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Exploring Virtual Reality-Induced Anhedonia: A Novel Approach to Reducing Claustrophobic Responses in PTSD affected Individuals

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Abstract

Anhedonia is a psychological condition defined as the reduced capacity to experience pleasure with an increase in emotional numbness. Anhedonia, while not popular by name, is a commonly met symptom associated with post-traumatic stress disorder (PTSD), depression, and anxiety. This condition is increasingly understood as a deviation in the brain's reward processing system, particularly in the anticipatory and consummatory phases. Research suggests that emotional numbing and chronic stress occurs when dopamine pathways and motivational drive are disrupted. In this paper, a deep dive is taken into how Virtual Reality immersive programs, used in exposure therapy for treating anxiety disorders, can be adapted and programmed to specific scenarios that may help induce anhedonic states. The paper uses the Unpredictable Chronic Mild Stress (UCMS) model in animals to propose that VR scenarios simulating sensory deprivation and emotional desensitization stressors may replicate core features of anhedonia. Virtual platforms can be used to mimic disruptions in the hypothalamicpituitary-adrenal (HPA) axis and reward circuitry. Why is inducing anhedonia worth exploring? Inducing anhedonia in a controlled VR environment can help study whether this temporary psychological state can act as a bridge that can be used to mitigate negative reactions in humans, such as claustrophobia. When a subject experiences a temporal emotional numbing, it gives researchers the ability to reduce the emotionally heightened reactions commonly triggered by confined spaces. Ultimately, this research offers a novel direction in the use of VR: not only as a therapeutic tool but also as a controlled experimental medium to investigate emotional numbing and reward dysfunction.

Hypothesis

The hypothesis used for this paper is that utilizing a virtual reality (VR) environment specifically designed to induce anhedonia will prove to be an effective therapeutic intervention for diminishing claustrophobic reactions in subjects. This research paper proposes a narrative based on in-depth research exploring how anhedonia may be deliberately induced in a controlled virtual reality (VR) environment and its relationship to reward processing and emotional numbing. Anhedonia - the reduced ability to experience pleasure - is known to involve impairments in both the anticipatory and consummatory phases of reward processing (Eskelund et al., 2018). The challenge is to isolate how anhedonia differs from emotional numbing, a related symptom, especially in how each affects behavioral learning and emotional responses.

Virtual Reality platforms offer a rich opportunity to steer and control emotional and cognitive functions in a controlled setting. Although it has been used in exposure therapy for conditions like PTSD, its potential to induce anhedonic states is unexplored. By creating immersive VR environments that interrupt or dull normal reward-seeking behavior, this project will test how emotional disengagement can be simulated, observed, and ultimately better understood for further applications.

Anhedonia and Claustrophobia

Anhedonia and claustrophobia are two symptoms that are sometimes part of the diagnostics of post-traumatic stress disorders. Formally diagnosed or not, a PTSD condition is caused by a highly traumatic event in one's life.

The severity of the incident causing claustrophobia-induced PTSD could range from devastating natural disasters, such as earthquakes, hurricanes or tsunamis, to happenings causing life-changing traumas. Each incident of this nature is perceived differently at different ages and varies across cultures. Losing the family livestock in rural Thailand, such as a buffalo for example, can traumatize an entire family as it represents, in most instances, the only source of sustenance, while surviving an elevator crash in a city could cause a similar trauma triggered by a different event.

In contrast, Leng et al. (2024) suggest that anhedonia, another PTSD related condition, is a threat avoidance mechanism by naming it a coping strategy, which can evolve into a maladaptive behavior pattern that could be disproportionate to the actual threat. After experiencing a traumatic event, the involuntary adoption of the defense mechanism, anhedonia, will numb emotions and serve as a protective wall against perceived threats. Such dissociation from a threat induced by a lack of emotions is an expression of anhedonia.

Anhedonia is generally associated with conditions such as post-traumatic stress disorder (PTSD), depression, and anxiety. A severe case of anhedonia could have a lasting mental health impact, which can result in a poor quality of life if left untreated. Eskelund et al. suggest that anhedonia is closely linked to deficits in reward processing (Eskelund et al., 2018). This being said, new and creative therapeutic approaches, such as **virtual reality (VR)**, must be explored to understand and find answers to these conditions. In this context, inducing a mild, temporary state of anhedonia in VR is unlikely to cause harm and can be used to test whether emotional blunting can reduce intense fear responses, like claustrophobia. If successful, this could support more targeted and tolerable treatments for claustrophobia.

As an analogy to engineering terms, (Tye, 2018) an MIT Associate Professor, suggests that dopamine is 'the signal that tells the router to switch over to sending information down the pathway for escape-related behavior.' (*Dopamine Primes the Brain for Enhanced Vigilance*, 2018).

Neurochemical Basis

How do the chemicals in the body react to these stressors? According to medical journals, amygdala corticotropin-releasing hormone (CRH) is directly related to the body's stress response to emotional stimuli. (Mitchell et al., 2024) suggest that one of the key features of depressive behavior, including anhedonia, is an impaired motivational drive, which is directly linked to CRH neuropeptide production. This hypothesis is further supported by Bolton et al. (2018) who performed an anhedonia related experiment on rats. The experiment confirmed that an overactivation of CRH release will dampen the brain's reward system (dopamine) causing a suppression of pleasure signals, in this case craving sucrose. The above is an example of induced anhedonia. With time passing and lack of exposure, anhedonia symptoms might fade away.

Hermann Englert in his Scientific American article called "*Chronic stress makes people sick. But how? And how might we prevent those ill effects?*", articulates that CRH also plays a critical role in subjects with claustrophobia, indicating that when giving CRH as a drug the glands secrete not enough ACTH to help the body deal with this stressor (Englert, H, 2004). ACTH is short for the adrenocorticotropic hormone that is triggered by the release of the corticotropin-releasing hormone (CRH).

As stated in the research above, the two PTSD related conditions are physically triggered by the same CRH neuropeptide production. A CRH overload suggests inducing anhedonia, and the inadequate amount of CRH will disrupt the right amount of ACTH release, causing claustrophobia.

VR Experiment Design

In the virtual reality experiment, participants with PTSD symptoms who suffer from claustrophobia will be immersed in controlled virtual environments designed to trigger anxiety related to confined spaces. Using VR environments to induce anhedonia by manipulating CRH levels in the brain, effectively numbing emotional responses tied to pleasure and fear, the experiment will assess whether this emotional suppression can reduce the intensity of claustrophobic reactions.

This chapter explains the chosen methodology that is used in this experiment. The research is based on a case study focus group of 911 first responders. The goal is to understand how Virtual Reality (VR) environments can help them in their qualification process and everyday work-related activities. The study uses a simple and organized approach based on VR engineering systems. This method helps keep the project on track and sets up an experiment that matches the everyday challenges of 911 first responders. By working with small- and medium-sized groups, the study makes sure the findings are practical and useful in real life. The chosen method ensures the results are relevant and easy to understand for similar establishments that might use them in the future. In addition to looking at how VR can assist first responder organizations, the research also considers the challenges that might arise when using this technology. For example, the study examines how well first-responders can adapt to VR tools and whether these tools fit into their current training programs. By taking a detailed look at both the opportunities and obstacles, this research aims to provide a balanced view of how VR can be used in emergency response work.

VR Development Architecture

The development lifecycle used for creating the VR environment includes four main steps:

1. Planning: This step is created for coming up with the goals and producing a plan for creating the VR environment. It also includes defining the main features of the program. Additionally, it involves collecting data to ensure the VR environment meets real-world needs.
2. Design: During this stage the focus is on creating a user-friendly design, a list of requirements and key elements to which the client, in this case, the first responders, can easily navigate and understand.
3. Coding: This is the step where the VR environment is developed on a programming platform of choice. The researcher writes code and works on developing features such as animations and interactive tools in alignment with the list of requirements.
4. Testing and Validation: Here, the program is validated end to end. The researcher walks through use cases and makes sure the VR environment is easy to use and performs well.

This structured process helps ensure the VR environment is built well and meets the research needs. The next parts of this section will explain how this process was used in the case study. The experiment lifecycle ensures that each step builds on the previous one, creating a seamless transition from planning to the finished product.

Assessment Tools

Component	**Description**
Polar H10	Bluetooth Heart Rate Sensor
CPU speed	64 MHz
Connectivity	Bluetooth: Bluetooth® LE ANT version:2.1 USB cable:No Broadcast range:9000 cm
Sensors	Accelerometer
Battery	Coin cell, 165 mAh

Table 1: Research Technology Specifications

Component	**Description**
Engine	Roblox Engine
Platform Type	Online user-generated content (UGC) platform / virtual world
Deployment Model	Client/Server architecture
Research Role	Experimental, observational platform
VR headsets (optional)	Meta Quest (supported)

Input Modalities	Keyboard, mouse, touchscreen, game controller, VR controllers
Display	2D, 3D, stereoscopic (VR)

Table 2: Platform system Specifications

What is the assessment named Temporal Experience of Pleasure Scale (TEPS)? According to David John Hallford and David W. Austin, the Temporal Experience of Pleasure Scale (TEPS) is a multidimensional self-report measure used to better understand the anticipation ("wanting") and consummation ("liking") aspects of reward. The TEPS has also been employed to assess anhedonia in individuals with clinical depression.

Sensory Deprivation and Emotional Numbing VR environments can be designed to limit sensory stimulation. For the initial phase of this experiment, the Roblox platform is considered a safe and appropriate option, as opposed to using VR enabled headsets, which in an initial phase caused cybersickness, panic and discomfort.

Anhedonic Priming and VR Exposure

The method of studying the hypothesis mentioned earlier is to explore whether inducing a mild, temporary form of anhedonia in a controlled virtual reality (VR) environment can help reduce intense emotional responses, specifically, those triggered by claustrophobic situations in individuals with PTSD symptoms.

To test this, participants are placed in low-stimulation VR environments designed to feel emotionally flat or monotonous, such as desolate places, bland color palettes, and minimal interaction. This is known as *anhedonic priming*. According to Cherry (n.d.), priming is a technique in which the introduction of one stimulus influences how people respond to a subsequent stimulus. See Figure 1:

Figure 1. *Illustration of desolated environment to induce anhedonic state*

Stress Induction in VR environments

VR System Description

The VR system developed for this case study leverages virtual reality technology in order to study the therapeutic impact of temporarily inducing anhedonia on subjects seeking to address claustrophobia related symptoms in PTSD subjects.

The system utilizes VR technology to induce, through exposure, emotionally neutral sensations intended to temporarily suppress participants' emotional responses (inducing anhedonia). Once an anhedonia state is induced, the subject is exposed to virtually built claustrophobic scenarios. This strategy is designed to analyze if inducing anhedonia can reduce claustrophobic reactions.

The data collected is physiological and self-reported anxiety measurements. Building on the Unified Chronic Mild Stress (UCMS) model in animal studies, which has effectively induced anhedonia to simulate depressive symptoms for assessing therapeutic outcomes, this VR system adapts similar concepts (Burstein & Doron, 2018). In the UCMS model, inducing anhedonia in mice through exposure to unpredictable, low-level stress, has shown significant reductions in pleasure-seeking behaviors. The measurements were verified via the Sucrose Preference Test (SPT), which showed a reduced interest in sucrose after anhedonia induction.

The UCMS research results support the notion that anhedonia can be systematically induced and measured, and is offering a valuable model for understanding mood and anxiety-related disorders. The VR System suggested for this experiment applies these principles in human participants, and is providing an ethically feasible approach to evaluate anhedonia's impact on claustrophobia within a PTSD context.

After repeated exposure to these conditions, participants will then enter VR scenarios that simulate mild claustrophobic stress, like enclosed elevators, mazes, or tunnels - see Figure 2-3.

Figure 2. *Illustration of a virtual maze*

Figure 3. Illustration of a VR dark claustrophobic tunnel

By comparing emotional and physiological responses before and after the anhedonic priming, the method will assess whether the induced emotional numbing dampens the typical fear response. Mitchel et al. research suggests that anhedonia is linked to a reduced response in the brain's reward circuitry (Mitchell et al., 2024).

When an individual is repeatedly exposed to a neutral or monotonous VR scenario, the response to stimuli may weaken over time. This method is similar to the Unpredictable Chronic Mild Stress (UCMS) model in mice, in the research performed at the Tel Aviv lab by the National Institute for Psychobiology, where anhedonia was successfully induced by exposing animals to unpredictable mild stressors (Burstein & Doron, 2018).

Virtual reality customized scenarios can create a digital equivalent of chronic environmental monotony, potentially dampening dopamine release and altering reward processing. Inducing and controlling emotional dulling in a safe, virtual environment can help us study anhedonia and alleviate claustrophobia, while also potentially leading to more effective interventions for trauma-related anxiety. This approach is particularly valuable where emotional overstimulation makes traditional exposure therapies difficult to tolerate.

Translating Animal Stress Models to VR

In theory, the principles demonstrated in the UCMS study conducted on mice at the National Institute for Psychobiology (NIP) — where prolonged exposure to mild, unpredictable stressors resulted in long-term depressive-like behaviors (Burstein & Doron, 2018) — can be translated into virtual reality applications for humans. Personalized or adaptive VR environments may help replicate similar, mildly stressful conditions, triggering comparable neurochemical changes in subjects.

Phased Experimental Procedure

Phased Approach

The VR System engages participants in multiple experimental phases:

Phase 1: Physiological Responses setup and creating baseline

Purpose: Establish a baseline for participants at resting state

Measurements:

Self-Reported Claustrophobia :
Claustrophobia Questionnaire (CLQ): Measures anxiety level in response to confined spaces. Collected during both pre- and post-anhedonia exposure.

Self-Reported Anhedonia :
Temporal Experience of Pleasure Scale, TEPS: Assesses both anticipatory and consummatory pleasure on a six-point Likert scale to verify the induction of anhedonia (Case et al., 2021).
Physiological Responses:
Heart Rate (HR/RR): Elevated heart rate will indicate heightened anxiety or stress.

Phase 2: Anhedonia Induction:

Purpose: anhedonia induction, characterized by emotional desensitization or reduced ability to experience pleasure, aimed to experiment if it can act as a buffer against claustrophobic anxiety.
Procedure: Participants are immersed into a monotonous, non-engaging VR environment specially designed to produce an anhedonic state.
Duration: Participants will experience the anhedonic VR environment for a predetermined number of minutes.
Verification: After exposure, participants will complete the Temporal Experience of Pleasure Scale, TEPS to assess the induction of anhedonia.

Phase 3: Post-Anhedonia Claustrophobia Testing:

Purpose: Reassess claustrophobic anxiety post-anhedonia to examine changes in emotional reactivity.
Procedure: Immediately following the anhedonia induction, participants re-enter the original claustrophobic VR scenarios.
Verification: After exposure, participants will complete the Claustrophobia Questionnaire (CLQ): Measures anxiety level in response to confined spaces.
Metrics Recaptured: The system again captures HR, and self-reported anxiety to compare with baseline levels.
Control Condition:
To provide a basis for comparison, participants also complete the entire protocol without anhedonia induction (in a neutral VR environment) during a separate session.

Outcome Measurement and Analysis:

- **Objective**: Determine if the anhedonic state mitigates claustrophobic anxiety by comparing baseline and post-anhedonia data.
- **Expected Results**: Reduced CLQ scores, lower HR readings, and fewer avoidance behaviors would suggest that anhedonia acts as a buffer, decreasing claustrophobic anxiety.

Expected Outcomes and Experimental Procedure

The first expectation is checking if anhedonia has been effectively induced, and for this, participants will complete the Temporal Experience of Pleasure Scale (TEPS) before and after the VR exposure. A measurable reduction in TEPS scores would suggest a temporary dampening of both anticipatory and consummatory pleasure. Following the anhedonia phase, participants will be placed in a second VR environment designed to induce claustrophobic discomfort, such as a confined elevator or narrow tunnel. During this virtual exposure, physiological responses like heart rate and behavioral data such as exit attempts (i.e.,asking to stop the experience) will be recorded. Theoretically, we expect that participants who experience the anhedonia-inducing VR conditions will show a reduced stress response during the claustrophobic scenarios.

Physiologically, the expectation is lower heart rate readings, fewer exit attempts, and decreased self-reported anxiety. If these outcomes are observed, they would support the hypothesis that temporary emotional numbing - when deliberately and ethically induced - can reduce the intensity of fear-based reactions. This could offer a new direction in therapeutic design, where emotional modulation becomes a preparatory step for exposure to difficult psychological stimuli.

Pilot Study and Feasibility Assessment

VR Feasibility Assessment

In the first pilot experiment performed on a young male, the key RR variations are analyzed according to the selective criteria of any changes beyond ±100 ms are most likely meaningful responses to stimuli or activity. RR intervals calculated in milliseconds represent the time between two consecutive peaks recorded by an ECG machine. It captures the instantaneous heart rate as:

- **Shorter RR → faster heart rate** (HR ↑)
- **Longer RR → slower heart rate** (HR ↓)

According to Smith and Smith (1981) heart rate variability in healthy subjects has the resting RR interval in the range of 654.6-1141.4 ms and a mean value of 864.7 ms.

In the analysis of the anhedonia inducing experiment for reducing claustrophobic reactions in subjects, we will be using 787 ms as the *starting baseline*. This value is the lowest value recorded at the beginning of the session.

The pilot experiment lasted for 11:32 minutes. Because the RR intervals are recorded in milliseconds, the first step is to convert data collected from ms into seconds and then into minutes.

After the conversions, the following step was to match significant RR variations timestamps to events happening during the recorded session and put them in a table.

Key RR variation events for Subject number 1

Summary of findings:

- The data collected contains both short, sharp accelerations at timestamps: 0:30, 2:54, 11:13 and long slow periods at timestamps: 4:58, 6:25, 9:21.
- Indicators for large positive (>400 ms) are strong indicators of slowing heartbeats (HR falling into ~45–50 bpm) which suggest positive anhedonia induction.
- Indicators for large negatives (-197, -203, −251 ms) indicate strong heartbeats activation (HR rising into >100 bpm) suggesting sudden stress, or intense emotions.
- The sequence of these variations correspond to VR activities designed for inducing anhedonia and mitigating claustrophobic reaction.

Key RR variation events Subject number 2

Summary of findings:

- For Subject number 2, there are slightly less significant variations in RR and HR data.
- The data collected contains mostly mild RR variations at timestamps: 8:34, 8:35, 11:43; with only one long significant RR shift at timestamp 11:47.
- Indicators for large positive (>400 ms) are strong indicators of slowing heartbeats (HR falling into ~45–50 bpm), which suggest positive anhedonia induction – in case of Subject number 2, claustrophobia mitigation.
- The sequence of these variations for Subject number 2, confirms expected outcomes triggered by VR activities designed for inducing anhedonia and mitigating claustrophobic reaction.

Notable Adjustments

In the initial stage of the experiment, during the anhedonia induction phase, one of the candidates started to experience cybersickness, which resulted in an immediate termination of his session.

An adjustment of eliminating the use of the VR headset for future experiments was put in place, and for the safety of the participants, we decided to refrain from using VR headsets while participating in the experiment. The future interactions will be limited to the other modalities provided by the Roblox platform and use standard game controllers used in 2D virtual environments.

Novelty of VR-Induced Anhedonia

This paper takes a new approach by using virtual reality (VR) to intentionally induce anhedonia in humans, something that has not been done before. While past studies, such as the UCMS research on mice by the National Institute for Psychobiology (Burstein & Doron, 2018), have shown that prolonged exposure to mild, unpredictable stress can cause long- term depressive-like behaviors, this study translates those findings into immersive VR environments. By designing virtual scenarios that simulate unpredictable and mildly stressful experiences, this project explores whether similar neurochemical responses, particularly changes in cortisol and CRH levels related to the hypothalamic-pituitary-adrenal (HPA) axis, can be triggered in humans (Englert, 2004).

Unlike previous research that uses VR primarily as a treatment tool for anxiety and PTSD, this work investigates whether VR can also be used to simulate the emotional and cognitive disruptions seen in anhedonia. This represents a shift in how VR is used: not just to reduce symptoms, but to recreate them in a controlled setting for research purposes.

The novelty of employing virtual development platforms and creating rich, emotionally neutral, or monotonous environments to help simulate the blunted emotional responses and disrupted reward processing found in individuals experiencing anhedonia.

Directions for Future Research

The project also opens up new possibilities for future studies. By testing how VR affects emotional responsiveness and reward sensitivity, researchers may be able to better understand how anhedonia develops and persists. Over time, this could lead to more targeted therapies that restore healthy reward functioning.

What makes this work truly novel is its use of VR not just as a treatment, but as an experimental platform to simulate emotional numbing. This technology-driven method offers a new way to study anhedonia and deepen our understanding of how emotional and reward systems break down in conditions like depression and PTSD.

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Author Biography

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Dan Benedict received his Master of Science in Project Management (MSPM) from the University of Southern California (USC) in 2021 and is currently a PhD candidate in Systems Engineering at Colorado State University, with a research focus on virtual reality systems, immersive technologies, and their interaction with human behavior. He is a 20-year veteran technologist who has worked on cutting-edge technology development at major technology companies, including Microsoft and, more recently, Google, where he focuses on managing ASICs and smart NICs to enhance global data center performance, as well as advancing machine learning and AI lead engineering systems.

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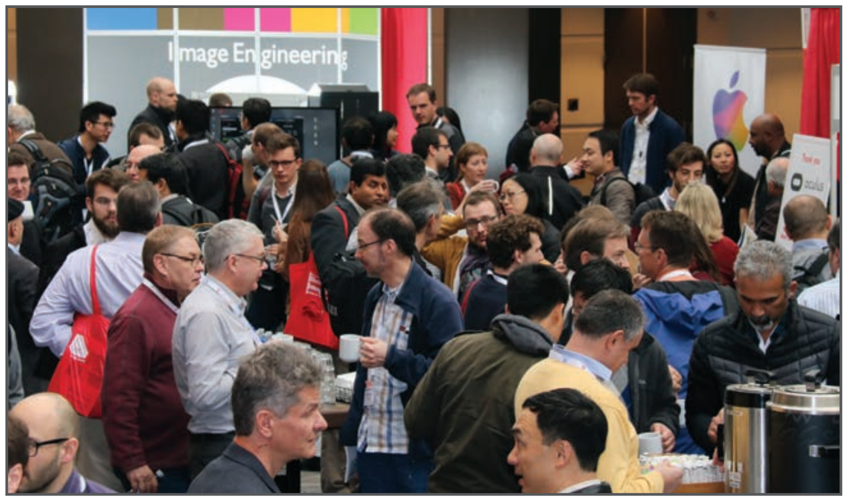

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