

Effects of immersive virtual nature on nature connectedness: A systematic review protocol

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Abstract

Objective: Nature Connectedness, an individual's cognitive, affective, and behavioral connection with the natural world, has been linked to various health and well-being outcomes. As Nature Connectedness can be elicited and strengthened through direct contact with nature, in the past decade studies have investigated whether similar effects can be achieved through technologies that simulate highly immersive and realistic experiences of nature, such as Immersive Virtual Nature. This protocol describes the methodology for a systematic review that will summarize the existing evidence on the effects of Immersive Virtual Nature on Nature Connectedness in non-clinical populations.

Methods: The review will be conducted following the guidelines of Preferred Reporting Items for Systematic Reviews and MetaAnalyses. Terms such as “immersive virtual environment,” “natural setting*,” and “contact with nature” were searched in Scopus, WebOfScience, GoogleScholar, Medline, and GreenFILE (22–28 November 2021). Papers in English, describing experimental studies, with or without control/comparison, and testing the effects of Immersive Virtual Nature interventions on Nature Connectedness outcomes in non-clinical populations were included. The risk of bias will be assessed using Cochrane's Risk of Bias 2 for randomized studies, and the Risk Of Bias In Non-randomized Studies - of Interventions. The data synthesis will be performed through meta-analysis, assuming that the Cochrane Consumers and Communication Group guidelines are met.

Conclusion: The findings will be relevant for understanding the potential and challenges of Immersive Virtual Nature as a tool to promote health and well-being in the general population, providing information on the consistency and limitations of the existing literature and recommendations for future research.

Keywords

Nature connectedness, human–nature interactions, natural environments, immersive virtual environments, virtual reality, immersive technology, outdoor

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Introduction

The salutogenic benefits of nature connectedness

A growing body of evidence demonstrates the positive effects of human–nature interactions on physical and mental health. While direct exposure to nature, such as contemplating views of nature or spending time in natural environments, has been recognized as an important salutogenic factor across socioeconomic strata and genders,¹ recent attention has been given to the concept of Nature Connectedness (NC), which builds on cognitive, affective, and behavioral engagement with nature. Different aspects of NC have been previously introduced and defined such as “emotional affinity towards nature,”² “inclusion of nature in the self,”³ and “connectedness to nature,”⁴ and

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specific instruments have been developed to measure them, such as the Connectedness with Nature Scale,⁴ Nature Relatedness Scale,⁵ or Nature in Self Scale.³

NC is linked to a variety of health and well-being outcomes based on the extant evidence.⁶ According to Cervinka et al.,⁷ NC plays a decisive role in human health since it is robustly correlated with indicators of well-being, such as general psychological well-being, vitality, and meaningfulness. Lower symptoms of stress-related mental disorder and enhanced self-reported vitality were found to be positively correlated with NC, independent of cultural and climatic contexts.^{8–10} Mayer et al.⁸ found that NC significantly mediated the positive affective responses elicited by experiences in nature, as well as influenced the ability to cope with life problems. Other studies demonstrated that higher levels of NC positively correlated with happiness, mood, and life satisfaction,^{11,12} and provided benefits for social, psychological, physical, and general well-being.^{13–15} The health benefits of NC may also manifest through enhanced physical activity in contact with nature (or “green exercise”),¹⁶ which is known to provide health benefits above and beyond those provided by physical activity in other environments (e.g. indoor or urban settings).¹⁷ This may be due to the fact that, as indicated in an integrative systematic review by Calogiuri and Chroni,¹⁷ NC may influence the perception of natural environments as supportive for physical activity. Indeed, findings from Norwegian cross-sectional studies found that people with more positive attitudes towards nature tend to be more likely to use natural environments for physical activity and exercise purposes.^{18,19}

Immersive virtual nature to promote NC

Studies suggest that NC may be influenced by human–nature interactions. In particular, frequent experiences of nature during childhood seem to be particularly important to foster higher and stable levels of NC in adulthood.^{18,20,21} Nevertheless, some studies indicated that experiences of nature in adulthood may also have an impact on people’s feelings about NC. For instance, acute increases in NC have been shown in adults after a 10-min walk in an arboretum⁸ or participation in tree-planting activities.^{8,22} Unfortunately, opportunities for nature experiences are globally decreasing due to, among others, increased urbanization.^{6,23} It has been suggested that this progressive disconnection from nature may, especially among children, lead to a range of deleterious health challenges including excessive sedentary behavior, overweight/obesity, and cognitive deficiencies, also referred to as “nature deficit disorders.”^{6,23,24} A survey published by Natural England (2009), indicated that as few as 10% of today’s generation of youth has regular access to nature.²⁵ The degraded status of urban natural environments and the limited access to urban nature can be detrimental to happiness and life satisfaction across

generations.^{11,26} More recently, increasing opportunities for indoor entertainment also contribute to reducing the time spent in contact with nature. In particular, screen-related activities (e.g. watching TV or playing video games), which are facilitated by the continuous development of new (and affordable) technological devices, can exacerbate this phenomenon. On the other hand, technology has been proposed as part of the solution to integrate more nature experiences within people’s lives, with increasing attention being given, in particular, to virtual reality (VR) technology.²⁷

VR is becoming increasingly popular (and economically accessible) for consumers, especially in form of the so-called immersive virtual environments, a technology that provides the illusion of being *inside* a virtual place by substituting the primary sensory input with data generated by a computer.²⁸ In particular, the term Immersive Virtual Nature (IVN) has been recently proposed to specifically refer to VR technology that provides the illusory perception of being enclosed within and interacting with a natural environment.²⁹ Such technology usually implies the use of the so-called head-mounted displays (also known as “VR goggles” or “VR masks”), a device that provides a 360° range of vision of a virtual environment, whilst excluding the view of the surrounding (real) premises. Studies investigating the effects of IVN exposure on psychological outcomes have increased considerably in the past years.^{27,30,31} A number of these studies specifically focus on whether and to what extent IVN may hold the potential to increase NC in the general population. The underlying assumption of these studies is that, similarly to what is observed in relation to experiences in contact with actual nature, exposure to IVN may elicit enhanced levels of NC. While these changes may be only temporary or short-lived, such acute changes may have the potential to lead, through repeated exposures and/or by catalyzing behavior changes with respect to actual nature interactions, to long-term and stable changes. While recent narrative reviews emphasize the potential of IVN technology in leading to enhanced NC²⁷ or even persuading people to visit actual natural environments,³² a systematic review of the literature on this specific topic is merited.

The present study

In spite of the increasing interest in investigating the effectiveness of IVN on different health outcomes, including NC,^{27,30,31} a systematic synthesis of the scientific evidence in this context is still missing. A systematic review will allow establish the extent to which IVN is an effective tool to promote health and well-being in the general population. Additionally, as the advent of commercial (and relatively inexpensive) IVN technology is boosting the interest in and use of these devices in different contexts (e.g. schools and workplaces), the findings of a systematic

Table 1. PICOS framework with inclusion and exclusion criteria.

PICOS	Inclusion	Exclusion
Participants/ population	- General population (any age).	- Clinical population, e.g. hospitalized patients and people following rehabilitation programs.
Intervention	- Digital simulations of natural scenarios (such as natural environment, wildlife, and fauna) through highly immersive (e.g. head-mounted displays, CAVE, immersive room) and semi-immersive VR technology (e.g. immersive screen or display, mixed-reality devices).	- Non-Immersive VR (e.g. desktop, smartphone, picture) or other forms of digital reproductions of nature.
Comparison	- Where applicable, placebo, control, or comparison group who did not undergo exposure to virtual nature through highly- or semi-immersive VR technology.	- No exclusion criteria applied.
Outcome	- Any quantitative outcomes indicative of NC, including specific assessments of NC through validated instruments, but also other assessments of affective beliefs about and attitudes towards the natural world, environment, and wildlife, as well as behaviors relative to or behavioral intention to visit actual nature or natural locations.	- Qualitative assessments of NC.
Study design	- Controlled experimental trials (randomized or non-randomized) and quasi-experimental studies with pre- and post-assessments or post-assessments only. - Non-controlled trials with pre-post assessments.	- Correlational studies; - Qualitative studies; - Protocols; - Reviews.

review can highlight the challenges and limitations of this specific technology for health-promotion purposes. The evidence generated from a systematic review would then provide valuable information regarding the consistency of the existing evidence, strengths and limitations of the existing studies, and recommendations for future research.

The present protocol describes the rationale and methodology of a planned systematic review of the scientific literature that summarizes the evidence of the effects of IVN exposure on NC, operationalized as a variety of affective, cognitive, and behavioral outcomes, in the general population. Specifically, the following research question is outlined: What are the effects of IVN exposure on NC in the general population?

Methods

The proposed systematic review will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist and guidelines.³³ The protocol was registered in PROSPERO (CRD42021290442) on 16 December 2021. The literature search was performed in the period 22–28 November 2021, and the screening process was completed in January 2022. The data extraction was completed in February 2022, while the risk of bias assessment and the data synthesis are planned to be completed within November 2022.

Eligibility criteria

Eligibility criteria have been defined in line with the PICOS framework,³⁴ as outlined in Table 1. No restrictions regarding geographical location or publication period were applied. Only studies written in the English language were included. Only peer-reviewed papers (e.g. journal articles and post-review pre-prints) in form of reports of original research were included, while non-peer-reviewed grey literature (e.g. reports, working papers, theses, non-peer-reviewed conference papers, and pre-review pre-prints) were excluded.

Participants/population

Studies including samples of the general population or specific sub-groups (e.g. participants in public events, students, strategic samples of healthy adults) were included, with no age-related exclusion criteria being employed. No limit was set with respect to the participants' previous VR experiences. In line with the reviews' purpose of summarizing the evidence on the effects of IVN on NC outcomes in the general population, studies with a specific and primary focus on clinical populations or patient groups, such as individuals with psychosocial disorders (e.g. depression, post-traumatic stress disorder, etc.) or diagnosed physiological pathologies (e.g. stroke, paralysis, Alzheimer's disease, cancer, etc.), were excluded.

Intervention

Eligible papers had to include interventions consisting of exposure to IVN, intended as reproduction or simulation of any natural environments, through immersive or semi-immersive technology. Both, filmed content and computer-generated (e.g. 360° videos or 3D scenarios), providing either passive (e.g. viewing the virtual content while sitting on a chair, with no possibility to interact with the virtual environment) or interactive experiences (e.g. interaction with the scenario by moving in the space or picking objects), were considered eligible. The definition of natural environment previously used in Calogiuri and Chroni¹⁷ was applied to the context of virtual exposure, as any “open outdoor spaces that allow the individual to be surrounded by the elements of nature (trees, plants, grass, mountains, water, etc.).” Immersive technology was intended as any device that can provide a 360° view of the virtual world and can create the illusory perception of being enclosed within, and interacting with, a real environment,^{35,36} such as head-mounted devices, Cave Automatic Virtual Environment (CAVE), and immersive rooms. Semi-immersive technology is intended as devices that do not completely exclude the view of the external world or do not provide a 360° view of the virtual environment, such as mixed-reality devices, head-mounted displays with limited range of vision (i.e. below 360°), and immersive screens or displays (such as large-screens, immersive displays, and projections on curved, spherical, or cylindrical surfaces), were also considered eligible. Virtual/digital nature interventions that simulated nature through non-immersive technologies such as smartphones, pictures, tablets, desktops, laptops, TV screens, paintings, or posters were excluded.

Comparison

Studies either with or without a control or comparison group were considered eligible. Where applicable, any placebo or control group who did not undergo exposure to a highly- or semi-immersive virtual nature. No restriction regarding the characteristics of the control group was applied.

Outcomes

Study designs considered eligible included quantitative assessments of NC, intended as measurements indicative of psychological and affective attachment to the natural environment. This included psychological constructs defining the human sense of belonging, inclusion, or feeling emotionally connected to the natural world assessed through validated instruments (such as the *Connectedness to Nature Scales*,⁴ the *Nature Relatedness Scale*,⁵ and *Inclusion of Nature in Self Scale*.³) Similar measurements assessed through non-validated instruments were also included, such as affective beliefs about and attitudes towards the natural world, environment, and wildlife, as

well as behaviors related to or behavioral intention to visit actual nature or natural locations.

Study design

Eligible papers had to contain at least one study with experimental or quasi-experimental design. Randomized and non-randomized controlled trials (either with parallel conditions or cross-over design), with pre-post or only post-assessments, were considered eligible. Non-controlled trials with pre-post assessments were also considered eligible. Correlational, qualitative studies, protocols, and reviews of literature studies were excluded.

Information sources

Five databases were systematically and electronically searched: Scopus, Web of Science, Google Scholar, Medline, and GreenFILE. The reference lists of selected studies and review articles were also scrutinized to identify further eligible studies. Relevant papers identified through other sources (e.g. papers recommended by experts in the field) were also considered, assuming that they complied with the eligibility criteria.

Search strategy

Relevant search terms and subject headings covering technology, technological nature, nature connectedness, attitudes, and behavior were searched, and combined in four different ways:

- Technology AND nature connectedness
- Technological nature AND attitudes
- Technological nature AND behavior
- Technological nature AND nature connectedness

Since this is a fairly novel field with a limited extent of literature, no additional filters were used.

An example of an algorithm used in the database search, relative to the combination of “technology AND nature connectedness,” is presented in Table 2. The search terms were adapted for each database, according to their specific search rules.

For detailed search strategies, see Appendix A.

Study records

Data management and selection process

Search outcomes were first scrutinized by title and abstract by two authors (EB and KS), with a third author (GC) resolving disagreements. Rayyan (HBKU Research Complex, Doha, Qatar) was used as a tool to organize the results and exclude duplicates. The full text of possibly

relevant papers was independently scrutinized by two authors (EB and GC), with a third author (TM) resolving any disagreements. The contact authors of the original papers were contacted by e-mail when clarifications were needed. The search strategy and outcomes will be reported in a PRISMA flow diagram³³ in the upcoming systematic review publication.

Data collection process

Data from each selected article was extracted using standardized tables in Microsoft Excel. The following data were collected: article's general information (article identification, authors, publication year), study design, sample size, sample information (sex, age, any specific sub-group), type of IVN technology, duration of IVN exposure, control/comparison condition, NC outcome/s and instrument/s with which it was assessed, and summary of main results (including means and standard deviations of the outcome). The procedure was completed by two authors (EB and EP) and quality-ensured by a senior author (GC). Contact authors of the original papers were contacted by e-mail when additional information was needed.

Risk of bias

A critical appraisal and risk of bias of the included studies will be assessed independently by two authors (EB and VS). In line with the guidelines of the *Cochrane*

Handbook for Systematic Reviews of Interventions,³⁷ the revised tool to Assess Risk of Bias (RoB 2)³⁸ and the tool for Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I)³⁹ will be used, for randomized and non-randomized trials, respectively. These tools provide a proposed judgment on the risk of bias arising from each domain generated by an algorithm based on answers to the signaling questions.

Data synthesis

Firstly, the characteristics of the studies, as emerged from the extracted data, will be examined to identify clusters of studies based on the features of the participants' (age, sex, or population sub-group) and/or the studies' (study design, type of IVN, type of comparison condition). For each cluster of studies, a narrative synthesis will be performed, presenting the findings of each included study regardless of the assessed risk of bias. Information will be presented both in text and in tables. In line with recommendations provided by the Cochrane Consumers and Communication Group guidelines,⁴⁰ quantitative syntheses of data through meta-analysis will be performed for each cluster of studies (i.e. sub-group analysis) assuming that: (i) all the outcomes are comparable and can be pooled together meaningfully, (ii) all the interventions and control/comparisons conditions are reasonably similar, (iii) the necessary data are available for the included studies or provided by the authors, and (iv) at least two of the identified studies will present all previously described characteristics. Additionally, heterogeneity will be evaluated using I^2 statistics, with $I^2 \leq 25\%$ being considered acceptable for conducting a meta-analysis.⁴¹ In studies with pre- and post-assessments, change-from-baseline scores will be imputed according to the *Cochrane Handbook for Systematic Reviews of Interventions*.³⁹ The mean effect will be expressed as a standardized Hedge's g .

Confidence in cumulative evidence

The strength of the body of evidence will be assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework.⁴² Specifically, the quality of the evidence will be categorized into one of four levels—high, moderate, low, and very low.⁴³

Discussion

Given the increasing popularity and economical convenience of VR devices among the general population, as well as various actors that can implement IVN-based health-promoting interventions (e.g. schools, workplaces, and primary healthcare services), alongside the growing body of evidence investigating the effects of this

Table 2. Example of algorithm used in the database search, relative to the combination “technology and nature connectedness.”

Main topic	Database Search algorithm
Technology	((immersive OR virtual OR mixed OR extended OR simulat* OR high-immersive OR semi-immersive OR “full immersive”) W2 (realit* OR technolog* OR environment* OR screen* OR experience* OR world* OR room* OR device* OR display* OR video* OR scenario*) OR “Cave Automatic Virtual environment” OR CAVE OR “360 degree scenario*” OR “360 degree video*” OR “computer generated” OR “head mounted” OR headset OR “head set” OR CAREN OR “Computed assisted rehabilitation environment”)
Nature connectedness	((connect* OR contact OR relatedness OR involvement OR inclusion OR oneness OR commitment OR relationship*) W2 (natur* OR environment*))

technology on NC, a systematic review of the literature in this specific topic is merited. VR nowadays has applications in various fields (e.g. education, tourism, and rehabilitation^{44–46}). Considering the increasing urbanization, which is likely to result (for many) in reduced opportunities for nature interactions and other challenges to people's health (see e.g. the issue of nature deficit disorder,²⁴ but also the premature deaths which may be prevented by better access to nature⁴⁷), IVN has been proposed as a solution to integrate more frequent nature experiences within people's everyday lives, and even persuade them to actively seeking more opportunities for actual nature interactions. Importantly, IVN could promote NC in form of psychological attachment to nature, positive attitudes toward the natural world, and enhanced motivation to visit natural locations, which has been suggested as a psychological construct associated with, or even supporting, wellbeing.^{7,8}

This planned systematic review will provide an evidence-based evaluation of whether, and to what extent, IVN can indeed be an effective tool to elicit and strengthen NC. Moreover, as the research and applications of IVN in the health-promotion context, especially with respect to NC outcomes, is still in its infancy, this planned systematic review will provide valuable recommendations for future IVN research and interventions. Not least, the review will contribute to the ongoing debate on whether NC is a stable personality trait or a modifiable psychological state.

Expected limitations of this systematic review include possible inconsistency of methods, interventions, and study design across the included studies (i.e. especially a challenge considering that the studies are likely grounded in a variety of scientific fields, such as computer sciences, psychology, health sciences, etc.). Other possible limitations regard the inability of identifying all potentially relevant papers due to the broad variety of search terms relative to IVN and NC outcomes, and the exclusion of grey literature and papers written in other languages than English.

Abbreviations

IVN Immersive Virtual Nature
NC Nature Connectedness
VR Virtual Reality.

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Author contributions: EB, with the supervision of GC, conceived and designed the study. EB performed the literature search, in collaboration with KS and GC, performed the scrutiny of the papers, and, in collaboration with GC, drafted the manuscript. EP, KS, VS, and TM provided substantial contributions to the conception of the review protocol. All authors reviewed, provided substantial contributions to, and approved the final version of the manuscript.

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