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REVIEW

A prescription for "nature" – the potential of using virtual nature in therapeutics

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Abstract: Many studies suggest that increased exposure to urban greenness is associated with better population health. Accessing nature can in some circumstances, however, be difficult, especially for individuals with mobility constraints. Therefore, a growing body of work is investigating the ways to replace the in vivo experience with forms of "virtual" contact, in order to provide these individuals with at least some benefits of the natural environment. The aim of this paper is to provide a review of previous use of virtual reality (VR) nature in health and care settings and contemplate the potential use of this technology in future. Our central question is whether engaging with virtual nature can contribute to enhanced physical and emotional well-being in housebound or mobility-constrained individuals. We conclude that while contact with real-world nature is preferred, VR use can be an alternative in cases when in vivo contact with nature is not possible. There are many possibilities for the use of VR technology in psychiatric and medical care; however, the risks, benefits, and cost efficiency of these attempts should be carefully assessed and the outcomes should be measured in a scientifically valid manner. The current review has nonetheless demonstrated that VR nature could play a role in each of the proposed mediating mechanisms linking natural environments and health.

Keywords: virtual reality, green space, blue space, clinical use of VR, elderly care, mobility-constrained individuals, life quality, pain relief, life quality

Introduction

A wealth of evidence now exists to suggest that even short-term exposure to natural settings such as woods, parks, and beaches can have a range of positive outcomes for health and well-being, especially among urban populations.[1–7] Many international studies, including a report from the WHO,[8] suggest that increased exposure to urban greenness (urban vegetation) is, for instance, associated with reduced general mortality, improved mental health, increased physical activity, and better birth outcomes.[8–10] However, accessing nature can in some circumstances be time consuming and difficult, especially for individuals with mobility constraints, eg, physical disabilities or in care situations.[9–13] Therefore, a growing body of work is investigating the ways to replace the in vivo experience with forms of "virtual" contact, in order to provide these individuals with at least some benefits of the natural environment.

In the current paper, we focus on both previous use of virtual reality (VR) nature in health and care settings and future potential use, in a rapidly growing technological field. Our central question is whether engaging with virtual nature can contribute to enhanced physical and emotional well-being in housebound or mobility-constrained individuals. We refer to urban vegetation as the "green structure" and to urban bodies of water as the "blue structure".

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Defining VR

The definition of VR is rather ambiguous. Often this term is simply used to refer to the physical equipment, ie, the hardware (eg, head-mounted displays [HMDs]), which enable viewing of virtual worlds. In this technological sense, VR has existed in one form or another since the 1950s and has been frequently used in space, flight, and military training and research. Commercially, however, this kind of technology has only recently become viable, through development of mobile, stand-alone HMDs such as Oculus Go (https://oculus.com/go) and high-end HMDs with so-called room-scale tracking and advanced hand controllers (such as the HTC VIVE, https://www.vive.com/eu/ and Oculus Rift, https://www.oculus.com/en-us/). Others define VR in terms of the virtual content, ie, the presentation format of the virtual worlds. Most often, this entails a computer-generated three-dimensional (3D) environment that permits some level of user immersion and interactivity (sometimes referred to as "true VR"). VR in the present review refers to an interaction between a person and a computer-based environment, including different set-ups such as nonimmersive flat screens, semi-immersive exposures consisting of picture projection on walls/floors, and immersive experiences through HMD.

VR in psychiatry and medicine today

Since the 1990s, the potential of using different types of VR devices in prevention and treatment of both mental and physiological health problems has been of increasing interest.[14] Generally, studies show that the use of VR technology in medicine is both easy and safe and results in high patient satisfaction.[14] Examples of present therapeutic applications of VR devices are briefly reviewed below with specific attention to cases where virtual natural landscapes have been used. However, as far we are aware, only two existing studies[15,16] have compared the exposure effect of virtual nature views to the effect of any other type of virtual view, which makes it difficult to conclude whether the observed effects depend on the exposure to VR nature per se or if they are created by a simple distraction effect of an VR experience.

Virtual reality in pain management

Alleviation of the sensation of pain is probably the most thoroughly investigated area concerning the possibilities of using VR techniques in therapeutics. Accurate pain management is of great importance and prevents several long-lasting consequences associated with adverse physical and psychological sequelae.[17–19] In pharmacological treatment, severe pain is typically managed by blocking sensory information via opioid analgesics. Opioids, however, have several negative side effects including nausea, constipation, immunosuppression, and respiratory and cognitive implications.[19] Furthermore, there is a risk of increased tolerance and a need for higher doses with chronic use, as well as a risk of developing a psychophysiological drug dependence.[14,20,21] Thus, VR devices have been presented as a noninvasive alternative, with minimal (known) side effects.

When discussing the applicability of using VR in pain management, it is important to differentiate between acute and chronic pain, as the physiological mechanisms leading to these two types of pain sensations can be quite different. While acute pain is caused by a demonstrable tissue injury and is associated with increased activity in a set of brain structures referred to as the "pain network", chronic pain may not be a symptom of an observable injury or disease at all. More usually, chronic pain is regarded as a disease entity in its own right and involves activity changes in very different neural circuits than acute pain.[22]

Most VR approaches used in attempts of acute pain alleviation involve some type of immersive game. The underlying principle of these games is that attention is diverted away from the painful stimulus through immersion in virtual action, so called "distraction therapy".[23] Examples include the SnowWorld VR system (HITLab, New York, NY, USA), RelieVR (AppliedVR™, Los Angeles, CA, USA), and the Bear Blast (AppliedVR), which have been used effectively during wound care in patients with burn injuries and other kinds of painful treatments in bedbound adults and/or children.[14,20,21,23–26]

Only a couple of studies have tested the possibility of providing distraction from an acute painful procedure by exposure to VR nature in particular. Tanja-Dijkstra et al reported an alleviating effect on pain experience and pain recollection in dental patients who were exposed to virtual coastal views but not in those exposed to virtual urban environments, compared to standard care controls.[15] However, as patients were also treated with local anesthetics, the effect of the VR nature exposure may be rather due to the reduction of anxiety and expectations of pain, than of the pain sensation per se. An earlier study by Tanja-Dijkstra et al showed that letting the participants of a simulated dental procedure experience a VR coastal walk resulted in reduced anxiety and vividness of memories when compared to the individuals who were not exposed to VR.[27]

In chronic pain management, using VR technology, depicting nature has shown promising results, especially when combined with various psychotherapeutic approaches. A study by Patterson et al[19] combined visual VR treatment with hypnotic suggestions in hospitalized trauma patients. Through a HMD, the patients were first exposed to views of an icy canyon, starry skies, and a gently flowing river and continued thereafter their virtual flight into a lush valley with a lake. Adding this combination of VR/hypnosis treatment to the standard analgesic care resulted in reduced subjective pain at both 1 and 8 hours posttreatment compared to standard care alone, although it is unclear what role VR nature played over and above the hypnosis element. Gromala et al[28] combined virtual forest walks with mindfulness meditation in chronic pain patients and found that the combination of VR and mindfulness-based stress reduction training was more effective at reducing perceived pain than the mindfulness training alone. A combination of mindfulness meditation, education in pain management, and usage of VR devices depicting either beach or meadow scenarios (including the natural sounds), has also shown long-term benefits in form of significantly reduced pain and depression in fibromyalgia patients.[29]

Neurological disorders and stroke rehabilitation

Everyday activities demand certain aspects of body functioning. Unfortunately, many neurological disorders (eg, Parkinson's disease, cerebral palsy) or life events (eg, strokes, traumas) can decrease individuals' mobility, resulting in reductions to life satisfaction and well-being.[30] Consequently, rehabilitation programs that increase individuals' physical abilities have been of great interest. VR rehabilitation programs (most of which have been nonimmersive, but there are exceptions) have focused on four primary outcomes: motor control,[31–36] balance,[37–41] gait,[42–46] and strength. A recent meta-analysis concluded that, in general, these programs constitute an efficient form of therapy, which is occasionally more effective than the comparable standard rehabilitation programs.[30] One reason for the success of VR treatments may be that the traditional rehabilitation programs often involve repetitively performing "movements without purpose" while the VR environments may provide the patients with more stimulating and motivating tasks. Most of these VR approaches also include a "feedback moment" that is achieved by recording the movements of the patient during the VR exposure and directly projecting these movements into the VR world, which in turn allows the patient to immediately adjust their motions. The effect of natural environments as such has not been a focus in any VR rehabilitation studies that we have come across. However, in some cases, elements of nature or nature views have been used as a background to an interactive game.[31,40,43] One approach of VR rehabilitation of children with neurological gait disease has included a navigation game depicting a walk in virtual nature.[43] Furthermore, rehabilitation treatments combining walking on a real-world treadmill with, for example, trying to avoid collision with virtual objects[41,45,46] have in some cases[41] depicted walking in a natural landscape.

Virtual reality as a distraction and relaxation tool in cancer treatment

Cancer treatment involves a wide variety of physically and emotionally depleting procedures, such as chemotherapy, painful invasive procedures, and hospitalization.[47] Oyama et al[48] published the first study on the topic and demonstrated that viewing beautiful scenery with nature sounds and scents significantly decreased negative emotions, pain, and anxiety in patients during ongoing chemotherapy infusion. Several later studies that have used VR technology in order to relieve chemotherapy-related distress symptoms (ie, either ocean or art views) indicated reduction in anxiety, distress and fatigue (see Chirico et al[47] for review) and perception of shorter treatment time in patients using VR compared to the ones who did not.

Exposure to VR nature has also been used in attempts to reduce the distress of hospitalization in cancer patients. Baños et al[51] investigated the effect of an intervention that consisted of four 30-minute sessions during 1 week in which cancer patients navigated through virtual environments, such as an urban park or a wild forest. Although an increase in positive emotions was detected in VR-treated patients, the authors also noted some difficulties with using the VR devices, potentially limiting the technology's feasibility. A similar experimental design was used by Espinoza et al,[52] who reported that exposure to the VR intervention resulted in reduction of stress and significant improvements in levels of happiness in hospitalized cancer patients.

Mental health and well-being

The use of VR therapies for mental health and well-being has focused mainly on treatment of anxiety disorders, eating disorders, phobias, and post-traumatic stress disorder. According to a recent systematic review by Valmaggia et al,[53] studies published pre-2012 generally showed that VR was an effective form of therapy for mental disorders compared to "treatment as usual"; however, generally, their effect was either equal or less efficient than conventional cognitive behavior therapy

(CBT).[53] Studies published after 2012 provide evidence for VR being more effective than "treatment as usual" and also indicated that VR can be as effective as or in some case even more effective than CBT. This may reflect improvements in the immersiveness of the experiences achieved through technological advances over this period.

Eating disorders and obesity

Eating disorders are widespread and often chronic mental disorders. Use of VR treatment in eating-disorder patients has typically involved exposure to food items in virtual supermarkets or kitchens, where the patients are encouraged to reflect over food cravings and to make healthy food choices; alternatively, these provide training for improved body image through repeated exposure to diverse body types.[54–60] This kind of VR treatment is typically combined with other psychological therapies, teaching coping skills in the real world. The results generally show that using VR devices improves the capacity of obesity patients to maintain long-term weight loss.

To the best of our knowledge, only one of the eating-disorder studies has used VR nature imaging as a form of therapy. In this study a relaxation therapy, provided by a trained psychologist, was used either alone or in combination with VR nature images in individuals belonging to a weight-loss program.[61] At 3-month follow-up, the patients using VR in combination with relaxation therapy were found to be better at reducing emotional eating than the ones who were exposed to the psychologist-provided therapy only.

Phobias, anxiety, and agitation

Phobias and social anxiety disorders significantly affect quality of life and hinder various everyday and/or recreational activities. In studies attempting phobia treatment through VR devices, patients are typically introduced to virtual objects, conditions, or environments containing the person-specific type of fear (ie, spiders, crowds, heights, needles, listening audience) gradually over the course of repeated sessions over several weeks, in a process known as systematic desensitization.[62–70] In general, the combined data from these studies are promising and encourage continued development of VR in treatment of phobias and social anxiety, especially in cases where in vivo treatment may not be safe or feasible.[68]

Post-traumatic stress disorder entails past involvement in a traumatic event, and symptoms, such as intrusion, avoidance, negative alternations in cognition and mood, and/or changes in arousal and activity.[68] The VR therapy of this disorder has involved, for example, exposing patients to an environment with sounds and images similar to the site of the past traumatic event.[70–72] The practicality of this approach is obvious as recreating certain environments in vivo may, in many cases, be both undesirable and physically impossible. Results suggest that VR treatments in this field show robust improvements (with medium to large effect sizes) in key outcomes compared to standard exposure treatments.[68] Natural landscapes and natural sounds have been used in specific cases, involving for example rehabilitation of the veterans of Vietnam war, where the images (viewed from a helicopter) of the Vietnamese jungle were used, although clearly in this case, the natural scenes were not necessarily intended to be calming and restorative in the way in which many other VR nature interventions often aim to be.[72]

A slightly different form of anxiety relates to the agitation experienced by many people with dementia, a state that imposes large burdens of care on caregivers. Reynolds et al[16] compared the effect of VR nature (nonimmersive, in this case) to one of VR with other content (a generation movie in this particular case) and found that heart rate declined significantly when the patients were exposed to virtual nature compared to the control group. A trend toward happier emotional states during VR nature exposure was also observed.[16]

Depression

Although anxiety and depression have different etiologies and symptoms, co-occurrence is common[73,74] and the initial medical treatment of these disorders is often very similar. Thus, we might expect a similar number of studies exploring the use of VR in the treatment of depression. To date, however, there have been far fewer VR studies looking at depression than anxiety-related issues and the few examples that do exist have all chosen very different approaches. VR devices have been used, for example, to present an educational video of different relaxation techniques,[75] to enable patients to practice delivering and receiving compassion through a virtual body,[76,77] or to train people with depression to cope with everyday situations.[78] Despite epidemiological evidence and controlled field studies that suggest that greater exposure to natural settings can reduce the risk and help in the treatment of depression,[3,79] we found that no studies attempted to investigate the effects of exposure to virtual nature in depressed individuals.

The greater number of studies looking at the use of VR to support the treatment of anxiety-related disorders compared to depression is intriguing but perhaps not surprising. Anxieties are often related to specific targets or triggers (eg, snakes, memories of trauma, situational uncertainty), which may be impossible or unsafe to recreate in "real" treatment situations but have the potential to be tackled individually and "synthetically" and "safely" with the use of targeted VR treatments. Depression, by contrast, is often a more diffuse condition characterized by a general lack of interest in daily activities and lower energy levels and feelings of self-worth, which are less obviously tackled with specific VR interventions.[80] Moreover, depression may also be accompanied with greater apathy and reluctance to try new things, making it difficult to engage people with innovative treatments such as VR. These thoughts are largely conjecture at this stage, and further research is needed to tease apart if and why VR may be more productive in the treatment of anxiety than depression-related issues.

Cognitive rehabilitation

Cognition refers to the mental processes associated with processing information and responding with appropriate actions.[81] Cognitive impairment is a common effect of neurodegenerative diseases, traumatic brain injuries, and stroke and can lead to reduced ability to perform self-care tasks and participate in social and community activities. Different multistimuli therapeutic VR systems, for example, BTS-Nirvana[82] and VRROOM[83] have been tested in attempts to provide relaxation, or as tools for attention and memory training in traumatic brain injury and stroke patients.[82,83] Depending on the aim of the rehabilitation and of the target group, the VR approaches may include, for example, views of a natural marine environment,[82] or a 3D city (NeuroRehabLab, Madeira Interactive Technologies Institute, Funchal, Portugal) where the patients will be able to train how to accomplish specific everyday tasks.[84] Generally, VR is considered to be a new, useful, and cost-effective tool for cognitive rehabilitation;[85] however, more research is needed to identify the patient and treatment factors that contribute to successful outcomes.

Present development of VR technology

Presently, VR technology is developing at an unprecedented speed and transforming from a "hyped, overrated technology" to a commercial reality.[86] Still, VR has some way to go before it can be considered as a "mainstream technology", comparable to the user friendliness of laptops and smartphones. Current commercial VR systems, such as the HTC VIVE and Oculus Rift, are still relatively expensive and require a high level of computer proficiency, which reduces accessibility for most people.

Today, features such as increased resolution, larger field of view, wireless data transmission, and more possibilities for interaction are the main areas for the development of the major VR producers. In addition, the social dimension of VR, which presently is relatively underdeveloped, is expected to gain more importance in the future. Companies, such as Facebook and Sansar, are investing a lot of effort into bringing a social dimension to their virtual worlds.

Developing realistic VR nature has been, and still is, especially challenging. Due to the complexity and variety of the natural environments, many attempts to depict virtual nature have resulted in static, flat, and artificial impressions. Trees, for example, have often been modeled as a collection of texturized planes, and it has been even harder to mimic the appearance and behavior of water environments, attempts of which have often resulted in "plastic" and lifeless images. However, greater accessibility to open-source data, courtesy of major VR software developers (eg, Unreal Engine 4, https://www.unrealengine.com/en-US/what-is-unreal-engine-4), provides new opportunities for building realistic VR nature applications.

Taking a longer perspective, VR systems will most likely not be limited to visual and auditory stimuli. For example, Long et al[87] have demonstrated that it is possible to render volumetric haptic shapes in mid-air using ultrasound. Integrating this technology in VR technology would make it possible to not only see a virtual ball but also to touch it, even without using a haptic-enabled device (such as haptic gloves). Furthermore, developers are working on olfactory displays, which make smelling a virtual flower possible. However, many technological hurdles need to be overcome before this technology finds its way into consumers' hands.

Pathways linking health with nature exposure and the applicability of these in VR-based therapies

There are now numerous empirical studies[1–7] supporting the contention that expose to natural environments may be beneficial for human health. In the following sections, we consider the underlying mechanisms behind any possible benefits so that VR designers can begin to incorporate them in their designs in order to help optimize the experience and outcomes for patients.

The WHO's 2016[8] report "Urban green spaces and health: A review of evidence" suggested nine possible pathways linking the observed health outcomes and urban green and blue infrastructure (ie, urban nature). These included:

- Improved relaxation and restoration
- Improved social capital
- Improved functioning of the immune system
- Enhanced physical activity, improved fitness, and reduced obesity
- Anthropogenic noise buffering and production of natural sounds
- Reduced exposure to air pollution
- Reduction of the urban heat island effect
- Enhanced pro-environmental behavior
- Optimized exposure to sunlight and improved sleep.

Below, these mechanisms are briefly discussed from the viewpoint of possibilities for using VR nature as a tool to promote positive outcomes in different groups of patients.

Relaxation and restoration

Green and blue environments are suggested to have a relaxing effect, allowing people to recover from demanding situations.[8] It is plausible that green space affects the brain and body via psychoendocrine mechanisms, including the function of the hypothalamic pituitary adrenal (HPA) axis. The HPA axis regulates stress hormone (cortisol) secretion, and its dysregulation is associated with a wide range of disease outcomes and immune system malfunction.[88] Several studies have provided evidence for this theory;[89] however, the complexity and sensitivity of the stress regulation physiology are often a methodological complication.

One pilot study has been conducted to investigate the effect of VR nature (with and without nature sounds) on physiological stress recovery in healthy volunteers.[90] During this experiment, the virtual environment was presented by using a CAVE™ system (EON Development Inc., Gothenburg, Sweden) including three rear-projected walls and a floor projection. The results were promising, indicating enhanced stress recovery and parasympathetic activation in the group exposed to the VR nature including sounds, compared with the individuals exposed to the VR nature without sounds, or controls who got to read a popular science magazine. Interestingly, the authors reported that being exposed to a silent virtual forest (in contrast to the virtual forest with natural sounds) occasionally was perceived as a bit uncanny by the participants. This indicates that for being able to provide a coherent "nature-like experience" combining multiple sensory (eg, visual and auditory) cues may be important.

VR interventions depicting rich natural environments with multisensory stimuli may thus have a potential for use in a range of medical, psychiatric, and possibly even in palliative care contexts, as a means for recovery from or reduction of stress and anxiety in individuals who are either bedbound or experience reduced mobility. Stroke, cancer patients, and the elderly might be examples of groups, in particular, where VR nature exposure could be used for increased mental well-being. Since decreased rumination and increasing meditation may be an effect of exposure to nature environments,[91,92] VR nature treatment may also be beneficial for the reduction of depressive symptoms, associated with, for example, long-term illness, chronic pain, or hospitalization.

Improved social capital

Social relationships have a well-known protective health effect.[93,94] Social isolation on the other hand is a predictor of morbidity and mortality.[95,96] Both the quantity and quality of green and blue space have been suggested to foster social interactions and promote a sense of community, among adults and children,[97–100] whereas a shortage of green space in the residential environment is associated with feeling lonely and lacking social support.[101,102]

On the face of it, improved social capital as a mechanistic pathway linking health and green and blue structure does not sound particularly relevant when discussing the possible use of VR nature in therapeutics. However, providing individuals with limited mobility with easily used technology that allows experiencing virtual nature walks or ocean explorations in combination with virtual (eg, online) meetings with friends or family members (using VR devices, as well) is an interesting possibility. Previous studies have shown that increasing the computer skills in the elderly and introducing social networking and videoconferences in care homes can reduce the level of loneliness in the elderly.[103–105] Adding a component of a virtual world where the elderly can "walk" together with friends or relatives and share their observations and experiences while "walking" may thus increase the perception of quality of life. Loneliness is a common problem in older adults, in particular, and strongly associated with the risk of different health problems and decreased functional capability.[106,107] Chronic pain and long-term illness, on the other hand, increase the risk for loneliness.[108,109] Combining virtual social interaction with the relaxation effect of VR nature could thus contribute to both avoiding feeling lonely and to decreasing the risk for illnesses associated with loneliness.

Improved functioning of the immune system

Enhanced immune functioning has been suggested to be a central pathway between nature and health.[110] However, as far as we are aware, no cohort/population studies exists that link the urban green or blue structure to improved the immune system. Thus, this hypothesis is mainly based on publications that are, for example, reporting the immune system-stimulating effects of Japanese "forest bathing" tradition[111] as well as on studies indicating that increased exposure to biodiversity, natural allergens, and diverse microorganisms in natural environments is associated with beneficial health outcomes.[112,113]

For obvious reasons, VR will not be able to copy the microbial or biochemical effects of in vivo nature. On the contrary, using VR devices in hospitals, for example, would expose the users to a "clean nature", while the presence of indoor plants may entail some exposure to allergens and microorganisms. Thus, the only way we can see of VR nature affecting the immune system would be through the previously described pathway of relaxation/stress reduction.

When discussing stress, it is important to differ between the physiological pathways activated during acute vs chronic exposure. While acute stress is a fundamental and adaptive survival mechanism, that is generally without long-lasting effects on the immune system, then long-term, chronic stress suppresses and dysregulates both innate and adaptive immune response.[114,115] Consequently, chronic stress is also likely to increase susceptibility to a large number of diseases. Thus, exposure to VR nature may, by inducing relaxation and thereby reducing the immune deleterious effects of chronic stress, improve the functioning of the immune system and physical recovery in hospitalized patients or in individuals suffering with long-term illness.

Enhanced physical activity, improved fitness, and reduced obesity

One of the most often mentioned behavioral pathways linking green and blue structure and health is the motivation for physical activity. Abundant vegetation and bodies of water provide an inviting setting for physical activity, which has a well-established positive impact on both physical and mental health.[8] Studies conducted in different parts of the world have reported that recreational walking, increased physical activity, and reduced sedentary time are associated with the use of and access to green and blue space,[9,116–124] particularly among certain groups such as dog owners.[125]

Public use of VR devices is more often associated with physical inactivity than activity. Using VR in medical care should, therefore, be recommended primarily for the treatment of patients with reduced mobility or in cases when in vivo nature exposure is not possible. However, as described above, a number of motor rehabilitation studies have found that using VR technology increases the enthusiasm and motivation of the patients for rehabilitation training compared with traditional physiotherapy. Thus, motor rehabilitation exercises enabling virtual walking, swimming, or paddling in natural landscapes may provide a more motivating training environment and combine the positive health effects of both physiotherapy and green and blue structure.

Reduced exposure to harmful environmental exposures

Urbanization increases citizen's exposure to noise and air pollution as well as the urban heat island effect.[126] Although urban nature can mitigate some of these effects, it rarely eliminates them. Thus for particularly vulnerable individuals (eg, people with COPD or elderly), it may be better to recommend virtual contact with nature than actual contact with (urban) nature when conditions are poor (eg, high temperatures and high noise or air pollution levels).

Enhanced pro-environmental behavior

Pro-environmental behavior entails "behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world".[8,127] It has been suggested that external stimuli, in the form of exposure to natural environments, especially during childhood, may be important to induce pro-environmental behavior.[128,129] The beneficial health effect of this pathway is suggested to be achieved by increasing people's motivation to create (and give rise to) a less polluted outdoor environment.

It is possible that being exposed to virtual nature can modify people's attitude and interest for environmental thinking.[130] A key concern in recommending the use of VR devices for a "nature experience" is that it might increase the likelihood for stationary lifestyle and decrease individual's motivation to in vivo nature exposure. However, in some groups of patients, such as the sufferers of specific anxieties and phobias (ie, water, fish, insects, and many more) or of depression-related apathy,[131] exposure to VR nature might provide the kind of external stimuli needed to trigger an appreciation and interest for in vivo nature exposure.

Optimized exposure to sunlight and improved sleep

If access to green and blue structure is associated with more time spent outdoors, it is also likely to be accompanied by increased exposure to sunlight. Exposure to sunlight is crucial for vitamin D production in human, and optimum levels of vitamin D are important for a multitude of physiological functions contributing to health and well-being. Increasing the time spent on outdoor activities significantly decreases the risk for vitamin D deficiency.[132,133] Furthermore, exposure to ultraviolet (UV) light has often been associated with negative health effects; however, a recent study has indicated that UV-induced release of nitric oxide in the skin might contribute to better health by lowering the risk of hypertension and cardiovascular disease.[134] Exposure to daylight, in general, stimulates alertness, controls circadian rhythms, and promotes healthy sleep. Adequate sleep is crucial for good health, and sleep deprivation has been linked to many adverse health effects.[135–137] Several studies suggest that living in a greener neighborhood lowers the risk for insufficient sleep.[8,138,139] It is possible that increased greenness increases people's exposure to natural daylight and in this way helps to maintain circadian rhythms.

VR is not likely to become a replacement for sunlight exposure, although it could be used in conjunction with sunlamps, which have been demonstrated to help combat mood disorders among individuals who get little direct sunlight (eg, in winter).[140] However, by increasing the interest in or decreasing the fear of experiencing nature in vivo (as described in the section above), it may in some cases result in increased interest in spending time outdoors. In northern latitudes, the usage of light therapy devices or light rooms is increasing in popularity during periods of cold weather and short days. Combining light therapy with exposure to virtual nature could provide additional health benefits.

Challenges and considerations for using VR in clinical or care home settings

Besides opportunities, use of VR technology also involves certain challenges and risks. The feasibility and cost efficiency of using VR technology instead of classical treatment methods may be more suitable in some groups of patients than in others and needs careful evaluation.[141,142]

The mental and physical capability of the user is important to be taken into account when the use of VR devices is considered. Cybersickness is the most often mentioned complication associated with the use of HMD VR devices. As HMDs, at least partly, eliminate visual cues from real world and involve high level of stereoscopic and stereophonic immersion in virtual world, this can give rise to a mismatch between visual and vestibular systems and occasionally trigger cybersickness.[143] Old age and certain neurodegenerative diseases have been occasionally observed to hamper the ability to use HMDs in physical training.[144] For example, older individuals have been observed to have more difficulties to readjust their posture[145] and walking direction[145,146] while using HMD compared with younger ones. Older people also experience greater difficulties when exposed to incorrect or mismatched visual, somatosensory, and vestibular information than younger individuals do.[147] Thus, it has been suggested that integration of visual and vestibular sensory information should be specially designed for use by older people.[148] The new generation of HDMs, such as the HTC VIVE, may eliminate some of the risks for sensory mismatch thanks to their tracking system, which allows the generated real-time 3D view to be updated according to the user's orientation and movements.[149] Other simulator display technologies (such as spherical and angled 3-panel) that induce vection[150] (ie, illusions of self-motion) and, thus, a heightened degree of immersion, have been suggested as an alternative to HMDs. However, the risk of simulator sickness in older people has also been reported with angled 3-panel driving simulator.[151]

Scientific reports generally concentrate on reporting results provided by individuals participating in the studies. However, to be able to learn from past experiences, we may occasionally benefit from learning about patients who for different reasons were not able to participate. For example, when Mosadeghi et al[152] investigated the applicability of HMD in hospital setting, 57 out of 87 eligible patients declined to take part in the experiment. Two participants reported symptoms of cybersickness and one additional dropout was due to frailty to support the weight of the device. Old age was, in this particular case, the only statistically differentiating factor characterizing the refusers. Other reasons for refusal included:

> not understanding the purpose of VR, feeling anxious about using the goggles, feeling too tired or too ill to participate, concerns about "losing control" of one's personal environment at a time when control is already limited, and harboring concerns that VR is a "psychological experiment".[152]

Potential issues and fears like fitting corrective eyeglasses inside HMD, clumsiness of the wired apparatus, and limited extent of the VR content have also been reported in another study.[153] Thus, in order to create a successful intervention, the need for proper training of both the users and the assisting staff should not be neglected.[89] Dockx et al[154] reported that initially less enthusiastic attitudes of older participants toward the use of VR in fall prevention training improved considerably after VR experience. A gradual introduction to VR by using television screens or angled 3-panel setups could be a solution to reduce feelings of fear among the potential patients. Perceived and actual abilities to stop and customize the content of the VR experience by the users have been reported as factors making the study environment more friendly and nonpushy.[153] In addition to caretakers, care-providers will need support and training before VR interventions are introduced. Frequent use of VR technology in care homes is today largely hindered by the complexity of the technology and its maintenance. Thus, improvements in both design (in form of increased robustness and simplicity) and support packages, assisting with staff training, are necessary before VR technology can be routinely used in care facilities.

Finally, being a relatively new technology, there is currently a lack of longitudinal VR studies in clinical settings. Thus, there are research gaps to be addressed, both in terms of whether beneficial effects of virtual nature can be sustained with repeated exposure and whether there are any associated long-term adverse effects.

Other potential drawbacks of long-term VR use – addiction and mood changes

Due to the relatively recent emergence of consumer VR, the number of studies exploring long-term negative health or behavioral impacts of VR in humans is very limited. Thus, no studies to date have explored potential overuse and addictiveness of VR, and controversially, VR is, in fact, currently being utilized as a clinical tool to treat addiction.[155,156]

According to the researchers working in the field of human–computer interactions, until recently VR systems have presented too many short-term adverse effects to allow for long spells of immersion.[157,158] Thus, it is conceivable that VR addiction among general public is going to increase following recent development of VR versions of popular console games that are designed to encourage long periods of uninterrupted gameplay. However, it is difficult to imagine that VR nature programs would promote overuse of the technology, in the way that gamified experiences might. Nevertheless, implementation of long-term VR nature use in clinical and care settings still requires a cautious approach, as some effects of it may be rather unexpected. For example, it is possible that VR nature experiences lead to lowered mood if users, especially those with health conditions that limit traveling opportunities, reflect that they may never be able to visit the depicted environments in vivo.

No studies to date have investigated what constitutes the optimal "dose" of the VR nature exposure. Positive health impacts of VR nature exposure in lab settings have been observed following both 5- and 15-minute treatment periods.[90,159,160] Although these exposure times were intentionally selected to avoid potential adverse effects of VR HMDs (eg, cybersickness, eyestrain), some evidence suggests that short periods of nature exposure may be most beneficial for health. For example, Barton and Pretty [161] reported that 5-minute bursts of exposure to real natural environments were most beneficial for improving mood and self-esteem, irrespective of age, gender, location, and health status. Another study[162] found that recovery from stress, in terms of pulse rate, skin conductance, and muscle tension, occurred much more rapidly in the first 4 minutes of exposure to nature photographs than at subsequent time intervals. According to a recent publication,[163] viewing a virtual forest on a TV screen for just 90 seconds was sufficient to significantly reduce oxyhemoglobin concentrations in the right prefrontal cortex (indicative of physiological relaxation) compared to exposure to a virtual city. Thus, though to our knowledge, no studies have yet compared the relative effects of different VR nature exposure durations, short-term exposures may in fact prove optimal for well-being.

Conclusion

While contact with real-world nature is, in many cases, preferred and recommended, VR use can be an alternative in cases when in vivo contact with nature is not possible or not recommended for various reasons (eg, individual frailty, excess temperatures). There are many possibilities for use of VR technology in psychiatric and medical care; however, the risks, benefits, and cost efficiency of these attempts should be carefully assessed and the outcomes should be measured in a scientifically valid manner. The current review has nonetheless demonstrated that VR nature could play a role in each of the proposed mediating mechanisms linking natural environments and health, as proposed by the WHO, suggesting it needs not just be considered as a "nice to have gimmick". Since this technology is changing and developing constantly, we can expect more technically advanced and fine-tuned VR approaches in the future.

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Disclosure

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