# Nature Pills and Current Virtual Nature Implementations

Literature Review

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## ABSTRACT

Interaction with nature, whether it be walking in a forest or simply sitting on a park bench, can lower stress levels and improve a person's wellbeing. However, with today's technological age, the availability and access to "real" nature is decreasing, and the Computer Science industry is looking for virtual alternatives. Creating access to nature from the comfort of one's own home, through a virtual nature pill, is important for our society. Virtual nature exposure has been explored in the past, ranging from images or videos projected onto a screen, showing users 360-degree videos while they wear a VR headset, to computer generated environments that allow users to discover the environments themselves. These studies' experiments, techniques, and results are discussed.

## KEYWORDS

Virtual Reality, Nature Pills, Virtual Nature, Technological Nature, Immersion, Interaction

## 1 Introduction

Spending time in nature has a positive impact on people's mental health and wellbeing [1], by helping reduce stress [2], improve sleep [3], and bring greater happiness and life satisfaction [4]. But not everyone has access nature sites, whether it be due to distance, lack of time, or lack of transportation and/or mobility. As technology improves, there has been a shift in habits in urban environments, and with availability of online shopping and virtual meetings with friends, the need to go outdoors decreases, which leads to increased screen time and time spent indoors. Therefore, we need to start looking for alternative ways to access the benefits of nature. Research shows that even just looking at nature can help recover from mental fatigue [5], and from stress [6]. Digital and Virtual Reality (VR) nature pills could allow people to explore nature from the comfort of their own homes.

The following topics will be looked at in this review: existing research on nature pills, in the form of exposure to virtual nature on a two-dimensional screen, as well as VR-based implementations, which range from 360-degree videos that can be watched with a VR-headset, to computer generated interactive environments. Research on how to make more pleasant environments in VR will also be discussed.

## 2 Nature Pills

Exposure to nature is an important aspect of life and has been studied extensively in the past to showing its many positive impacts on one's wellbeing. One study finds that the amount of green (gardens/dedicated nature sites) in the surrounding neighbourhood is a significant predictor of stress, and as green space increased, perceived stress levels of participants decreased [2]. Encouraging regular visits to local nature is seen to be important to general health. In a study testing the self-reported sufficiency of sleep among US adults, access to nature reduced the chance of reporting insufficient sleep, indicating that there is a link between nature exposure and sleep sufficiency [3]. Another study found that access to a diverse set of nature, as well as being able to view nature from a window, is associated with higher life satisfaction [4]. The strength of the individual's connection to nature was found to enhance the benefits gained from nature exposure. With clear benefits of this nature interaction, healthcare providers in some countries have started to prescribe nature, often referred to as "nature pills".

Nature pills in the context of this review is a digitalised exposure session to nature, however other studies use different terminology referring to similar concepts. The term "Technological Nature" has been used to describe the technologies that imitate, simulate, and/or promote the interactions between humans and nature [7]. Examples of this are real-time/live viewings of nature, and Nintendo's mobile game *Pokémon Go*, which during its most popular point in 2016, promoted outdoor activity [8]. Though *Pokémon Go* gamified physical activities outdoors, spending time outside does not necessarily imply nature interaction. Although this mobile game is a good example of technological nature (given that definition), our focus lies in systems that can have users fully experience nature from indoors, which we will continue to refer to as virtual nature. We first look at five papers that use only two-dimensional versions of virtual nature.

McAllister et al. [9] showed that exposure to virtual nature (or a nature pill), through video-based exposure to nature clips, for only two to three minutes could produce significant improvements in an individual's underlying mood. This experiment was done by measuring the perceived restorativeness, positive and negative affect in participants when exposed to videos of either 'wild' nature (far from any urban environments), 'urban' nature (nature found near buildings, houses, and streets), or non-nature (of buildings, parking lots, and roads). Restorativeness is the ability of the environment to re-establish cognitive capabilities for human information processing. The two nature experiences resulted in higher perceived restorativeness (compared to the non-nature setting), with wild nature generating the highest and best results. Urban nature was found to not be significantly different from non-nature in evoking positive affects in participants, but wild nature was shown to enhance positive emotional states.

Kjerllgren et al.'s [10] experiment comparing real nature to a 2D slideshow of the same environment found that both settings produced the same stress reducing effects. They had 18 participants (all suffering from stress and/or burnout syndrome) split into two groups, one group going to a real nature environment, and the other being placed in a room seated 2m away from the screen, to be presented with pictures of the same environment in the form of a slideshow. Based on both physiological measures (including pulse and blood pressure) and self-reported standard psychological measures (e.g., a scale for measuring stress levels), they found real nature to be more beneficial in some areas, such as increased energy, but found that the stress reducing effects of the two settings were the same.

Brooks et al. [11] finds that only real nature increases positive affect, but negative affect and mood can be improved (though less significantly) by nature photographs. Their study was testing the differences in effects on mood the season and type of nature contact could produce, by analysing self-reported standardised measurements of participants across three studies. The first study compared walking indoors (through hallways) to outdoor (in an urban park), the second repeated the first but with photographs of the two settings instead, and the third directly contrasted actual nature with pictures of nature. Similarly to Kjerllgren et al.'s study [10], this study only used pictures of nature and no audio.

One study combined non-immersive virtual nature (i.e. videos or images projected on a screen) with physical activity by running on a treadmill [12]. Figure 1 shows the experimental setting of this study. They had 30 participants perform three 20-minute treadmill runs at self-selected paces while viewing three different medias. The first being a static image of nature, the second a video of a nature environment, and the third a self-selected entertainment media chosen by the individual participant. They measured distance run, heart rate, and self-reported emotional states through the Sport Emotion Questionnaire (SEQ). Self-selected entertainment was found to produce greater physical benefits, while the nature designs reported greater happiness. Although they used some form of a nature pill, since this study focused mostly on finding the best environment for exercising specifically, and not on creating a relaxing nature environment, we will not look at it in more detail.

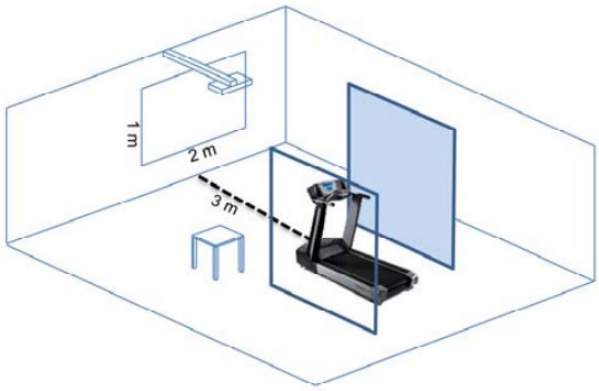


**Figure 1. The treadmill was placed 3m away from the wall and the image/video was projected on a 2x1m screen. Partitions were placed on each side of the treadmill to reduce surrounding distractions [12].**

De Kort et al. [6] researches whether an environment where a user feels more present has stronger restorative and stress reducing effects. Participants performed a stress inducing task, namely a set of mental arithmetic tasks while industrial noises were played, and were then presented with a nature film on either a high (large) or low (small) immersive screen. Both physiological (skin conductance level and heart period) as well as self-reported affect and presence were measured. Interestingly, increased immersion did not influence self-reported affect, but the physiological measures did produce a significant difference, thereby concluding that more immersive projection (through increasing screen size) has a higher restorative potential for a projected nature pill.

# 3 VR Nature Emulators

## 3.1 360-Degree Videos

More immersive, 360-degree video environments allows users to look around but not to move in a direction of their choosing. We shall review three of these studies here.

Browning et al. [13] seeks to compare short exposure of nature in real life to 360-degree nature videos experienced in Virtual Reality. Participants were randomly allocated to one of three settings, the first being a real outdoor forest, the second a 360-degree video (replayed in VR) of the same forest setting, and the last an indoor setting with no visual or auditory experiences. The VR environment had sounds played through noise cancelling headphones. In all three settings, skin conductivity, and self-reported restorative effect and mood of the participants were recorded. 98 students who had been deemed eligible had volunteered, but some surveys were

incomplete, and some equipment failure occurred, leaving only 89 participants with mood and restorativeness data, of which only 65 had skin conductivity data. Some surveys were taken before, and some both before and after experiencing virtual nature. Skin conductivity was measured throughout the experiment. Both real and virtual nature conditions were found to be better compared to the indoor condition without nature, and were found to increase physiological arousal, though only real nature showed a measurable increase in positive affect. They concluded that nature may provide beneficial alternatives to real nature visits, especially to those who may not always have access to restorative outdoor environments.

Calogiuri et al. [14] aimed to do a similar experiment, but instead with a nature walk. 26 participants experienced 3 experiments: they went on a real nature walk and were later exposed to a 360-degree video of the same nature environment, while sitting down and then walking on a treadmill. Figure 2 shows the experimental conditions of their study. Environmental perceptions (presence and restorativeness), physical engagement (treadmill and real-life walking speed, heart rate, perceived exertion), perceived affective responses (enjoyment and affect) and qualitative information were collected from participants, but they could not reproduce the psychophysical benefits of the real nature walk in the VR setting.


**Figure 2: Participants went on a walk in real nature (A), saw a 360-degree-video of a walk in the same location while sitting (B), and while walking on a treadmill (C) [14]**

The third study, by Yu et al. [15], aimed to compare the influences of a virtual forest and virtual urban VR environments on restoration. 30 participants were each exposed to both these environments, one week apart to avoid the carry-over effect. The urban 360-degree video was recorded in a shopping district with crowds, traffic, noise, and little greenery, The forest video was recorded in a national forest and included waterfalls, trails, and trees. Both these videos were recorded in high quality. Figure 3 shows a flow diagram of their experimental procedure, which in summary are two sets of 5 stages: getting base physiological measurements, doing a stress-inducing task, remeasuring and recording psychological responses, being exposed to one of the two environments, and then taking measurements and responses one last time. Their experiment finds that both settings have no significant differences with participant physiological responses, and that forest environments have positive impacts on psychological health, while urban environments impact this negatively.

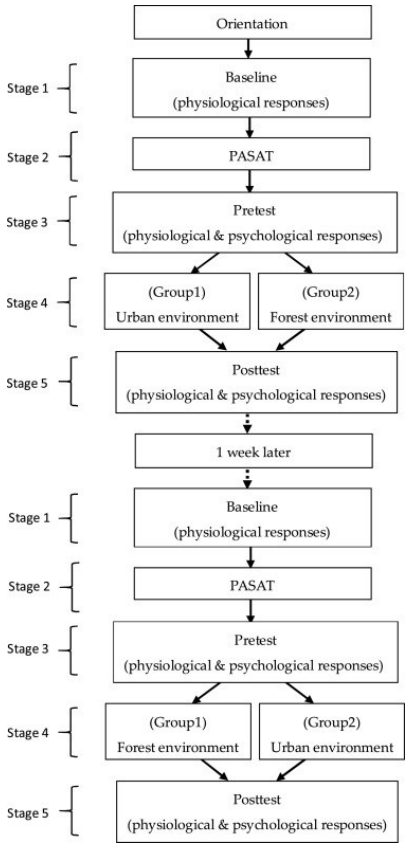


**Figure 3: A flow diagram of Yu et al.'s experimental procedure. PASAT stands for Paced Auditory Serial Addition Test, and was used as their stress inducing task [15].**

## 3.2 Interactive Computer-Generated Nature Environments

Finally, we discuss two researches which include computer generated VR environments.

Yeo et al. [16] aims to find the best way to deliver a nature environment to improve an individual's mood. They performed a study on 96 individuals that compared the effects of three increasingly immersive forms of virtual nature: Television, 360-degree videos, and interactive Computer-Generated Virtual Reality (CG-VR). The CG-VR environment allowed users to move around in an underwater environment within the confines of the room, and allowed interaction with fish and corals using provided handheld controllers. Self-reported experienced presence, boredom, mood,

and nature connectedness were recorded. As hypothesized, on average a greater feeling of presence was felt in VR over the TV exposure, with CG-VR producing the best results overall, likely due to the additional interactive factor. The CG-VR environment reduced boredom and negative affect while increasing connectedness to nature and positive affect. While the reductions (of boredom/negative affect) were similar across the three forms, CG-VR had the most significant improvement in positive affect when compared to TV.

One research, by Deltcho et al. [17], creates an environment with very high immersion, by having users experience four senses in their environment. They research the restorative effects of Virtual Nature when participants are exposed to a slide show in VR, and are allowed to explore a virtual forest in VR. The latter environment allowed participants to freely explore a forest with greenery, bodies of water, rocks, and terrain elevations. The environment was rendered in real time in high resolution with realistic lighting, and used multiple user senses by including nature sounds (hearing), forest air freshener (smell), and somatosensory[1] feedback (feeling) by having users stand on a rumble pad that would shake slightly upon every step taken in the VR environment. They had 22 participants experience the two environments while recording heart rate, skin conductivity, and self-reported restorative effects. Their most important results find that computer generated nature in VR can promote restorative effects. Another interesting result is that the artificial nature of the forest did not seem to negate the benefits of walking in a virtual forest.

## 4 Discussion

See appendix A for a comparison of the most important review papers discussed.

Although McAllister [9], Kjerllgren [10], and Brooks [11] et al. showed that 2D screen-based exposures produced similar (though sometimes weaker) positive effects on an individual when compared to regular nature exposure, their studies do not place users in an immersive, or explorative environment, which could be shown more useful in reproducing the positive effects of nature. The lack of exploration, and minimum use of senses can cause participants to not appreciate the virtual environments the same way they would a real one, leaving participants feeling as if "something is missing". This was seen in both Kjerllgren [10] and Brooks et al.'s [11] study, who only used photographs of nature (instead of videos) and included no audio sounds. This could be avoided by adding the use of additional senses such as sound, and allowing user to interact with virtual environments such as free motion around the virtual forest, or engaging with objects in the scene, perhaps by allowing users to throw sticks and/or rocks. Despite the lack of interaction, these 2D projection experiments are our first indication that virtual environments are a good way of reducing stress from an indoor, virtual environment. And in line with de Kort et al.'s findings [6], by creating a more immersive environment, stronger stress reducing effects could be generated.

Advances in the computer science industry now allow for extremely realistic virtual environments, and the use of VR-headsets could allow users to be completely emersed in such an environment. The game development community has contributed significantly to allowing rich and realistic virtual environments to be developed using affordable or open-source technologies. This allows us to create new exploratory environments to allow users to emerge themselves into, and would allow us to control factors that would not be controllable in real nature such as weather. It could give users access to a variety of nature, which would help increase life satisfaction [4]. However, many existing studies that simulate nature in virtual reality do not take advantage of this, and instead expose users to 360-degree videos of real nature instead [13, 14, 15].

The experimental setting of these studies have already been discussed in this review. Interestingly, Browning et al. [13] chose to have their users sit on a camping chair for the VR experience. This may be understandable since they wanted to keep the seating arrangements for the three settings constant, and it is impractical to carry a swivel chair out into a forest, but it would be difficult to make full use of the 360-degree surrounding view in virtual reality. Yu et al. [15] does this better by having participants sit on swivel office chairs, and giving them the option to stand. Calogiuri et al.'s [14] nature walk experiment also uses a stationary, non-turntable chair, but this is understandable since it is unlikely participants would want to look behind them when moving forwards during the walk.

Cybersickness is a form motion sickness experienced in VR and would make the user-experience unpleasant. Yu et al. [15] addressed cybersickness by making their participants aware of it, allowing them to sit or stand, and drop out of the experiment should they feel discomfort, and found that very few participants suffered from it. Since Calogiuri et al. [14] had participants walk on treadmills for the third setting (as seen in Figure 2), but their physical actions had no impact on their virtual ones, participants experienced cybersickness and this negatively impacted their findings. Browning et al. [13] does not address cybersickness in their article, so its presence and potential effects on their research is unknown.

All three of these studies had some form of physiological measures, which makes their results more reliable. Yu et al.'s [15] finding regarding the lack of differences in physiological responses between the virtual urban and forest environments, may be attributed to the fact that their stress inducing task did not have the

[1] "The somatosensory system is the part of the sensory system concerned with the conscious perception of touch, pressure, pain, temperature, position, movement, and vibration, which arise from the muscles, joints, skin, and fascia." [18]

desired effect, possibly due to the math questions being too easy for the participants, all having come from a prestigious university.

These 3 studies had participants be passive spectators of first person videos, and were not at all interactive. Interactive or not, however, increasing immersion from a desktop screen to an immersive virtual reality environment show lower stress levels and higher positive affects in participants when being exposed to virtual nature [19]. This indicates that these immersive virtual reality environments are a good way to promote relaxation.

The advantage of 360-degree videos is that the footage used does come from real nature and will always look more realistic than what a computer can generate. Despite this, as technology advances, virtual environments are becoming more and more realistic, and development tools are becoming increasingly powerful. Yeo et al.'s [16] research focus was on the delivery method of virtual nature, and found that CG-VR offers a qualitatively different experience when compared to the television and 360-degree video exposure methods. However, their CG-VR environment was not created specifically for their study, and although worked well in the context of their research, possibly stronger results could have been generated. Since the environment was not created with the intent of capturing the relaxation properties of nature, there is an opportunity to research further with that in mind. Deltcho et al. [17] did create their environment themselves, but they used the *Elder Scrolls IV: Oblivion* world construction set to create a nature environment equivalent to 1600 $m^2$. Though large, it is not endless, and if users planned to emerge themselves into this environment every day, they could find themselves becoming bored, limited by a park only approximately one third of the size of our very own Kirstenbosch gardens (which is 5280 $m^2$ [20]).

Deltcho et al.'s [17] study is an excellent example of an environment that uses as many senses as possible, being the only study reviewed that used four senses out of the four you would usually experience in a forest (since it is unlikely you would be tasting the environment). Their environment only allowed participants to walk around, and unlike Yeo et al.'s [16] environment, they did not allow interaction with objects in the scene, and the addition of this could possibly make for a more pleasant user experience, but this is yet to be researched.

Although impressive virtual environments were used, both Yeo [16] and Deltcho et al.'s [17] studies do not address cyber sickness and its potential impacts on their findings. Yeo et al. takes no physiological measures and has a larger sample size of 96, compared to Deltcho et al.'s 22, who did however measure heart rate and skin conductivity. This influences the reliability of their findings.

## 5 How to make pleasant immersive environments

This leaves us with an important question: how do we best make an interactive environment that users will find easy to immerse themselves into?

Of course, making realistic looking elements of the forest is an important aspect to improving user experiences, but it is also important to consider the other senses. One study using eye-tracking experiments to investigate audio-visual interaction on forest landscapes (with images and sounds) found that light music with ancient temple bells, or bird twittering, insect chirping, and water flowing sounds enhanced participant's sense of immersion and involvement while reducing mental strain [21]. This suggests that suitable auditive nature sounds should be added to all environments aiming to reproduce the relaxation properties of nature. Scent has also been found to influence and enhance virtual experiences [22], and though can sometimes be difficult to include, should be kept in mind in planning for user experiences.

It is also important to keep cybersickness at a minimum. Something to keep in mind with 360-degree videos is that the camera stabilisation is vital in order to reduce motion sickness and to improve the virtual experience [23]. This is not as big of an issue for computer generated environments who do not suffer from shaky cameras, however there are tips to reducing motion sickness in interactive environments, such as creating modes that would require fewer drastic head motions, by including transport mechanisms such as "teleporting" [24].

## 6 Conclusions

Existing research indicates that virtual nature environments are beneficial and can help reduce stress. Most of the these involves exposing participants to 360-degree videos where they can look around freely, but not move in any direction or interact with the environment. Though two environments discussed (Yeo et al. [16] and Deltcho et al. [17]) produced interactive and explorative environments respectively, there is still an opportunity to create and research the relaxation effects of an interactive and immersive forest environment. To the best of our knowledge, there are unanswered questions in the discussed field, including to research how important including different senses are for a nature pill, and what the effects of leaving out individual senses are. Another possible research topic is to see what the impact of interaction with scene objects are on the relaxation properties of a virtual environment.

## Appendix A

| Author and reference | Main research goal | How did they measure their success? | Summary of most important findings | Number of participants | Type of virtual environment (360-degree video, etc) | Could users look in direction of choice? | Could users move in direction of choice? | If in VR, was cyber sickness addressed? | Senses used in virtual environment (taste not applicable) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Sight | Hearing | Touch | Smell |
| McAllister et al. [9] | Finding the effects of virtual contact with nature on positive and negative effect. | Perceived restorativeness<br>Perceived positive and negative affect | Nature videos had better positive affects, less negative affects, and better perceived restorativeness compared to the non-nature control video. | 220 | 2D video presentations on a screen | No | No | N/A | Y | Y | N | N |
| Kjerllgren et al. [10] | Comparing restorative effects of relaxation in natural environment and a simulation (slide show) of the same environment. | Physiological measures (pulse and the systolic and diastolic blood pressure), self-reported psychological measures (e.g. a scale for measuring stress levels) , and qualitative reports | Real nature resulted in higher degrees of altered states of consciousness and energy than simulated nature, but both were equally efficient in reducing stress. | 18<br>(all suffering from stress and/or burnout syndrome) | 2D images on a Slideshow | No | No | N/A | Y | N | N | N |
| Brooks et al. [11] | Comparing the effects of nature and the built environment (in winter and warmer seasons) through contact with real nature and pictures of nature, tested through 3 studies. | Self reported standardised measurements. | Seasons did not influence nature contact effects on mood.<br>Only actual nature increased positive affect, but negative affect and happiness were improved (to a lesser degree) by nature photographs. | 120 (study 1)<br>116 (study 2)<br>47 (study 3) | 2D images on a Slideshow | No | No | N/A | Y | N | N | N |
| De Kort et al. [6] | Does a more immersive environment have stronger restorative and stress reductive effects? | Physiological (skin conductance level and heart period) and self-reported affect | A more immersive projection (through increasing screen size) has a higher restorative potential. | 80 | 2D video presentation on a screen | No | No | N/A | Y | Y | N | N |
| Browning et al. [13] | Comparing simulated nature experiences with real outdoor interaction. | Skin conductivity, and self-reported restorative and mood | 6 minutes of virtual (VR) nature exposure produced similar effects as real outdoor nature exposure of the same length, both being superior to no exposure to nature. | 65 | 360-degree video | Yes | No | Cybersickness and its potential effects on results were not addressed nor examined. | Y | Y | N | N |
| Calogiuri et al. [14] | Comparing simulated nature walk (while sitting or walking on a treadmill) with a real outdoor nature walk. | Environmental perceptions (presence and restorativeness), physical engagement (treadmill and real-life walking speed, heart rate, perceived exertion), perceived affective responses (enjoyment and affect) and qualitative information | The psychophysiological responses of the real nature walk were not reproducible in the virtual environment. | 26 | 360-degree video | Yes | No | Poor image quality, and the conflict between the individual and the video's pace lead to many participants feeling cyber sick, negatively impacting results. | Y | Y | N | N |
| Yu et al. [15] | Comparing the influence of forest and urban VR environments on restoration. | Physiological (blood pressure, heart rate, and salivary tests) and self-reported psychological responses. | Greater psychological benefits were found when participants were immersed in the forest environment. | 30 | 360-degree video | Yes | No | To address cybersickness, participants were free to sit or stand while immersed, and were told they could drop out at any time of discomfort. Very few participants reported dizziness, but the influences of the minor dizziness is unknown. | Y | Y | N | N |
| Yeo et al. [16] | Comparing the effects of three increasingly immersive forms of virtual nature: Television, 360-degree videos, and interactive Computer-Generated Virtual Reality (CG-VR). | Self-reported experienced presence, boredom, mood, and nature connectedness | VR had greater presence over TV, with CG-VR producing the best results. | 96 | 2D video presentations on a screen, 360-degree video, Interactive CG-VR environment (the last will be used in the next comparison fields) | Yes | Yes, within the confines of the room | Cybersickness and its potential effects on results were not addressed nor examined. | Y | Y | N | N |
| Deltcho et al. [17] | Comparing the restorative effects of virtual nature of a slide show in VR and an explorative VR forest. | Self reported restorative effects, skin conductivity, and heart rate. Two short mental arithmetic quizzes. | Computer generated nature in VR can promote restorative effects.<br>Artificial nature of the forest did not negate the benefits of walking in a virtual forest. | 22 | Slideshow viewed in VR, and an explorative CG-VR environment (the last will be used in the next comparison fields) | Yes | Yes, within 1600m bounds | Cybersickness and its potential effects on results were not addressed nor examined. | Y | Y | Y | Y |

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