Review

Immersive Virtual Nature to Promote Mental Health and Nature Connectedness in Youth: Scoping Review

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Abstract

Background: Mental health disorders are increasing among adolescents and young adults. While contact with real nature provides mental health benefits, access to natural environments is not always possible. Immersive virtual nature (IVN) represents a potential alternative to promote mental health and nature connectedness.

Objective: This scoping review aims to map and synthesize how IVN has been used to promote mental health and nature connectedness among adolescents and young adults (<24 years).

Methods: A systematic search was conducted across 6 databases (PubMed, Scopus, PsycINFO, Embase, Cochrane Library, and CINAHL) in November 2025 and updated in August 2026, supplemented by citation tracking and expert consultation. Inclusion criteria encompassed quantitative and qualitative studies examining IVN interventions with mental health and/or nature connectedness outcomes.

Results: Sixty-one studies were included (4630 participants). The majority involved young adults (n=55), almost all university students, while only 6 studies included adolescents. Overall, included studies reported improvements in mental health and nature connectedness outcomes following IVN. Single-session IVN studies (n=26) reported immediate improvements, multisession IVN interventions (n=11) reported short-term benefits, and environments characteristics comparisons (n=30) compared different virtual environments. This last category indicated that visual characteristics (brightness and vegetation density), auditory stimuli, and interactivity substantially influence outcomes.

Conclusions: IVN shows promising potential to support mental health in youth populations. However, current evidence is limited by methodological heterogeneity, the predominance of laboratory-based single-session interventions, and the scarcity of research in adolescents. Future research should prioritize rigorous multisession interventions in younger and more clinically diverse populations, while also exploring personalization strategies based on environmental characteristics.

Trial Registration: OSF Registries osf.io/7vc5y; https://osf.io/7vc5y/overview

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Keywords: virtual reality; VR; mental health; young adults; teens; adolescents; stress; anxiety; nature

Introduction

In recent years, there has been a marked global increase in the prevalence of mental health disorders among adolescents and young adults, with depression and anxiety emerging as leading causes of disability in this population [1-3]. In 2019, it was estimated that 14% of the world's adolescents aged 10 to 19 years were living with a mental health disorder [4]. Adolescents and young adults, particularly Generation Z (the generation born between 1997 and 2012), report high levels of stress and burnout [5]. This increased prevalence of mental health difficulties among adolescents and young adults can be attributed to a combination of broad societal and technosocial stressors, including the COVID-19 pandemic [6,7] and the pervasive influence of social media, which has been linked to higher levels of depression, anxiety, and stress [8]. Mental health difficulties in adolescents are also linked with impaired academic learning and may therefore have long-term consequences for life opportunities and success [9]. These difficulties can create a self-perpetuating cycle in which stress and mental health problems reinforce one another, leading to more severe and persistent problems over time [10-12]. Taken together, these findings underline the need for accessible, acceptable, and engaging strategies to support mental health in adolescents and young adults.

Current treatment approaches for adolescent anxiety and depression are multimodal, with psychotherapy (particularly cognitive behavioral therapy) recommended as the first-line intervention and medication added in more severe cases or when initial treatment is insufficient [13]. Access to evidence-based psychotherapy nevertheless remains limited for many young people, with waiting times, cost, and availability of trained therapists reported as common barriers [14], while concerns persist regarding the tolerability of antidepressants in this age group [15]. Alongside standard care, adjunctive and lifestyle-oriented approaches (including physical activity, sleep and screen time management, and nature-based interventions) are therefore increasingly recommended to complement psychotherapy and pharmacotherapy [13]. Among these, contact with natural environments, particularly forests, has received growing attention due to its restorative potential. Restoration refers to the recovery of psychological and physiological resources depleted by everyday demands. Grounded in Attention Restoration Theory [16] or Stress Reduction Theory [17], it is considered a key pathway through which nature supports mental health. Consistent with these theoretical frameworks, multiple meta-analyses in adults showed that contact with real forests improved mental health, notably by reducing stress and anxiety, enhancing positive emotions, and decreasing negative ones [18-22].

In addition to physical contact with nature, nature connectedness, defined as the subjective sense of feeling emotionally and cognitively connected to the natural world, has been shown to play an important role in promoting mental health [23,24]. Adolescents who report stronger nature connectedness tend to show fewer depressive symptoms, lower levels of learning burnout [25], and higher resilience [26]. Moreover, connection to nature has been identified as a protective factor supporting adolescents' mental health during stressors such as the COVID-19 pandemic [27]. Given the potential bidirectional relationship between nature contact and nature connectedness, empirical studies have shown that direct experiences in real nature, such as forest walks, significantly enhance the sense of connection to nature among adults [28,29].

Despite these well-documented benefits, access to real nature is not always possible. People can live far from natural spaces or have mobility issues, allergies, or fear of insects, unfamiliar sounds, or going outside, and in the case of inpatients, there may be institutional restrictions on access to nature. In such contexts, immersive virtual nature (IVN) delivered through virtual reality (VR) may be an alternative enabling immersion in natural environments indoors in a safe and controlled way.

Advances in digital technology have enabled the creation of immersive VR environments, which consist of either computer-generated 3D simulations or 360° video-based content. Over the past decade, VR has been increasingly used across healthcare, including in psychiatry and clinical psychology [30-35]. Immersive VR environments are typically delivered through a head-mounted display (HMD), a cave automatic virtual environment (CAVE), or an immersive room in which the virtual environment is projected onto the surrounding surfaces. Compared with nonimmersive displays (eg, a television [TV] or computer-based two-dimensional [2D] screen), immersive VR systems provide environments that surround the viewer and allow exploration in all directions, fostering higher levels of presence [36]. This heightened sense of presence and immersion has been shown to amplify the beneficial effects of VR on mental health and well-being [37,38]. Moreover, it has been shown that children and adolescents may experience virtual environments more vividly and perceive them as more real compared to adults [39], which could increase their engagement. This potential for strong engagement makes VR particularly appealing for use with youth populations.

The growing interest in VR's potential to support mental health has led to several reviews on this topic. Among these, a number have specifically explored the use of IVN and its impact on psychological outcomes [40-48]. However, these reviews have primarily focused on adult populations, and although some have been conducted among higher education students [44] or young adults [48], none have specifically targeted both adolescents and young adults. In contrast, a few reviews examining VR more broadly have included adolescents and assessed mental health outcomes [33,49-52], but none have focused specifically on IVN.

In this context, the current scoping review aims to map and synthesize how IVN has been used to promote mental health and nature connectedness among adolescents and young adults younger than 24 years, a combined focus that has not been addressed by previous reviews.

Methods

Study Design

An a priori protocol was published on the Open Science Framework on November 3, 2025 [53]. This scoping review followed the methodological framework proposed by the Joanna Briggs Institute (JBI) [54] and was reported in accordance with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines [55].

Research Question

This review aimed to answer the following question: "How has IVN been used to promote mental health outcomes and nature connectedness among adolescents and young adults (<24 years)?"

Eligibility Criteria

The eligibility criteria in this study were determined based on the PCC (Population, Concept, Context) framework recommended by JBI.

Population

This scoping review focused on adolescents and young adults. Studies were included if the mean age of participants was younger than 24 years. The World Health Organization [56] defines adolescence as the period between ages 10 and 19, and "Youth" as individuals aged 15 to 24 years. This upper limit was chosen to encompass late adolescence and early adulthood, developmental stages characterized by ongoing brain maturation [57]. These stages involve rapid physical and psychological changes, alongside major neurodevelopmental reorganization [56,58,59]. This period represents a critical window of brain development that extends into early adulthood, during which individuals remain particularly vulnerable to the emergence of psychiatric disorders [60]. Where a mean age was not reported, eligibility was assessed based on the reported age range together with the composition of the sample. These studies were included only if the sample consisted exclusively of students and the age range suggested that the mean age was likely below 24 years, assuming an approximately symmetric age distribution. This eligibility criterion was refined during screening rather than prespecified in the protocol [53].

Concept

Immersive virtual nature interventions that simulate natural environments to promote mental health and/or nature connectedness. Eligibility was defined by the display rather than by the content: the system had to surround the viewer, so that the natural environment remained present in whichever direction the viewer turned. HMDs, CAVE systems, and immersive rooms meet this criterion, whether or not the image is stereoscopic. Desktop monitors or single-screen projections do not, even when they present 360° or 3D content, as the viewer remains outside the scene and the sense of presence is correspondingly lower [36,61].

Context

No restrictions were applied to the setting or geographical region. Studies conducted in educational, clinical, community, or laboratory contexts were eligible for inclusion.

Inclusion criteria encompassed quantitative and qualitative studies that reported outcomes related to (1) mental health (mood, anxiety, depression, stress, relaxation, calmness, and restoration), and/or (2) nature connectedness. Consistent with JBI guidance for scoping reviews, a broad and inclusive approach was adopted to capture the full range of interventional study designs, including randomized controlled experiments, quasi-experimental studies, feasibility or pilot studies, and case reports. Eligibility was not restricted by the presence or type of comparator, including active or passive control groups, or no comparator. Studies published in peer-reviewed journals as well as gray literature and unpublished studies were included.

Exclusion criteria encompassed studies focusing on participants with neurodevelopmental disorders, studies not involving virtual nature-based content, and studies addressing procedural anxiety or pain management. Studies were also excluded if they were not written in English or French, did not include mental health or nature connectedness outcomes, involved participants with a mean age of 24 years or older (or reported no age information), used only a 2D-screen display for the VR intervention, or if the full text was unavailable.

Search Strategy

The search strategies were drafted and refined through team discussion and with an experienced librarian. Six bibliographic databases were searched from inception to November 5, 2025: PubMed, Scopus, PsycINFO, Embase, Cochrane Library, and CINAHL. The search was updated in the same databases on August 26, 2026.

The search combined controlled vocabulary (MeSH terms) and free-text keywords relating to (1) youth populations, (2) mental health, (3) nature-based interventions, and (4) virtual reality. The search strategy was first developed for PubMed and then adapted for each database to account for differences in indexing systems. The final search strategy for each database can be found in Multimedia Appendix 1. Gray literature and unpublished studies were sought within these same database searches rather than through a separate search arm. No document-type, source-type, or peer-review limiters were applied to any database, so that nonjournal material indexed in these sources was retrieved alongside journal articles. In addition, citation tracking, reference list screening of relevant systematic reviews, hand searching of relevant journals, and expert consultation were performed.

Study Selection

All retrieved references were imported into Covidence (Veritas Health Innovation) [62] for management and duplicate removal (performed automatically and verified manually when necessary). Two reviewers (MEM and BK) independently screened titles and abstracts according to the inclusion criteria. Potentially eligible studies were assessed in full text, and disagreements were resolved through discussion or by consultation with 2 supervisors (MK and JVC).

Charting the Data

Data extraction was performed by the main author (MEM) using a structured charting form developed in Microsoft Word, and the charted data were subsequently verified by one supervisor (MK). Extracted variables were summarized into 2 tables. Given the volume and level of detail of the charted information, these tables could not be accommodated within the main manuscript and are therefore provided in full as Multimedia Appendices 2 and 3. Multimedia Appendix 2 includes the country, target population, sample size, sex, age range and/or mean age (SD), study design, VR technology, and description of the virtual environments. Multimedia Appendix 3 presents primary aims, description of the intervention, number of sessions, IVN exposure duration, measured outcomes and associated tools, and key findings. When key information on participant characteristics or intervention details was unclear or insufficiently reported, study authors were contacted.

For each study, we charted in Multimedia Appendix 3 whether IVN was delivered as a stand-alone exposure or as part of a multicomponent IVN exposure, which is a combination of IVN with a structured psychological or behavioral component (eg, mindfulness, meditation, guided breathing, or physical exercises).

Study designs were classified descriptively based on the intervention structure and comparison strategy of the studies, without applying a hierarchy of evidence. A study was considered "controlled" when it included at least one condition that did not involve immersion in nature-related virtual environments, for example, a virtual urban environment or a control condition (eg, sitting in front of a blank wall). Urban environments that included natural features were considered as IVN, not as a control condition. Studies were classified into 5 study types: (1) randomized controlled experiments included studies in which participants were randomly assigned to at least one virtual nature-based condition and one control condition; (2) controlled experiments were studies comparing a nature-based condition with a nonnature condition, without random assignment; (3) comparative experiments referred to studies comparing 2 or more nature-based conditions, with or without randomization; (4) one-arm pre-post experiments were studies in which a single group was exposed to one nature-based condition; and (5) qualitative experiments referred to studies using exclusively qualitative methods to explore participants' experiences of an IVN condition.

Synthesis of Results

Following an initial analysis of the included studies, and to better address the research question and facilitate interpretation, we classified the studies into 3 categories according to their design and objectives:

- Single-session IVN, exposing subjects to one session of virtual nature.
- Multisession IVN, exposing subjects to multiple sessions of virtual nature.
- Environments' Characteristics Comparison, comparing the beneficial effects of distinct IVN environments or of varying specific visual, auditory, and interactivity features within the same initial environment.

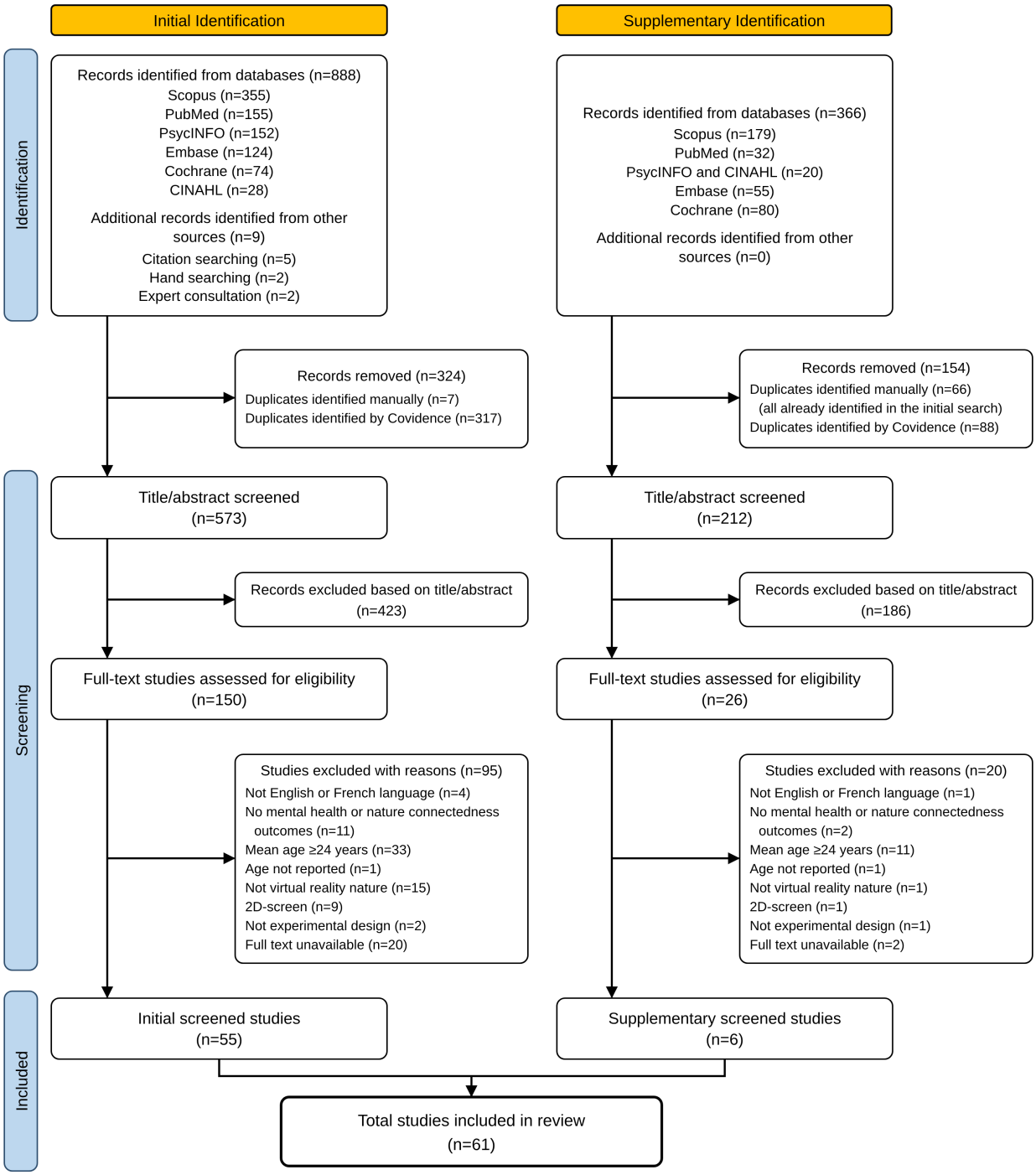
These categories were not mutually exclusive, and some studies were included in 2 categories.

Results

Study Selection

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed (Checklist 1), and the study inclusion flowchart is summarized in Figure 1. The initial search yielded 888 database records, and 9 studies from citation searching, hand searching, and expert consultation. After removing 324 duplicates, 573 records were screened by title and abstract by 2 reviewers (MEM and BK). Most (n=423) were excluded, leaving 150 studies for full-text screening, of which 95 were excluded, yielding 55 studies. The supplementary search yielded 366 records and, following the same screening process, identified 6 further eligible studies. The final sample included 61 studies [63-123].

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart. Searches were conducted in 2 phases: the initial search covered inception to November 5, 2025, and the supplementary search covered November 5, 2025, to August 26, 2026. 2D: two-dimensional.



Study Characteristics

Country and Study Types

Most studies were conducted in Asia (n=33) [63-95], followed by Europe (n=15) [96-110] and North America (n=12) [111-122], with 1 study not reporting its country for "blind peer review" [123] (Table 1). Randomized controlled experiments were the most common design (n=28) [63,73,74,78,80,82,84,86,87,89,90,97,98,100-102,105-107,111,113-119,123], followed by comparative experiments (n=21) [64,66,68-71,75-77,79,81,85,91,92,94-96,103,108,121,122], one-arm pre-post experiments (n=6) [67,88,109,110,112,120], controlled experiments (n=5) [65,72,93,99,104], and qualitative experiment (n=1) [83]. Most of the studies used quantitative data, and 3 studies used a mixed methods design [74,96,120].

Table 1. Summative results per characteristics of IVN[a] research.

Category	Number of studies	Studies
Region		
Asia	33	[63-95]
Europe	15	[96-110]
North America	12	[111-122]
Not reported	1	[123]
Participant characteristics		
Adolescents	6	[90,96,97,109,110,112]
Young adults	55	[63-89,91-95,98-108,111,113-123]
Healthy participants	50	[63,64,66-77,79,81,83,85-89,91-96,98,100,103,105-123]
At-risk/symptomatic participants	11	[65,78,80,82,84,90,97,99,101,102,104]
Self-reported measured outcomes		
Affect and mood	34	[64,65,68,70,71,74,78-81,83,85,86,88,90,91,93,95,96,100-108,112,114,119,121-123]
Anxiety	18	[63,67,71,75,77,78,80-82,84,93,94,97,104,109,113,116,117]
Stress	13	[63,67,72,73,83,87,90,93,100,103,104,108,112]
Restoration	15	[66,70,74,77,78,81,85,86,92,103,105,106,114,116,118]
Depression	6	[63,93,97,104,112,113]
Relaxation	9	[74,79,91,98,99,104,110,120,121]
Perceived safety	5	[75-77,118,121]
Posttraumatic stress symptoms	1	[104]
Nature connectedness	7	[65,80,95,96,104,108,111]
Physiological measured outcomes		
Cardiovascular activity	24	[64-67,70-73,75,80-82,84,86,89,90,92,94,98,99,109,115,119,122]
Skin conductance	12	[64,66,72,75,82,89,90,92,114,117,119,122]
Brain activity	10	[68-70,78,79,86,87,89,91,94]
Eye-tracking metrics	5	[66,76,77,79,88]
Stress induction task before VR[b]		
With stress induction	18	[64,66,68,71,72,75,82,84-87,90,92,94,115,117,119,122]
Without stress induction	43	[63,65,67,69,70,73,74,76-81,83,88,89,91,93,95-114,116,118,120,121,123]
VR HMD[c] technology		
Tethered HMD	30	[64-67,69,70,72,75-79,82,84,85,87,88,90,91,94-96,101,103,111,114,115,117-119]
Stand-alone HMD	28	[63,68,71,73,74,80,81,83,86,93,96-100,104-110,112,113,116,121-123]
HMD type not reported	4	[89,92,102,120]
VR HMD brand		
HTC[d]	26	[64-67,69,70,72,75-79,82,84,85,87,88,90,91,94-96,101,111,115,117]
Oculus/Meta	25	[63,71,73,74,81,83,96-100,103-110,112,113,116,118,121,122]
Pico	3	[68,80,86]
Samsung	2	[114,123]
nVIS	1	[119]
Procus One	1	[93]
Brand not reported	4	[89,92,102,120]
Study classification		
Single-session IVN	26	[65,72,78,80,82,84,86,87,89,90,98-102,105-107,109,111,114-117,119,123]
Multisession IVN	11	[63,67,73,74,83,93,97,104,110,112,113]
Environments' characteristics comparison	30	[64,66,68-71,75-77,79,81,83,85,88,90-92,94-96,100,103,105-108,118,120-122]
IVN characteristics investigated		
Content format (computer-generated, video/photo)	2	[96,120]
Type and visual characteristics (landscape type, brightness,	22	[64,68-70,75-77,79,83,85,88,90-92,94,95,106-108,118,121,122]

Category	Number of studies	Studies
vegetation density/permeability, realism, etc)		
Auditory stimuli	3	[66,71,105]
Interactivity	6	[81,95,96,100,103,120]

[a]IVN: immersive virtual nature.
[b]VR: virtual reality.
[c]HMD: head-mounted display.
[d]HTC: High Tech Computer Corporation.

Participants

Across the 61 included studies, a total of 4630 participants were included (Multimedia Appendix 2). The number of participants per study ranged from 20 to 320. Overall, the study populations included slightly more females (approximately 60%, 2836/4630) than males. One study did not report participants' sex [81]. Most studies focused on young adults (n=55) [63-89,91-95,98-108,111,113-123], almost all university students. The remaining 6 studies involved adolescents recruited in school settings [90,96,97,109,110,112], including 1 study with a mixed sample of children and adolescents (6 to 15 years) [109].

Eleven studies specifically targeted populations experiencing cognitive or psychological symptoms. These included first-year high school students at elevated risk of executive dysfunction [97] and adolescents with high academic stress [90]. Six studies recruited university students with moderate to high anxiety levels, identified through elevated scores on validated scales like the State-Trait Anxiety Inventory (STAI) [78,82,84], Pasco Hernando Community College Test Anxiety Questionnaire (PHCC TAQ) [101,102], Beck Anxiety Inventory (BAI), and Generalized Anxiety Disorder-7 (GAD-7) [80]. Two studies were conducted during the COVID-19 pandemic and included university students experiencing stress related to quarantine and lockdown restrictions [65,104]. Finally, 1 study involved inpatients diagnosed with borderline personality disorder [99].

Outcome Variables

Across the included studies, outcome measures were grouped into 2 domains according to the type of assessment: self-reported and physiological measures (Table 1 and Multimedia Appendix 3).

Self-reported measures encompassed a range of mental health and nature connectedness outcomes, as detailed in Table 1. These outcomes were captured through standardized self-report questionnaires (Table 2) and interviews.

Table 2. Assessment tools according to outcomes.

Domain	Assessment tools
Self-reported measures	
Affect and mood	POMS[a], PANAS[b], VAMS[c], SEES[d], VAS[e], ZIPERS[f], SVS[g], AWE-S[h], SPANE[i], Physical Activity Affect Scale
Anxiety	GAD-7[j], STAI[k], STAIC[l], CALM[m], PSWQ[n], MASQ[o], S-AI[p], DASS-21[q]
Stress	VAS, PSS[r], POMS, BJSQ[s], DASS-S[t], DASS-21
Restoration	PRS[u], ROS[v], POMS, SRRS[w]
Depression	K-PROMIS[x], PHQ[y], MASQ[z], RCADS-47[aa], DASS-21
Relaxation	RSQ[ab], VAS
Perceived safety	Likert scale
Posttraumatic stress symptoms	Trauma Screening Questionnaire
Nature connectedness	CNS[ac], INS[ad], NR-6[ae], VAS
Physiological measures	
Cardiovascular activity	ECG[af], PPG[ag] (resting BP[ah], HR[ai], and HRV[aj])
Skin conductance	GSR[ak]/EDA[al] sensor
Brain activity	EEG (α, β, δ, and θ frequency bands), fNIRS[am]
Eye-tracking	HMD-integrated[an] eye tracker

[a]POMS: Profile of Mood States.
[b]PANAS: Positive and Negative Affect Schedule.
[c]VAMS: Visual Analogue Mood Scale.
[d]SEES: Subjective Exercise Experiences Scale.
[e]VAS: Visual Analogue Scale.
[f]ZIPERS: Zuckerman Inventory of Personal Reactions.
[g]SVS: Subjective Vitality Scale.
[h]AWE-S: Awe Experience Scale.
[i]SPANE: Scale of Positive and Negative Experiences.

[j]GAD-7: Generalized Anxiety Disorder-7.
[k]STAI: State-Trait Anxiety Inventory.
[l]STAIC: State-Trait Anxiety Inventory for Children.
[m]CALM: Current Anxiety Level Measure.
[n]PSWQ: Penn State Worry Questionnaire.
[o]MASQ: Mood and Anxiety Symptom Questionnaire.
[p]S-AI: State Anxiety Inventory.
[q]DASS-21: Depression Anxiety Stress Scales-21.
[r]PSS: Perceived Stress Scale.
[s]BJSQ: Brief Job Stress Questionnaire.
[t]DASS-S: Depression Anxiety Stress Scale - Stress subscale.
[u]PRS: Perceived Restorativeness Scale.
[v]ROS: Restoration Outcome Scale.
[w]SRRS: Short-version Revised Restoration Scale.
[x]K-PROMIS: Patient-Reported Outcome Measurement Information System-Short Form.
[y]PHQ: Patient Health Questionnaire.
[z]MASQ: Mood and Anxiety Symptom Questionnaire.
[aa]RCADS-47: Revised Child Anxiety and Depression Scale-47 items.
[ab]RSQ: Relaxation State Questionnaire.
[ac]CNS: Connectedness to Nature Scale.
[ad]INS: Inclusion of Nature in Self.
[ae]NR-6: Nature Relatedness Scale-6 items.
[af]ECG: Electrocardiography.
[ag]PPG: photoplethysmography.
[ah]BP: blood pressure.
[ai]HR: heart rate.
[aj]HRV: heart rate variability.
[ak]GSR: Galvanic Skin Response
[al]EDA: Electrodermal Activity.
[am]fNIRS: functional near-infrared spectroscopy.
[an]HMD: head-mounted display.

Physiological measures (Table 1) were assessed using objective recording devices (Table 2). Cardiovascular assessments included resting blood pressure, heart rate, and heart rate variability (HRV), as these measures reflect autonomic nervous system function. Because parasympathetic activity increases during states of relaxation, parasympathetic regulation was assessed using time-domain indices such as the root-mean-square of successive differences (RMSSD) and frequency-domain measures, including high-frequency (HF) HRV and the low-to-high frequency ratio (LF/HF) [64-67,70-73,75,80-82,84,86,89,90,92,98,99,115,119]. Sweat secretion typically increases during emotional reactions, leading to higher skin conductance. Because sweat glands are innervated exclusively by the sympathetic nervous system, skin conductance is used to index sympathetic activation and is considered a physiological marker of emotional arousal intensity, with higher values reflecting greater arousal [90,114,117]. However, as skin conductance changes reflect both positive and negative arousal, they require interpretation in conjunction with self-reported measures [114]. Brain activity was primarily measured using electroencephalography (EEG), most often through power spectral density analyses in the delta, theta, alpha, and beta frequency bands across cortical regions, while one study used functional near-infrared spectroscopy (fNIRS) [79]. These measures were used to index relaxation, restoration, and preferences for specific environmental characteristics [68-70,78,79,86,87,89,91,94]. Finally, eye-tracking data, including the duration and frequency of gaze fixations within predefined areas of interest, were collected using HMD-integrated eye trackers to identify visually salient elements. Pupil diameter was additionally analyzed as an indicator of physiological stress, emotional arousal, and cognitive load across environments [66,76,77,79,88].

VR Technology

Details of the VR technology used in each study are provided in Multimedia Appendix 2. The included studies used a diverse range of HMDs, reflecting the rapid advancement of VR technology in recent years. As shown in Table 1, we separated the HMDs into 2 types: tethered HMDs and stand-alone HMDs. Tethered HMDs are connected to a computer or console to deliver high-performance graphics and tracking, whereas stand-alone HMDs operate independently without external hardware, integrating all necessary components within the headset. Notably, none of the included studies used CAVE systems or immersive rooms.

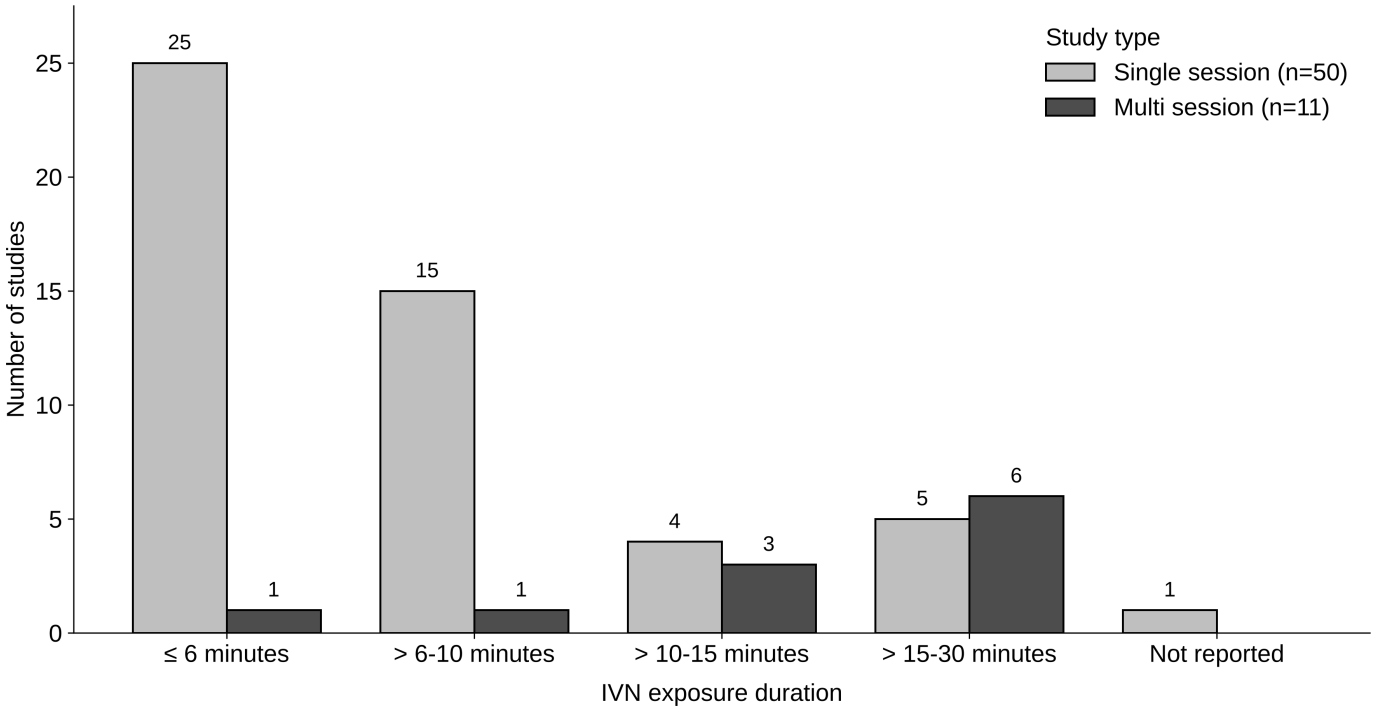
Early studies (conducted before 2022) used old-generation tethered HMDs, such as the nVIS HMD [119] and the Oculus Rift CV1 [103,118], which preceded more advanced models like the HTC Vive Pro series. In contrast, studies conducted more recently (from 2022 onward) tended to use stand-alone HMDs, most notably the Quest 2. This model was initially marketed as the Oculus Quest 2 and was later renamed the Meta Quest 2 following Facebook's rebranding to Meta in late 2021; both names refer to the same headset.

Brand reporting was dominated by HTC (n=26) for tethered systems and by Oculus/Meta (n=25) for stand-alone HMDs (Table 1). Among tethered HMDs, HTC Vive models were the most frequently used. One study [96] reported using 2 HMDs: an HTC Vive Pro 2 (tethered) and an Oculus Quest 2 (stand-alone). Specialized versions such as the HTC-Vive-Pro-McLaren 2.0 were reported in a single study [69]. Less frequently reported brands included the Pico series (n=3) [68,80,86], the Samsung Gear VR (n=2) [114,123], and the Procus One (n=1) [93].

Intervention Dosage

IVN exposure duration and overall intervention length varied widely. Independently of the 3 analytic categories used in the synthesis below, we describe dosage according to whether IVN was delivered as a single session (n=50) or across multiple sessions (n=11). Figure 2 shows the distribution of IVN exposure durations in each group, and per-study values are reported in Multimedia Appendix 3.

Figure 2. Immersive virtual nature exposure duration by study type. IVN: immersive virtual nature.



Single-session exposures ranged from 2 to 30 minutes, and most lasted 10 minutes or less. Multisession interventions were conducted over periods ranging from 1 to 5 weeks (eg, daily, weekly, or several sessions per week), with sessions ranging from 4 to 30 minutes, most of which exceeded 10 minutes. Brief exposures therefore predominated in single-session designs, whereas studies that repeated exposure favored longer sessions. Six studies presented several short IVN stimuli within one session, such as sequences of different 360° photographs or short videos [76,79,85,88,94,121].

Results of Synthesis

Single-Session IVN

Twenty-six studies were included in this category (Table 1 and Multimedia Appendices 2 and 3). Most adopted a randomized controlled experiment or controlled experiment design, contrasting a single-session IVN intervention with a wide range of control conditions, including no intervention, VR or non-VR neutral or indoor environments, VR urban settings, real nature exposure, or alternative interventions. Only 1 was a one-arm pre-post experiment with no comparison group [109]. Nine studies used a stress-induction task to ensure comparable stress levels across participants before VR immersion (Table 1).

Two studies compared IVN to a nonintervention group [80,86], 2 compared IVN to a VR blank wall condition [89,100], and 2 to a non-VR blank wall condition [114,117], 3 compared IVN to a VR indoor office condition [72,87,115], 1 compared IVN to a VR indoor classroom [90], 1 compared IVN to a VR slideshow of abstract paintings [119], 8 compared IVN to a VR urban environment [65,78,90,101,102,105-107], and 1 study compared IVN to outdoor real nature [114].

In addition to these standard control conditions, several studies explored alternative or hybrid forms of comparison. Four compared IVN to a 2D-screen nature-based condition [78,82,111,116]. One study compared IVN combined with mindfulness to audio-guided mindfulness without VR, and to a control group listening to natural science audio [84]. Another compared VR meditation exercises versus audio-guided meditation, and to a control group instructed to sit in silence for 10 minutes facing a blank wall [117]. Two studies compared IVN to breathing exercises performed using an app [98,99]. One compared an intervention combining IVN with therapy exercises (including psychoeducation, mindfulness,

cognitive restructuring, and meditation) to IVN alone and to the therapy exercises alone [116]. Finally, 1 compared cycling in IVN to the same cycling exercise performed without VR [123].

Multisession IVN

Eleven studies were included in this category (Table 1 and Multimedia Appendices 2 and 3).

In this category, studies adopted a randomized controlled experiment, controlled experiment, or one-arm pre-post experiment design, examining IVN against various control conditions including no intervention, real-nature exposure, or alternative relaxation methods. Five studies compared IVN to a group with no intervention [63,73,93,104,113]. One study compared IVN to real nature [74]. One study compared IVN combined with meditation to meditation alone [73]. Moreover, one study compared an IVN condition combined with guided breathing to a VR-based cognitive training program targeting executive functions [97]. Finally, 4 studies examined the effects of repeated IVN sessions without including a comparison group: 3 one-arm pre-post experiments [67,110,112] and 1 qualitative experiment [83].

Environments' Characteristics Comparison

Overview

Thirty studies compared different IVN environments or variations in their characteristics, with 10 studies including a stress-induction task before IVN immersion (Table 1 and Multimedia Appendices 2 and 3). These studies were organized into subcategories according to the specific features being manipulated within the virtual environments.

Content Format

Two studies compared IVN content delivered in different formats. One contrasted 3 formats: a computer-generated scene, a 360° video, and 360° photographs presented via the Google Earth VR app [120]. Another study compared a computer-generated IVN scenario with a 360° nature video [96].

Type and Visual Characteristics of IVN Environments

Twenty-two studies investigated how the type or visual characteristics of IVN environments influenced outcomes.

Seven studies focused on the influence of landscape type, comparing green and blue environments or specific natural sites such as forests, parks, beaches, lakes, Arctic landscapes, rainforests, rivers, undersea, and sky environments [68,83,90,95,106,107,121].

Beyond the type of landscape, several studies explored how visual and structural features of IVN environments–such as density, brightness, color, or spatial configuration–influenced participants' psychological and physiological responses. Seven studies examined scenes varying in forest type, canopy density, vegetation density or diversity, height, and permeability [68,69,76,88,94,118,122]. Three studies investigated differences in realism and composition, contrasting extraordinary (arctic, underwater, and cosmos) versus ordinary natural scenes (forest, seaside, and snowscape) [70], natural versus artificial landscapes [88], and a realistic versus dreamlike virtual forest environment [64]. Two studies compared forests differing in brightness [75,77], while another investigated VR photographs of blue-space sites varying in perceived naturalness [79]. Xu et al [85] examined different forms of university green spaces, including commuter, natural, and transitional green spaces, investigating how variations in spatial context influenced participants' responses. Seasonal contrasts were also tested by comparing summer versus winter forests [108]. Moreover, 2 studies compared IVN environments with varying density of people present in the environment [92,94]. Finally, 1 study examined multiple VR relaxation environments varying in landscape type and visual composition, including a national park, a snowy mountain, the Great Wall of China, and a pastoral setting [91].

Auditory Stimuli

Three studies examined how adding or manipulating auditory stimuli modulated the effects of virtual nature exposure on psychological and physiological outcomes. Overall, these studies contrasted visual-only versus audio-visual IVN conditions, and varied the type (eg, natural soundscapes, traffic noise, or mindfulness narration) and/or intensity of auditory input. Specifically, Chen and Ma [66] compared visual-only versus audio-visual presentations of urban park scenes using different soundscape combinations (eg, birds, cicadas, and traffic noise). Another study compared low versus high decibel water sounds, and a condition without sound [71]. Finally, awe-related responses were compared across 3 conditions, including an Arctic virtual environment with or without mindfulness narration and a virtual urban environment accompanied by the same narration [105].

Interactivity

Six studies compared different modes of interactivity with virtual nature. Interactivity refers to the extent to which participants can actively control their movement within the virtual environment, or physically engage with it through posture. Two studies contrasted interactive versus noninteractive versions of virtual nature environments [100,103]. Two studies compared seated IVN exposure to walking [81] or standing [95] IVN exposure. Calogiuri et al [96] compared an interactive exploration of a computer-generated urban green environment using a "walk-in-place" system to a passive 360° paragliding video. Williams [120] compared 3 IVN experiences involving different forms of interactivity: viewing an immersive 360° video recording, exploring a computer-generated scene, and visiting a natural site via the Google Earth VR app.

Discussion

Principal Findings

This scoping review provides an overview of the applications of IVN interventions to promote mental health outcomes and/or nature connectedness among adolescents and young adults.

We identified a total of 61 experimental studies focusing on the use of IVN. The studies examined (1) self-reported outcomes including affect and mood, anxiety, stress, restoration, depression, relaxation, perceived safety, posttraumatic stress symptoms, and nature connectedness; and (2) physiological indicators including cardiovascular activity, skin conductance, brain activity, and eye-tracking metrics. Studies included in this review generally reported beneficial effects of IVN interventions on mental health and nature connectedness outcomes in adolescents and young adults. Given the high heterogeneity across studies, these findings should be interpreted as signals of potential benefits rather than as evidence of demonstrated effectiveness.

To facilitate interpretation, we structured the discussion into 4 categories: immediate effects (single-session IVN), short-term effects (multisession IVN), effects on nature connectedness, and impact of VR environment characteristics. This categorization highlights that the youth IVN literature has developed along 2 parallel lines: assessing whether IVN produces observable effects and examining which features of virtual nature environments are associated with greater effects.

Immediate Effects Using Single-Session IVN

Single-session IVN studies accounted for 26 of the 61 included studies [65,72,78,80,82,84,86,87,89,90,98-102,105-107,109,111,114-117,119,123] and typically contrasted a single IVN exposure with a nonnature control condition. These experiments most consistently reported immediate postsession improvements in negative affect, perceived stress, and restoration-related outcomes, although results varied depending on baseline stress/anxiety levels (Multimedia Appendix 3). For instance, O'Meara et al [102] suggested that young people with higher levels of anxiety may benefit more from IVN exposure than those with lower baseline stress or anxiety. This pattern is consistent with prior research suggesting that brief interventions often produce greater benefits among individuals experiencing higher baseline distress, likely due to greater room for improvement and restoration potential, whereas ceiling effects may limit observable gains among individuals with lower initial symptom levels [124].

Improvements in parasympathetic regulation were observed during or immediately after IVN immersion, including in multicomponent IVN studies, as reflected by reductions in resting blood pressure and heart rate, along with increases in HRV [65,72,80,82,84,86,89,90,99,115,119]. When assessed following stress induction or in stressed or anxious participants, skin conductance levels generally decreased during IVN exposure, indicating reduced sympathetic activation and lower stress and negative arousal [72,90,117]. By contrast, some studies reported increased skin conductance compared with neutral control conditions, suggesting heightened positive arousal and engagement with the immersive experience [82,89,114,119]. EEG findings further suggest that IVN promotes neurophysiological relaxation, indicated by increased alpha activity [86,89], enhances attentional readiness, reflected by stronger parietal theta oscillations [87], and increased prefrontal activation, supporting cognitive recovery [78].

Although these physiological measures suggest promising effects, the strength of this evidence depends critically on methodological rigor. Several important contextual and procedural factors warrant careful consideration when interpreting these findings. First, in most studies, physiological measures were collected only during or immediately following IVN exposure and were predominantly derived from single-session interventions. Moreover, the quality and reliability of cardiovascular measures (particularly HRV indices) as well as brain activity recordings are highly dependent on the equipment used, the standardization of data acquisition conditions, and the rigor of data preprocessing and computational analyses [125,126]. Although most studies reported the timing and duration of physiological recordings, many did not describe the exact recording conditions and instructions given to the subjects. In addition, several studies relied on nonresearch-grade devices (eg, photoplethysmography-based measures for HRV or consumer-grade EEG systems that primarily capture global frontal activity), thereby limiting spatial resolution, data acquisition quality, preprocessing options, and the range of possible analytical approaches and physiological indices.

Studies that incorporated therapeutic content within the IVN intervention (eg, mindfulness or structured exercises) suggested that IVN may be more than a passive exposure to nature. Rather, it can also serve as an engaging setting for therapeutic activities. Indeed, several studies indicate IVN may enhance participant engagement with the therapeutic process [80,84,105,116]. This observation situates IVN within a broader literature in which immersive VR is used as a delivery medium for established psychological treatments in young people, most notably exposure-based therapy for anxiety disorders, with recent meta-analyses in samples aged 4 to 18 years reporting reductions in anxiety symptoms [127,128]. These approaches remain conceptually distinct from IVN: VR-based psychotherapy delivers structured therapeutic content through an immersive medium, whereas IVN relies primarily on exposure to restorative natural environments, with the environment itself as the hypothesized active ingredient. Distinguishing IVN as a stand-alone exposure from IVN used as a delivery context for structured psychological content is therefore important when interpreting the present findings, as studies combining IVN with mindfulness, meditation, guided breathing, or psychological/behavioral exercises [80,84,105,109,116,117,123] cannot be read as evidence for the effects of IVN alone.

Overall, single-session IVN interventions have predominantly examined immediate effects in youth populations, with findings suggesting potential clinical relevance that warrants confirmation through longer-term interventions.

Short-Term Effects Using Multisession IVN

Studies using multisession IVN interventions remain relatively rare, representing only a small proportion of the included literature (11 of 61 studies [63,67,73,74,83,93,97,104,110,112,113]). These studies reported short-term improvements in mental health outcomes, particularly anxiety and stress, after stand-alone IVN [63,104,113] and after IVN combined with meditation [73], guided breathing [97], or psychological exercises [93]. However, the findings for depression were uniformly negative, with no significant improvements reported across multisession IVN studies [63,93,97,104,112,113]. The authors mainly attribute this to floor effects, having recruited nonclinical students whose baseline depression scores were within the normal range [63,112]. Two studies reported that IVN positively influences mean arterial pressure and pulse rate, and physiological indicators associated with autonomic nervous system regulation during or immediately after the final session [67,73]. However, none of these studies assessed the persistence of these psychological and physiological benefits at follow-up. This is particularly important for assessing whether observed benefits are sustained over time, rather than merely reflecting the novelty of the VR experience [129]. A recent study [130] investigating acute and longer-term physiological and psychological responses to a 6-week VR relaxation intervention found reductions in momentary autonomic arousal and increases in subjective calmness among psychiatric outpatients. However, these effects attenuated over time, highlighting the need for longer-term studies to assess the sustainability of intervention effects.

Multisession IVN interventions varied substantially in terms of protocol and comparison conditions. Indeed, across the 11 studies investigating multisession IVN, intervention dose varied widely, ranging from brief daily microsessions (eg,~4 minutes/day over several weeks) to longer sessions lasting 15-30 minutes delivered 1 to 3 times per week over several weeks. The inclusion of both passive control conditions [63,73,93,104,113] and active comparators, such as meditation without VR [73] or VR cognitive training [97], further complicates study comparisons.

In parallel to the studies conducted in laboratory settings, one investigation examined the feasibility of a home-based VR relaxation intervention during the COVID-19 pandemic and demonstrated its feasibility, acceptability, and effectiveness on mental health outcomes. However, engagement declined over time, partly due to technical barriers [104]. Such implementation-related barriers are commonly reported in digital mental health interventions and may limit long-term engagement despite favorable initial acceptability [131,132]. Another study compared an IVN intervention with exposure to real nature, showing that while IVN can be restorative, it may not fully match the mood benefits associated with real-nature experiences [74]. This discrepancy may be expected, as immersive virtual environments cannot fully reproduce the multisensory richness and ecological complexity of real natural settings [114].

Some studies suggest also that the effectiveness of repeated IVN exposure may depend on both individual characteristics and the nature of the psychological symptoms targeted [113]. Browning et al [113] showed that participants identifying as women, past VR users, experienced with the outdoors, and engaged with the beauty in nature benefited particularly strongly from virtual nature. Virtual nature did not help symptoms of anhedonic depression in this study, but anxious arousal (panic) and anxious apprehension (worry) decreased with IVN exposure.

Taken together, these studies provide early signals of short-term mental health benefits of repeated sessions of IVN in youth. However, the extent to which these interventions lead to sustained benefits over the longer term remains largely underexplored.

Effects on Nature Connectedness

The included studies tend to show that IVN increases nature connectedness, regardless of environmental characteristics such as seasonality (summer vs winter) [108] or interactivity (interactive vs noninteractive) [96], suggesting that this outcome may be relatively robust across different IVN characteristics. Nature connectedness was assessed with self-reported measures (Table 2), which capture a subjective sense of connection with real nature. One study went further and assessed intentions toward real nature, finding no increase in intention to visit green spaces [96]. No included study measured subsequent contact with real nature, so whether IVN acts as a stepping-stone toward real-world nature engagement remains untested.

Impact of VR Environment Characteristics

Studies comparing different environment types or variations within the same environment (30 of 61 studies [64,66,68-71,75-77,79,81,83,85,88,90-92,94-96,100,103,105-108,118,120-122]) offer valuable insights into which specific design features may underpin improvements in nature connectedness and psychological outcomes, including stress and anxiety, affect and mood, relaxation and restoration (Multimedia Appendices 2 and 3). More specifically, studies within this category compared different content formats, landscape types (eg, green vs blue spaces, forests vs beaches, ordinary vs extraordinary nature), visual structures (eg, vegetation density, brightness, and enclosure), soundscape types and volumes, and levels of interactivity.

Similarly to single- and multisession IVN interventions, subjective responses were supported in some of the studies by objective physiological responses to different environments and to specific visual and auditory elements. These findings suggest environment-specific effects on autonomic nervous system regulation, indexed by cardiovascular activity and skin conductance measures [64,66,70,71,75,81,90,92,94,122], as

well as by brain activity [68-70,79,91,94]. Visual salience, along with physiological stress and emotional responses, was further assessed using eye-tracking measures [66,76,77,79,88].

Visual design features appeared particularly relevant. Studies manipulating forest brightness reported a consistent pattern: environments that were "too dark" or "too bright" tended to be less beneficial than those with moderate brightness levels for reducing anxiety and supporting stress recovery assessed through physiological measures [75,77]. Similarly, vegetation enclosure and permeability were linked to perceived safety and restorativeness, suggesting that achieving an appropriate balance of vegetation density and visual permeability is important when designing IVN environments [76,118].

Several studies indicated that adding or optimizing soundscapes can amplify restorative responses and relieve anxiety. Chen and Ma [66] showed that audio-visual IVN outperformed visual-only IVN for restoration-related outcomes, and that traffic noise reduced restoration benefits by shifting attention toward artificial elements. Similarly, Xu et al [85] found that anthropogenic sounds such as traffic and human activity decreased perceived restoration. Moreover, the intensity of natural sounds (eg, water sounds) also appears to play a role, with lower-intensity sound producing more calming and anxiety-reducing effects than higher-intensity sound [71]. These findings support designing IVN not only for visual realism but also for soundscape quality and congruence.

Interactivity emerged as a relevant design factor, although findings across studies suggest that its effects are nuanced. Some studies indicated that, compared to noninteractive IVN, interactive IVN significantly enhances mood [96] and reduces stress and tenseness [100], while another study showed limited or no added benefit of interactivity compared to passive experiences, particularly regarding stress reduction [103]. Qualitative studies provide evidence that preferences for interactive versus noninteractive formats may vary considerably among users, pointing toward the need for flexible and user-tailored IVN designs [120].

Several studies also investigated mediators and moderators of IVN effects. Restorativeness repeatedly emerged as a key pathway through which IVN may increase subjective vitality [106,107]. Nature connectedness was also proposed as a mediator of mood/stress effects in a virtual forest walking context [65]. In addition, individual differences also seem important: emotion regulation style (eg, habitual cognitive reappraisal) moderates benefits of IVN [107], and qualitative research highlighted heterogeneity in environmental preferences and responsiveness, supporting a personalization approach rather than a "one landscape fits all" model [83,96,121].

From an implementation perspective, findings from studies comparing IVN characteristics imply that IVN interventions should be conceptualized as designed experiences with configurable ingredients (eg, visual openness, safety cues, biodiversity cues, soundscapes, and interaction style), rather than as generic exposure to "any nature-themed" content.

Strengths and Limitations

One of the key strengths is the comprehensive approach to synthesizing evidence across diverse IVN interventions, study designs, and outcome measures. By incorporating varied methodologies, this scoping review offers a broad perspective on how IVN has been used across diverse mental health outcomes and nature connectedness in youth.

Another major strength of this review is its structured mapping of IVN interventions specifically targeting adolescents and young adults, a population that has been underrepresented in previous reviews dominated by adult samples. By grouping studies according to their primary objectives and aligning the results and discussion sections with these categories, the review highlights immediate effects (single-session interventions), short-term effects (multisession interventions), and potential active ingredients (ie, environmental characteristics, levels of interactivity). This organization improves the clarity of the findings and facilitates the identification of well-explored versus underexplored research questions, thereby helping to pinpoint existing gaps in the literature.

This review highlights several gaps and limitations, the first of which relates to the characteristics of the included populations. The evidence base is primarily composed of university student samples and shows a strong regional concentration (notably in Asia), which may limit the generalizability of findings to other cultural and clinical contexts, as well as to more diverse youth populations. This overrepresentation of university students likely reflects practical factors, such as ease of access and recruitment within academic settings. University samples are also socioeconomically narrow, whereas mental health problems are more prevalent in socioeconomically disadvantaged groups [133], so the young people most likely to benefit from such interventions are the least represented in this literature. In addition, 7 studies reported an upper age range exceeding 24 years without specifying the mean age [81,84,89,91,100,116,119]. These studies were included when samples consisted exclusively of students and the age distribution suggested a likely mean below 24 years, although this approach may have introduced some imprecision. Also, adolescents remain markedly underrepresented, with only 6 of the 61 included studies conducted in adolescent samples. Research in younger populations remains scarce, which may be explained by ethical constraints, safety considerations related to immersive technologies, and the need to develop age-appropriate content and study designs. Moreover, studies focusing only on young people with neurodevelopmental disorders were outside the scope of this review, and only one included study documented participants' neurodevelopmental status, with 2 participants with ADHD and 3 with dyslexia among a sample of 105 [109]. Consequently, the acceptability and potential benefits of IVN for neurodivergent young people remain insufficiently examined.

Second, all included studies relied on HMDs, and none evaluated other immersive systems such as CAVE systems or immersive rooms. This limits conclusions regarding whether alternative immersive technologies might elicit different responses or levels of tolerability in youth populations.

Third, there is considerable heterogeneity across studies in IVN environments, content formats, levels of interactivity, comparator conditions, and outcomes. Even when the same outcome was assessed, the measurement tools sometimes differed in what aspect of the outcome they captured. While such diversity may foster innovation, it reduces the comparability required to draw robust conclusions about the core components necessary to achieve reliable mental health benefits in youth, and highlights that IVN cannot be considered a technically uniform intervention category. In addition, 18 of the 61 included studies used an experimental stress induction prior to IVN exposure [64,66,68,71,72,75,82,84-87,90,92,94,115,117,119,122], suggesting that part of the observed heterogeneity may reflect whether IVN was evaluated as a restorative intervention following acute stress or as a stand-alone exposure under nonstressed conditions.

Implications and Recommendations for Future Research

Given the methodological heterogeneity described above, it remains difficult to determine which IVN interventions are most effective for mental health, the magnitude of their effects, and which specific outcomes are consistently impacted. These findings support the need for a subsequent systematic review and meta-analysis. However, such a review should be guided by a narrowly defined research question and apply clearly specified eligibility criteria, focusing on specific populations, intervention characteristics, and outcome measures. This approach would enable a more meaningful quantitative synthesis and help clarify which IVN interventions are effective for mental health and nature connectedness in adolescents and young adults.

Taken together, the present findings suggest that IVN may represent a promising and flexible tool for supporting mental health in young populations. However, they do not indicate that IVN could serve as a viable replacement for real nature, particularly when access to natural environments is readily available. Rather, IVN may offer a useful alternative or complement in situations where access to real nature is limited, impractical, or impossible. Its clinical potential nevertheless remains to be fully established. Future research should prioritize more diverse youth and clinical samples, rigorously designed multisession interventions with follow-up assessments, and standardized outcome measures, while also advancing personalization approaches and identifying the active ingredients driving therapeutic effects.

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Generative AI Use

During the preparation of this manuscript, the authors used ChatGPT (GPT-5) to improve the language, grammar, and readability of this manuscript. The authors subsequently reviewed, edited, and verified all AI-assisted content and take full responsibility for the content of the published article.

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Data Availability

The authors declare that the data supporting the findings of this study are available within the main manuscript and supplementary materials.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Search strategies for all databases.
[DOCX File (Microsoft Word File), 33 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Study characteristics, demographics, virtual reality technology, and description of the virtual environments.
[DOCX File (Microsoft Word File), 76 KB-Multimedia Appendix 2]

Multimedia Appendix 3

Summary of the primary aims, procedure, outcome measures, and key findings of studies.
[DOCX File (Microsoft Word File), 116 KB-Multimedia Appendix 3]

Checklist 1

PRISMA-ScR checklist.
[DOCX File (Microsoft Word File), 85 KB-Checklist 1]

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Abbreviations

2D: two-dimensional
BAI: Beck Anxiety Inventory
CAVE: Cave Automatic Virtual Environment
EEG: electroencephalography
fNIRS: Functional near-infrared spectroscopy
GAD-7: Generalized Anxiety Disorder-7 item
HF: high frequency
HMD: head-mounted display
HRV: heart rate variability
IVN: immersive virtual nature
JBI: Joanna Briggs Institute
LF: low frequency
PCC: Population, Concept, Context
PHCC TAQ: Pasco Hernando Community College Test Anxiety Questionnaire
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews
RMSSD: root-mean-square of successive differences
STAI: State-Trait Anxiety Inventory
TV: television
VR: virtual reality

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