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Research Article | Journal of Neurology, Psychiatry and Brain Research | JNPBR-122
ISSN: 2641-7049

The Effects of Virtual Reality on Mental Wellness: A Literature Review

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Received Date: February 28, 2019; **Accepted Date:** March 12, 2019; **Published Date:** March 21, 2019

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Abstract

Virtual Reality (VR) has been gaining popularity as a means to tackle a variety of issues in medicine and beyond, one of which is improving individuals' mental wellness. The purpose of this review is to examine the body of research specific to the application of VR in improving mental wellness, oftentimes in the context of physical illness or disability. Using keywords "Virtual Reality", "Mental Wellness", "Mental Health", "Mood", "Stress", "Distress", and "Quality of Life", a search of the literature was conducted and 22 articles were identified for inclusion in this review. Results suggest that in many cases VR has been effective in improving various attributes of mental wellness in a variety of samples, and that the quality of the VR technology itself may play a role in these results. Overall, more research considering the long-term and large-scale effects of VR, as well as clarifying which technological features of VR are most successful, should be conducted in order to strengthen the applicability of VR for mental wellness in clinical settings.

Keywords: HMD; Immersion; Mental Health; Mental Wellbeing; Mental Wellness ; Oculus; Quality of Life; VR ; Virtual Reality; Virtual Therapy

Introduction

What is Virtual Reality?

Although the field of clinical technology is lacking a strict consensus regarding the definition of Virtual Reality (VR) and which specific technologies fall under it, broadly,VR has been defined as a form of technology that permits advanced, dynamic interaction between humans and a computer interface **[1]**. VR is often additionally described as being immersive and/or interactive. Yet, despite the frequency of these terms, much like VR itself, "Immersive" and "Interactive" tend to take on various meanings throughout the literature.

A few experts have insisted that immersion refers to the level of sensory actuality a system provides **[2]**. In order to facilitate comparison and avoid excessive categorization, for the purposes of this review, any technology that provides 360-degree content will be considered "Immersive". Immersion is often (but not always) achieved through the wearing of a Head-Mounted Display (HMD) in which a screen with head-tracking capabilities is worn over the eyes. Furthermore, in accordance with Jonathan Steuer's oft-cited definition, a technology will be considered interactive if a user is able to intentionally impact the form or content of the simulated environment **[3]**. This can occur via use of a touch screen, remote control, mouse, head/body movements, etc.

The content of a VR interventionism typically either game-based or environment-based. Game-based interventions require some sort of goal-directed behavior from users, while environment-based interventions allow for self-directed exploration or viewing of some situation. Occasionally a technology will incorporate elements of both game-based and environment-based interactions; these programs will be denoted accordingly.

How has the application of VR in a clinical setting been studied to date?

VR has been studied in a number of clinician-oriented (i.e. surgical training) and patient-oriented applications. The latter field in particular has covered a vast array of potential uses for VR in the clinic, including for the purpose of diagnosing psychiatric **[4]** and nervous system disorders **[5]**, educating patients about medical procedures **[6]**, prompting physical **[7]** and cognitive rehabilitation **[5]**, managing acute and chronic physical pain **[8]**, and treating a variety of psychiatric disorders like anxiety disorders via exposure therapy **[9]**, and eating **[10]** and substance use disorders **[11]** via cognitive control training.

The present review aims to examine the VR literature in a specific division of mental health research deemed "Mental Wellness". According to the World Health Organization, mental wellness 1) refers to a state of well-being characterized by self-actualization, stress resilience, and communal contribution, and 2) is directly implicated in sustaining a high quality of life **[12]**. Mental wellness can be broken into three areas relevant to clinical VR research: Distress, the psychological byproduct of acute physical pain (often in the form of fear or anxiety); mood, the experience of a lasting emotional state(often examined relative to chronic pain and illness); and stress, an individual's response to psychological stressors. These divisions are, by nature, somewhat overlapping, especially in the context of medicine, but also have their own unique contextual attributes that make examining them separately worthwhile. Mental wellness, with its direct ties to quality of life, is important for a variety of reasons, but in the context of medicine is especially important given the documented bidirectional relationship between mental and physical health **[13,14]** as well as issues of treatment compliance **[15]** and poor health-related behaviors (smoking, inactivity, overeating, etc.) **[16]** that arise from mental wellness issues.

Methods

Articles were sourced from Google Scholar and MEDLINE (PubMed) using search terms "Virtual Reality", "Mental Wellness", "Mental Health", "Mood", "Stress", "Distress", and "Quality of Life". A study was selected for further analysis if the abstract mentioned the utilization of virtual reality technology and measured distress, mood, or stress in response to the technology use. Additional articles were secondary-sourced from various reviews appearing in the original search query. Articles were excluded for the following reasons: full text not available, purpose of VR intervention is exposure therapy, purpose of VR intervention is physical or cognitive rehabilitation, purpose of VR intervention is purely educational, purpose of VR intervention is pain relief (without a psychological component), technology is both non-immersive and non-interactive (e.g. watching videos alone), article is a thesis/dissertation/case studies, participants used varying amounts of narcotic analgesics alongside the VR technology, study was published before 2004. Ultimately 22 studies were selected for inclusion in this review (for details on the included studies, see **Table 1**).

Author	**Year**	**Technology**	**Level of Immersion**	**HMD (Head-Mounted Display)**	**Sample**	**Variable**	**Measurement**	**Use**	**Result**
Gershon et al.	2004	Immersive, interactive, HMD game	360-degree	Not specified	Cancer patients (children)	Distress	Objective (pulse, muscle tension)	Single	+
Windich-Biermeier et al.	2007	Immersive, non-interactive HMD environment	3 DoF	Virtual I-O I-Glasses	Cancer patients (children)	Distress	Objective (CAS, Glasses Fear Scale – completed by nurse)	Single	+
Van Twillert et al.	2007	Immersive, interactive, HMD game	3 DoF	Cybermind Hi-Res900	Burn patients	Distress	Self-report (STAI)	Single	-
Nilsson et al.	2009	Non-immersive, interactive screen display game	N/A	N/A	Cancer patients (children)	Distress	Self-report (CAS, FAS)	Single	-
Piskorz et al.	2018	Immersive, interactive, HMD game	6 DoF	Oculus Rift	Nephrology patients (children)	Distress	Self-report (VAS)	Single	+
Schneider et al.	2004	Immersive, interactive, HMD	3 DoF	Sony Glasstron	Cancer patients	Mood	Self-report (SAI)	Single	-

		environment/game							
Riva et al.	2007	Immersive, interactive, HMD environment	360-degree	Not specified	Healthy controls	Mood	Self-report (VAS, PANAS, STAI)	Single	+
Schneider et al.	2007	Immersive, interactive, HMD environment/game	3 DoF	Virtual IO I-Glasses	Cancer patients	Mood	Self-report (SAI)	Single	-
Li et al.	2011	Immersive, interactive, projection game	Projection	N/A	Cancer patients (children)	Mood	Self-report (CES-DC)	Multi	+
Banos et al.	2013	Non-immersive, interactive screen display environment	N/A	N/A	Cancer patients	Mood	Self-report (VAS)	Multi	Mixed
Herrero et al.	2014	Non-immersive, interactive, screen display environment	N/A	N/A	Fibromyalgia patients	Mood	Self-report (SCID-I, SCID-II)	Single	+
Mosadeghi et al.	2016	Immersive, interactive, HMD game/environment	3 DoF	Samsung Gear	Medical inpatient (general)	Mood	Self-report (qualitative interview)	Single	+
Chawla et al.	2018	Immersive, interactive, HMD environment	6 DoF	Oculus Rift	Cancer patients	Mood	Self-report (modified EORTC-QLQ)	Single	+
Bittner et al.	2018	Immersive, interactive, HMD game/environment	6 DoF	HTC Vive	Sub-threshold depressed	Mood	Self-report (BDI-II)	Single	+
Moyle et al.	2018	Non-immersive, interactive, screen display environment	N/A	N/A	Dementia	Mood	Objective	Single	Mixed
Yu et al.	2018	Immersive, non-interactive, HMD environment	6 DoF	HTC Vive	Healthy controls	Mood	Objective & self-report (HRV, POMS)	Single	Mixed
Annerstedt et al.	2013	Immersive, non-interactive, projection-environment	Projection	N/A	Healthy controls under acute stress	Stress	Objective (ECG T-Wave Amplitude)	Single	+
Shah et al.	2015	Immersive, non-interactive, HMD therapeutic videos	360-degree	ITG-PCX3	Depressed/Bipolar	Stress	Objective & self-report (Skin temp, HR, DASS-21, PRS)	Multi	+
Serrano et al.	2016	Non-immersive, interactive, screen display environment	N/A	N/A	Healthy controls	Stress	Self-report (STAI, VAS, SAM)	Single	+
Anderson et al.	2017	Immersive, non-interactive, HMD environment	6 DoF	Oculus Rift	Healthy controls under acute stress	Stress	Objective & self-report (EDA,	Single	+

							PANAS)		
Amores et al.	2018	Immersive, non-interactive, HMD environment + olfactory necklace	3 DoF	Samsung Gear	Healthy controls	Stress	Objective (EEG alpha and theta bands)	Single	+
Liszio et al.	2018	Immersive, non-interactive, HMD environment	6 DoF	Oculus Rift	Healthy controls under acute stress	Stress	Objective & self-report (HRV, PANAS)	Single	+

Table 1: A Summary of the Studies Selected for Inclusion.

Results

Distress (n=5)

All studies included were conducted while participants were undergoing some sort of acutely painful medical procedure; four of the five studies were conducted in children (under the age of 18). Studies examined either "Anxiety", "Fear", or "Stress" during the painful procedure. Four studies utilized game-based VR interventions. The first of these, Gershon et al (2004), examined the effectiveness of an immersive, interactive game (in which participants were tasked with interacting with gorillas in a zoo habitat) in relieving anxiety in pediatric cancer patients undergoing a brief medical procedure. Although the participants that used the VR intervention during the procedure had significantly less distress (lower pulse and less muscle tension) than those receiving care as usual, there were no significant differences in distress reduction between the VR game and a non-VR variant of the game played on a computer monitor **[17]**. The HMD that the VR variant of the game was played on was not specified, so it is difficult to tell whether or not the two technologies were sufficiently different.

Other early game-based VR interventions were not as successful in relieving self-reported distress during painful medical procedures, as was the case when Van Twillert, Bremer, and Faber (2007) examined the use of a specially-engineered game ("Snow World", played on the Cyber mind Hi-Res 900 HMD) in adult burn victims during dressing changes. Though the researchers found significant reductions in pain with technology use, they found no significant reduction in anxiety compared to individuals receiving care as usual **[18]**. Similarly, Nilsson and colleagues (2009) failed to find significant reductions in distress in pediatric cancer patients during a medical procedure using a non-immersive VR game, despite the fact that most (15 of 21) patients reported wanting to use the technology again during their next procedure **[19]**.

In general, distraction seems to be a useful tactic for distress reduction-Windich-Biermeier and colleagues (2007) allowed pediatric cancer patients to choose a distraction (e.g. video game, book, environment-based VR intervention) to use while undergoing a painful medical procedure, and found significant reductions in anxiety throughout the procedure compared to patients who did not use a distraction **[20]**. Therefore, the unsatisfactory outcomes of many of the VR interventions examined could be a result of the failure of early VR technologies to adequately distract patients. This assertion is supported by the fact that Gershon and colleagues (2004), despite finding VR technology effective in relieving distress, failed to find differences between VR and a non-VR distraction. In a much more recent study, Piskorz and Czub (2018) found that a memory game (memorizing and selecting a variety of objects using head movements) played on the Oculus Rift, a headset renowned for its ability to elicit a strong sense of immersion, was successful in significantly reducing self-reported distress in pediatric nephrology patients undergoing a painful medical procedure **[21,22]**.

Given Piskorz and Czub's recent example of success in distress relief with the use of modern technology, perhaps the best avenue forward for the continued development of distress-relieving VR interventions is to clarify which qualities of distraction (i.e. engaging multiple senses, using highly-detailed environments, etc.) are most successful in relieving distress and explore how VR can best incorporate these qualities. In addition, to date, no study has explored the effect of multiple-use VR interventions in relieving distress associated with acute pain. Multiple-use interventions might procure the benefit of acclimating participants to the VR environment in a non-painful context, or improving quality of life in general over time (see discussion of mood), which could increase the effectiveness of the technology when used during painful medical procedures. Lastly, the study of VR in relieving distress would certainly benefit from higher-powered studies, as most trials have not examined the effectiveness of the technology in a sample larger than 20.

Mood (n=11)

Although the impact of VR on mood has predominantly been examined in clinical samples, two studies in healthy controls have established the ability of the technology to provoke certain moods in healthy participants. Riva and colleagues (2007) used an immersive, interactive virtual park system (displayed on an unnamed HMD) designed to elicit either an anxious (environment with heavy shadows, low light, ominous sounds)or relaxed (environment with natural light and relaxing sounds) response, and successfully induced both self-reported anxiety and relaxation in a small group of healthy controls **[23]**. Yu and colleagues (2018) conducted a similar study using the HTC Vive HMD to immerse healthy controls in either an urban environment (inner-city Taipei) or natural environment (Aowanda National Forest), and found that the natural environment significantly decreased self-reported fatigue, tension, and depression (the urban environment had no effect) **[24]**.

The largest body of mood-focused VR research appears to have been done in chronically ill populations (8 of the 11 included studies were conducted in patients with chronic medical illness), which is arguably more complex and challenging given the nature of chronic illness and its direct impact on quality of life. One of the earliest studies on the ability of VR to impact mood in chronically ill individuals was run by Schneider and colleagues (2004), in which a large sample of adult cancer patients were given the opportunity to use a Sony Glasstron HMD with three preloaded immersive, interactive scenarios (deep sea diving, walking through an art museum, or solving a mystery) during chemotherapy **[26]**. Although self-reported levels of generalized anxiety were not significantly impacted by the use of this intervention, they were, on the whole, lower. This result was replicated by Schneider and colleagues in 2007 using a similar technology in another large group of adult cancer patients **[25]**. As in the case of distress, more recent studies have tended to find more promising results for the ability of VR to make significant impacts on patient mood. In 2011,Li and colleagues tested a headset-free virtual reality program ("Play Motion", accomplished through interactive wall projections) for pediatric cancer patients and found that one week of use significantly reduced depressive symptoms measured via the Center for Epidemiological Studies Depression Scale for Children (CES-DC) **[27]**. In the same year, Banos and colleagues examined the use of an interactive screen display VR environment over four sessions for mood improvement in adult cancer patients. Although this study found reductions in self-reported sadness and significant increases in relaxation and joy, these results only reached statistical significance in the second and fourth sessions of use **[28]**. While these inconsistent results could potentially indicate that in order to be significantly effective the VR intervention needs to be used multiple times, participants also reported high levels of physical discomfort (i.e. they had to assume an uncomfortable position while using the intervention) which may have negatively impacted results.

In 2014, Herrero and colleagues found significant improvements in mood state, sadness, anxiety, calmness, and joy in Fibromyalgia patients after using a non-immersive (screen display) interactive VR program. The program engaged patients in a video beach environment with supplementary motivational narratives, yet was offered concurrently with traditional Cognitive Behavioral Therapy (CBT) making interpretation of the effect of the VR alone impractical **[29]**. A similarly-engineered study was published by Moyle and colleagues in early 2018, in which the researchers provided dementia patients with an interactive screen display environment, but then coded patients' facial expressions to determine objective rates of joy, pleasure, anxiety, etc. during use of the program (rather than using self-report measures). During technology use, patients' facial expressions indicated greater rates of pleasure and alertness but also anxiety and fear. However, the study was conducted in a very small sample split between two facilities, one of which was described as being very noisy and disruptive, which may have influenced the objective measurements **[30]**.

In 2016, Mosadeghi and colleagues published the first study in which an immersive, HMD VR intervention successfully and significantly improved mood in medical inpatients after one use. After using the Samsung Gear VR HMD with four pre-loaded immersive environments (interactive paint studio, ocean exploration, cirque de solei, and a tour of Iceland) 61% of patients reported significant improvements in mood; however, many patients had been excluded from the study for having a variety of pre-existing medical conditions, and even those who qualified often reported issues of discomfort (headset too heavy, not easily adjustable) **[31]**. Chawla and colleagues (2018) addressed some of these questions of inclusion by openly inviting cancer patients, regardless of health status, to participate in a study in which they were able to experience a variety of immersive and interactive natural environments using the Oculus Rift HMD. Despite moderate rates of simulator sickness, almost all patients reported significant improvements in relaxation, positive effect, depression/anxiety, and tension **[32]**.

Only one study to date has examined the use of VR to influence mood in a sample of individuals with mood disorders. Bittner and colleagues (2018), using an immersive VR program on the HTC Vive HMD, in which participants were placed in a "Relaxing" natural environment and given the task of flying up to flowers using directed head movements, found significant improvements in depressive symptoms as reported as on the Beck Depression II (BDI-II) **[33]**. Importantly, no improvements in mood occurred in the control group (care as usual) or in a group that used an adaptation of the VR program experienced on a non-immersive tablet, suggesting that something about the immersive VR experience was important for obtaining significant alterations in mood.

Considering that only one of the three non-immersive VR programs examined found clear-cut, significant improvements in mood, and this particular program was offered concurrently with CBT, it seems that immersion might be an important aspect of VR to secure improvements in mood (without incorporating a therapeutic element), though this could be examined further through studies comparing similarly formatted immersive and non-immersive interventions (see Bittner et al, 2018). In addition to looking at mood alone, a few of the studies considered also looked at the impact of VR on mood and physical symptoms, with little success in alleviating the latter (see Schneider et al, 2004; Schneider et al, 2007; Mosadeghi et al, 2016). As in the case of distress, however, multi-use technology may potentially improve the effectiveness of VR mood interventions and could be especially helpful in achieving desired improvements in physical symptoms in response to long-term improvements in mood. Although some studies have begun to examine VR's ability to impact patient quality of life holistically (see Chawla et al, 2018) a refined methodical approach, in which VR is examined long-term and compared to other possible interventions, would strengthen these results.

One study that did not find significant results reported issues of positional discomfort (Banos et al, 2011), and two studies that did achieve significant results still had issues with discomfort due to HMD size and fit and simulator sickness. Issues of HMD size and fit can perhaps be addressed by adding adjustable straps or additional supports. Simulator sickness is a bit more complex. Thought of being the result of visual-vestibular conflict, per sensory conflict theory **[34]**, some publications have offered suggestions for ways to limit simulator sickness, such as incorporating visually-coordinated movements to provide alignment in vestibular and visual feedback **[35]**. Adjustments that improve comfort and limit sickness (especially in relation to new technologies) should be examined to improve the effectiveness of the technology.

Stress (n=6)

Most of the literature on VR and stress relief has been conducted in healthy control samples. Beginning in 2013, Annerstedt and colleagues induced stress in healthy controls using a VR-adapted variant of the Trier Social Stress Task (TSST) and then exposed them to an immersive projection-based VR forest environment. Stress recovery occurred more quickly (as measured by ECG T-wave amplitude) in the VR environment than in a control (no media exposure) condition **[36]**. Liszio and colleagues achieved similarly positive results in 2018 using an Oculus Rift HMD and underwater simulation ("The Blu") and VR-TSST to induce stress. As with ECG T-wave amplitude in the preceding study, Heart Rate Variability (HRV) was significantly higher (lower stress) in the VR group than in the control group, but importantly was also higher in the VR group than in an equivalent non-VR condition **[37]**. Anderson and colleagues (2017) expanded upon these results by using an arithmetic stress task to induce stress in healthy controls and then exposing them to three different immersive environments (a beach, Ireland, and an empty classroom) using the Oculus Rift HMD. While in general, the use of VR led to decreased Electro dermal Activity (EDA Skin Conductance),EDA was even lower than baseline when participants experienced the Ireland and beach environments (only beach was statistically significant), presumably as a result of their calming natural qualities **[38]**.

In 2016, Serrano and colleagues piloted a non-immersive multimodal VR system (VR plus lavender oil diffusion and faux grass stimuli) to promote relaxation in healthy controls using a screen display with interactive house environment. Overall, VR significantly increased levels of relaxation, and this effect was not moderated by the incorporation of olfactory and/or tactile stimuli **[39]**. Despite these results, Amores and colleagues (2018) piloted a similar technology using an immersive Samsung Gear HMD with beach environment and olfactory necklace to promote relaxation in healthy controls. Although the study reports a 25% decrease in alpha and theta frequency bands measured via EEG, the technology was not compared to a control condition (instead was compared to baseline measurements) and uses a fairly novel metric which leaves the results open to interpretation **[40]**.

To date, it appears that only one stress-focused study has been conducted in a clinical population. Shah and colleagues (2015) tested the use of 360-degree videos about breathing and muscle relaxation, as well as relaxing environmental imagery, to relieve stress in a sample of clinically depressed/bipolar participants over a three-day span. Use of the technology resulted in significantly higher skin temperature and lower heart rate (lower stress), as well as higher self-reported relaxation. Although patients were also receiving psychiatric care as usual which has the potential to impact results, these initial results are promising regarding the use of VR in clinical psychology to relieve stress **[41]**.

Broadly speaking, results for the use of VR in relieving stress are positive, but since all of the technologies are differing, it could be worthwhile to move forward by doing more controlled studies looking at which specific aspects of VR are promoting the relaxation observed in most of these studies. For example, some of the studies (i.e. Anderson et al, 2017) point towards the use of natural environments for more successful relaxation. Furthermore, given the initially promising results Shah and colleagues achieved in their use of VR to reduce stress in depressed and bipolar individuals, more studies should be conducted to follow up the use of VR to potentially aid in psychiatric treatment.

Future Directions

As the technology behind Virtual Reality has grown to more closely mimic natural human experience, the technology industry has begun to classify VR systems based on their level of immersion. Considered the least immersive is "360-degree" content (essentially panoramic video); middle-ground immersion is achieved through content with "three degrees of freedom (3DoF)", in which an environment records and responds to rotational head motion (i.e. looking around); and the most immersive content is considered that with "six degrees of freedom (6DoF)", in which an environment responds to both translational and rotational body movements (i.e. walking and looking around).

Mirroring these technological advancements, the body of research surrounding the use of that technology to promote distress management, mood enhancement, and stress relief is also growing. Nonetheless, there are a number of questions that remain unanswered or have not yet been adequately addressed in the current literature. In general, moving forward, future research should consider 1) the long-term and large-scale effects of VR as they relate to mental wellness and quality of life, and 2) which specific aspects of VR are most successful in promoting these benefits, including aspects such as using hard surfaces (indoors) versus natural settings. Currently, use of VR in clinical settings has been largely restricted due to hardware costs, lack of quality content, difficulty of setting up and maintaining equipment, and a lack of mainstream adoption. Future VR headsets are looking to change this by making VR affordable and simple to use (wireless), which will in turn drive quality content and mainstream adoption. By expanding the use of VR outside of the clinic among the patient population, the ability to truly test the long-term effectiveness of mental wellness through VR 'therapy' can be assessed. Furthermore, studies with larger samples, control groups, and consistent, reliable measures could broaden the applicability of these results, which the wireless VR headsets would also more easily help provide. Given the increasing affordability of VR, this intervention could serve as an extremely useful tool in and out of the clinic, especially once the true scope of its capabilities is clarified.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Citation: *Roche K, Chawla S, Liu S, Siegel S (2019) The Effects of Virtual Reality on Mental Wellness: A Literature Review. Jr Neur Psych and Brain Res: JNPBR-122.*