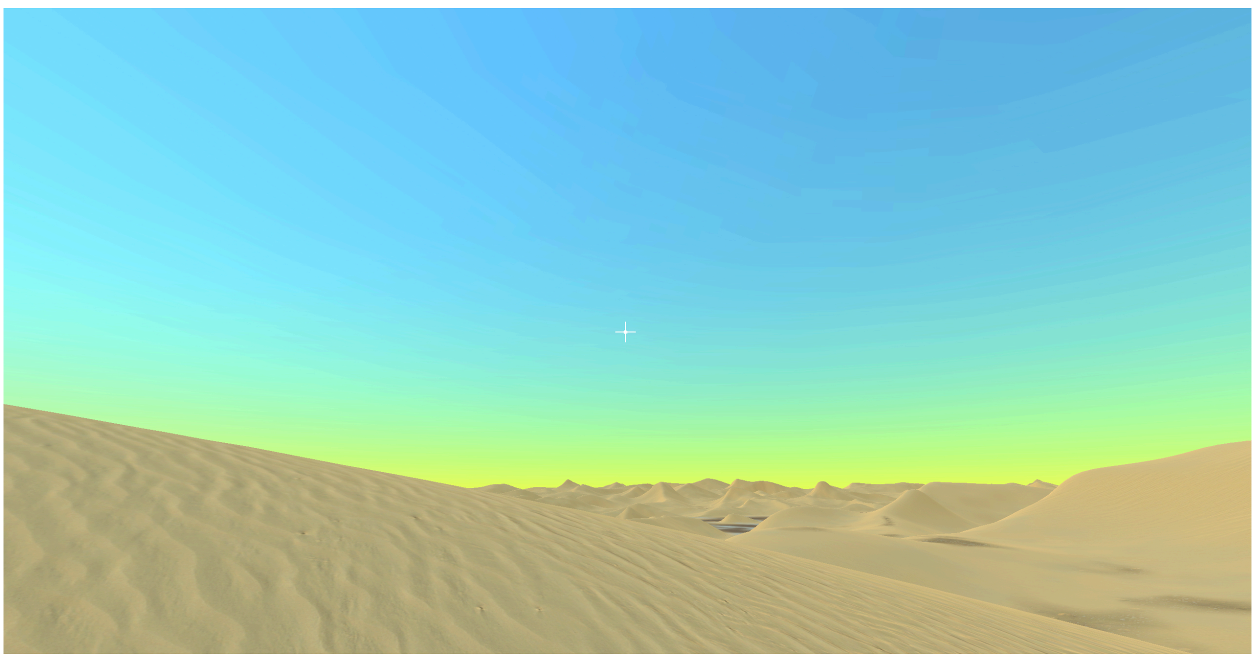

Figure 12. MIRAGE still illustrating a user's view of the desert terrain

Figure 13. MIRAGE interactive website screenshot

Appendix B

Year	Landmark	References
1943	LSD's psychoactive effects discovered by Albert Hofmann (16th and 19th April)	Hofmann, 1980
1947	Werner Stoll publishes first paper on psychological effects of LSD in humans	Stoll, 1947
1950	First English language publication on LSD	Busch and Johnson, 1950
c. 1953	ACNP Founding president Joel Elkes (President in 1961) publishes on LSD after openly self-experimenting with it	Bradley *et al*, 1953; Roberts, 2008
1954	Aldous Huxley's 'The Doors of Perception' published: documents mescaline self-experiment	Huxley, 1954
1956	Term 'psychedelic' coined by Humphrey Osmond in communication with Aldous Huxley	Huxley, 1980
1957	Term 'magic mushrooms' coined by LIFE magazine	Wasson, 1957
1958	Identification of psilocybin in magic mushrooms by Albert Hofmann	Hofmann *et al*, 1958
1959	Closed conference held in Princeton on 'the use of LSD in psychotherapy', Jonathan Cole attends, an early ACNP president	Abramson, 1959
1960	First major European conference on psychedelics; Sidney Cohen publishes positive meta-analysis on LSD safety	Passie, 1996; Cohen, 1960
1961	Jonathan Cole (ACNP president 1965-66) expresses 'very mixed feelings on psychedelic research' as critical commentaries emerge	Mangini, 1998
1962	The Marsh Chapel or 'Good Friday' experiment conducted at Harvard under Timothy Leary's supervision but without institutional approval	Pahnke, 1966; Mangini, 1998
1963	Leary dismissed from Harvard; Aldous Huxley and JFK die (both on 22nd November)	Stevens, 1987
1964	Cole takes 'sober look' at psychedelics in JAMA; discussions on LSD take center stage at 1964 APA meeting; Ken Kesey travels across US taking LSD with 'Merry Pranksters'	Mangini, 1998; Cole and Katz, 1964; Stevens, 1987; Wolfe, 1968
1965	Sandoz stop manufacture of LSD and psilocybin	Stevens, 1987
1966	Prohibition of psychedelics and curtailment of research begins in US; Senator Robert Kennedy formally questions this move	Stevens, 1987; Lee and Shlain, 1992
1967	Timothy Leary declares 'turn on, tune in and drop out' at festival in Golden Gate Park	Stevens, 1987
1970	President Nixon signs Controlled Substances Act, LSD and psilocybin made Schedule I	Stevens, 1987; Lee and Shlain, 1992

Figure 14. Notable landmarks of mid-century psychedelic research with events of cultural significance (Carhart-Harris and Goodwin, 2017)

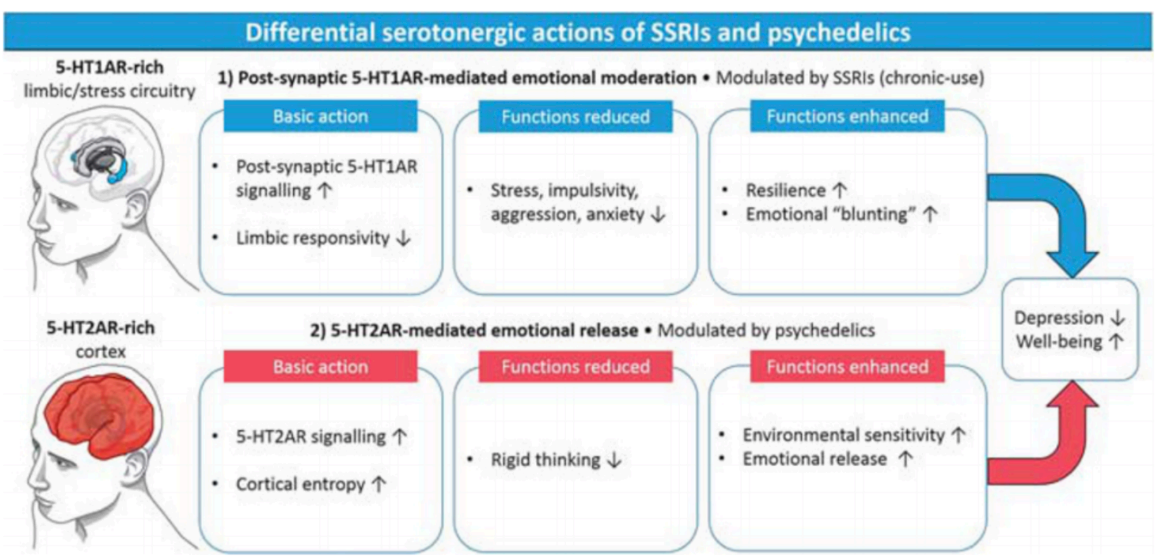

Figure 15. Model of serotonergic functioning of 5-HT1AR and 5-HT2AR receptors (Carhart-Harris and Goodwin, 2017)

	Psychostimulants (cocaine, amphetamine)	Dissociative anesthetics (PCP, ketamine)	Psychedelics (LSD, psilocybin)	Schizophrenia (paranoid)
Supposed pharmacological mode of action	D2R activation	NMDAR blockage	5HT2AR activation	D2R activation/NMDAR blockage
Main type of hallucinations	Auditory	Visual	Visual	Auditory
Most frequent associated delusions	Paranoid	paranoid	Mystical	Paranoid
Most frequent associated behaviour	Agitation	Social withdrawal	Mystical feelings	Variable
Insightfulness	No	No	Yes	No

Figure 16. Characteristics of hallucinations (Rolland et al., 2014)

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