AmbiPlant - Ambient Feedback for Digital Media through Actuated Plants

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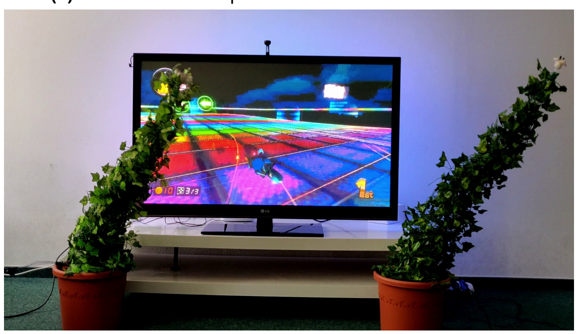
(a) AmbiPlant in idle position.



(b) AmbiPlant leaning to the right.

Figure 1: AmbiPlant providing ambient feedback through visual choreography synchronized with on-screen events. Here, AmbiPlant is actuating from an idle position (a) to a sideways lean (b) as the on-screen character turns.

Abstract
To enhance viewing experiences during digital media consumption, both research and industry have considered ambient feedback effects to visually and physically extend the content presented. In this paper, we present AmbiPlant, a system using support structures for plants as interfaces for providing ambient effects during digital media consumption. In our concept, the media content presented to the viewer is augmented with visual actuation of the plant structures in order to enhance the viewing experience. We report on the results of a user study comparing our AmbiPlant condition to a condition with ambient lighting and a condition without ambient effects. Our system outperformed the "no ambient effects" condition in terms of engagement, entertainment, excitement and innovation and the ambient lighting condition in terms of excitement and innovation.

Author Keywords
Ambient interfaces; ambient effects; empathic living media; user study.

CCS Concepts
•Human-centered computing → Human computer interaction (HCI); Ubiquitous computing; Ubiquitous and mobile computing systems and tools;

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Introduction

Commonly known as 4D experiences, synchronized physical effects applied during 3D movies aim to enhance viewer immersion by extending events occurring on-screen. Such sensor-based augmentations for cinematic experiences, like the Sensorama [10], have been around since the early 1960's. The device provided additional vibrotactile, aromatic and wind feedback while the viewer was immersed in a 3D movie. However, it remains challenging to transfer such effects to living room settings and only limited approaches are available for digital media consumption at home. Examples can be found with the Philips Ambilight system which provides immersive light effects around a television or vibrotactile feedback provided by a game controller.

In our approach, we consider visual movement as an ambient effect to extend the content during digital media consumption. As we specifically focus on the home setting, visual integration with the environment is desirable. As plants are ubiquitous and integrated members of our environment, we envision employing the living environment around us. Plants have been shown to incite human affect for them [6], therefore we aim to make physical effects during digital media consumption more enjoyable by actuating structures visually resembling plants.

In this paper, we present AmbiPlant, a system using support structures for plants as interfaces for providing ambient effects during digital media consumption, see Figure 1. Here, we elaborate on our concept and report on the results of a user study comparing our system to an ambient lighting condition and a condition without ambient effects.

Related Work

Our work builds upon previous research towards ambient effects for digital media and plants as ambient interfaces.

Ambient Feedback for Digital Media

To enhance the user's sense of presence in terms of immersion and realism, research in ambient feedback for digital media consumption considers two main approaches, i.e., providing ambient effects and visually extending display space. In the former, often marketed as 4D effects, a 3D viewing experience is augmented through ambient physical effects such as air movement, moisture generation, olfactory stimulation, or tactile vibrations [12, 18]. During movie scenes, such effects have been shown to improve the perception of the presented scene [18]. While increased effort is required to implement ambient effects, automatic generation is still able to increase immersion, appeal, interest, and understanding of the presented film [14]. Ambient sensory effects are generally perceived positively, but their effectiveness is dependent on the presented genre [21].

Research in visual screen extensions augment the viewing display by visually extending the image shown. The main motivation for this is that larger displays can increase intrinsic immersion [11, 25]. Arguably the most well known approach for this is the Philips Ambilight technology[1]. Here, border colors of the screen image are extended through projection around the display using LEDs attached to the back. Compared to the classic TV experience, Ambilight is able to induce higher levels of immersion [26]. With "Illumiroom" [13], authors increase the size and resolution of the visual effect by using a projector to extend the content.

More recently, research investigated combinations of ambient effects and visual screen extensions. In "ambiPad" [17],

[1] Ambilight TV - https://www.philips.co.uk/c-m-so/tv/p/ambilight

Figure 2: Our initial *Overgrown* prototype where an endoskeleton is "overgrown" with artificial ivy [8].

the viewing experience on a tablet is enhanced by combining the Ambilight approach with thermal feedback using Peltier elements to the back. The thermal feedback communicated content related events such as a character's anger, which resulted in a highly attractive and desirable media experience. Similarly, Wilson and Brewster combined thermal, vibrotactile and visual stimuli to expand the affective range of the feedback provided [28]. Our work is closely related to "ambiPad" as our system extends digital media by communicating content related events through movement.

Plants as Ambient Interfaces

While plants are ubiquitous in our environment, we often overlook them instead of understanding them as active beings [1]. As living media promotes human empathy [6, 19], research in HCI has shown an interest in considering both real and artificial plants as potential ambient interfaces.

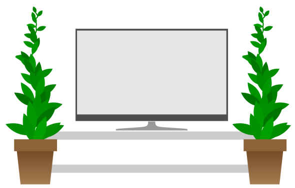
Empathetic biological media considers the behavior of plants in order to construct interfaces for augmented human-plant interactions [15, 20, 23]. For thigmonastic plants, their natural movement response to touch was used for prototyping ambient media [16] and for creating plant-based displays [9]. In Flona [24], authors present their concept of *intimate technology* showcased by a real domestic plant capable of conveying lifelike behaviors through actuation. Building upon this, plants were used to represent smoking activity in a room [22]. More smokers led to lower hanging leaves of the plant to bring awareness of smoking habits. More recently, the nutrition of real-world physical plants was changed based on how regularly the user achieved their daily step goal [7]. As participants could identify which plants belonged to which activity level, they were able to interpret the appearance of each plant correctly. However these approaches are time-consuming, as plants need time to adapt to changes in their nutrition or environment.

The use of artificial plants allows for more real-time interfaces while aiming to maintain the human empathy effect. An early approach is "Office Plant #1", a robotic plant responding to a user's e-mail activity through slow and rhythmic movements as well as ambient sounds [5]. In augmented reality plants have been used to convey information about the status of a coffee machine [2, 3]. Depending on upcoming tasks such as refilling the water or required maintenance, the virtual plant changed its appearance such that people were able to successfully identify the issue and act accordingly. Previously, we investigated using actuated robotic skeletons for ambient notifications in ubiquitous environments while allowing the system to be "overgrown" by artificial ivy [8]. In this work, we extend our system to provide ambient effects for digital media.

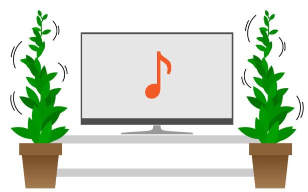
Concept

Our concept of *AmbiPlant* is built upon previous research in ambient interfaces for ubiquitous environments. To make notifications more desirable, in *Overgrown* actuated robotic structures provide ambient notifications while aiming to support plant growth [8], see Figure 2. As the plant overgrows the technology, continuous integration within the environment ensures a technologically aesthetic design.

In this work, we present *AmbiPlant*, an extension of our previous work consisting of two *Overgrown* prototypes placed on either side of a TV. The system's multi-directional movement capabilities are orchestrated using a web interface in order to provide ambient effects during digital media consumption. Pre-programmed sequences synchronized to specific video scenes actuate the individual structures in horizontal directions, i.e., sideways to the left and right and perpendicular directions, i.e., to the back and front.

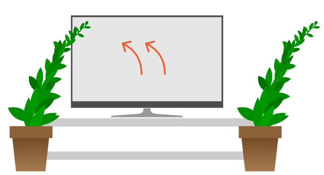


(a) AmbiPlant in an idle position.



(b) AmbiPlant shaking.

(c) AmbiPlant opening.



(d) AmbiPlant leaning to the right.

Figure 3: AmbiPlant example actuation sketches.

Study

To assess the effect of the AmbiPlant system in terms of user experience and perception, we performed a user study.

Design

We performed the user study in our lab and compared three output modalities for digital media consumption, i.e., our AmbiPlant condition, an ambient lighting condition similar to Philips Ambilight, and a condition with no ambient effects present. To be able to generalize from the content shown, the output modalities were presented with three videos of varying genres, i.e., a music video[2] (V1), a movie scene[3] (V2), and a console game sequence[4] (V3). All videos were about 1 minute in length to fit the scene depicted.

The study consisted of a within subjects design. We counterbalanced all 9 conditions (3 output modalities x 3 videos) using experimental design tables according to the Williams design using Latin squares [27].

Apparatus

We programmed the AmbiPlant system to the content of each video. During V1, plants would perform left to right shaking movements, synchronized to the beat of the music, see Figure 3b. For V2, plants would remain idle, see Figure 3a, until an on-screen explosion occurred, i.e., The Destruction of Alderaan, upon which both would swiftly move outwards from the screen, see Figure 3c. Lastly, in the case of V3, both plants would lean synchronously, in the opposite of the turning direction of the character driving, see Figure 3d. Other in-game events, such as a character jumping or being hit by an item, would result in both plants leaning towards the participant for the duration of the event.

[2] Major Lazer – Light it Up (feat. Nyla & Fuse ODG)
[3] The Destruction of Alderaan from Star Wars: Episode VI
[4] Mario Kart 8 Rainbow Road (1 lap) by ProsafiaGaming

The ambient lighting system performed in a manner similar to the Philips Ambilight system by averaging and extending the screen colors on the border of the depicted image using projection to the back wall. The colorful compositions of V1 caused varying amounts of colors to be projected on the wall behind the TV. In the case of V2, the lighting remained dark and lit up very brightly to depict the on-screen explosion. For V3, as the lower part of the image was considerably more colorful than the top, the ambient lighting was more active to the sides of the display.

The room had white walls and was dimmed during the study. On one side of the room a couch was placed facing the TV on the other side of the room. Two white movable wall sections were placed on either side of the TV, with a distance of about 1 meter. This setup allowed the experimenter to move the AmbiPlant setup behind the walls during the other conditions, while ensuring that the ambient lighting condition was still visible. During the video sequences, participants wore wireless headphones with active noise cancellation to dim out any distracting sounds.

Participants

From our university campus, we randomly recruited a total of 21 unpaid participants (7 female), aged between 21 and 30 years old ($M = 24.86$, $SD = 2.35$), with backgrounds in Computer Science, Linguistics, and Law. One participant was excluded from the analysis due to a visual disorder impeding their depth and color perception. While all participants indicated to regularly consume online streaming services (e.g. Netflix, YouTube), only two participants had previous experience with ambient lighting systems for digital media consumption. Regarding the accessibility of display formats, all participants indicated to own a smartphone, all but one owned a laptop, 8 participants had a tablet device, and the same amount of participants had a TV at home.

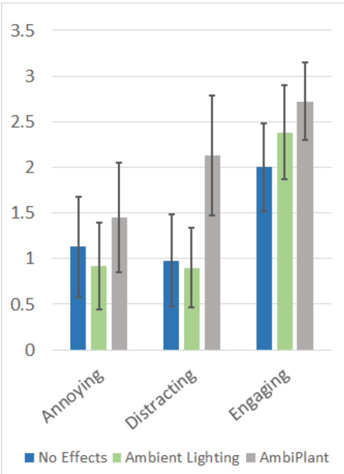


Figure 4: Averages with standard deviations of the answers to “The experience was...” (0 - Strongly disagree, 4 - Strongly agree).

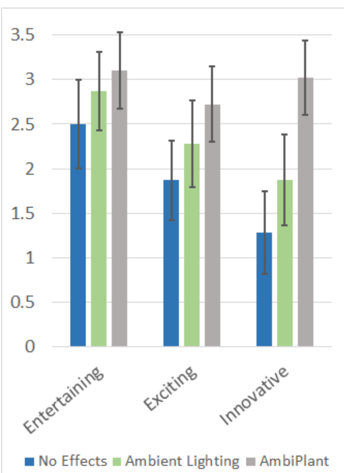


Figure 5: Averages with standard deviations of the answers to “The experience was...” (0 - Strongly disagree, 4 - Strongly agree).

Procedure

Before starting the experiment, each participant signed a consent form, agreed with the data protection statements and was briefed regarding the upcoming course of events.

Participants were asked to sit on the couch facing the TV and to put on noise cancelling headphones. Depending on the condition, the participants were presented either the AmbiPlant setup consisting of the two plants on either side of the TV, or just the plain display with the plants hidden. As our implementation focused on enhancing the hedonistic factors during media consumption, similar to [17], our evaluation used an adapted version of the Microsoft Product Reaction Cards [4]. After each condition, participants were asked to choose five adjectives from a total of 64. Additionally, participants rated six aspects of the experience on a five-point scale (0 - Strongly disagree, 4 - Strongly agree) to assess the value of entertainment, excitement, innovation, annoyance, distraction, and content engagement.

After the experiment, participants completed a post-study questionnaire inquiring about their demographics, and their personal preferences and potential comments regarding the presented output modalities.

Results

The results of the Product Reaction Cards were grouped per output modality. In Table 1, the top five of selected adjectives per output modality and their summed amount of indications can be seen.

For the experience related questions, we used non-parametric Friedman's ANOVA tests as normality could not be assumed and performed post-hoc analysis using Wilcoxon signed-ranks tests with Bonferroni correction. Overall, significant differences were found for the values of entertainment ($\chi^2(2) = 17.320$, $p < .001$), excitement ($\chi^2(2) = 27.433$, $p < .001$), innovation ($\chi^2(2) = 61.316$, $p < .001$), annoyance ($\chi^2(2) = 7.628$, $p < .05$), distraction ($\chi^2(2) = 30.678$, $p < .001$), and content engagement ($\chi^2(2) = 18.921$, $p < .001$). For the condition without ambient effects, the answers to the experience related question indicated a minimum of 0 and a maximum of 4 for all videos. The minimum for the ambient lighting condition was 1 for entertainment and excitement and 0 for all other answers, while the maximum was 3 for distraction and annoyance and 4 for all other answers. Considering the AmbiPlant condition, the minimum was 0 for distraction and annoyance and 1 for all other answers, while the maximum was 4 for all. The averages of the answers for the experience related questions can be seen in Figure 4 and Figure 5.

No Ambient Effect	Ambient Lighting	AmbiPlant
Attractive (22)	Fast (19)	Inconsistent (32)
Powerful (20)	Advanced, Attractive & Inconsistent (16)	Essential (27)
Clean (19)	Stressful (15)	Simplistic (16)
Advanced (17)	Creative (13)	Intimidating (14)
Consistent (15)	Ineffective (12)	Unattractive (12)

Table 1: The top 5 of the selected adjectives to describe the 3 different output modalities. Per output modality a total of 300 adjectives were indicated (5 adjectives, 3 videos, 20 participants). Multiple adjectives for one cell indicates an equal scoring.

Post-hoc analysis showed AmbiPlant was found to be more distracting than other conditions (no ambient effects: $p_{adj} < .001$, $T = -4.199$; ambient lighting: $p_{adj} < .001$, $T = -3.880$). AmbiPlant outperformed the condition without ambient effects for the assessment of engagement ($p_{adj} = .001$, $T = -3.606$), entertainment ($p_{adj} = .003$, $T =$

-3.286), excitement ($p_{adj} < .001, T = -4.519$) and innovation ($p_{adj} < .001, T = -6.710$). Compared to ambient lighting, AmbiPlant was rated significantly higher for excitement ($p_{adj} < .05, T = -2.602$) and innovation ($p_{adj} < .001, T = -4.793$). After correction, there were no significant differences between output modalities found for the amount of annoyance caused. Neither were there significant differences found for all experience related questions when comparing no ambient effect to ambient lighting.

The results of our post-study questionnaire indicated 13 participants preferred ambient lighting, 5 preferred AmbiPlant, and 2 preferred no ambient effects. Half of the participants indicated they would like to have a moving plant in their house. When asked what they would use it for, all answers either directly or indirectly indicated AmbiPlant's entertainment value, specifically for visually communicating music. One participant stated the system could be used to play with her cat and provide a form of companionship and inspiration. Participants not wanting to have AmbiPlant at home, indicated so because of space requirements (3 participants), the fact that they saw no use for it (2 participants), or considered it too distracting (2 participants). One participant emphasized she found it scary, while two participants provided no answer.

Discussion

The results of the Product Reaction Cards depict a difference in selected adjectives between the output modalities. By looking at the 5 most selected terms in Table 1, it is clear these terms seem to be more negative for AmbiPlant than other conditions. However, as the totals shown remain low, the Reaction Cards do not clearly indicate a clear consensus for any of the output modalities across participants.

For experience related questions, AmbiPlant as an output condition was being favoured. However, the current prototype and its programmed behavior is prone to causing distractions and annoyances during the viewing experience. As indicated during the post-study questionnaire, AmbiPlant was well suited for being combined with music. While not being preferred by most participants across all videos, we see that there was entertainment value in the movements communicated by AmbiPlant. The comment of one participant that AmbiPlant could provide companionship hints at its capability of generating human affect towards itself.

Conclusion

In this paper, we presented AmbiPlant, a system using support structures for plants as interfaces for providing ambient effects during digital media consumption. In our concept, the media content presented to the viewer is augmented with visual actuation of the plant structures in order to enhance the viewing experience. In a user study ($n = 20$), we compared our system to an ambient lighting condition and a condition without ambient effects. The 3 output modalities were presented with 3 video sequences, i.e., a music video, a movie scene and a console game sequence. While being more distracting, AmbiPlant outperformed the no ambient effects condition for engagement and entertainment, and both other conditions for excitement and innovation. While not being the preferred output modality by most participants across all videos, we see that there was entertainment value in AmbiPlant, specifically in the case of visually communicating music through movement.

As artificial plants were used for our prototype, in future iterations we aim to support real physical plant growth in order to create a living ambient effects system. To fully understand the contribution of living media, a next experiment could compare our setup to one without an overgrown plant.

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