Respireal: Enriching Human-Nature Connection through a Breath-Controlled Mixed Reality Experience

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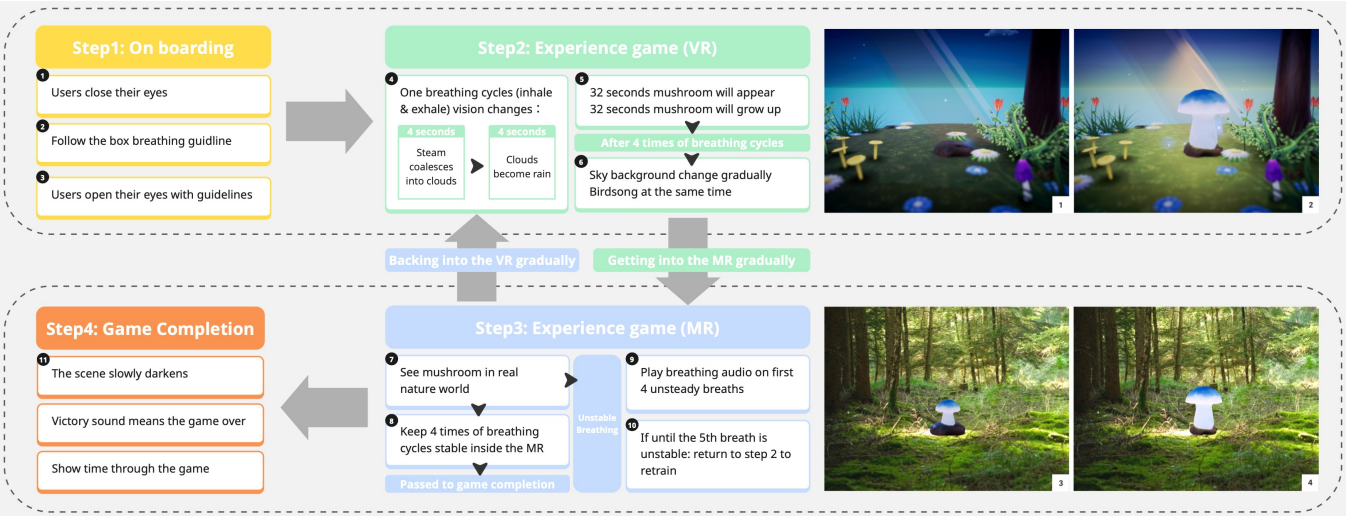

Figure 1: Respireal, a mixed reality breathing game

Abstract

Biofeedback in mixed reality offers a powerful means of enhancing users' bodily awareness and reconnecting people with nature. "Respireal" is an innovative mixed reality breathing game that enables participants to foster the growth of virtual plants through conscious breathing, while also facilitating seamless transitions between virtual and real natural environments via breath control. A preliminary study involving seven participants indicated that the system not only heightened their awareness of breathing but also enriched their engagement with nature. This work aims to inspire HCI researchers to further explore how interactive technologies can deepen the connection between humans and the natural world.

CCS Concepts

• **Human-centered computing** → **Interaction design**.

Keywords

Mixed reality, Human-nature interaction, Breathing biofeedback, Game design

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1 Introduction

Connecting with nature provides numerous benefits for individuals, including enhanced well-being, happiness [9], and physical health [20]. Consequently, Human-Computer Interaction (HCI) researchers have increasingly explored how digital technologies can foster engagement with the natural world [27]. Design research demonstrates that mixed reality (MR) offers a promising opportunity to create immersive and meaningful interactions with nature [16, 39]. Concurrently, bodily engagement can also enable the development of affective connections with natural environments [29]. In contrast, biofeedback (e.g., respiration, heart rate, and electrodermal activity), as an emerging form of physical interaction [30], enhances users' bodily awareness, deepens their understanding of the external environment, and cultivates empathy [37]. Although prior studies have explored biofeedback as a means of strengthening the connection between the body and nature [32], the potential of MR technology in facilitating this connection remains underexplored.

These findings have directed our research focus toward the intersection of immersive MR experiences and active breathing interactions, aiming to better understand how to design interactive technologies that connect people's breaths with nature. To explore this opportunity, we developed "Respireal," a novel mixed reality breathing experience. Respireal enables users to transition their vision from a virtual natural environment to the physical nature around them through active abdominal breath sensing, encouraging mindful breathing regulation and sustained attention to nature [6]. In conclusion, our work aims to provide insights for HCI researchers to further explore how breathing control and mixed reality technologies can foster a deeper connection with nature. Our work features the following contributions and benefits:

- A novel MR system designed to enable participants to transition between real and virtual nature through active breathing control, aiming to enhance individuals' awareness of and engagement with the natural environment.
- A pilot study conducted in an open natural environment with seven participants revealed the potential of our system to enhance awareness of breathing and strengthen participants' connection with nature.

2 RELATED WORK

This section outlines the insights gained from previous work, specifically focusing on state-of-the-art 3D environments designed to facilitate interaction with nature and various applications that take advantage of breath control.

2.1 Interacting with nature through immersive 3D technology

Computer-generated 3D nature environments are increasingly being explored as alternatives to direct contact with nature [28]. For instance, Ismo et al. [3] developed an AR program that enhances learning by utilizing 3D plants and pine cones as markers in a virtual natural environment. Similarly, "Zenctuary VR" [4] enables the creation of interactive 3D virtual gardens, while "Equine Eyes" [17] incorporates wearable props in 3D environments to let users experience the world from the perspective of other species. These studies highlight the potential of immersive 3D environments to simulate nature-like experiences [36].

With the advancement of MR technology, research highlights the benefits of mixed reality with nature on human mental health. For example, MR natural environments have been shown to produce emotional recovery effects comparable to those of real-world nature [8, 22]. Additionally, several studies have also explored MR's potential for facilitating interactions with nature. For instance, "Immersive Flora" [18] integrates plant electrophysiology with 3D reconstruction to illustrate plant interactions in a forest through MR, while "EchoVision" [19] simulates animal behaviors in MR to explore perspectives beyond the human experience. Although these studies have emphasized the role of bodily engagement in MR interactions, few studies have combined MR with the experience of deep connection that inspires people and nature. Biofeedback enhances users 'perception of the body and connection with nature, and MR provides the opportunity to gain this experience. In response, we utilize mixed reality technology combined with biofeedback to explore how it strengthens the human-nature connection.

2.2 Applications based on breath control

Zaccaro et al. [38] noted that "breathing is a unique physiological function in that it can be both autonomic and voluntarily controlled." Breath control typically encompasses techniques such as interval breathing [15], box breathing [13], and rhythmic breathing [25]. These techniques are often employed to achieve health-related goals [34], such as reducing anxiety [11] and improving focus [21].

In particular, breathing control is increasingly being applied creatively as part of interactive experiences. From simple interactions, such as blowing out candles on a digital screen, to exploring breath control as an interactive medium in games [33], its potential is evident in various applications. For instance, BreathPrint [10] uses sensory-deprivation audio to enhance breath-based interactions, while BreatHero [35] combines combat elements with breathing exercises. These applications demonstrate how breath control, as part of biofeedback systems [2], provides individuals with quick and enjoyable moments of relaxation, helping to reduce stress by encouraging deep, conscious breathing. Additionally, "Stairway to Heaven" [23] fosters mindfulness through gamified breathing feedback, while "InExChange" [24] strengthens social relationships by facilitating shared breathing experiences in a mixed reality environment. Similarly, "Lotus" [12] guides users through breathing exercises with animated petal movements, linking virtual plants to real environments [38].

These studies highlight the health and well-being benefits of breath control. However, previous research has yet to explore how

mixed reality technology can leverage breath control to connect people with nature—a gap our work aims to address. Thus, our research seeks to answer the question: *How do we design biofeedback in mixed reality breathing experiences to connect people with nature?*

3 Methodology

Our research is structured into three stages, as illustrated in Figure 2. In the first phase, we organized a social event to gain a deeper understanding of participants' perspectives on mixed reality technology and breathing control (Section 4). Six participants were invited to the event, during which we conducted interviews to gather insights that informed the design of our mixed reality breathing experience.

In the second phase, building on the feedback from the first phase, we developed a mixed reality system that enables users to transition from virtual nature to real nature through breath sensing (Section 5).

In the third phase (Section 6), we conducted a pilot study where each participant used the system for 20 minutes. Subsequently, we held 60-minute semi-structured interviews [1] with each participant and performed a thematic analysis of their responses [5].

4 Phase 1: User Research

This phase focused on the user's thoughts on mixed reality and breathing control.

4.1 Setup

We organized an informal event and invited 6 participants. During the event, participants used mixed reality headsets (Meta Quest 3[1]) to engage in games and try breathing-controlled activities. We observed their interactions with the mixed reality devices and conducted 60-minute semi-structured interviews to gather their feedback and expectations on using mixed reality for breathing exercises.

4.2 Findings and discussion

Overall, feedback centered around the goal for the mixed reality breathing experience discussed included natural visual styles, synchronized breathing feedback, and smooth program settings.

4.2.1 Natural visual style. Participants emphasized that natural scenes are essential for creating a sense of being in the a natural environment. P2 said, *"I like large forests, and green trees help me relax."* P3 mentioned, *"Green scenes are important. It's hard for me to see green plants in the office every day."* After experiencing mixed reality users pointed out that an immersive experience needs more detailed elements, such as sounds, not just visuals. P6 noted, *"If there are sounds from nature, it makes me feel very happy."* P1 added that changes in natural light would increase the sense of realism.

4.2.2 Synchronized breathing feedback. Participants highlighted that controlling breathing can be crucial for syncing with the dynamics of virtual nature. P4 said, *"It would be great if my body could control the changes in the mixed reality natural scene."* P5 suggested, *"Rhythmic changes in nature could help me focus more on its details."* P3 mentioned, *"I need some real-time feedback to know that my breathing is correct."* Taken together, it appears that a breathing feedback mechanism might help participants feel more connected to nature.

4.2.3 Smooth program settings. We observed that participants agreed that easy and smooth program settings are key to a positive experience. P4 said, *"I like tasks that are easy to control and provide direct fun."* P3 added, *"Gradually unlocking mixed reality natural scenes makes me want to explore what happens next."* However, some participants expressed concerns that there may be a disconnect when switching from virtual nature scenes to mixed reality. For instance, P4 questioned, *"For technology, the virtual world and the real world are always different. Will this affect my experience?"*

Through further discussions, we realized that while mixed reality breathing experiences might help people interact with nature, they differ from traditional mixed reality games. Breathing control requires precise device capture and consistent breathing behavior, which may take time for users to adapt to. In the next phase of the interactive system design, we therefore decided to focus on making the mixed reality breathing experience accessible to people without needing extensive experience in breath control.

5 Phase 2: Interaction Concept Development

Building on the findings, we developed "Respireal", a mixed reality breathing experience aimed at connecting users with nature. The application uses a breathing sensor to allow users to transition between virtual and real nature through breath sensing. First, the user is invited to use the system in a real nature setting, such as a park. Once the user puts the headset (Meta Quest 3) and a respiration sensor on, the system provides audio guidance for rhythmical abdominal breathing with a slow-paced technique of box breathing [35], which was chosen for its simplicity and effectiveness in promoting relaxation, and the user is meant to follow the instructions while closing their eyes. After completing the breathing instruction exercises, the user moves to the second phase, where they open their eyes to see a virtual forest. The objective is to help the user breathe rhythmically to collect virtual water droplets, which in turn helps virtual mushrooms grow. Once the user achieves the desired breathing in the virtual environment, the user moves to the third phase, the MR headset transitions from the virtual world to the real nature outside. The user must continue breathing rhythmically to encourage the growth of the virtual mushrooms overlaid on top of the real environment. If the user fails to maintain breathing rhythmically, they return to the second phase virtual nature to redo the breathing exercises.

6 Phase 3: Interaction Concept Evaluation

We conducted a second study to observe participants' experiences with "Respireal".

6.1 Hardware and software for measurement

We used a custom wearable device to measure respiration (Figure 3). The device consists of a Plux wireless 4-channel hub[2], an inductive respiration (PZT) sensor[3]. This setup measures displacement

[1] https://www.meta.com/au/quest/quest-3/

[2] https://www.pluxbiosignals.com/collections/data-acquisition-systems/products/4-channel-biosignals-kit

[3] https://www.pluxbiosignals.com/collections/plux/products/respiration-pzt

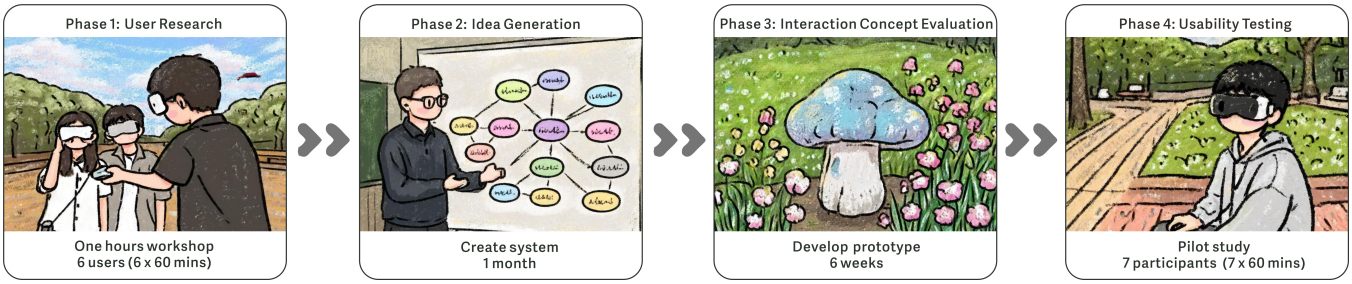

Figure 2: Schematic flow of the study

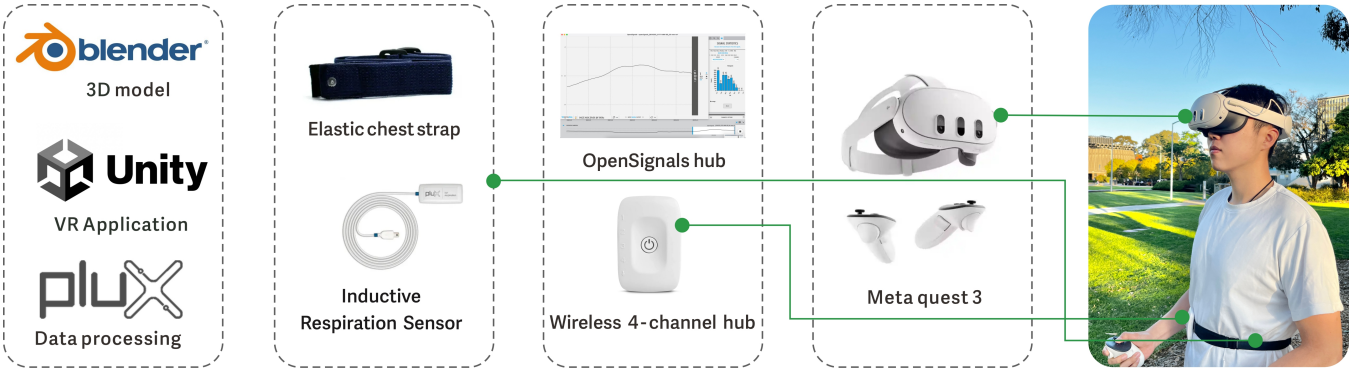

Figure 3: Overview of the hardware and software in the Respireal system

changes in chest or abdominal volume during the respiratory cycle (inhalation and exhalation), tracking parameters like respiratory cycle, rate, and relative amplitude. For the visual natural scene and 3D plant models, we used Blender[4] (version 2023). The respiratory signal data, including respiratory rate and amplitude, were processed using the OpenSignals software platform[5]. These data were then transmitted in real time via Bluetooth USB adapter to support the development of the mixed reality breathing game.

6.2 Participants

We invited 7 participants (3 men and 4 women, no non-binary or self-described, ages 20–29 years, M=26.57 SD=2.26). The participants included a teacher (P1), an architectural designer (P2), a college student (P3), two programmers (P4, P5), and two waiters (P6, P7). Half of the participants had prior experience with breath training. Most participants reported spending less than 2 hours per week in nature, aligning with research stating that people find limited opportunities to engage with the natural world in their daily routines [31]. Participants were taken to a real forest and asked to sit on the grass, where we aimed to ensure a comfortable setting with limited non-nature noise. Researchers assisted them in putting on the headset and sensor (a belt with an abdominal flexion sensor) and performed a calibration procedure. After experiencing "Respireal" (approximate 20 minutes), participants took part in a 60-minute semi-structured interview. They were asked about their feelings, mood, focus of attention, gaming experience [14], and their views on nature and sense of connection with it.

7 Results

We conducted a preliminary analysis revealing three themes: multimodal approach, intuitive breathing feedback, and dynamic bridge building.

7.1 Multimodal approach promotes an immersive experience

The formation of user cognition is closely linked to the physical environment [14]. Participants noted that scene restoration enhanced their immersive experience. Participants highlighted that the virtual scene effectively recreated the natural environment. P1 stated, *"The colors and lighting in virtual nature surprised me."* Similarly, P3 commented, *"I really liked the sounds of virtual birds, the wind, and water, which made me feel like I was in a real natural environment."* These findings suggest that the embodied restoration of multiple senses, such as sight and hearing, can help users bridge their virtual experience with the real world.

7.2 Intuitive breathing feedback and building a shared body

Participants emphasized that intuitive breathing feedback assured them that their breathing actions were successfully recognized, fostering a deeper connection with nature. P5 noted, *"I was always*

[4]https://www.blender.org
[5]https://www.pluxbiosignals.com/collections/opensignals

watching how my breathing was reflected, like controlling the dripping of water in the scene." When asked about the most memorable part of the experience, P1 shared, *"When the mushrooms finished growing, the sky gradually brightened, which mirrored the rhythm of nature. I felt like my breathing was directly influencing the mushrooms' growth, and that made me really happy."* However, some participants pointed out that the scene's multiple elements could be distracting. P3 explained, *"I kept focusing on the water drops on the right, which made it hard to concentrate on my breathing."* Despite these challenges, most participants believed that with more practice, with more practice they would be able to better control the transitioning from virtual to real nature.

7.3 Dynamic bridge building to enhance connection with nature

Most participants felt that breath control acted as a bridge between virtual nature and real nature, helping them realize the complex and fragile relationship between humans and nature. P6 mentioned, *"I can only stay in real nature if I keep my breathing stable."* P1 added, *"My breathing controls the changes in virtual nature, which helped me understand the impact of human behavior on the environment."* P5 reflected, *"I have started paying more attention to nature. I rarely had the opportunity to truly observe a tree before, and this experience encouraged me to engage more with nature."* P4 shared, *"I feel a sense of harmony with nature and now see myself as part of it."* These responses suggest that mixed reality breathing games have the potential to strengthen the connection between humans and nature.

8 Discussion and Limitations

This study expands the common breathing training methods in traditional HCI, which are often limited to indoor environments or static exercises based on videos [7][26]. We use real nature as the interaction background and emphasize active interaction through embodied breathing in an open environment: on the one hand, users promote the growth of virtual nature through rhythmic breathing control; on the other hand, mixed reality technology integrates real natural scenes and virtual elements, stimulating users' motivation and emotional resonance to engage with nature. This virtual-real world fusion through breathing interaction gives users the role of "participants in nature" rather than "passive observers of nature", which helps to stimulate deeper nature empathy. This research demonstrates how a mixed reality breathing game could help people interact with nature. However, there are several limitations to consider. To validate the system's effectiveness, larger-scale studies are needed. Specifically, further research is required to explore the relationship between the body and the natural world. Additionally, more empirical evaluations are necessary to expand and refine the effectiveness of the system. Looking ahead, we aim to explore more interactive modalities between the body and nature, to foster a stronger and more profound connection with the natural world.

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