



The Potential of Digital Nature on Mental Health and Environmental Learning: Opportunities and Challenges

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Abstract. Digital technologies have revolutionized the way we interact with the world, blurring the lines between the physical and digital realms. This manuscript delves into the transformative potential of these technologies in bridging the gap between humans and nature. Specifically, we focus on the evolution of digital technologies and their role in enhancing well-being through a closer connection with nature. By exploring various applications, from mobile apps to immersive VR environments, this chapter discusses the potential psychological benefits of digital nature experiences. We also examine implications for future technological advancements and nature conservation strategies, emphasizing the balance between technological progress and natural harmony.

Keywords. Positive Technology, mHealth, Virtual Reality, Virtual Nature, Emotions, Well-being.

1 Introduction

The advent of digital technologies has enabled us to establish and maintain connections with individuals and access various resources on a global scale. The popularity of online games has witnessed a steady rise, offering consumers captivating and immersive virtual experiences that present a multitude of entertainment options. However, the progression of technology use has facilitated individuals in pursuing predominantly sedentary occupations, leading to increased indoor activities and reduced levels of physical exertion, leading to adverse effects on human health.

The implications of this contemporary way of life are particularly disconcerting for youngsters, who allocate a significant portion of their time to engaging in activities such as television viewing, video game playing, computer usage, and media consumption. According to Pergams and Zaradic (2006), the pattern is particularly prominent in contemporary metropolitan regions, which are now home to most of the population.

Urban residents face a heightened susceptibility to both physical and mental health issues due to their disconnection from nature, which is an essential element of human

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well-being. This phenomenon is evident across various aspects of urban life and poses a significant risk to people's well-being (Turner et al., 2004).

Today, electronic media is widely embraced across all age groups, but there's much to discover about its impact on the natural environment. For instance, digital tools used in environmental education not only enhance learning but also improve communication among adults in families (Marsh et al., 2017; Plowman et al., 2010; Major et al., 2018). The digitization era has transformed education, including environmental education. Digital tools are increasingly recognized for their crucial role in environmental education. They incorporate emotional, action-oriented, and spiritual elements, expanding experiential learning. This essential role helps deepen understanding of environmental issues, promotes active engagement in conservation efforts, and drives positive behavior and attitude changes for long-term environmental benefits. There is an emerging trend in digital technologies where elements of nature are being incorporated into their design, serving multiple purposes at once. This can be seen through the development of applications that support meditation, mindfulness practices, and health tracking. Conversely, some technologies are intentionally designed to cultivate a positive connection with the natural world, potentially leading to enhanced user well-being.

In the following sections, we will delve into the ways in which digital tools, particularly mobile applications, are reshaping our interaction with the natural world and people well-being, utilizing the conceptual framework of Positive Technology (Riva et al., 2012; Gaggioli et al., 2017). The chapter is organized as follows: Section 2 will investigate mobile applications that bridge the gap between nature and technology, aiming to improve individuals' well-being. Section 3 will focus on the potential of virtual reality for providing nature experiences to enhance mental well-being and promote environmental awareness. It will also address the challenges and factors to consider when designing these simulated environments.

2 Digital applications that harness nature to foster wellness and mental well-being

Numerous studies have confirmed a strong link between increased physical activity, improved physical fitness, and access to local parks and greenways (Kaczynski & Henderson, 2007; Kaczynski et al., 2008; Sallis et al., 2000). Furthermore, there is substantial evidence supporting the idea that well-designed and well-maintained local parks contribute significantly to the overall health of communities (Frumkin, 2003). This recognition of the connection between exposure to natural environments and human health and well-being is widespread today (Bratman et al., 2012; Douglas, 2012; Maller et al., 2006). Initiatives aimed at promoting engagement with the natural world are readily available and cost-effective, offering substantial benefits for well-being and a reduction in health disparities (Bragg & Atkins, 2016). The World Health Organization has also emphasized the critical role of urban green spaces, considering them essential for fostering healthy, sustainable, and livable urban environments (Callaghan et al., 2021; McEwan et al., 2019). As a result, the use of digital technologies that incorporate nature as a central theme is on the rise, driven by individuals' desire to integrate wellness practices into their daily lives. Digital tools are seamlessly integrated into wellness apps, with the goal of fostering a positive connection with nature and

enhancing environmental awareness. For example, fitness applications like *Strava* (Strava Inc., 2022) and *ASICS Runkeeper* (ASICS Digital Inc., 2010) incentivize users to participate in outdoor pursuits such as jogging and cycling, thereby cultivating a heightened sense of admiration for the natural environment. Furthermore, educational applications such as *iNaturalist* (iNaturalist, 2011) and *PlantSnap* (PlantSnap Inc., 2018) provide users with the chance to enhance their knowledge regarding biodiversity and ecology, hence promoting the adoption of sustainable values and behaviors in everyday existence.

These applications utilize technological advancements to establish connections between users and the natural world, thereby promoting and fostering a heightened sense of responsibility for environmental conservation. In addition, apps designed for meditation and mindfulness, health monitoring, and fitness encourage outdoor activities and an appreciation of our surroundings. They not only promote individual well-being but also nurture collective environmental stewardship, highlighting the significance of sustainable living. In reviewing existing tools, apps were chosen based on their target audience and availability in today's app stores. Additionally, the criteria for selection included the ability to download and use the apps for free, without requiring a subscription. Another criterion was a strong emphasis on promoting well-being or providing information related to nature¹.

To classify the app in terms of their potential relevance to wellbeing, we used the Positive Technology conceptual framework developed by Riva et al. (2012). The framework delineates three levels of experience that technology can enhance to promote well-being:

- *Hedonic Level*: This level focuses on using technology to generate positive and pleasant experiences, which are fundamental to high emotional well-being. It seeks to foster positive emotions and immediate enjoyment, aiming to improve affective quality. Hedonic digital nature technologies may include virtual environments or apps that simulate or augment experiences of nature to evoke relaxation and pleasure. Examples could be virtual reality nature walks or apps with natural soundscapes that provide relief from stress.

- *Eudaimonic Level*: At this level, technology is harnessed to support engagement, personal growth, and self-actualization, which contribute to high psychological well-being. Eudaimonic technologies are not just about transient pleasure but rather aim to provide meaningful activities that engage users in a process of self-improvement and personal empowerment. This could involve educational software, productivity tools, or apps that challenge users to develop new skills. In the context of digital nature wellbeing, eudemonic technologies should encourage users to engage with the natural world in a meaningful way, such as apps that teach about biodiversity or encourage outdoor activities. These technologies would also aim at fostering a deeper connection and understanding of nature, leading to personal growth.

- *Social/Interpersonal Level*: This level pertains to enhancing the connectedness between individuals, groups, and organizations, thus fostering high social well-being.

¹The only app that deviated from these criteria was "Nature Strikes Back," developed by Digital Will Inc (2017). However, its incorporation of nature through gamification elements aimed at increasing engagement with both the app and nature itself appeared to align with its intended purpose, thus its inclusion in our synopsis.

Technologies at this level aim to improve social integration and create a sense of community and mutual awareness among users. They can range from social networks to collaborative platforms that connect individuals with shared interests in nature, enabling them to share their experiences, knowledge, and support each other's well-being. This could be, for example, in the form of social media groups, online forums dedicated to nature enthusiasts, or apps that facilitate group activities related to nature conservation.

Table 1. Examples of digital applications that harness nature to foster wellness and mental wellbeing.

Type of Positive Technology	Name app	Key functionalities	Target users	Scope or mean
Hedonic	Calm Headspace: meditation & sleep The positive app Relaxing Nature Nature Strikes Back Nature Relaxation Green Valley WildEarth TV – Nature Safari National Geographic Wild Journey – Nature Sounds Nature Relaxing Night – Nature Sounds Nature Dose Nature Today Wildfulness 2 – Nature Sounds Sonus Island Wildfulness: Meditate & Relax Soundscapes Atmosphere – sounds Somewhere – Sound app Beathable Plantie PlatNanny Forest	Promote mindfulness, meditation to lower stress and improve sleep; promote relaxation; self-management of psychological stress; interactive game; audio narratives	Adult, family, older adult, > 65 (Banskota et al., 2020)	Mean, Scope
Eudaimonic	Nature ID Nature’s Notebook Natural Atlas Planto Globe Seek iNaturalist Plantum PictureThis	Virtual assistant (AI) which assists in the nature management; to observe and record life cycle events of plants and animals; to scan, organize, learn to recognize	Adult, family	Mean, Scope

	PlatNet Planta Plant Parent PlantIn Carl Flora PlantID – Plant identifier++ Plant Identification – PlantAD NatureSnap – Plant Identifier Plant Identifier – FREE of ads Blossom Plantyx – Plant Identification LeafSnap – Plant Identification Botan AI Plant Identifier App – PLNT PlantMe – AI Plant Identifier Lily – Plant, Flower Identifier Plant App Iplant – Plant Identifier Garden Answers Happy plant			
Social	iNaturalist Nature Today Strava PlantSnap Plantsome PlantSwap SmartPlant Bloomz EarthSnap – Animal & Plant ID	Social network for sharing information; Discover animals and plants, read about nature activities	Young people, adult	Scope

Overall, the analysis and classification of these apps indicate a growing trend to incorporate technology into efforts to improve well-being, connect with nature, and foster social connections. The variety of target audiences and functionalities shows an understanding that well-being is multifaceted and that different strategies are needed to cater to diverse needs and preferences. In particular, the table allows to identify three categories of positive technology apps.

- *Hedonic Apps*: These apps aim to promote mental wellness through relaxation and mindfulness, using in some cases, digital natural environments as a medium. Apps like *Calm*, *Headspace*, and various nature-themed apps provide tools for meditation, stress management, and sleep improvement. They often include audio narratives or interactive elements to engage users. These apps target a broad audience, including adults, families, and the elderly, reflecting a recognition of the universal need for stress management. The key function of these apps is mainly to provide psychological relief via digital nature environments.

- *Eudaimonic Apps*: This category includes apps that promote personal growth and connection with nature. For example, *Nature ID* and *Nature's Notebook* help users identify and record natural elements, fostering a deeper understanding and appreciation of the environment. These apps seem to have an educational component and encourage active engagement with the natural world. The target audience includes adults and families, suggesting these apps are not only for individual use but also for educational activities within a family setting.

- *Social apps*: The apps listed under this category, such as *iNaturalist*, *Nature Today*, and *Strava*, have a strong social component. They serve as platforms for sharing information about nature, and for some, like *Strava*, about physical activities. These apps are particularly appealing to young people and adults who are looking to connect with others sharing similar interests. The scope here could imply the extent of the social network and the range of social interactions available within the app.

3 The Potential of Using Virtual Reality in Nature-Wellbeing Applications

Numerous studies have consistently shown that exposure to the natural environment can lead to various restorative effects, including improved mood, better emotion regulation, and enhanced psychological well-being. Additionally, contact with nature has been associated with the reduction of anxiety and depression symptoms, as well as a potential decrease in cognitive decline risks, including dementia (Kline, 2009; Akers et al., 2012; Wooller et al., 2018; Briki & Majed, 2019). Research suggests that virtual exposure to nature can also have a positive impact on mental well-being. It may reduce stress and anxiety, boost positive emotions and creativity, and potentially lower mortality rates (Yaden et al., 2018; Mitchell & Popham, 2007; Vujcic et al., 2017; Wang et al., 2019; Williams et al., 2021; Riches et al. 2023).

However, challenges related to accessing natural environments exist, particularly for individuals with mobility limitations. Uneven access to natural areas in urban settings and factors like mobility, safety concerns, and pandemic-related lockdowns have hindered such access (Jennings et al., 2019; Astell-Burt & Feng, 2021; Stieger et al., 2021). As a result, there is a growing body of research aimed at exploring ways to substitute in-person experiences with various forms of virtual interaction. This research aims to provide individuals with at least some of the benefits associated with the natural world (Browning et al., 2020).

Growing evidence suggests that virtual nature experiences can offer comparable benefits to those of real nature, encompassing feelings of restoration, stress alleviation, wonder, awe, and spirituality (Valtchanov et al., 2010; Browning et al., 2020; Reese et al., 2022a; Herman & Sherman, 2019). These experiences have been associated with heightened positive emotions, reduced stress, and improved mood levels (Valtchanov et al., 2010; Browning et al., 2020; Herman & Sherman, 2019). Additionally, they can boost subjective vitality and provide similar levels of rejuvenation, regardless of the presence of human-made elements within the virtual environment (Reese et al., 2022a). Nature's benefits, like restorativeness and relaxation, are influenced by environmental characteristics, such as quality and structure (Pretty et al., 2005; Gatersleben & Andrews, 2013; Lopez-Pousa et al., 2015).

Virtual environments in virtual nature experiences can be designed to present these structural elements to generate optimized and enjoyable digital landscapes (Mattila et al., 2020). High-quality visuals and audio in these environments strive to offer an immersive and augmented experience with psychological and physiological advantages.

3.1 Walks in virtual nature

Research has shown that virtual walks in nature can have a positive impact on psychological well-being and cognitive ability (Rigaux-Bricmont, 2018). However, challenges remain in creating a truly immersive and stress-free experience (Nilsson et al., 2018). Bornioli et al. (2019) conducted two studies supporting the benefits of walking in natural areas. Participants walked in five different virtual environments, showing the positive impact of walking on psychological well-being (Bornioli et al., 2019). Calogiuri et al. (2018) explored whether immersive virtual environments can simulate the psychophysiological benefits of green exercise, which combines physical activity with nature exposure. Twenty-six adults participated in a real nature walk, and two immersive virtual environments conditions (sitting and treadmill). Despite satisfactory ratings for sense of presence in the simulated nature environments, participants experienced discomforts like flatness and cyber sickness. The nature walk yielded higher enjoyment and positive affect compared to the less enjoyable immersive virtual environments, despite similar perceived environmental restorativeness. Furthermore, results showed that cyber sickness was linked to negative affect in immersive virtual environments, suggesting that VR could support green exercise if image quality and cyber sickness issues are improved. Compared to urban environments, interactions with natural environments have been associated with several health benefits including psychological restoration and improved emotional well-being. In a recent study, Brancato et al. (2022) studied how pine forest walk significantly improved happiness relative to urban walks. As previous studies have shown (Kaplan, 1995; McMahan & Estes, 2015; Ulrich et al., 1991), this study demonstrated that even virtual exposure to nature (via a simulated walk) can produce significant improvements in psychological well-being. These findings imply that virtual walks hold potential as an intervention for psychological restoration in real-world settings, beyond the confines of experimental environments (Chirico & Gaggioli, 2023).

3.2 Virtual nature for improving stress and mood

Veling et al. (2021) conducted a trial with 50 mood disorder patients, comparing 360-degree videos of nature to guided meditation with audio only, across ten days. Results showed a reduction in depressive and anxiety symptoms, especially for the virtual nature group, with a 10% decrease in depression and a 29% decrease in anxiety symptoms.

Lakhani et al. (2020) studied the effects of three 20-minute sessions of 360-degree nature videos on 16 spinal cord rehabilitation patients, showing reductions in depressive symptoms, particularly in a subgroup of six patients. Reynolds et al. (2022) held a trial for 38 women with metastatic breast cancer, with daily 13-minute virtual nature experiences for a week. They reported significant decreases in depressive and anxiety

symptoms, especially among those who initially did not feel strongly connected to nature.

Additionally, virtual nature has been used for managing pain, eating disorders, phobias, PTSD, and cognitive rehabilitation (White et al., 2018; Maples-Keller et al., 2017; Cieřlik et al., 2020). The focus on mood, stress, and perceived restorativeness in these studies is likely due to the nature of short interventions and the need for sensitive psychological measures. Although still preliminary, results of these studies may suggest that virtual nature can have a positive impact on psychological well-being, indicating its potential as a therapeutic tool for mental health conditions.

However, this potential requires further investigation, to differentiate the specific circumstances and target populations in which virtual nature therapies influence mental health outcomes. For example, Browning et al. (2023) examined the impact of a daily virtual nature intervention on symptoms of anxiety, depression, and rumination in forty college students. The longitudinal study saw a gradual reduction in both anxious arousal (panic) and anxious apprehension (worry) over a period of several weeks following exposure to virtual nature. Individuals who self-identified as women, had previous experience with virtual reality, possessed a familiarity with outdoor environments, and shown a strong appreciation for the aesthetic aspects of nature derived significant advantages from engaging with virtual nature. The utilization of virtual nature did not yield significant improvements in the symptoms associated with anhedonic depression or rumination.

In the study conducted by Anderson et al. (2017) VR technology was utilized to assess the impact of immersive natural settings on stress reduction and mood enhancement. The researchers conducted a comparison of individuals' reactions to natural environments in VR with their responses to a neutral indoor control scene. The outcomes of the study indicate that participants experienced greater relaxation when exposed to natural settings presented through VR, compared to the VR control scene. These findings align with previous research in attention restoration theory (Berto, 2005; Hartig et al., 2003). In a recent study, Karacan et al. (2021) conducted two intervention studies to examine the therapeutic potentials of virtual natural environments, considering varying levels of immersion and different environmental types. The findings confirmed initial hypothesis, demonstrating that highly immersive simulations were associated with a heightened perception of restorative qualities compared to low immersive simulations. Additionally, both studies revealed that highly immersive simulations indirectly influenced positive affect and diminished negative affect by facilitating a sense of being away from the current physical environment.

Shinrin-yoku, also known as forest bathing, is a practice involving immersion in nature that has proven to have positive effects on mental health (Hansen et al., 2017; Kotera et al., 2020). Recently, Reese et al. (2022b) have explored the use of VR to replicate benefits of *Shinrin-yoku* (also known as forest bathing) for individuals who lack direct access to natural environments. Twenty-six participants were exposed to a computer-generated virtual natural environment with either a high biomass (forest) or low biomass (canyon) setting, following an arithmetic stressor task. The study compared various restorative outcomes between the high and low biomass groups and assessed preference ratings for both real and virtual high and low biomass scenes among all participants. Results indicated that both VR and physical nature experiences had the anticipated positive effects on well-being indicators. Participants reported more

positive emotions, fewer negative emotions, a slight increase in subjective vitality, and a slight decrease in stress levels after both interventions. Notably, there were no significant differences between the two settings regarding any of the measured variables, although slightly stronger effect sizes were observed over time within the physical condition.

These results collectively suggest that immersive VR nature experiences has the potential to produce restoration effects comparable to those of physical nature experiences, offering valuable intervention strategies in situations where physical access to nature is limited.

3.3 Virtual nature for promoting sustainable behaviors

VR has emerged as a promising tool for encouraging sustainable behaviors, especially within the realm of environmental conservation. Recent work by Chirico et al. (2021), Scurati et al. (2021) and Deringer and Hanley (2021) underscores the potential of VR in this context and introduce frameworks for designing VR experiences aimed at supporting sustainable behavior change (Chirico et al., 2021; Scurati et al., 2021).

Simulation technologies offer two key advantages for motivating individuals and organizations to alter their habits. Firstly, VR enables the creation of a sense of "presence" (Riva et al., 2019) wherein individuals subjectively perceive themselves as actually being in a different place, thanks to interactive multisensory stimulation.

This feeling of "presence" in a simulated environment allows individuals to move beyond mere "symbolic" learning, which relies on statistics and abstract concepts, such as global temperature increases.

VR provides a direct avenue to experience the tangible effects of ecological disruptions. For example, it can vividly portray scenarios such as floods, hurricanes, or the consequences of ocean acidification (Markowitz & Bailenson, 2021; Fauville et al., 2020). Additionally, the use of visualizations depicting processes like tree-cutting has been shown to significantly influence the conservation of paper resources (Ahn et al., 2014). Similarly, virtual depictions of underwater environments effectively illustrate the consequences of rising seawater levels (Markowitz et al., 2018), while portrayals of the Greenlandic landscape help elucidate the phenomenon of ice sheet melting (Zhang et al., 2020).

Secondly, VR provides a platform to elucidate the cause-and-effect relationships between people's actions and their environmental impact. VR can construct highly realistic "possible" worlds, potentially leading to "transformative experiences" characterized by strong emotional impacts (Gaggioli, 2016; Riva et al., 2019). For instance, a recent study conducted by Chirico et al., (2021) emphasized that presenting information about plastic consumption in a concrete 3D-analogical format, as opposed than a mere numerical representation, significantly influences people's attitudes and intentions regarding plastic use, waste, and recycling. Specifically, these authors showed that enhancing the vividness of statistical information within a virtual reality environment can be an effective strategy for fostering pro-environmental behaviors. Chirico et al. (2023) further emphasizes the role of complex emotions, such as awe, in virtual nature experiences, which can influence pro-environmental attitudes and behaviors.

3.4 Design considerations for creating effective virtual natural environments for positive change

When developing a natural VR environment, immersive designers are faced with a multitude of choices. These choices encompass aspects such as the extent of visual realism, which pertains to the graphical fidelity of the virtual environment, the level of interactivity afforded inside the virtual world, and the incorporation of avatars. From the standpoint of developers, it is crucial to ascertain the specific elements inside a VR environment that have the most impact on fostering positive changes in attitudes.

In the development of virtual nature environments geared towards well-being, several design considerations emerge from the analysis of the available literature:

- *Computer graphics (CG) scenarios are more effective than 360° videos:* Studies highlight a distinction between 360° videos and CG scenarios, with research by Yeo et al. (2020) showing that CG-VR significantly increases the sense of presence and mood over 360-VR. Further, Nukarinen et al. (2022) found that CG-VR was more emotionally restorative than 360-VR, suggesting the superiority of CG-VR for simulating nature exposures intended for well-being.

- *Relaxation is a core function of virtual nature:* The primary purpose of most virtual nature applications that have been developed so far is to induce relaxation, often measured through physiological markers and self-reported questionnaires. Virtual nature relaxation has been shown to induce similar positive affect and restorativeness as actual nature, also affecting attention restoration, cognitive performance, and pain experience (Chirico & Gaggioli, 2019; Palanica et al., 2019; Mostajeran et al., 2021; Tanja-Dijkstra et al., 2018).

- *Visual aesthetics and natural sounds:* Key visual and sound elements, such as the attractiveness of nature visuals and calming sounds like birdsong, are crucial in reducing stress and promoting positive emotions during virtual nature exposure, leading to potential physical and psychological benefits (Kline, 2009; Akers et al., 2012; Wooller et al., 2018; Briki & Majed, 2019).

- *Multisensory environment:* VR nature experiences have been limited to audiovisual stimuli, with multisensory VR, particularly those involving olfactory and haptic stimuli, being less explored. While olfactory stimuli from nature, like tree scents, have been found to reduce stress, the potential of full multisensory VR experiences remains underutilized due to device limitations.

- *Cybersickness:* On the downside, cybersickness is a known issue in the VR experience, but it has received insufficient attention in the context of virtual nature (Martirosov et al., 2022; Li et al., 2021). Only two studies related to the virtual nature have investigated cybersickness conditions, and neither study employed methods to mitigate this issue or explored its effects (Liszio & Masuch, 2019; Mostajeran et al., 2021). Consequently, as noted by Li et al. (2021), it remains unclear whether the benefits of a virtual nature might be diminished by negative symptoms like cybersickness and to what extent.

- *Theory-driven design:* Choosing an appropriate theoretical well-being framework is critical for guiding the design of virtual nature interventions and selecting well-being measures. This includes understanding the role of subjective emotional states induced by virtual nature and their impact on well-being (Chirico et al., 2023).

4 Conclusion

Digital technologies, particularly emerging simulation tools like virtual and augmented reality, hold promise for enhancing mental well-being through simulated nature experiences.

These technologies offer advantages in treatment accessibility, cost-effectiveness, and continuity of care. Virtual nature has been shown to induce relaxation, augment attentional resources, improve cognitive performance, and alleviate pain. Furthermore, digital technologies are increasingly recognized for their role in fostering connections with nature and enhancing nature's intelligence. They have been documented to offer positive effects on mental well-being from both actual and simulated natural exposures. These effects are crucial for individuals with limited access to outdoor environments.

However, most studies focus on short-term exposures, indicating improvements in stress, mood, and perceived restorativeness. Moreover, most VR experiences have been limited to audiovisual stimuli, with multisensory VR, particularly those involving olfactory and haptic stimuli, being less explored.

Interactive VR scenarios, especially those created with computer-generated imagery, seem more effective at eliciting psychological benefits than 360° videos. Finally, issues like cybersickness and its impact on the benefits of virtual nature need more investigation.

Although several technological improvements are still needed, virtual nature presents a significant opportunity to promote various aspects of well-being and facilitate new learning experiences to enhance people connection with nature. This approach could unlock new opportunities for experiencing nature, particularly for those with limited access to natural environments, and contribute to a more sustainable future. Yet, as technology progresses, it's crucial to balance innovation with privacy considerations and the engagement of diverse audiences. Moving forward, the development of digital technologies should maintain a respectful balance with nature, maximizing benefits while avoiding potential downsides.

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