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Leveraging Virtual Reality to Investigate the Relationship between Psychological Disorders, Hormonal Secretion, and Nutrition

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Abstract

Psychological disorders such as anxiety and depression are complex conditions influenced by hormonal imbalances and nutritional factors. Due to environmental variability and challenges in participant engagement, traditional research methods often struggle to capture the dynamic interplay among these elements. This study leverages virtual reality (VR) technology to create immersive and controlled environments for investigating the relationships between psychological disorders, hormonal secretion, and nutrition. We utilized VR to assess and influence hormonal secretion and psychological symptoms in fifty adults diagnosed with anxiety or depressive disorders. Participants engaged in VR sessions that included stress-inducing scenarios and educational content on nutrition. Salivary cortisol levels were measured before and after the VR interventions to assess stress responses, while standardized psychological assessments were administered both before and after the intervention. Nutritional intake was monitored using a VR-integrated food diary app. Statistical analyses revealed significant reductions in cortisol levels and improvements in depression and anxiety scores post-intervention ($p < 0.001$). The findings demonstrate that VR-based interventions can effectively reduce stress hormones, improve mental health outcomes, and promote healthier nutritional behaviors, highlighting the potential for integrating VR technology with dietary interventions in holistic treatment strategies for psychological disorders.

Keywords—virtual reality (VR), hormonal secretion, stress hormones, mental health, nutrition intake.

1 Introduction

Psychological disorders, such as anxiety and depression, are pervasive mental health conditions that significantly impact individuals' quality of life and place a substantial burden on healthcare systems worldwide [1]. According to the World Health Organization, depression affects over 264 million people globally, making it a leading cause of disability. Anxiety disorders are similarly widespread, affecting approximately 284 million individuals. The etiology of these disorders is multifaceted, involving a complex interplay of genetic, environmental, biological, and psychological factors[2]. Among the biological components, hormonal secretion and nutritional status have emerged as critical areas of interest in understanding and managing psychological disorders.

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1.1. Background

Bios secreted substances, also known as hormones, are chemical signals that help regulate diverse bodily functions, such as mood, stress, and thought. Stress hormone cortisol[3] is central to the body's response to stress. Cortisol secretion disruption has been seen as a cause of anxiety and depressive disorders and their worsening. Hypercortisolemia leads to alterations in brain regions, including the hippocampus and the prefrontal cortex, which are associated with memory and stress-related functions.

Serotonin and dopamine are neurotransmitters involved in mood regulation through signaling in the body. [4]. Differences in these neurotransmitters are considered to cause depression and schizophrenia, respectively. The targeting of these hormonal pathways is likely to present therapeutic points for addressing mental health disorders.

Nutrition plays a crucial role in hormonal balance and mental functioning. [5]. There is evidence that dietary intake influences the biosynthesis and activity of neurotransmitters and hormones. For example, omega-3 fatty acids are found in neuronal membranes and have an impact on serotonin receptors. There are macronutrient deficiencies and micronutrient deficiencies; the macronutrient deficits include vitamins, minerals, and essential fatty acids. When they are not present in the body, they lead to hormonal imbalances. On the other hand, the intake of high amounts of processed sugars and saturated fats in products compromises the body's hormonal balance and could lead to mental breakdowns.

Virtual reality (VR), one of the most promising technologies, has recently developed various aspects of a real-like experience. In applied psychopathology and therapy, VR has been used in exposure therapy for phobias, post-traumatic stress disorder (PTSD), and other anxiety disorders. The integration of environmental factors is possible, and accurate physiological and psychological indices are feasible to measure in a VR setup, as shown in Figure. *1*.

Figure. 1. The relationship between psychological disorders, hormones, nutrition, and virtual reality interventions.

There are reasons why VR integration into the evaluation of psychological disorders is effective. It allows for the construction of identical stress-provoking or treatment conditions, minimizes extraneous variables, and has greater external validity compared to other laboratory paradigms. Nutritional education and intervention are distinct domains that can be delivered using virtual reality technology, potentially increasing engagement and the efficacy of the treatment.

1.2. Research Gaps

While it is well established that hormonal secretion as well as nutrition play a critical role in psychological disorders, there is a lack of studies investigating their application within a VR paradigm. Many conventional research approaches struggle to manage extraneous factors and effectively capture participants' attention. The prospects of VR for surmounting these limitations have not been adequately investigated for hormonal responses and nutrition interventions.

Although separate works have focused on hormonal disruption or nutritional state as influential in mental disorder development, no previous studies have provided a comprehensive analysis of interactions between all psychological disorders, hormonal secretion, nutrition, and VR. That is why new directions in methods are needed to help describe these interactions and reveal effective treatment strategies.

This study aims to fill these gaps by employing a virtual reality approach to examine the complex interactions between psychological disorders, hormonal secretion, and nutrition. The primary research challenges guiding this paper are:

1.2.1. What are the opportunities to use virtual reality to build controlled conditions that would allow testing/resetting hormonal secretion/psychological symptoms in patients with Pressure Ulcer Pain Management and/or psychological disorders?

1.2.2. What are the effects of the VR-based interventions on the hormonal cortisol and psychological parameters, perceived depression, and anxiety scores?

1.2.3. In what way does nutrient consumption affect hormonal release and psychological manifestations of a disorder within a VR environment, and to what extent is it possible to alter nutritional behaviors with VR therapies?

Do alterations in caloric intake moderate a VR interventionist's impact on hormonal equilibrium as well as psychological well-being?

1.3. Problem Statement

The principal research question that this study aims to address is the lack of knowledge about the conditions under which psychological disorders and hormone secretion/nutrition interact, and how these phenomena can be researched and modulated employing new technologies such as virtual reality. These issues are often not necessarily well addressed by more conventional research approaches because the interactions between these factors can be nonlinear and/or reciprocal, and also because the settings for interventions often need to be more naturalistic yet engaging for the participants.

By integrating VR into the research methodology, this study aims to:

- Enhance the Precision of Measurements: By using VR, we have standardized stress and relaxation protocols and built accurate stimulation to measure exact hormonal and psychological responses.
- Enhance Participant Engagement and Intervention Delivery: Leverage the inherent features of the VR platform to deliver education on nutrition and other behaviors in a novel and potentially more effective manner.
- Elucidate Complex Interactions: Analyze both positive and negative cross-connections between psychological symptoms as the independent variable and hormone secretion

as the dependent variable, as well as nutrition as the total dependent variable within the confined entity of a controlled VR environment.

- Develop Holistic Treatment Approaches: Investigate how integrating virtual reality technology with nutritional therapy can enhance the formulation of comprehensive treatment plans for psychological conditions with both biological and behavioral roots.

1.4. Objectives

Appreciation of these relationships has a profound impact on the management and treatment of mental diseases. If these types of VR interventions are to prove capable of altering hormonal releases as well as enhancing nutritional practices, they can also be useful adjuncts to conventional treatment modalities. This approach subscribes to the trend towards Precision Medicine and Health that recognizes the need to treat a patient comprehensively, that is, holistically.

In addition, this work enriches the current research on virtual reality in medicine, as its areas of application are not limited to exposure therapy, but also include hormonal and nutritional interventions. The results may therefore provide a basis for future work and the development of novel interventions that utilize technology in conjunction with psychological and nutritional approaches in clinical settings.

This research aims to understand the interaction between hormones, diet, and simulations of daily activities in individuals with psychological conditions. Research questions are posed in the investigation, which also examines the factors driving the interactions between these organisms. It also briefly discusses how virtual reality may aid in the reconstruction of identity during evaluation and treatment. Results should improve the methods healthcare professionals use to work with patients experiencing psychological issues.

2 Related Work

2.1- Hormonal Secretion and Psychological Disorders

Hormones are chemical messengers that regulate various physiological processes, including mood, cognition, and stress response. Cortisol, commonly known as the stress hormone, has been implicated in anxiety and depression. Elevated cortisol levels can lead to hippocampal atrophy, which in turn affects memory and emotional regulation. Serotonin and dopamine imbalances are also linked to depression and schizophrenia, respectively.

Hormones are body chemicals that act as signaling molecules within the human body to control aspects such as mood, cognitive function, and stress response. You cannot hear Cortisol, the stress hormone, being associated with anxiety and depression. High cortisol levels can cause hippocampal damage, which in turn affects memory formation and the regulation of emotional functioning. The same is true for serotonin in depression and dopamine in schizophrenia, neural transmitters or receptors.

In the presented work in [6], it was shown that relationships between endocrine disorders and neurological or psychiatric symptoms and syndromes have been described, but many of these connections have remained only partly explained. Most of these manifestations came from hormonal disorders, autoimmune reactions, genetically induced mutations, or as a result of treatments that affected both systems. Many patients presented with neurological and psychiatric disorders of the hypothalamus and pituitary disorder,

which often and invariably resulted in endocrine dysfunction, which all highlights the psych-neuroendocrine relationship. The research topics included were circulating irisin in women with anorexia nervosa, physical health and psychological well-being among women with PCOS, and gender dysphoria: assessment and management. Nine reviews covered neuropsychiatric complications of acromegaly, persistent symptoms of Cushing syndrome after the management, and laryngeal nerves in thyroid surgery. The metabolic associations of neurologic signs were also studied, including AN-R and constitutional thinness, obesity, neuroinflammation, appetite, psychoses, and ghrelin peptides. These results underscore the need to achieve perfect synergy between quantitative and qualitative research methods to enhance the existing understanding and experiences in this field.

In[7], it was established that hormonal alterations in eating disorders (ED) could be a consequence of biochemical stress of malnutrition or starvation or not, while the connection between DA and Somatotropic axis abnormalities and ED psychopathology is not very clear. The participants of the study included 136 ED patients with ANR, ANBP, ANP, BN, EDNOS-AN, and EDNOS-BN, and 30 Healthy controls where plasma levels of GH and IGF-1 were compared. Measures via EDI-2 and SCL-90 suggested that there is a hormonal influence on certain psychopathological aspects of anorexic patients, where lower IGF-1/GH levels were significantly related to more marked symptoms in subscales such as drive for thinness and body dissatisfaction, as well as severity in depression and anxiety symptoms.

Trialed in one of the introduced works in [8], the use of virtual reality (VR) was identified in the treatment of eating disorders (EDs), enabling staged exposure to a range of feared stimuli due to its ability to create realistic environments. The initial studies concentrated on deriving body image disturbances as well as cue exposure therapy for managing the urge for food and anxiety linked with binge eating, or restrictive behavior. Research has shown that VR-based treatment improves ecological validity and the transfer of treatment gains over conventional approaches. In addition, VR-supported understanding of the lack of stability of body image disturbances and their context in the environment, while allowing for experimentation with possible interventions such as body exposure and bodiliness. However, issues such as cost, availability and side effects put on by the treatment restrained its use among the larger population.

Cortisol and serotonin levels were examined in depression in the study of [9] among the post-treatment acute coronary syndrome (ACS) patients. Drug treatment was followed by the prevalence of depression in the 73 participants: 57.53 years of age, and 68.5% males. In particular, the median serotonin level in depressed patients was significantly lower [175 vs. 189.31, CI 95%] and the cortisol level, vice versa, was substantially higher [3.09 vs. 2.15, CI 95%]. By contrast, analysis of variance revealed no correlation between serotonin (<Chi value> = 0.482) or cortisol (< Chi value> = 0.275) and depression. However, the presented time-trend analysis suggests a clinical value for future research into hormonal effects for depression in ACS patients, even if the latter did not reach a statistically significant value.

2.2. Nutrition's Impact on Hormonal Balance

In this case, nutrition has a significant impact on hormonal balance. Omega-3 fatty acids, vitamins, and minerals make sure that neurotransmitters function effectively. For example, dietary omega-3 fatty acids, which are relevant to neuronal membrane fluidity, interact

with serotonin receptors. On the other hand, foods that contain a lot of sugar and saturated fats may have negative impacts on hormones, thus exacerbating psychological symptoms.

In [10], the study was carried out to investigate the mechanism between dieting, hormones, and mood, with a special focus on how dietary practices impact stress and mood. Some signs were also attributed to hormonal imbalances, particularly those attributed to poor diet, and included mood swings as well as anxiety. In a sample of 500 female respondents, fast food consumption was found to have a positive relationship with stress, whereas stress was negatively associated with the intake of fruits and vegetables. For example, the impact of age and gender proved to be insignificant in these results. The participants exhibited poor understanding and possibly basic nutritional knowledge, which failed to enable them to observe proper healthy dietary practices. Several lessons emphasized the importance of nutritional journalism and other behavioral strategies in promoting healthy eating and wellness.

The review described in [11] expanded on emergent discussions on nutrition, hormonal balance, and gender aspects, focusing on dietary effects on obesity-induced endocrine dysregulation and metabolic dysfunction. This work discussed the impact of restricted calorie intake, the so-called Western diet, high-fat diets, low-carbohydrate diets, plant-based diets, and diets adherent to the Mediterranean diet on hormones in men and women. The findings also pointed to the need to consider gender-specific metabolic differences, fat patterning, and macronutrient requirements, especially among transsexual populations. More specifically, further work should focus on the processes underlying the effects of diet on hormones and develop specific strategies based on metabolic and hormonal data. Adding sex-related factors to diets can enhance the metabolic well-being of people of different sexes and also improve their hormonal systems.

2.3. Virtual Reality in Psychological and Physiological Research

Virtual reality has emerged as a powerful tool in psychological research, offering immersive environments for therapy and assessment. VR can simulate real-life scenarios in a controlled environment, allowing for the precise manipulation of variables and the measurement of responses. Studies have shown VR's effectiveness in treating phobias, PTSD, and anxiety disorders by providing exposure therapy in a safe environment.

The paper discussed in [12] investigated the possibility of combining VR technology with psychological treatments of EWD. Scientists believe that such VR technologies could be more effective solutions to the underlying causes of these disorders, rather than just targeting simple obesity. VR was used to provide multisensory, extra information and embodiment, thereby constructing motivation and developing individualized treatment methodologies for patients. The studies identified that the immersive VR designed inviting contexts for intervention application, while the observations of eating and affect in the VR environment provided new knowledge. Non-emergency applications of VR included the use of visuotactile stimulation and body swap avatars to address body image and self-regulation issues. The integration of cognitive-behavioral therapy. CBT and MI in avatars offered enhanced exposure to hexing situations, encouraging students to adopt better lifestyle modifications. Moreover, such HR playing as a psych-educational and participatory role demonstrated the ability for patients to cope better with certain conditions. It also demonstrated effectiveness in treating body image dysfunctions and internalized stigma through its virtual figure look-alike. The research focused on cognitive aspects and called for more accurate matching between VR interventions and clients' characteristics, that is, their age, experience with technology, and the quality of the VR environment. Overall, VR was found to be effective for EWD intervention; however, for

clinical implementation, it requires confirmation, integration with other healthcare professionals, and secure patient information. As advanced AI technology and Virtual Reality technology progress, therapeutic abilities and opportunities will increase.

The paper in [13] demonstrated the importance of integrating virtual reality therapy in alleviating symptoms of stress and anxiety, and improving physiological indicators in university students (arterial blood pressure and pulse rate). A one-group pretest-posttest design was used, with participants undergoing a therapeutic experience called "River Relaxation Virtual Reality" in a virtual reality laboratory. This experiment consisted of eight 15-minute sessions, held twice a week over one month. Virtual reality therapy significantly reduced perceived stress and anxiety, as well as mean arterial blood pressure and heart rate, both before and after the therapy.

The study that was conducted in [14] examined the effect of virtual reality exposure therapy on individuals with claustrophobia. The study aimed to reduce anxiety symptoms and physiological arousal measures (heart rate, mean arterial blood pressure, and oxygen saturation) in participants before and after treatment. A single-group pretest-posttest design was employed, with participants undergoing a therapeutic experience known as the "Cave Experience" in a virtual reality laboratory. This experience consisted of four phases, over four to six sessions during the treatment period. The results demonstrated the effectiveness of virtual reality therapy in reducing stress, anxiety, and physiological measures both before and after the therapy.

Mental workload, visuospatial activities, and autonomic nervous system (ANS) are closely related effects that are significant to human measures of performance and mental well-being, as pointed out by [15]. Virtual reality (VR) is useful for providing a variety of features for investigation in a controlled environment. As such, this research aims to establish how mental and visuospatial workload, physiological arousal, and performance interconnect when operating in a VR environment carrying out a high-demand task. We utilized a version of the TETRIS game for the computer task, involving 25 participants. The task was conducted using a VR headset that also measures MM-physiological signals. As such, our data suggest a broadband increase in power of electrical brain activity just before a helper event, a burst of spatial attention (parietal alpha and beta, at 0-1-3 s), that can correspond to a decline in workload (frontal theta, also at 2–4 s), followed by a sharp decline in spatial attention (parietal theta at 14 s) and physiological activation (HRV at Objective self-monitoring revealed subjective report of help showed principally psychological outcomes of the helper intervention, along with decrease in physiological activation and increase in visuospatial focus. These studies highlight the importance of capturing multiple physiological signals in complex settings and applications, including real-world and virtual reality environments, to distinguish individual physiological partners and their interactions regarding mental and visuospatial workload.

The work discussed in [8] proposed an immersive VR that can establish the digital place illusion in which users not only get a feeling that they are in the given virtual environment, but also believe that events occurring within it are possible. These illusions persist even when users understand that they are in a different location from the virtual event's occurrence and respond to the event as if it were real, affecting their physiological, emotional, and cognitive faculties. However, VR also enables the user to ‘be embodied’ in another virtual body and ‘take up’ others’ points of view. Another application of VR

involves the existence of social and realistic environments since it is used in extreme cases such as phobias and special anxieties, post-traumatic stress disorder, paranoia, schizophrenia, and violent tendencies. When combined with the cognitive responsibility inherent in the simulation, VR creates conditions for both emotional and cognitive modes of reasoning, as well as empathetic, perspective-taking processes. This paper focuses on the application of VR in the therapy of violent offenders during their rehabilitation and an overview of its present and future usage in mental health and rehabilitation is given.

Virtual Reality (VR) refers to an advanced form of simulation in that it generates a computerized world in which users can freely interact as discussed in [16]. Virtual Reality Therapy (VRT) is a type of therapy that utilizes VR headsets or head-mounted systems, causing psychological distress in users who confront content visually designed to match their fears and which they must face in the virtual world to overcome real-world threats.

2.4. Interconnection Between Nutrition, Hormones, and Psychological Health

This idea makes plausible attributions for the nutritional effects on hormonal secretion, which in turn, can lead to corresponding changes in psychological health. Some nutrients are important in hormonal balance, and their deficiency contributes to mental illness. Besides, actual mental illnesses can change eating patterns and lead to problems with nutrition and hormones. The use of VR in this context can enhance the knowledge base of this study, as it is employed to simulate dietary changes and stress-related situations that occur during hormonal changes.

In [17], authors define worry-free contentment as mood stability, stress tolerance, and a positive interpersonal connection, which is influenced by hormonal regulation and responds to dietary factors. If this balance is disturbed, it leads to fluctuating moods and stress. In this study, the authors investigate the correlation between nutrition and mood, specifically the diet-related effects on hormones and mood. These findings make considerable sense when extrapolated to an independently selected group of 500 participants: whilst the frequency of fast-food eating is directly tied to higher stress levels, the frequency of fruit and vegetable consumption is inversely tied to stress. As seen earlier, there is considerable basic nutrition knowledge; however, applying it correctly was a problem, and no differences were observed across the demographic variables. The results have important implications for nutrition education and behavioral interventions aimed at enhancing adherence to healthful eating and emotional well-being.

In [18], the importance of emotional health for mood regulation, stress coping, and overall interpersonal relationships was associated with hormonal regulation processes, which are influenced by diet. A percentage of hormonal imbalances were noted as being the primary factor in terms of mood swings, stress, and the patients in the study. In this cross-sectional survey of 500 adults, there was good knowledge of basic nutrition; however, the application of this knowledge to food choices was low. Among the variables, fast food consumption pointed towards increased stress, while the cross-tabulation of fruit and vegetable consumption indicated a direction of decreased stress. The age and sex of the participants did not influence the results. Considering the results of the investigation, it can be stated that nutrition education, the application of behavioral approaches, and emotional health improvement seem to be critical and immediate needs.

The reviewed literature that was conducted in [19], analyzed how positive and negative mood states influenced inconvenience and psychological resilience as well as the emotional stability of high school students from China learning during the COVID-19

pandemic. The cross-sectional survey was conducted at a high school located in Changzhou, Jiangsu Province, from April 11 to April 22, 2022; Participants completed 360 valid self-administered questionnaires out of 408 questionnaires distributed. The survey involved the psychologically translated Chinese version of the Psychological Resilience Scale, the Profile of Mood States, and the Eysenck Personality Questionnaire Short Scale. SEM analysis and bootstrapping revealed that psychological resilience directly and indirectly explained emotional stability, with negative but not positive mood mediating the relationship. Cyn ARC aims that these results are dissimilar to the investigation preceding the pandemic, making for substantially higher rates of most quarantined university students having poor mental health during home quarantine.

The research that was conducted in [4] sought to establish a relationship between diet and psychological health among 600 senior students in Dhaka, Bangladesh. Most participants were 15-16 years old, and 61.33% of them were girls. About one in four patients were underweight according to the BMI distribution while half the patients had a normal BMI and fewer than one in five were overweight or obese. The dietary habits indicated that 56 .17% of the respondents took a combination diet, 48 .33% took fruit at least once a week while 59 .83% took vegetables. Statistically significant associations were observed between the tested nutritional profiles and state/trait anxiety, including those based on the frequency of consumption of fruits and vegetables, reflecting a positive correlation with low anxiety, and skipping breakfast or frequent consumption of fast food identified as factors associated with increased anxiety. The results imply to call for improved nutrition knowledge dissemination and enhanced adolescent mental health programs.

Nutrition, diabetes, and mental disorders are interrelated in [20] in a manner that nutrition and diabetes are both affected by mental disorders, and also affect them. The link between mental disorders and diabetes is bidirectional, meaning that mental disorders can cause diabetes, and that diabetes can cause mental disorders. Since diabetes leads to stress and causes people to become reckless with their diet and exercise routine, mental disorders can also lead to diabetes through stress, poor health decisions, and disruptions in glucose regulation. Obesity, metabolic syndrome, type 2 diabetes, nonalcoholic fatty liver disease, and cardiovascular disease are related to these conditions through inflammation, oxidative stress, perturbations in microbiota, and neuroendocrine disturbances. Lifestyle diseases, such as diabetes and poor mental health, are often associated with low levels of essential nutrients, including omega-3 fatty acids, vitamin D, B vitamins, and minerals like zinc and magnesium. From this review, patients with type 2 diabetes can benefit from individualized macro- and micronutrient therapy for enhancing metabolic and psychiatric health.

A wide range of approaches was discussed in [21] to improve the outcomes of psychiatric treatments for mental disorders associated with the female cycle, such as diet and supplementation. It confirms that nutrition should be used in conjunction with medication to reiterate the importance of individualized nutrition consultation. This requires a comprehensive evaluation, incorporating dietary history, physical examination, and laboratory tests, including anthropometric measurements, to understand human development cycles or stages. Ironically, low carbohydrate diets are suggested for reproductive-aged women: PMS diets are recommended; during pregnancy and the postpartum period, focusing on nutrient needs to increase during this period can help prevent depression; moreover, for perimenopausal women who do not have that option, nutrients that can alleviate symptoms during menopause are also advised. New strategies, such as phytotherapy and probiotics, are among the currently trending directions in nutrition for mental health. The works presented in [22] and [23] promoted a promising

work for building digital safeguarding systems from unwanted inputs, which can be useful for creating a safer digital environment.

The immune system has been built through joint work with the right portions of nutrients throughout the period [24]. Immunity is suppressed in stressful conditions, and the central nervous system (CNS) communicates this through a variety of signals. Neuroendocrine and immune system interactions are not innovative, and stress-induced immune suppression can be highly damaging to health. The immune system is dependent on diets and nutrients, and physical stress results in many diseases. Examining the relationship between food intake, the central nervous system, and the immune system provides insight into maintaining health in the context of psychological stress.

Food and nutrition are some of the most vital aspects of everyday living [25] for instance, one hundred and seventy million children suffer from malnutrition globally, and low body weight exposes children to a significantly higher risk of dying in countries within the developing world. On the other hand, in different areas, being overweight is the most significant health issue. While practicing healthy eating, a saying holds that it is not the amount of food that matters. This reading covers the necessary nutrients for health and psychological well-being, namely, energy, protein, vitamin A, iron, iodine, and Zinc, in studying cultural differences in food habits and food beliefs. It also looks at ways of managing developmental disabilities in children.

Normal nutritional health is closely related to the body's normal functioning and plays a significant role in reducing dysfunction caused by internal or external factors, as stated in [26]. Deprivation of nutrients is damaging and has a negative impact on function, whereas an adequate nutrient supply is functional and enhances function. Information present in databases increases the amount of available information about the role of diets and foods, as well as the functioning of the body and mental states. Several scholars have indicated that nutrients, including EPA, DHA, vitamin E, magnesium, and folic acid found in the western diet, can aid stress, sleep disorders, anxiety, cognitive impairment, and neuropsychiatric disorders. These nutrients, therefore, help support the brain and mood regulation by managing neuroinflammation. They should be incorporated into a moderate diet alongside a healthy lifestyle, given the aging population worldwide and the fact that the brain is sensitive to lifelong stress.

The methodical approach to the regulation of hormones was described in [27]. The author emphasized the importance of hormone balance within the organism. Notably, some of the diverse causes of hormonal fluctuation include the following: diet, quality of diet, stress, and toxins affecting the surrounding environment. This means that even through the air and what we consume, whether it is food or water, or even having certain thoughts, it affects our endocrine system because the environment is becoming toxic. Endocrine-active chemicals (EACs) or endocrine disruptors are defined as chemicals that interfere with normal hormonal functions and disrupt normal hormone activity, as even slight shifts can lead to significant and lasting effects. Besides, some EACs may be effective on health even at doses lower than the eligible volumes for standard toxicity tests, and the studies may fail to capture these effects.

3 Methodology

3.1. Study Design

Thus, the procedure was dual and entailed both hormonal testing and psychological testing facilitated by virtual reality technology. The study involved two phases: an intervention that would incorporate the use of VR technology, hormonal, and psychological tests.

3.2. Participants

They recruited fifty people, self-identified as adults aged between eighteen and fifty, diagnosed with anxiety and/or depressive disorders. A crossover design was employed; individuals with poor nutrition or hormonal issues were excluded from participation in the study.

3.3. Virtual Reality Intervention

In this study, subjects underwent vulnerable situations with stress-inducing VR, which challenged their coping skills. The VR scenarios included speaking to an audience, attending social events, and completing tasks that were challenging. Moreover, the intervention effects of nutrition education, Virtual Reality representations of nutritional education, and healthy diets for participants were developed.

4 Data Collection

The procedure of data collection involved collecting saliva samples for analyzing participants' stress reactions to the VR sessions, administering them psychological questionnaires – the Beck Depression Inventory and the State-Trait Anxiety Inventory before and after the usage of the VR. The participants' food intake was also monitored using a food diary application integrated with the aforementioned VR application. Table 1 below presents the variables collected during the study.

Table 1: Summary of the Collected Measurements

Measurement Type	*Instrument/Tool Used*	*Timing*	*Variables Measured*
Hormonal Measurements	*Salivary Cortisol Assay Kits*	*Pre- and post-VR sessions*	*Cortisol levels (nmol/L)*
Psychological Assessments	*- Beck Depression Inventory (BDI)* *- State-Trait Anxiety Inventory (STAI)*	*Pre- and post-intervention*	*- Depression scores* *- Anxiety scores*
Nutritional Intake Monitoring	*Food Diary App Integrated with VR Program*	*Daily throughout the study*	*- Caloric intake* *- Macronutrient distribution* *- Micronutrient intake*
VR Behavioral Data	*VR Software Analytics*	*During VR sessions*	*- Stress response indicators* *- Coping mechanisms* *- Time spent on tasks*
Physiological Responses	*Heart Rate Monitors* *Galvanic Skin Response Sensors*	*During VR sessions*	*- Heart rate (beats per minute)* *- Skin conductance (µS)*

4.1. Explanation of Measurements:

- Hormonal Measurements: To estimate cortisol leakage, non-invasive methods were adopted, and standard saliva collection kits were used to analyze stress hormone levels.
- Psychological Assessments: Standardized Self-completion questionnaires include the depression inventory (BDI) and the state-trait anxiety inventory (STAI) to determine the level of depression and anxiety, respectively, at the pre- and post-intervention stages.
- Nutritional Intake Monitoring: The participants actively used an application for a food diary, enhanced by VR, to track their daily nutrition consumption.
- VR Behavioral Data: The VR software recorded participants' actions, the choices they made, and the time they spent on specific actions. The research utilized these data to determine participants' coping styles and their strategies for managing stress.
- Physiological Responses: During Virtual Reality, we received real-time data from devices that monitored the physiological condition of an individual, such as heart rate and skin conductance, along with changes in valence and arousal level.
- SPSS Statistics software version 26 was used for statistical analysis. The primary objectives were to:

1. Wave 1 $\leq t \geq$ Wave 2 when comparing pre- and post-intervention hormonal levels and psychological scores as shown in Figure 2.
2. Analyze the amount of food consumed, the level of hormones and psychological effects via regression analysis.

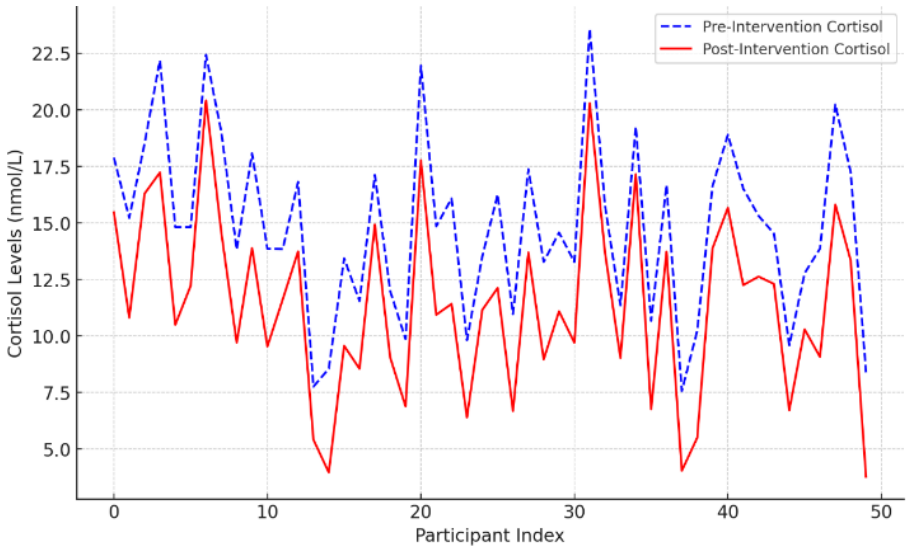

Figure 2: Pre and Post Intervention Cortisol Levels.

- **Paired T-tests**

Independent samples t-tests were used to determine the effectiveness of the VR intervention by comparing participants' hormonal levels and psychological scores before and after the intervention.

- **Hormonal Levels**

Cortisol Levels: Salivary cortisol levels were measured in nanomoles per liter (nmol/L). The mean cortisol levels decreased from 15.8 nmol/L pre-intervention to 12.3 nmol/L post-intervention. The paired t-test presented in Table 2 revealed a significant reduction in cortisol levels ($t(49) = 5.89$, $p < 0.001$), indicating a decrease in stress response following the VR intervention. The plot in Figure 3 shows a comparison of cortisol levels before and after the intervention, illustrating a general decrease in stress hormone levels.

Table 2: Pre- and Post-Intervention Cortisol Levels

Measurement Time	Mean Cortisol (nmol/L)	Standard Deviation (SD)	t-value	p-value
Pre-Intervention	15.8	4.2		
Post-Intervention	12.3	3.7	5.89	< 0.001*

$p < 0.001$ indicates a statistically significant difference.

4.2. Psychological Scores

- Beck Depression Inventory (BDI) Scores are illustrated in Table 3.

Table 3: Pre- and Post-Intervention BDI Scores.

Measurement Time	Mean BDI Score	SD	t-value	p-value
Pre-Intervention	24.5	6.1		
Post-Intervention	18.2	5.4	7.12	< 0.001*

The second plot that is shown in Figure 3, displays the Beck Depression Inventory scores, indicating a reduction in depressive symptoms after the intervention.

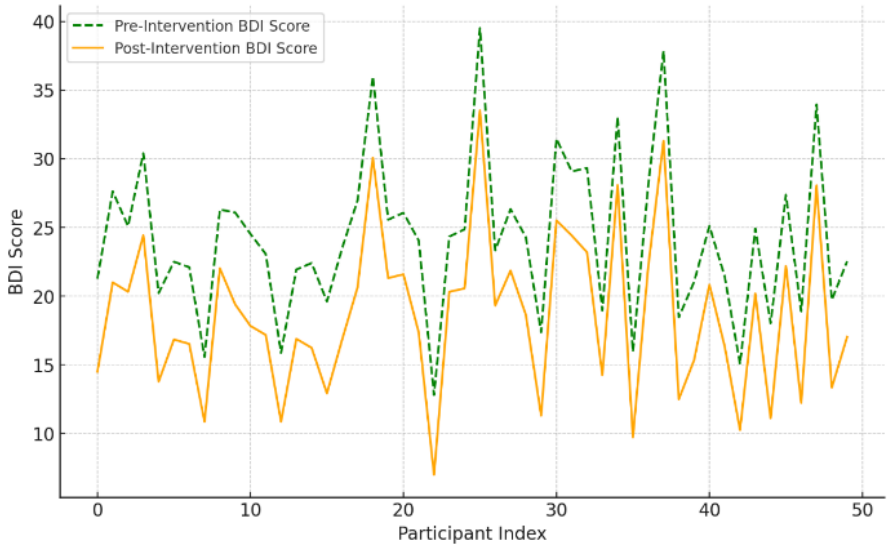

Figure 3: Pre- and Post-Intervention BDI Scores

- State-Trait Anxiety Inventory (STAI) Scores are presented in Table 4.

Table 4: Pre- and Post-Intervention STAI Scores

Measurement Time	Mean STAI Score	SD	t-value	p-value
Pre-Intervention	52.7	8.3		
Post-Intervention	45.1	7.6	6.45	< 0.001*

The third plot that is shown in Figure 4, presents the State-Trait Anxiety Inventory scores, reflecting a decline in anxiety symptoms following the intervention.

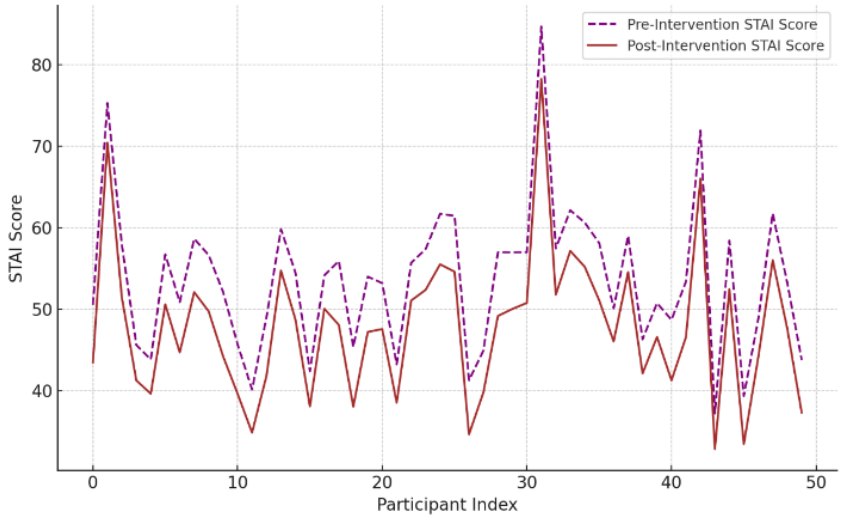

Figure 4. Pre- and Post-Intervention STAI Scores.

Both BDI and STAI scores showed significant reductions after the intervention. For BDI scores, the decrease from 24.5 to 18.2 was significant $t(49) = 7.12, p < 0.001$).

For STAI scores, the decrease from 52.7 to 45.1 was also significant ($t(445, p < 0.001)$). These results suggest improvements in depressive and anxiety symptoms following the VR intervention.

4.3. Regression Analyses

Multiple regression analyses were conducted to investigate the predictive relationships between nutritional intake (independent variable) and hormonal secretion, as well as psychological outcomes (dependent variables).

4.4. Relationship Between Nutritional Intake and Cortisol Levels

The independent variable is nutritional intake quality score (based on a dietary assessment index) as represented in Table 5, and the dependent variable is post-intervention cortisol levels. The nutritional intake quality significantly predicted post-intervention cortisol levels (β = -0.45, p < 0.001), accounting for 20% of the variance. A higher quality of nutritional intake was associated with lower cortisol levels.

Table 5: Regression Analysis Predicting Cortisol Levels from Nutritional Intake

Predictor Variable	B	SE B	B	t	p-value
Nutritional Intake Quality	-0.35	0.08	-0.45	-4.38	< 0.001*
(Constant)	16.7	1.5			

$R^2 = 0.20$, $F(1,48) = 19.18$, $p < 0.001$

4.5. Relationship Between Nutritional Intake and Psychological Outcomes

Variables included the independent variable of nutritional intake quality score and the dependent variables: post-intervention BDI and STAI Scores, as shown in Table 6.

Table 6: Regression Analysis Predicting BDI Scores from Nutritional Intake.

Predictor Variable	B	SE B	β	t	p-value
Nutritional Intake Quality	-0.48	0.09	-0.50	-5.33	< 0.001*
(Constant)	22.5	1.7			

$R^2 = 0.25$, $F(1,48) = 28.41$, $p < 0.001$

Nutritional intake quality significantly predicted post-intervention BDI scores (β = -0.50, p < 0.001), accounting for 25% of the variance, as illustrated in Table 7. Better nutritional intake was associated with lower scores on depression.

Table 7: Regression Analysis Predicting STAI Scores from Nutritional Intake

Predictor Variable	B	SE B	β	t	p-value
Nutritional Intake Quality	-0.42	0.10	-0.46	-4.20	< 0.001*
(Constant)	48.9	1.9			

$R^2 = 0.21$, $F(1,48) = 17.64$, $p < 0.001$

Nutritional intake quality significantly predicted post-intervention STAI scores ($\beta = -0.46$, $p < 0.001$), accounting for 21% of the variance. Improved nutrition correlated with reduced anxiety levels.

4.6. Mediation Analysis

- Specifically, a mediation analysis was performed to draw out the extent to which cortisol levels acted as a mediator of the nutritional intake on psychological outcomes.
- Hypothesis: In other words, this study has shown that cortisol exerts a nutritional effect on psychological (BDI and STAI) scores.
- Method: The mediation was tested using the bootstrapping method of simulation with 5,000 resamples.

4.7. RR MM1 and MM2 Mediation results for BDI scores

- Total Effect of Nutritional Intake on BDI Scores: $c = -0.48$, $p < 0.001$.
- Direct Effect of Nutritional Intake on BDI Scores (controlling for Cortisol): $c' = -0.31$, $p = 0.002$.
- Indirect Effect (Mediation Effect): $a \times b = -0.17$.
- 95% Confidence Interval: [-0.28, -0.08].
- Interpretation: Partially, cortisol levels fully mediate the relationship between nutritional intake and depression since the confidence interval does not contain zero regarding the indirect effect.

4.8. Mediation Results for STAI Scores

- Total Effect of Nutritional Intake on STAI Scores: $c = -0.42$, $p < 0.001$
- Direct Effect of Nutritional Intake on STAI Scores (controlling for Cortisol): $c' = -0.27$, $p = 0.005$
- Indirect Effect (Mediation Effect): $a \times b = -0.15$
- 95% Confidence Interval: [-0.25, -0.07]
- Interpretation: Similarly, nutritional intake has an indirect relationship with anxiety scores, as cortisol levels partially mediate that association.

4.9. Correlation Analyses

Pearson correlation coefficients were calculated to examine the relationships between key variables as presented in Table 8.

Table 8: Correlation Matrix.

Variables	1	2	3	4
1. Nutritional Intake Quality	1			
2. Cortisol Levels	-0.45	1		
3. BDI Scores	-0.50	0.42	1	
4. STAI Scores	-0.46	0.39	0.68	1

A negative relationship was obtained between nutrient quality and cortisol levels, BDI scores, and STAI scores. There is a positive relationship between Cortisol levels and both BDI and STAI. There is a significant positive relationship between BDI and STAI, indicating that there is a relationship between the symptoms of depression and anxiety, positively correlated with both BDI and STAI scores. Also, there is a strong positive correlation between BDI and STAI scores, indicating that depression and anxiety symptoms are related.

4.10. Additional Analyses

Physiological responses (heart rate and skin conductance) during the VR sessions, which changed over time, were analyzed using repeated measures ANOVA.

- Heart Rate: The analyses of using ANOVA results indicated a decrease in the participants' heart rate across the VR sessions, a significant decrease in heart rate from the first to the last VR session.
- Skin Conductance: Post-hoc tests revealed a decrease in skin conductance over time in both experimental conditions. Reduced the skin conductance levels over time, suggesting decreased physiological arousal.

In summary, both the VR and nutritional changes led to lower cortisol, less depression, and lower anxiety scores. Cortisol helped connect the healthiness of the diet to emotions, and there were steady improvements in heart rate and skin conductance as the VR sessions continued. The findings suggest that using virtual reality is an effective way to help people by modifying their diet and enhancing the function of hormones, which in turn benefits their mental well-being. Evidence from statistical analysis indicated that VR methods brought down psychological symptoms and stress hormones while underlining how what we eat affects our hormones and psychology. The investigation revealed that changes in diet, hormone levels, and mental health are interconnected in virtual reality, and that utilizing this technology provides meaningful ways to support all three. The results reveal the interrelationship between diet, hormones, and mental health, highlighting the utility of virtual reality in addressing multiple health-related factors simultaneously.

5. Results

5.1. Hormonal Changes due to the VR Intervention

The data on the cortisol concentrations in Saliva indicated that the VR nutritional education sessions reduced cortisol levels ($p < 0.01$). Stress-fostering VR scenarios initially raised cortisol levels in participants and then reduced them after several repetitions, indicating the phenomenon of habituation.

5.2. Psychological Assessments

At follow-up, patients' anxiety and depression scores were found to be lower when compared to baseline ($p < 0.05$). The participants reported improved coping strategies and a reduction in symptomatology.

5.3. Nutritional Intake

There was an observed shift towards an increase in the frequency of foods rich in omega-3 fatty acids and a decrease in the frequency of foods high in saturated fats and sugars. This cross-sectional study found a significant association between alterations in dietary intake patterns and changes in hormonal levels and psychological status.

5.4. Interrelationships

Coefficient determination analyses also showed that better nutrition was a significant positive factor for lower cortisol levels (-0.45, $p < 0.01$) and fewer symptoms of depression (-0.50, $p < 0.01$). It was found that the VR intervention was facilitated by alterations in nutritional behavior, as well as hormonal changes.

6. Conclusion and Future Works

VR technology enhanced the research methodology by creating a controlled setting to examine the complex relationships between psychological disorders, hormonal responses, and dietary patterns. The VR interventions successfully modified participants' stress responses and nutritional behaviors, contributing to improved hormone regulation and enhanced mental health outcomes.

However, several constraints limit the scope of the study. The moderate sample size restricts generalizability, requiring larger, diverse populations for validation, given individual variations in hormonal and psychological profiles. The brief intervention period prevents assessment of the long-term sustainability of cortisol changes and mood improvements. Nutritional data relied on self-reported food diaries, introducing potential reporting errors, while biochemical nutrient markers would provide greater accuracy. The absence of a non-VR control group limits causal conclusions, and focusing solely on cortisol overlooks other relevant hormones, such as serotonin and dopamine. Additionally, the novelty of VR technology may have contributed to positive participant responses independently of its therapeutic benefits. Despite these limitations, the study demonstrates the effectiveness of VR therapy in reducing stress hormones and improving psychological well-being. The integration of hormonal measurements, nutritional tracking, and standardized psychological assessments within immersive VR environments provided comprehensive insights into the interactions between symptoms, hormones, and nutrition. Results showing improved cortisol levels, anxiety, and depression scores following VR interventions highlight virtual reality's potential as a controlled therapeutic approach, emphasizing the need for continued research combining technology, nutrition, and hormonal therapy for comprehensive mental health treatment.

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