Growing Green Habits: Unobtrusive Gamified Eco-Feedback to Motivate Sustainable Behavior

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ABSTRACT

Promoting environmental awareness and sustainable behavior is an important action for climate protection. In this paper, we introduce a gamified eco-feedback approach using an interactive plant-like physical interface to encourage lower heating energy consumption in households. The interface is designed to be a part of the user's environment and evoke a caretaker relationship. It measures indoor climate parameters via sensors, awards users with points for environmentally friendly and healthy heating and ventilation habits, and changes its shape to mimic growing and flourishing. Through their mobile device, the users can retrieve detailed information in a companion app. A prototype implementation demonstrates the feasibility of the concept and serves as a basis for further work in this emerging research area.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; • **Hardware** → *Emerging interfaces*; • **Software and its engineering** → Interactive games.

KEYWORDS

plant-like interface, shape-changing interface, eco-feedback, gamification, ambient information

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1 INTRODUCTION

Climate change is an urgent threat to our planet's ecosystems and societies, as reported by the Intergovernmental Panel on Climate Change (IPCC) [34]. According to Hertwich & Peters [22], 72% of global greenhouse gas emissions are related to household consumption. When considering activities done at home, heating is responsible for more than 70% of energy consumption and greenhouse gas emissions in Germany [9]. Therefore, the reduction of heating energy consumption is an important objective. Even small savings are significant, as the overall impact is enhanced by the large number of households (about 40 million in Germany) [9]. Energy consumption can be reduced by about 6% if proper ventilation is practiced [19]. Lowering room temperature by 1°C can reduce energy consumption by approximately 7% [7]. This raises the following question: How can members of households be motivated to change their heating and ventilation behaviors to reduce energy consumption and greenhouse gas emissions?

According to [35], our behavior and knowledge is increasingly "more technologically mediated, produced, enacted, and contested". Inspired by embedded and persuasive technologies that aim to change or positively influence user attitudes or behavior through the use of digital systems (for an overview see, e. g., [1]), our work contributes a concept of a plant-like artifact that provides eco-feedback and motivates environmentally friendly heating and ventilation behavior in private living spaces through gamification. The plant-like physical representation is used so that the application becomes a tangible but unobtrusive and decorative home accessory.

2 RELATED WORK

With this work, we introduce our vision, concept and proof-of-concept realization of *Growing Green Habits* which draws inspiration from prior research on *plants as interfaces* (2.1) as well as *eco-feedback and gamification* (2.2) mechanisms.

2.1 Plants as Interfaces

Recent research on designing human-plant interaction (see [12] for an overview) shows promising potential for using floral and organic structures as an overarching design principle to stimulate new kinds of sustainable and personal interface artifacts. Much inter-disciplinary research has been done to investigate how real plants (e. g., [31]) or artificial, plant-like artifacts (e. g., [13, 24]) can be utilized, for instance, as emotional and ambient displays (e. g.,

[5, 15, 27]) or unobtrusive dynamic interfaces (e. g., [4, 25]). For example, Lee et al. [27] recently explored how shape-changing plant-like interfaces can serve as ambient information systems to notify users with personal health information. The study highlights the importance of a thoughtful expression design to avoid misinterpreting the movements and states of the plant. *FamilyFlower* [13] introduces an artificial flower designed to foster distant family connections by creating emotional closeness between two households. On the other hand, *Mechanical Flower Avatar* by Hong et al. [24] focuses on a better posture awareness. Furthermore, voice-enabled interactive plants as a kind of green pets, have been explored by Hwang et al. [25] to help children to perceive plants as alive. Finally, *Pudica* [31] demonstrates how living plants can be electrically augmented to design and realize human-flora interaction concepts.

Building on the literature stating that such physical artifacts are typically characterized as emotional [31] and unobtrusive [27] as well as capable of interacting with users through multiple senses [4], we take inspiration from such nature-inspired interfaces to provide behavioral advice to users without overloading them with yet another and easy to forget source of information. Another advantage in using such physical artifacts for data representation is that they can also protect privacy, as personal data is not publicly visible and not easily understood by others [27].

2.2 Eco-Feedback and Gamification

Laschke et al. introduce the concept of *things with attitude* [26] as a kind of interactive approach for transformational products, that attempt to actively shape their users' attitudes and behavior by engaging their users in an active material- and form-driven dialogue. In this context, artifacts such as the *Caterpillar extension cable* or the *Forget Me Not* reading lamp have been proposed as a design paradigm focused on visualizing personal sustainability issues to create self-reflection and awareness [26]. With an application scenario similar to our work, Laschke et al. [28] have also presented a tangible temperature artifact for the home that builds on the design principle of mediating between different comfort temperatures. In addition, Holstius et al. [23] used living and robotic plants as a kind of interactive plant display to provide motivational feedback on recycling behavior. Similar, Piccolo et al. [29] physically visualized progress in energy saving through a tree-like artifact with LEDs that incrementally light up correlated with progress. These approaches can be classified as *eco-feedback*, which Froehlich et al. [21] define as "technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact". Eco-feedback can be combined with the concept of *gamification* [20], which focuses on "the use of game design elements in non-game contexts" [16]. If gamification elements are incorporated in the context of sustainability, the term of *green gamification* [20] can be used. Here, it serves to motivate environmentally friendly behavior playfully. As an example, Dimitriou et al. [17] developed a game-based smartphone application to reduce energy consumption. While saving energy and completing tasks increases the score, a virtual growing tree motivates the user on an emotional level. Similarly, Avolicino et al. [6] introduced a mobile application to promote eco-friendly driving that includes awarding points and other game elements such as leaderboards and levels to provide real-time feedback to drivers so that they are rewarded or warned, as appropriate, for their good behavior. Finally, Degraen et al. [14] explored how physical garden elements can be used for gamification and highlighted the importance of having clear start and end states. Overall, physical implementations of eco-feedback can be perceived as more present [32] and physical elements of gamification as more significant [2]. Drawing on the promising findings in incorporating gamification and eco-feedback, we consider these mechanisms in our design.

3 A CONCEPT FOR A GAMIFIED, PHYSICAL AND NATURE-INSPIRED ECO-FEEDBACK APPROACH

The proposed system is intended to support users in the complex and tedious task of maintaining a good indoor climate in households with a focus on saving heating energy, but also taking into account efficient ventilation to ensure good indoor air quality without letting the room cool down for long periods of time. As colder air absorbs less moisture, low room temperatures lead to an increase of relative humidity which can promote the unhealthy growth of mold [8]. Additionally, preventing excessive CO_2 concentration helps to ensure healthy indoor air quality. Thus, our concept aims to holistically promote an environmentally friendly *and* healthy indoor climate. Therefore, information from various sources is brought together and represented in a special physical, shape-changing artifact that is inspired by nature, meant to reflect its purpose as an eco-feedback artifact. An important aspect is the playful design through the use of gamification, which not only serves to motivate the users and increase their awareness but also helps them to achieve a *good* indoor household climate in a joyful and aesthetic way.

3.1 Plant-like Interior Accessories

Eco-feedback given as a physical representation is assumed to be more persuasive and meaningful compared to virtual representations [2, 18]. We use a nature-inspired plant-like shape to: (1) reflect the general purpose of encouraging environmentally friendly behavior [11], (2) create an emotional bond by simulating a living being [27], and (3) allow for a seamless and fitting integration into the interior of households or office spaces. Like a decoration, the artifact should blend aesthetically and unobtrusively into the environment of the room. At the same time, the chosen shape should be abstract enough and present primarily positive manifestations of states to prevent feelings of guilt among the users [11, 27]. To implement gamification, the plant should have obvious start and finish states with intuitive, continuous and slow transitions. The slow organic movements of plants are suitable for providing feedback over a longer period of time. Metaphorically speaking, the plant thrives only in a climate that is suitable for it.

We propose three initial concepts for suitable shape-changing artifacts that meet the required properties. Figure 1 shows draft sketches of (A) a blossom-shaped model with unfolding petals, (B) a pot with artificial decorative grass growing in height, and (C) a pot with an artificial elephant's foot (*Beaucarnea recurvata*). The visually appealing blossom (A) offers the advantage that the degree of blossom unfolding (operated by a servo motor) represents

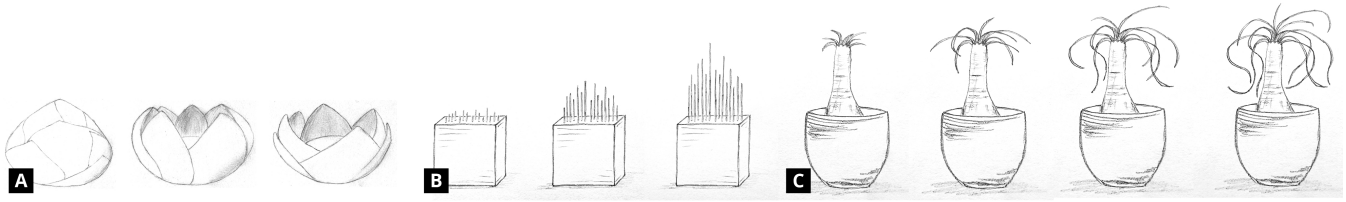

Figure 1: The three proposed concept designs of plant models and their change of state: (A) a blossom-shaped model, (B) a pot with growing grass, and (C) a pot with a plant similar to an elephant's foot (*Beaucarnea recurvata*).

different states of progress. A closed flower represents the start, and a completely opened blossom serves as the intuitive finite goal. The other two models also have intuitive start and end states, and change their shapes slowly and continuously by extending plant parts (from inside out) using, e. g., controlled pneumatic (B) or motorized unrolling (C).

3.2 Sensors and Eco-Feedback

The idea of a standalone and self-contained accessory already includes all the necessary sensors unobtrusively integrated into the physical artifact. However, it could also be connected to a smart home system to gather additional data or trigger automatic adjustments. The primarily necessary sensors include sensors for measuring room temperature, relative humidity and CO_2 concentration. An additional sensor on the radiator or heating surface enables a more precise measurement of the heating behavior. For the temperature-adjusted calculation of heat loss, an additional data source for retrieving the local outdoor temperature is required. The data collected by the sensors and data sources are gathered, evaluated and mapped to the current status of the plant model. In addition to the mechanical manifestation of different shape states, the plant model provides further capabilities to visualize eco-feedback, targeting almost all senses:

- Ambient lighting of the model provides information about the current room climate through respective colors.
- An integrated speaker is used for acoustic outputs.
- A vibration motor enables haptic feedback if the model is touched.
- A fragrance dispenser acts as a pleasant air freshener to reward good room climate.

The plant model's outputs are designed to harmoniously fit in with its calm and ambient aesthetics. If critical values of the indoor air quality are measured, the system notifies the user and requests that a window is opened. Notifications can occur in different states depending on urgency, as Lee et al. suggest [27]. If the measured value is only slightly beyond the preferred range, then a short, non-disruptive reddish illumination appears. If the user does not react and the room climate worsens, the plant model additionally emits a warning sound, vibrates, and shakes slightly.

To accompany users more flexibly and provide detailed information on the state of the plant model and the indoor climate, a connection can be established to the user's personal devices, e. g., to a smartphone. Especially if the user is not in the room, notifications and feedback can be sent to the mobile device as well. The combination of artistic (plant model) and pragmatic visualization (mobile device) can be complementary in an eco-feedback application, according to Sanguinetti et al. [30]. Furthermore, mobile devices can offer more detailed visual feedback and allow the examination of larger sets of data, e. g., current and past statistics.

3.3 Gamification

The use of gamification is a fundamental part of our concept. The main game element is the awarding of points, used to reflect a positive development and to define the status of the plant model. The challenge is to collect points over a whole week, reflected by the physical transformation of the plant model, with the goal to reach the final state by the end of the week. If a weekly challenge is completed successfully, the plant model uses its output capabilities to congratulate the user. Not all output capabilities are used from the beginning. In order to maintain the suspense, they are unlocked gradually through completed challenges. With the beginning of a new week, the plant model changes back to its start state. The weekly cycle can be easily integrated into everyday life and enables comprehensible historical comparisons.

Various input has an effect on the points. The main input parameters are the measured sensor data to evaluate the room climate and the user's confirming actions, e. g., that the window was opened completely for at least 5 minutes for ventilation. The concept also aims to teach users actions that will lead to a reduction in energy consumption. Every day, a short piece of advice is displayed on the mobile device, recommending low-cost actions that are easy to implement, including, e. g., tips for efficient ventilation, less heating in case of absence, or the use of curtains. An advice intends to convey knowledge to the users so that savings measures are known and applicable in the long term. To check the learning progress, quizzes can be completed and points are awarded for correct solutions.

To further increase the emotional bond and to encourage the user to take more care of their "plant" (and, consequently, the room climate), the plant model reacts to the user's proximity with a friendly sound, light effect, vibration, pleasant scent or shaking of the petals. If the indoor climate is good, the reaction is especially cheerful. Users are invited to interact with the artifact when they are near the plant model, using touch or proximity sensors. This way the current condition of the plant model and room climate can be queried by interacting with the artifact.

In order to not lose the awarded points at the beginning of a new week, they also contribute to the user's personal level. This level serves as a long-term indication of progress and one's own efforts. It is independent of whether the weekly challenge could be completed or not. Both the plant model and the companion

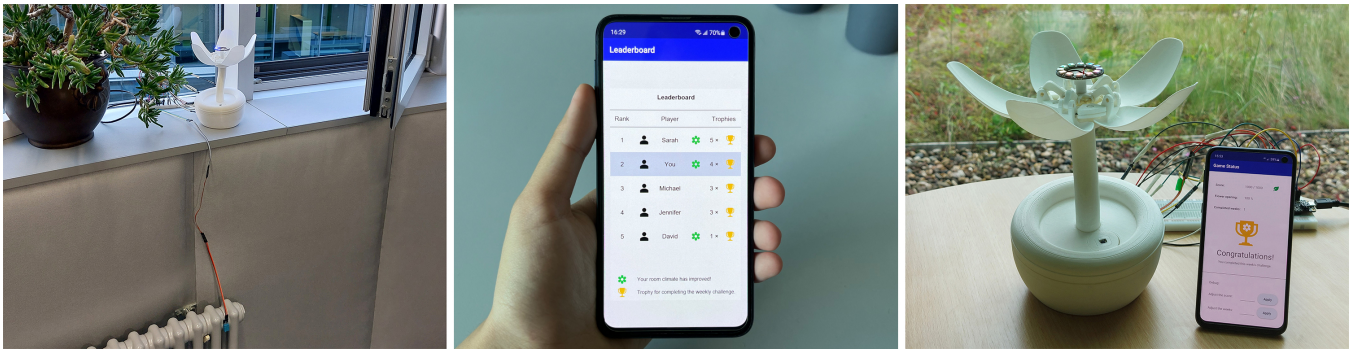

Figure 2: Our proof-of-concept prototype: The shape-changing plant model, connected to a radiator via its sensor (*left*), an example illustration of a leaderboard (*center*), and the plant model and the companion app when the weekly challenge is completed (*right*).

app visually represent the current level. How a representation of progress can be implemented is described in the following.

4 A PROOF-OF-CONCEPT PROTOTYPE FOR PLAYFUL ECO-FEEDBACK

To demonstrate the feasibility of our approach and gain initial insights about our concept, we developed an interactive prototype.[1] The setup consists of a physical blossom-shaped artifact, representing an abstract model of a five-leave *Myosotis*, environment sensors, and a smartphone application, as shown in Figure 2.

The **blossom-shaped artifact** (cf. Figure 1 A), chosen for the prototype as a representative example of our concept, was inspired by Jason Suter and makes use of his 3D model "blooming flower night light" [33]. All parts have been 3D-printed in neutral, minimalist white. In order to provide versatile output capabilities, our prototype integrates petals that can be opened and closed by means of a servo motor, a buzzer speaker, and a built-in RGB LED ring. Environment sensors measure room and heating temperature as well as relative humidity (Figure 2, left). If the measured humidity exceeds a threshold value, the LED ring pulses in red and the buzzer emits a soft warning tone. A congratulatory melody and a visual rainbow pattern appear as a reward for a successful weekly challenge. Furthermore, an additional segment of the LED ring lights up in blue for each completed challenge. Touching the button at the base, the blossom responds with a shaking of the petals, a friendly sound, and a colorful illumination of the LED ring.

Overall, the electronics are realized with a Bluetooth-enabled Adafruit Feather nRF52832 microcontroller, which can be connected to a custom Android smartphone app. The proposed **companion app** (Figure 2, center) displays measurements from the sensors in real-time and adds green symbols as evaluative positive feedback if the respective value is in a favorable range. At the same time, such a symbol means that points are awarded. Another view shows the current score and the number of completed weekly challenges. To better understand the position and state of the flower petals, the current degree of opening is shown. This equals the percentage of points needed to complete the weekly challenge. If enough points have been collected for the weekly challenge, a congratulatory message appears (Figure 2, right). To encourage improvement in one's behavior, each week the required score for the weekly challenge increases.

5 CONCLUSION AND FUTURE WORK

With this work, we contribute to a promising research avenue of unobtrusive gamified eco-feedback applications. We presented a concept and a prototype that aim to motivate sustainable behavior in a playful way. The concept we developed consists of a physical, interactive plant-like artifact and an accompanying mobile application to explore how this kind of novel hybrid interface can be a useful approach to maintaining an environmentally friendly and healthy indoor climate. Specifically, the system is designed to help reduce one's ecological footprint by motivating the change of habits through game elements like rewards and levels. Drawing on the emerging widespread use of IoT and smart-home sensors, our concept thereby expands general recommendations for ventilation or heating and provides targeted feedback and instructions for action at the relevant moments. Taking a mental step back from our specific implementation, we envision a future with personalized artifacts that offer sensory and aesthetic qualities while serving as intelligent environmental interfaces.

In future work, we plan to improve and extend our prototype and evaluate it in households to gain further insights into how the approach affects user behavior in the real world over time. We are also interested in investigating specific risks and potential negative aspects of gamification in our concept, such as addiction, unwanted competition or inappropriate rewarding, as described in [3, 10], and adjust certain measures. Furthermore, it is worth researching to what extent the physical artifact leads to a greater improvement of the room climate compared to a virtual plant on a mobile device. Conversely, it is also worth investigating whether a physical artifact itself provides enough information for changes in user behavior without the assistance of a connected mobile device. Instead of focusing on heating behavior, the operation of air conditioning systems and their economical use can be considered during summer. The general approach of a gamified and physical eco-feedback

[1] Further details can be found on our project website: https://imld.de/growing-green/

application can even be transferred to other application areas such as energy or water consumption, food purchase, etc.

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