NATURE-BASED INTERVENTIONS USING TECHNOLOGY FOR HEALTH: A SCOPING REVIEW

Intervenções baseadas na natureza usando tecnologia para a saúde: uma revisão de escopo

Intervenciones basadas en la naturaleza que utilizan tecnología para la salud: una revisión de alcance

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ABSTRACT

Background: nature-based interventions are generally recognized for their ability to improve health and wellbeing. **Objectives**: this scoping review maps the evidence on the use of technology to enhance nature-based interventions, examining various digital tools and their impact on maximizing the benefits of nature-based experiences. **Methodology**: a scoping review was carried out following the PRISMA ScR guidelines. The sources consisted of searching four electronic databases to identify studies published between 2014-2024. The selection process for this study was conducted using Rayyan software, and the retrieved data was then synthesized using a narrative approach. **Results**: there were 12 studies that met the inclusion criteria and of these, all used virtual reality or augmented reality to simulate natural environments; the studies varied equally in terms of the participants, with 33.3% being adults, 33.3% being young adults and 33.3% being elderly. **Conclusion**: the use of nature-based interventions using technology has been shown to have the potential to reduce stress, improve mood and increase general well-being. However, the analysis also emphasizes the importance of further research to understand the lasting impacts and the best ways to introduce these technologies to different populations and situations.

Keywords: technology; virtual reality; nature; health

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RESUMO

Enquadramento: as intervenções baseadas na natureza são geralmente reconhecidas pela sua capacidade de melhorar a saúde e bem-estar. **Objetivos**: esta revisão de escopo mapeia a evidência sobre o uso da tecnologia para aprimorar as intervenções baseadas na natureza, examinando várias ferramentas digitais e seu impacto na maximização dos benefícios das experiências baseadas na natureza. **Metodologia**: foi realizada uma scoping review seguindo as diretrizes PRISMA ScR. As fontes consistiram na pesquisa em quatro bases de dados eletrónicas para identificar estudos publicados entre 2014-2024. O processo de seleção deste estudo foi realizado utilizando o software Rayyan, e os dados recuperados foram então sintetizados utilizando uma técnica narrativa. **Resultados**: 12 estudos cumpriram os critérios de inclusão e desses todos utilizaram a realidade virtual ou realidade aumentada para simular ambientes naturais; os estudos variaram igualmente quanto aos participantes, sendo que 33.3% foram adultos, 33.3% foram jovens adultos e 33.3% foram idosos. **Conclusão**: a utilização de intervenções baseadas na natureza com recurso à tecnologia demonstrou ter potencial para diminuir o stress, melhorar o humor e aumentar o bem-estar geral. No entanto, a análise também salienta a importância de mais investigação para compreender os impactos duradouros e as melhores formas de introduzir estas tecnologias em diferentes populações e situações.

Palavras-chave: tecnologia; realidade virtual; natureza; saúde

RESUMEN

Marco contextual: las intervenciones basadas en la naturaleza son generalmente reconocidas por su capacidad para promover la salud y el bienestar. **Objetivos**: esta revisión de alcance mapea la evidencia sobre el uso de la tecnología para mejorar las intervenciones basadas en la naturaleza, examinando diversas herramientas digitales y su impacto en la maximización de los beneficios de las experiencias basadas en la naturaleza. **Metodología**: se llevó a cabo una revisión exploratoria siguiendo las directrices PRISMA-ScR. Las fuentes consistieron en la búsqueda en cuatro bases de datos electrónicas para identificar estudios publicados entre 2014-2024. El proceso de selección para este estudio se realizó utilizando el software Rayyan, y los datos recuperados se sintetizaron luego utilizando um enfoque narrativ0. **Resultados**: 12 estudios cumplían con los criterios de inclusión, y de estos, todos utilizaron realidad virtual o realidad aumentada para simular entornos naturales; los estudios variaron de manera equitativa en términos de participantes, con un 33.3% de adultos, un 33.3% de jóvenes adultos y un 33.3% de ancianos. **Conclusión**: se ha demostrado que el uso de intervenciones basadas en la naturaleza mediante tecnología tiene el potencial de reducir el estrés, mejorar el humor y mejorar el bienestar general. Sin embargo, el análisis también destaca la importancia de realizar más investigaciones para comprender los impactos duraderos y las mejores formas de introducir estas tecnologías en diferentes poblaciones y situaciones.

Palabras clave: tecnologia; realidad virtual; naturaleza, salud

INTRODUCTION

Engagement with nature holds significant importance for numerous individuals, and the various health and wellness advantages stemming from nature-based activities are gaining widespread acknowledgment across a spectrum of fields, ranging from urban planning to healthcare (Lee et al., 2022). Nature–based health interventions (NBIs), which are programs and activities where individuals engage with natural environments to improve their health and wellbeing, can facilitate behavioral change through a somewhat structured promotion of nature–based experiences and, in doing so, promote improved physical, mental and social health and wellbeing (Moeller et al., 2018). There are many pressing public health and environmental challenges associated with modern living, with rapidly growing levels of chronic, non–communicable physical and mental health conditions and global recognition of serious health risks posed by stressful living conditions (Xu et al., 2023). Engagement with nature is a common pursuit in cities, and it is becoming increasingly recognized as a means to alleviate many of these challenges (Lenda et al., 2023). Evidence now points to benefits for physical health (e.g., lower prevalence of high blood pressure and allergies), mental health (e.g., lower prevalence of depression and anxiety) and social wellbeing (Corazon et al., 2019). Moreover, there is evidence that the magnitude of such benefits can increase with the dose of nature (Corazon et al., 2019). It is thus of significant concern that urbanization and the challenges of modern life are leading to reduced engagement with the natural environment (Ferreira et al., 2020). For illustration, environmental manipulations where green and blue spaces are incorporated into metropolises can have positive issues associated with the operation of territories and inflow of ecosystem services to people, but there is also a growing body of evidence highlighting the potential of green space for the treatment and prevention of physical, mental and social health and wellbeing challenge (Ali et al., 2022). This acknowledgment marks a significant shift in public health perspectives regarding both the prevention and treatment of health issues, beyond considering nature solely as a risk–factor (e.g., through the transmission of insect–borne diseases) (O'Hogain & McCarton, 2018).

Reflecting the growing body of research demonstrating a concrete link between interactions with nature and health, many non-governmental organizations and stakeholders are now beginning to consider these potential benefits in their policy frameworks (Xing et al., 2017). In fact, many national legal instruments are being implemented around the world. These include, in particular, minimum area targets for public green spaces as well as doctors and other health professionals prescribing nature-based experiences for patients suffering from specific health problems (Foley et al., 2023; Keniger et al., 2013). However, despite this exponential movement, there is a dearth of guidance on the types of NBIs available and what specific health outcomes they can achieve (Keniger et al., 2013). That said, this may limit the potential for harnessing natural settings to improve health and well-being outcomes for individuals and communities, possibly leading to inefficient and poorly planned investment decisions (Shanahan et al., 2019).

Environmental factors can play a fundamental role in the prevention and promotion of mental health (Pretty & Barton, 2020). Traditionally, research in this area has focused on environmental risk factors, but more recent

studies are exploring the role of positive environmental conditions in promoting resilience and adaptation to stress (Pretty & Barton, 2020). Exposure to natural landscapes or specific features like plants and animals is increasingly recognized as a source of relaxation and regeneration (Gritzka et al., 2020). One possible connection between access to natural environments and health involves the enhancement of social relationships (Bloomfield, 2017). By providing opportunities for social interaction, natural environments, including urban green spaces, can promote social integration, social ties, and a sense of community, reducing loneliness, which are all known to benefit physical and mental health (Ma et al., 2023). Recently, the European Commission highlighted the crucial role of rural areas—which account for a large part of the European territory and population of the Member States—in addressing current and future societal challenges, providing public goods, promoting environmental sustainability, and improving social wellbeing for both rural and urban inhabitants (World Health Organization, 2016).

Mental health conditions represent one of the largest burdens of disease globally (Kemper et al., 2013). There is a need to seek innovative and indispensable interventions that can help and palliate internal health symptoms and NBIs may be a viable alternative (Moeller et al., 2018). People with mental illness often experience cognitive and functional impairments associated with poor health and social outcomes, frequent hospital admissions, long inpatient stays, and ongoing need for support from community-based mental health services (Sæther et al., 2023). With the rising social and fiscal burden associated with the frequency of mental illness, there is a critical need to explore indispensable interventions that can be used alongside or, in some cases, as a cover for traditional treatments, in some cases, as a substitute for traditional treatments (Mercer, 2014). NBIs can create both personal and economic benefits, reducing the high costs of mental health treatment and the burden on mental health professionals, evident in long waitlists (Tambyah et al., 2022). Moreover, receiving mental health support in a natural environment can transform the clinical approach for mental health consumers and facilitate their recovery (O'Brien, 2018).

The advantages of spending time in nature for one's health have garnered more attention in recent years. Contact with nature and health is interconnected in three domains: reducing harm from exposure to environmental hazards such as noise; restoring capacities diminished by stress and constant stimuli; and building new capacities to interact socially and engage in new activities (Vijayakumar & Srivastava, 2025). Nature walking groups, forest bathing, community gardening, and talking therapies offered in a natural setting are just a few examples of NBIs. However, their application in mental health settings remains sporadic (Shrestha et al., 2023).

The evidence of the mental health benefits of nature exposure is rapidly growing (Barnes et al., 2019). Contact with nature (e.g., parks) is associated with improvements in memory, cognition, and attention, reduction in symptoms of depression and anxiety, lower stress levels, and healthy sleep patterns (Marvier et al., 2023). Studies have also found that NBIs result in greater levels of confidence, self-esteem, happiness, feelings of safety, purpose, and empowerment (Trøstrup et al., 2019). Nature exposure has also been

linked to a lower incidence of loneliness (Trøstrup et al., 2019). When offered in groups, NBIs create opportunities for social connections, alleviating loneliness, which is one of the main indicators of mental and social wellbeing (Borek et al., 2015). Participating in NBIs with others who have similar lived experiences enhances engagement, contributes to feelings of togetherness and belonging, and improves social skills (Barton et al., 2015).

However, although contact with nature is very important, some people are unable to experience it, either for health reasons or due to disability, and this is where technology can bring people into contact with nature, albeit not in the same way. Furthermore, technology has been used to motivate people's involvement in nature through various devices and strategies that will be discussed and studied later (McClain & Zimmerman, 2016).

Thus, the aim of this study is to explore and gain a deeper understanding of the digital technologies currently being used for nature-based interventions. Our research focuses on addressing the following questions:

1. Which digital technologies have been employed to support nature-based interventions in the past ten years?

2. What health benefits have been reported in connection with the use of digital technologies to facilitate nature-based interventions?

3. What obstacles or challenges arise when implementing digital tools for nature-based interventions?

METHODOLOGICAL REVIEW PROCEDURES

A comprehensive search was conducted across multiple databases, including PubMed, Academic Search Complete, PsycINFO, and Web of Science, to locate references published or available online within the last 10 years. The search terms employed were derived from a combination of relevant keywords, such as: ("green care" OR "horticult*" OR "garden" OR "forest therapy" OR "ecotherap*" OR "eco therap*" OR "nature therap*" OR "nature assisted therap*" OR "nature intervention*" OR "animal assisted therap*" OR "animal assisted activit*" OR "wilderness therap*" OR "nature rehabilitation" OR "nature based rehabilitation") AND ("digital technology" OR "digital intervention" OR "mobile app*" OR "wearable device" OR "virtual reality"). These terms were selected by the authors based on a review of the literature and the specific objectives of the research.

For this study, the PICO framework (Participants, Interventions, Comparisons, and Outcomes) was applied to guide the research design. The established parameters were: a) adults; b) interventions involving digital technologies aimed at enhancing nature contact, such as mobile apps, wearable devices, online platforms, or virtual reality; c) standard nature-based interventions (NBI) compared with technology-enabled interventions; and d) outcomes measured included changes in physical activity, mental health outcomes (e.g., symptom reduction, mood improvement, quality of life), as well as intervention adherence, acceptability, and feasibility of the digital tools. The study protocol was pre-registered on the Open Science Framework (OSF) on May 2, 2024 (https://osf.io/5s6zp/).

To begin, the databases were queried using the

predefined search terms. Two independent reviewers (blinded to each other's evaluations) conducted an initial screening based on titles and abstracts, applying the eligibility criteria to filter out irrelevant articles. Following this, the full texts of the remaining articles were assessed by the same reviewers for potential inclusion. Any discrepancies in the selection process were resolved through discussion until consensus was achieved. As per the PRISMA-ScR guidelines and the Arksey and O'Malley (2005) framework, no formal quality assessment was conducted.

One author extracted data from the eligible studies, while another author verified the accuracy. The screening process was facilitated by the Rayyan software (Ouzzani, 2016). A data-charting form was collaboratively developed and used by both reviewers to ensure consistency in data extraction. Information such as the authors' names, country of origin, publication year, study design, and purpose were collected. The reviewers independently charted the data, discussed the findings, and refined the data-charting form iteratively. Figure 1 illustrates the study selection process, including the number of articles excluded at each screening stage.

RESULTS

A total of 484 titles were identified through the search platforms. Most studies were excluded for not meeting the eligibility criteria, either due to the absence of technology supporting nature-based interventions or their lack of relevance to the specific focus on various nature-based interventions. After reviewing the titles and abstracts, 21 papers were selected for further eligibility assessment, with their full texts screened. Ultimately, 12 papers published between 2014 and April 2024 met the inclusion criteria. A flowchart depicting the study selection process is provided in Figure 1.

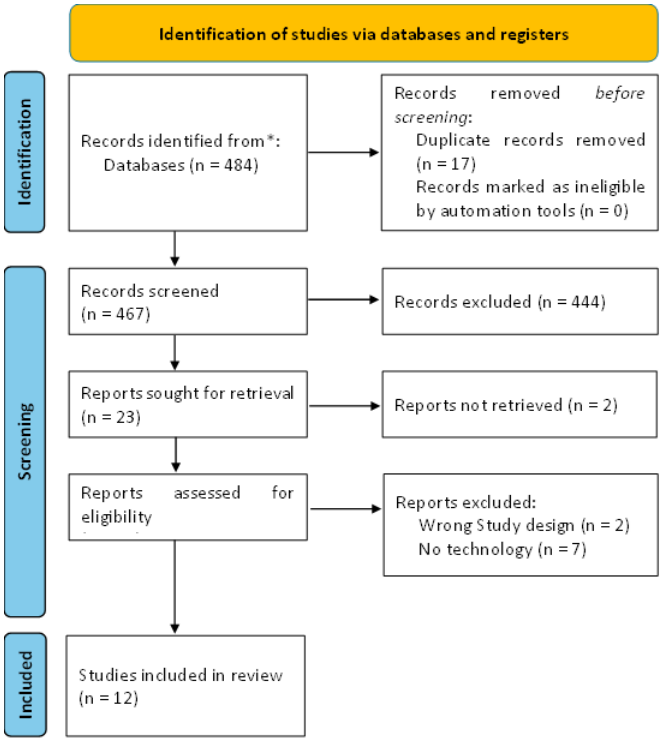

Figure 1

Selection of studies – PRISMA flowchart

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The studies originated from various countries, including the USA (n=4), South Korea (n=2), Taiwan (n=2), China (=1), New Zeeland (=1), Australia (=1) and Poland (n=1). The methodologies employed ranged from experimental (n=3) to quasi-experimental (n=2), with one study that was a clinical trial, another that was a randomized clinical trial, one randomized controlled trial, one quantitative study, one mixed method feasibility study, combining quantitative and qualitative approaches, a secondary analysis of a randomized controlled trial and a randomized pilot study. As a result, the sample size varied, ranging from 20 to 106 participants. However, the average number of participants was 37 participants. The subject dealt with in this study has grown exponentially, especially in the last 10 years, and is a topic that has become increasingly relevant, as can be seen in Figure 2.

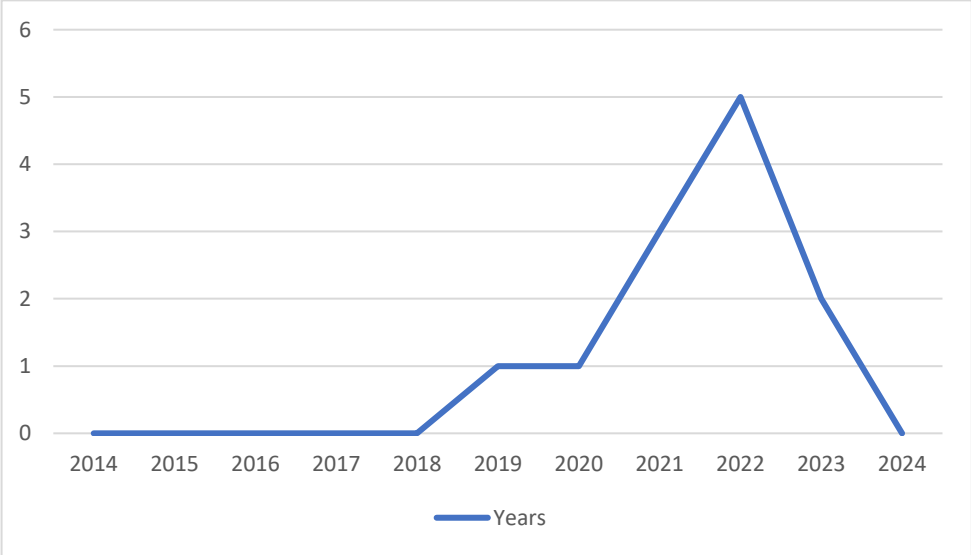

Figure 2

Research in the last 10 years

As can be seen in the figure above, there is a sharp drop in articles in the literature, especially in 2024. The reason for this drop may not be a lack of study on this topic, but rather a lack of scientific records on the advancement of these technologies. The same can be applied to the lack of technologies used beyond virtual reality and augmented reality.

The technologies used vary slightly in terms of their objective and purpose, but all the studies use virtual reality as the main technology. Despite this, many studies use virtual reality in a variety of ways, including immersive virtual reality, virtual reality in conjunction with still nature pictures or practical horticultural activities. The aim of most of these studies is to assess the ability of contact with nature using virtual reality to reduce stress and anxiety levels, increasing levels of relaxation and calm in healthy patients or those with different pathologies. Various instruments and devices have been used to collect this data, including mood questionnaires and anxiety, depression and stress scales, as well as instruments that assess the physiological response of heart rate and skin conductance. Of the twelve studies included, all used virtual reality, five used physiological sensors to assess heart rate, skin conductance, blood pressure and electroencephalogram. Nine of them also used pain

questionnaires and depression, anxiety and stress scales. All these technologies have been integrated into different contexts, from the care of patients with physical illnesses such as axial spondylarthritis (axSpA), breast cancer, hemodialysis patients, burns patients, spinal cord injury patients, healthy people, higher education students and people from general population. As far as the specific results and benefits are concerned, the most relevant is the reduction in stress and anxiety and the increase in the levels of relaxation of the participants who had contact with nature through certain technologies. Although there are clinical trials that provide quantitative data, qualitative data and data resulting from experimental studies are of greater importance to the study's conclusions. The satisfaction of the participants in contact with different nature scenarios was realized, especially those who had physical limitations that prevented them from accessing these scenarios. This is also realized through instruments measuring heart rate, skin conductance, among others, which show the effectiveness of these environments in reducing high levels of stress. It is also important to emphasize that some clinical trials use other forms of contact with nature, also obtaining excellent results in terms of satisfaction and feedback from participants. The use of virtual reality as an allied technology in all the studies included could create a long-term monotony, diminishing the effectiveness of the studies and the motivation of the participants. To counteract this, strategies were used to increase the experience of those involved, namely the possibility of walking through a forest, interacting with various visual and auditory elements, thus increasing the immersion of the participants. Another strategy was to carry out questionnaires about mood and wellbeing after the experiment, thus reinforcing the idea that the experience had in fact helped the participants to regulate their emotions. The possibility of exposure to neutral or unnatural environments (such as an urban environment) to compare the specific effects of the virtual forest environment was also a great benefit for emphasizing the results of the studies. Although there have been several benefits, the studies reveal some barriers and limitations, such as the variation in the quality and realism of these virtual environments, and there may be technological limitations such as the resolution of the VR headset. Another barrier is individual variability: individual factors such as age, gender and pre-existing mental health can influence the results, especially in studies where the population is randomized. Furthermore, the availability and willingness of health professionals to use these technologies for this purpose can also be a limitation. Detailed results are shown in Supplementary Material.

DISCUSSION

This study aimed to explore and gain a deeper understanding of the digital technologies currently being used to promote nature-based interventions. Specifically, we sought to answer three primary research questions: (1) Which digital technologies have been employed to support nature-based interventions in the past ten years? (2) What health benefits have been reported in connection with the use of digital technologies to facilitate nature-based interventions? and (3) What obstacles or challenges arise when implementing digital tools for nature-based interventions? The results presented not only show what is being implemented and researched in various

regions, but also enlighten us on the steps to follow to improve the implementation of these interventions using technologies. More importantly, they support research into the application of current technological solutions in diverse health situations, where it was discovered that these interventions covered a range of conditions and even healthy individuals. When analyzing the population used by the various studies, participants with a more severe pathological condition had lower levels of contact with nature than participants with less severe pathological conditions and healthy individuals. Although the pathologies themselves are very different from each other, the available literature suggests that individuals with pathological conditions that require hospitalization have little or no contact with nature, just as participants with mental illness also lack this contact. As a result, these groups may be more vulnerable to urban environments, which triggers a variety of effects on their physical and mental health. In addition, many participants significantly improved their mood scores while taking part in the intervention, which emphasizes the potential that technologies offer in terms of potential interventions to increase contact with nature (Joye & Bolderdijk, 2015; Yu et al., 2018). It is important to emphasize that, in this context, engagement is measured by the frequency with which individuals interact with the technology and its impact on the user's physical and mental health, in addition to the various instruments for measuring heart rate and skin conductance (McClain & Zimmerman, 2016). From this point of view, the frequency of use of a technological device is just as important, if not more important, than the way it is used (Choi et al., 2022). According to the literature, there is still uncertainty about the appropriate frequency of involvement in technological interventions, and the time spent using a technological tool varies depending on the different types of intervention, the participants involved and the environment (O'Connor et al., 2016; Yardley et al., 2016). In the field of nature-based interventions using technology, the ideal frequency varies depending on the environment, the participant and the type of intervention, because low participation can indicate that the participants have already achieved the previously outlined objectives or are using more beneficial resources at the time (Kalantari et al., 2022). Participant involvement can be influenced by multiple factors, including incentives to participate, health status, privacy and security, financial resources for accessing technological devices, adaptation in the use of these devices and ongoing technical support (Kalantari et al., 2022). Depending on the type of technology used, different types of strategies can be adopted to attract participants' attention and encourage their involvement in these interventions. The most common strategy is to increase the complexity of the experience, namely by increasing detail and realism in virtual reality sessions, which makes the session more appealing. The use of physiological markers and mood questionnaires showing the positive results of interventions has also been found to be equally satisfactory. Limitations still need to be considered, notwithstanding the good input from participants and service users. Health professionals report that the accessibility of these technological devices is sometimes limited, as is the digital and technological literacy of many participants (Anzovino et al., 2023). There needs to be an individual-centred approach to identify the personal or

equipment-specific factors that can contribute to engagement at different stages (Riches et al., 2021). Additionally, while interventions have been tested across age groups, there is limited research on their impact in diverse populations and long-term effects.

Regarding the low technological literacy, especially in the elderly population, it discourages and demotivates the participants, as there may be marked difficulties to understand the functionalities of the equipment or to memorize the necessary steps (Jeng et al., 2017). This review identifies key patterns in the use of technology for nature-based interventions (NBIs), with most studies focusing on virtual reality (VR) to enhance well-being. However, there is a gap in exploring other digital tools such as biofeedback, mobile applications, and wearable devices. The reality is that, in fact, VR equipment can recreate very complex and realistic natural spaces to the point of immersing the user in the experience, resulting in a decrease in anxiety, among other benefits already mentioned. However, this contact with nature remains artificial, so there is no contact with organic compounds such as phytoncides released by trees, thus losing the benefits of these compounds and even others (Thangaleela et al., 2022). Phytoncides have been shown to stimulate the immune system and increase the production of natural killer cells, which help to fight off infections and diseases, benefits that virtual reality is unable to offer (Thangaleela et al., 2022). One of the studies included uses VR glasses for horticultural activity, thus giving more meaning to the experience, however, using only technology, there is not really physical activity itself, losing the physical and mental benefits from it (Kang et al., 2022; Li et al., 2021). Although several stimuli have been inserted in the interventions analyzed, the use of technology is not able to fully replicate the complex sensory stimuli of nature, such as the breeze, the smell of plants or the sound of birds (Clemente et al., 2024; Melo et al., 2022). This is in addition to the environment of the interventions, that is, this contact with nature is usually a solitary experience, where social interaction is lacking.

Moreover, ethical and legal considerations surrounding technology-enhanced nature-based interventions must not be overlooked. The integration of digital tools, such as VR, into NBIs introduces complex ethical challenges, including issues of privacy, informed consent, and data security. Ensuring that participants are fully aware of how their data is collected, used, and protected is important to maintaining trust and safeguarding personal information. Moreover, the deployment of these technologies must comply with existing legal frameworks and regulations to prevent potential misuse and to protect both practitioners and participants from legal liabilities (Adams, 2024).

A scoping review has inherent limitations, particularly in its ability to provide concrete guidance on the effectiveness of specific interventions. These limitations include reliance on subjective user reports, which may be prone to bias, as they are often collected through qualitative methods or self-reported questionnaires. Additionally, objective measures, such as the data provided by technology, user behavior, and responses to interventions, may also be limited. Moreover, this review did not incorporate quality assessments at the level of individual studies, which may affect the reliability of the findings. Furthermore, the review primarily includes studies published in English, potentially leading to language bias and the

exclusion of relevant research in other languages. Nevertheless, the findings suggest that technology can play a valuable role for mental health professionals in facilitating contact with nature, offering significant benefits and serving as a useful complement to traditional treatments.

After the COVID-19 pandemic, guidelines began to emerge recommending the use of technology in healthcare delivery for nurses, occupational therapists, physiotherapists, and other professionals (Nguyen et al., 2023; Pimentel et al., 2022). Nature-based approaches can also be adapted digitally, offering an additional possibility for enhancing care. Given the promising benefits observed in reducing stress, improving mood, and enhancing general well-being using VR and AR in nature-based interventions, it is crucial to continue exploring this innovative approach. Future research should focus on understanding the long-term impacts of these technologies and optimizing their integration across diverse populations and settings to maximize their effectiveness (White et al., 2018). Furthermore, providing comprehensive training to healthcare professionals on the implementation of these nature-based interventions is also necessary for their successful integration.

CONCLUSION

This scoping review provided a broad overview of the devices and technologies that are being used to promote contact with nature and natural environments, including different virtual reality and augmented reality devices, as well as the health benefits and harms of using them in different contexts. Several benefits have been found, however the most significant is the increase in contact with nature in individuals who had little disposition or disability. To ensure the effective integration of these technologies, comprehensive planning and preparation are essential, including practical training for healthcare professionals and all relevant stakeholders. These results may inform future research into the effectiveness of using technologies to access natural environments. Future work should continue to explore new innovative technologies, as well as increase the functionality of existing ones, whereby technologies can support physical and mental health in a way that also calls on health professionals to adhere to this type of intervention.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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