Listen to the Plant: Exploring the Design of Plant Care as an Auditory Interface to Promote Caregiving Behavior

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Figure 1: (a) A person listening to sonification music based on changes in plant moisture signals; (b) A person listening to sonification music based on the sounds of touch; (c) A person sways happily to the music.

Abstract

Caring for indoor plants can promote human well-being, but automation technology diminishes the benefits plants provide during care. Based on this, HPI research has explored sound as an interface to amplify plant needs and promote human caregiving behavior. However, most of these systems reinforce the passive role of plants under spatial constraints from a human-centric perspective. To address this, we propose a wearable-plant headphone prototype, developed through three iterative design rounds. This prototype uses plant care as an auditory interface, employing bidirectional auditory feedback to acquire plant moisture signals and the sounds of human care, mapping them into real-time musical expressions and delivering them through an integrated plant headphones. Through this work, we contribute design considerations for leveraging sound as a bidirectional and creative interface to promote human caregiving behavior in Human-Plant Interaction research.

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CCS Concepts

• **Human-centered computing → Interactive systems and tools**.

Keywords

Human-plant interaction, auditory interface, sound, bidirectional

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1 Introduction

Indoor plants are considered beneficial to health and well-being [24]. Caring for indoor plants can also alleviate feelings of loneliness and disconnection from nature [20]. However, research on indoor plant care has highlighted significant challenges in maintaining plant health, with studies indicating that inconsistent care methods often arise due to the fundamentally different life cycles and rhythms of plants compared to humans [12, 14]. These situations often put plants on a dangerous edge. In response, HPI researchers have used technology to address these issues by replacing manual care with automated systems [16, 22]. For example, plant sensors have been used to detect dehydration [22], plant "health status" has been digitally visualized [11, 17], and care behavior has been directly manipulated through robots [23]. From these prior works, we understand that automated systems can replace manual care to improve efficiency [10]. Although plants may benefit from automation, humans no longer need to remember care steps, which may cause plants to miss out on the benefits of care.

Plants may possess unique forms of "intelligence" [6] and respond measurably to external environmental factors [8]. Initially, changes in plant electrical signals were transformed into sound art installations, allowing people to "hear" the state of plants and establish cross-species perception [15]. However, these systems are still designed from a human-centered perspective, primarily serving human needs [3]. With the development of theories such as more-than-human [5], some HPI research has shifted its focus to considering the plant's perspective, and has utilized these measurable signals to generate sounds as interactive tools to support plant care, such as amplifying plant needs [1], altering perceptions of plants [7], and fostering empathy [25]. Although sound has been proven to be a channel that can express the state of plants in real time [9] and increase people's care for plants, the passive nature of plants, which are immobile and spatially constrained, makes their needs difficult to actively perceive.

Recent studies attempt to break this imbalance by integrating plants into wearable devices. For example, "NugiTex" [26] translates the plant "comfort" (based on environmental conditions) into tactile feedback on the body. This inspires the transformation of plant signals into more easily received forms; however, plants may still be located in places that are not visible. "FloraWear" [18] uses plants as wearable "living interfaces," allowing people to more easily notice the state of plants to establish close connections, but the integration of the materiality of plants into people's daily lives has been overlooked. "Livingloom" [27] addressed this limitation by integrating plant growth processes into wearable fabrics, expanding the possibilities for long-term human–plant care. To reduce the passivity of plants in caregiving, we see the opportunity to combine these approaches to make the plants wearable and transform plant signals into more perceptible feedback—using sound as an interactive interface. Inspired by these insights, we pose the following research question: ***How can we design plant care as a playful auditory interface to promote caregiving behavior?***

To address this issue, we adopt a Research through Design (RtD) approach [28] where we have developed a bidirectional feedback system based on caregiving behavior, which is implemented through auditory interaction. We use sound input and output as channels for human–plant bidirectional interaction to create more playful forms of caregiving. The system can acquire the plant's moisture signal and the sounds of people caring for the plant, and we map these signals into dynamically changing musical pieces, which are played through plant-integrated headphones. Overall, this work explores how caregiving behavior can be viewed as a playful auditory interface to promote caregiving behavior, aiming to inspire novel forms of interaction in the HPI community.

2 Formative Study

We explored designing a sound system from people's plant care behavior, based on reflective practice [4], which emphasizes the value of purposeful design activities. To provide a reference for system design, we conducted a formative study [2] with 8 plant enthusiasts with extensive experience in plant care (M=12 years, SD=4.52). The purpose of this study was to understand their experiences in plant care and to identify the challenges that may be faced in integrating sound into the care process. Based on this, we analyzed the collected insights to guide the establishment of design goals. We conducted 30-minute semi-structured interviews with each participant. Each interview was recorded, and the audio content was transcribed. To ensure the reliability of the coding, two coders independently coded the interview transcripts using NVivo software and conducted two rounds of cross-comparison and reconciliation of coding categories and data units, resulting in the identification of four challenges from the final 108 codes.

2.1 Challenges of Integrating Sound into Plant Care

Through the analysis of interviews conducted in the formative study, we identified four challenges (Cs).

C1: Time misalignment of plant feedback. People often unconsciously neglect plant care due to the time misalignment of plant feedback. Participants infer whether watering is needed by remembering watering times or touching the soil. However, despite plants' unique "intelligence," they cannot move or make sounds. By the time people realize plants need care, they are often already in danger, and this usually occurs on a timescale that people are unaware of.

C2: Spatial constraints of plant care. Plant care has traditionally been confined to fixed spaces. When people leave their usual locations, such as balconies, living rooms, or desks, plant care becomes ineffective. While existing automated systems address the watering problem, during the plant's growth process, people and plants are often in different spaces and remain separate entities, resulting in reduced attention to plants and diminished care.

C3: Plant care as an invisible burden. Indoor plant care is often viewed as another daily chore. After purchasing new plants, people experience a series of attitude shifts, from enthusiastic care to indifference toward the plants' condition. This caregiving relationship quickly disintegrates once the pace of work increases or attention is diverted to other tasks, such as writing or meeting with others. Thus, conventional care methods struggle to motivate people to take active responsibility for plant maintenance.

C4: Human-centered perspective overlooks plants. Existing automated systems use "human-like" sounds to convey the plant's moisture deficit. However, these systems are still designed with a human-centered perspective, primarily serving human needs, such as improving watering efficiency and reducing the risk of plant death. This weakens people's active participation in the subtle care of plants.

Figure 2: Three iterative design rounds of a wearable-plant headphone prototype

2.2 Design Considerations for System Development

We invited four experienced HCI researchers with a passion for plants to brainstorm system design solutions. After more than ten brainstorming sessions, the following four design considerations (DCs) were finalized.

DC1: Sound as a bidirectional interactive interface. We use sound input and output as channels for interaction between humans and plants to create a more playful form of care. On the input side, the states of both humans and plants are involved in the interactive music creation process. On the output side, we consider sonifying the signals in real time into a set of dynamically changing musical notes with varying loudness and pitch to enhance the enjoyment of the care process.

DC2: Care as a means of an auditory interface. On one hand, we acquire the plant's own growth status as a Class A sound pattern to provide feedback on the plant's dehydration. On the other hand, when people care for plants, we detect the sounds produced by their hand movements during plant care. As a Class B sound mode, people can try different actions such as spraying, stroking, or touching the plants, and receive musical feedback, thus motivating their participation in plant care.

DC3: Everyday wearable forms to break spatial constraints. We consider integrating plants as wearable devices into everyday wearable products to reduce the problem of insufficient care due to spatial constraints. For the wearable component, we plan to combine existing technological products, using headphones as the basic container, seamlessly integrating them into people's lives without requiring the re-cultivation of new habits. We consider using 3D printing to adjust the headphone shape to store plants and adapt to their moisture needs. Therefore, people can enjoy the convenience of technology while subtly promoting plant care.

DC4: Sensitive and lightweight hardware detection devices. We consider sensitive detection and non-contact sensing devices. These devices can more reliably capture subtle but crucial movement sounds during plant care, laying the foundation for using sound as input for creative interfaces. At the same time, in order to better adapt to wearable devices, we consider a lighter and smaller device to reduce the burden during use.

3 System Iteration

In this section, we describe our thoughts and reflections on the three iterations of the system design process. In particular, regarding the different forms of human–plant bidirectional interaction as an auditory interface, our goal was not only to determine which sensor was most suitable, but also to understand why certain sensing mechanisms are better suited to real-world plant care scenarios (Figures 2).

3.1 Why Chia Seeds

We chose chia seeds as our experimental subject for three reasons: **(1) Chia seeds are sensitive to moisture loss:** Chia seeds have shallow roots and a small size, making them more sensitive to water deficit [13]. Therefore, under indoor microclimate conditions, daily watering is required to maintain their photosynthetic efficiency, which provides a suitable environment for our research. **(2) Chia seeds respond relatively quickly to the external environment:** under prolonged dry conditions, their leaves will wilt noticeably [21], but they can recover to a healthy state in about 3 hours. These changes make the plant's vulnerability obvious and persistent. **(3) Chia seeds are common yet easily overlooked:** Chia seeds are common in home gardening, and people have a natural sense of "utility" for them. This makes it easy for participants who lack plant care experience to access this plant, but because chia seeds are not rare, their care is often underestimated or neglected [19].

3.2 Iterative Design 1: Exploring the Use of Computer-Aided Human-Plant Interaction as a Sound Interface

In our initial exploration, we built a human-chia seed bidirectional interaction system for everyday work scenarios. The system embeds a soil moisture sensor within the growing medium to continuously monitor moisture levels. To ensure repeatable sound triggering, we first acquired sensor readings under "extremely dry" and "extremely wet" conditions, setting 30% of the reading range as the trigger threshold for a moisture shortage warning. The system performs soil moisture detection every 10 minutes and provides a fixed sound feedback each cycle: when the moisture reading is below the threshold, the system plays a piercing alarm sound to enhance the perception of water shortage and prompt the user to take care of the plant, such as spraying; when the reading is above the threshold, the alarm sound is not triggered. Meanwhile, the computer microphone remains on to capture the sounds generated by the user's caregiving actions toward the chia seeds, and sonifies the sound signals in real time into a set of dynamically changing musical notes with varying loudness and pitch to enhance the enjoyment of the caregiving process.

The researchers conducted a 3-day trial and found that the solution still had key limitations: due to the large pickup range of the computer microphone, the acquired signal was easily interfered with by environmental noise and other sounds in the work environment, making it difficult to stably distinguish and locate the specific caregiving behavior sound source, thus reducing the reliability of using "caregiving behavior" as a controllable input. Based on these findings, in the next iteration, we focused on a more compact form and a more precise sound acquisition structure to more reliably capture the subtle but crucial action sounds during caregiving.

3.3 Iterative Design 2: Exploring the Use of Mobile Interfaces to Capture Human-Plant Interactions as a Sound Interface

In the second iteration, to more accurately capture the sounds generated by plant care behaviors, we deployed a mobile prototype on an iPhone. Maintaining the same logic for humidity detection and sound feedback, we made a key adjustment only to the interaction: we placed a container filled with chia seeds on the phone's surface to utilize the iPhone's built-in microphone array to more specifically collect sound input from care actions. However, during continuous use and testing of this version, researchers found that the connection between the phone as an external device and plant care was not strong. Users, in their busy work schedules, might still neglect watering and observing plant conditions due to distraction or forgetfulness. In other words, even with improved sound acquisition accuracy, the system still struggled to reliably embed plant care into users' daily behaviors. Based on this finding, in order to further increase the continuity of care and make plant growth more closely integrated with users' daily lives, we planned to move the system from an external device to a wearable form in the next iteration, triggering reminders and interactions in a more perceptible way that is synchronized with physical activities, thereby more effectively supporting continuous care and a more engaging sound experience.

3.4 Final Prototype

3.4.1 ***Hardware design.*** To explore plant care as an interactive sound interface, we developed a sensing and audio system centered on a Raspberry Pi Zero 2 W. The container was instrumented with contact microphones mounted at the base of the substrate. These sensors captured the minute mechanical vibrations produced when users sprayed, touched, or moved the chia seeds. Because contact microphones are sensitive to structural vibration rather than airborne sound, they enabled accurate detection of care actions while reducing interference from environmental noise. The chia seeds were also equipped with a soil moisture sensor embedded within the substrate to monitor hydration conditions. Since the Raspberry Pi Zero 2 W does not include a native audio interface, an external USB sound card was used to provide audio input and output. The processed audio signal was then routed through a miniature speaker driver powering headphone-style speakers. This configuration provided a compact, low-power platform capable of sensing chia seed activity and producing sound feedback.

3.4.2 ***Sensor processing and calibration.*** Software running on the Raspberry Pi continuously sampled vibration signals from the contact microphones and moisture readings from the soil sensors. Microphone signals were analyzed to detect interaction intensity during plant care actions. To interpret plant condition meaningfully, a calibration stage was implemented to learn the chia seeds' moisture consumption patterns. Daily averages of soil moisture readings under normal environmental conditions were recorded, and the observed humidity range was discretized into levels at 10% intervals. These calibrated thresholds allowed the system to detect unusual dryness or saturation and to map hydration states consistently across the chia seeds.

3.4.3 ***Sonification and audio output.*** The collected sensor data were translated into sound through real-time sonification on the Raspberry Pi. Vibration intensity from the contact microphones controlled parameters such as loudness and pitch, enabling subtle care actions to generate perceptible auditory feedback. Additional audio effects—including extended reverb and controlled timbre brightness—were applied to make subtle interactions more noticeable and expressive. **Soil moisture levels** influenced longer-term musical characteristics. For example, higher hydration levels (e.g., above 70%) produced brighter, higher-register piano tones with shorter duration, while lower hydration levels (e.g., below 30%) resulted in slower, deeper sounds with longer sustain and darker timbre. In this way, the chia seeds' moisture states persisted as an audible musical texture rather than a discrete alert. **The audio output** was routed through the USB sound card and amplified with a miniature speaker driver to power headphone speakers, resulting in an interactive system in which plant touch, care actions, and hydration levels were transformed into responsive sound feedback.

4 Discussion, Limitations and Conclusion

We developed a bidirectional wearable-plant headphone prototype based on caregiving behavior, implemented through auditory interaction. Inspired by reflecting on people's daily plant care behaviors, we established a correspondence between plant care behaviors and sound to enhance their plant care experience. Throughout the design process, we focused on three aspects: **1) The bidirectionality of caregiving behavior**: To deepen our understanding of plant needs and foster a sense of responsibility for plant care, we used sound as the input and output interface, enabling better plant care while providing people with enjoyable music. **2) The richness of auditory feedback:** We developed a biofeedback system based on contact microphones, sonifying both the human and plant states in real time to create a rich auditory interactive experience. **3) The practicality of wearable devices:** We designed a modular structure to ensure the basic conditions of plants while maintaining the core functionality of wearable audio devices.

Therefore, we encourage HPI designers to consider using sound as an interface, especially considering the bidirectionality, richness, and practicality of the auditory interface, to inspire novel interactions between humans and plants. We recognize that the prototype still has some limitations, such as the need for better integration of the system with the full life cycle of plant growth and senescence. This suggests an opportunity for designing long-term wearable plant-care systems. Through further iterative improvements, we plan to conduct empirical research to observe the interaction between plant enthusiasts and the system in real-world scenarios.

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