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Plant playmate: exploring effects of interactive plants for mental wellness microbreaks during knowledge-based work

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Work stress is a crucial issue related to personal health and work performance. It has been proved that using plants in the office is helpful for stress relief. In this paper, we present the design and evaluation of Plant Playmate. This smart plant can augment human-plant interactions with interactive lights, anthropomorphic expressions, and virtual credits for stress relief. A within-subject experiment was conducted with 22 participants in work environments to compare the practical effects of Plant Playmate with an ordinary plant. Participants' stress levels were assessed through electrodermal data (EDA) and self-assessment Manikin (SAM). We also collected their experience through user experience questionnaire (UEQ) and interviews. EDA data showed that Plant Playmate effectively relieved work pressure, and SAM scores demonstrated that participants had higher levels of pleasure, arousal, and dominance after using Plant Playmate. According to UEQ, participants recognized Plant Playmate as attractive, effective, dynamic, and novel. The qualitative results also corroborated the effectiveness of the Plant Playmate in terms of user experience and stress relief. We further discussed the design implications of Plant Playmate for office vitality.

Keywords: plants; work stress; user experience; human-plant interaction; electrodermal activity

1 Introduction

Workplace stress has become prevalent in modern society, and this problem has become severer due to the heavier workload and work-life imbalance during and after the Covid-19 pandemic (Yen, 2022). It is essential to design interfaces and Human-Computer Interaction (HCI) that could help people ameliorate workplace stress. Through literature reviews, we established the plant as the interaction object since previous studies have confirmed that being in a natural environment or surrounded by plants can produce positive mental stimulations for humans (Chang & Chen, 2005; Deng & Deng, 2018). Plus, prior study has proved that green plants in the workplace could effectively facilitate

communication among colleagues, promote working performance, increase well-being, and help with stress coping (Thomsen et al., 2011).

However, people could easily ignore the existence of plants in their environment. Since plants tend to be motionless and silent in our daily lives, it is hard for us to get instant feedback, making them lack interactivity. Therefore, we introduce Plant Playmate, an anthropomorphic plant capable of reacting to users' input. We hypothesize that such an interactive plant would enhance human-plant interaction, thus promoting mental microbreaks during knowledge-based work.

Previous HCI studies have focused on augmented plants with optimized sensing and actuating capabilities in different scenarios, including public installation (Fastnacht et al., 2017), elderly caring (Angelini et al., 2015), and remote emotional communication (Degraen et al., 2021). Also, the value of interactive plants in improving human well-being has been widely acknowledged in the literature (Hammerschmidt et al., 2015; Park et al., 2016; Sabinson et al., 2021; Martindale et al., 2017). However, few projects focused on the working environment and explored the potential of utilizing interactive plants in workplace stress relief. To close this gap, we present the design and user study of Plant Playmate. It is an interactive system that leverages anthropomorphic plants to reduce work-related stress and promote mental health during office microbreaks, providing visible feedback based on users' operations, including approaching, touching, and watering. With the prototype, we conducted an experiment to evaluate to what extent it can affect work stress and the user experience, ultimately generating design insights for further study about interactive plants in the workplace.

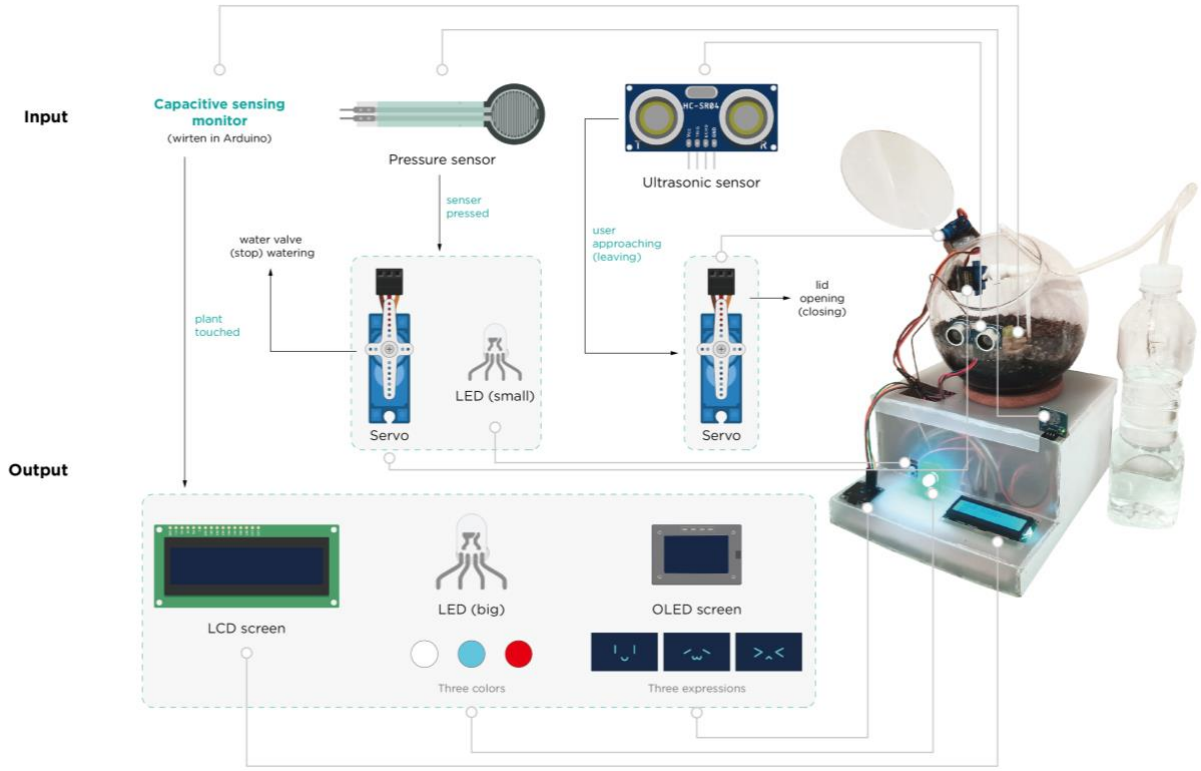

Figure 1. The hardware structure of Plant Playmate.

2 Design of Plant Playmate

In this section, we first introduce the design considerations regarding plant selection and the interaction modality. Then, we detail the implementation of Plant Playmate.

2.1 Design considerations

We employed the hardware structure (see Figure 1) to realize the following functionalities. Firstly, we selected the succulent plant as the medium of our design, which is familiar and welcomed in office settings. The volume of this plant is typically tiny, suitable for being placed on the desk. People can engage with interacting with Plant Playmate without leaving personal workstations. The easy accessibility can prompt more microbreaks, which benefit individuals' mental health.

We chose touch as the primary modality, which benefits both people and green plants. Prior HCI work has demonstrated the great potential of touch-based interaction in anxiety relief and sensory relaxation (Seo et al., 2015; Ozcan et al., 2022). Previous research has also suggested that gently touching can trigger plants' defence systems and make them more resistant to pathogens (Lohr et al., 1996). Besides, watering plants is an easy and accessible gardening-related activity in the workplace, known to be therapeutic.

Studies have also shown that anthropomorphism of nature enhances the connection between human and nature. Personifying plants or doing other creative activities like story writing, drawing, etc., can encourage active empathy with plants, which can effectively alleviate the problem of plant blindness (Balding & Williams, 2016). Hence, we added an emoticon display to the installation, which can always change the emoticon while the plant is touched. We designed different emoticons for Plant Playmate to express the emotions of happiness, discomfort, and anger, showing its response to different touch strengths. Also, when the plant has been touched, the light on the device will be flickered as if it is breathing.

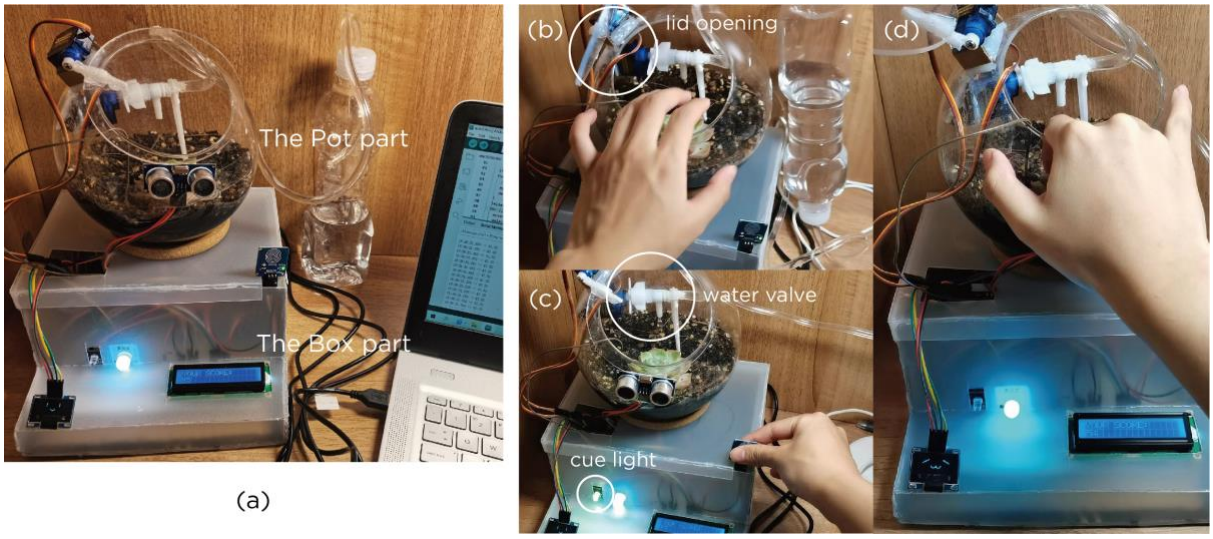

Figure 2. Main functions of Plant Playmate: (a) Two parts of Plant Playmate (b) Automatically opening and closing the lid; (c) Watering the plants; (d) Giving feedback to the touch.

2.2 Implementation of Plant Playmate

Plant Playmate contains two main parts: the Pot part (a glass ball with hardware) containing plant and the Box part containing Arduino boards (Figure 2a). Figure 2b-d shows the three main functions Plant Playmate has, each of which is triggered by different sensors. More detailed introductions come below:

- Automatically opening and closing the lid (Figure 2b). An ultrasonic sensor is placed near the lid, measuring the user's distance from the device. A servo linked to the lid will be driven if the user approaches or leaves Plant Playmate.
- Watering the plants (Figure 2c). A pressure sensor controls this part. When the user presses the sensor, a water valve (driven by another servo) will be opened and constantly watering until the user releases the sensor. A cue light keeps glowing during the watering process.
- Giving feedback to the touch (Figure 2d). Interactive feedback to the user's physical touch is the core function of Plant Playmate. We designed this part to strengthen the connection between plants and users since physical touch is one of the most direct and measurable ways for humans to contact the plant. Based on capacitive sensing, the touch can be detected and quantified. Corresponding to the force of the touch, we set 3 states of Plant Playmate, as shown in Figure 3. Each one gives specific feedback to users. We used an OLED screen with different expressions and LED lights as interactive feedback to anthropomorphize the plant. Besides, a point system is designed for Plant Playmate to make it more entertaining.

Figure 3. The interactive feedback from Plant Playmate: (a) Contactless mode; (b) Touch the plant gently; (c) Touch the plant hard.

3 User study

The aims of this user study were two folds: 1) To probe whether our interactive plant prototype, Plant Playmate, can play a role in relieving work stress; 2) To explore the detailed user experience of the Plant Playmate and find out how it can be improved and developed.

3.1 Participants

We recruited 22 participants (9 males and 13 females) by spreading information via word of mouth, aged between 20 and 59 (M=32.10, SE=3.26). Their occupations cover a wide range of professions, including student interns, teachers, engineers, and lawyers. They all need to work or study in the office for more than six hours a day in their daily lives. We labeled our participants P01, P02, …, and P22 for data analyses. All the participants consented to participate in the experiment and signed informed consent forms. During the study, participants have the right to withdraw at any stage. After completing the experiment, each participant received a commemorative item worth about 1 dollar.

Figure 4. Simulated workplace of the Experimental condition(a) and the Control condition (b).

3.2 Study design and procedure

The experiment was designed as a within-subject experiment with two conditions. As shown in Figure 4: in the experimental condition, the participant can interact with Plant Playmate or rest in place; in the control condition, the participant can view or touch the plant without feedback. Resting in place is also permitted. During the study, the exposure of participants to the two different conditions was fully counterbalanced. Besides, to balance the primary states in each condition, we separated the two conditions of the experiment by an hour or more for each participant to refresh themselves. Before the experiment, each participant was given a full explanation of the basic experimental procedure without the hypothesis and instructed on using the self-tracking device (E4 wristband).

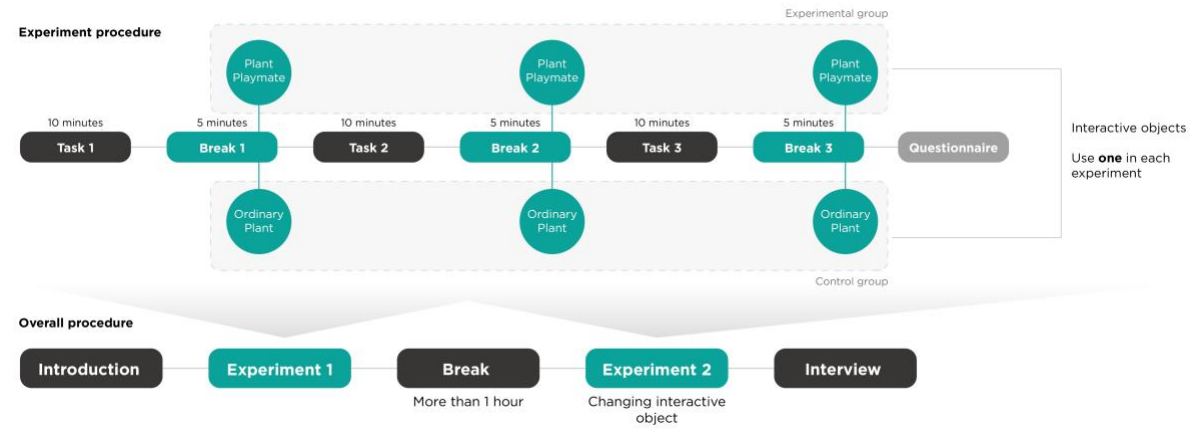

Figure 5. The procedure of each experiment (upper) and the order of the two experiments (bottom).

The duration of each experimental or control condition was 45 minutes, including three 10-minute work periods and 5-minute rest periods, as shown in Figure 5. To simulate the office state, we set several computer working tasks (arithmetic test, text typing, Stroop color-word test) for stress induction for participants to perform (Lutin et al., 2021). During every 5-minute break, the participants were exposed to either Plant Playmate or ordinary plants:

- Process of the experimental condition: During the break, participants interacted with the Plant Playmate or rested in place. Repeat the above session three times for one experiment.

- Process of the control condition: Replace the Plant Playmate with ordinary plants. Participants could engage in interactions similar to Plant Playmate without getting feedback.

After each experiment, participants were asked to fill out the self-assessment manikin (SAM) scale (Bradley & Lang, 1994) and User Experience Questionnaire (UEQ) (Laugwitz et al., 2008). At the end of each experiment, an interview was given to every participant about their user experiences and opinions on the Plant Playmate.

3.3 Data collection

As shown in Table 1, we collected both quantitative and qualitative data during the experiment. For quantitative data, we recorded the participants' Electrodermal Activity (EDA) data with the E4 wristband. EDA has been proven to be a reliable characterization of personal stress level (Hernando-Gallego et al., 2018). EDA data has been proven to independently indicate stress status, as the skin is the only organ controlled solely by Sympathetic Nervous System (SNS) (Ayzenberg et al., 2012). E4 wristband was chosen for two reasons: firstly, it is portable that can be easily deployed outside, as well as non-invasive and light weighted, which means that it has a minimal impact on participants (Milstein & Gordon, 2020); secondly, it is medically certificated. After each task or break period, tags were marked using the E4 button to label the end of each process. After each experiment, we used the SAM and UEQ scales to examine the emotional state and user experience of the two conditions. The SAM scale contains three subscales: pleasure, arousal, and dominance (from 1-negative to 9-positive). The UEQ scale measured the user experience from six aspects: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty, based on a 7-point Likert scale.

For qualitative data, we conducted a semi-structured interview after each experiment to collect participants' detailed feelings and suggestions about Plant Playmate. Questions like "What do you like most about Plant Playmate?" "Where else do you think Plant Playmate could be placed?" were asked. All the interviews were recorded and converted into text for analysis.

Table 1. Data collected from the study

Measures	Plant playmate	Plant	Post-study
Stress			
EDA data	✓	✓	
Emotional state			
SAM	✓	✓	
User experience			
UEQ	✓	✓	
Follow-up interview			✓

3.4 Data analysis

The psychological data were analysed by PyCharm ("Pycharm", 2023) for pre-processing and data analysis. In the open-source Python packages, Neurokit2 (Makowski et al., 2021) and pyphysio (Bizzego et al., 2019) can fulfil the pre-processing and feature extraction of EDA data. Initially, a rectangular convolutional kernel is employed to apply convolutional filtering and eliminate noise. The EDA data can be distinguished as Skin Conductance Level (SCL) and Skin Conductance Response (SCR),

between which the SCL is regarded as a valid indicator for stress reaction. It slowly rises during psychophysiological activation periods (Boucsein, 2012) and has been used for multiple stress detections (Setz et al., 2010; Shu & Ma, 2020). Also, the frequency of SCRs is considered as mental activation (Boucsein, 2012; Kappeler-Setz et al., 2013). Thus, in this study, we extracted features of EDA based on the extraction of SCL and SCR signals by pyphysio. SCL (μS) is usually calculated as the average value in a period (Goumopoulos & Menti, 2019). Given that a complete SCR response process typically lasts from 3 to 15 seconds (Kleckner et al., 2018), we chose 60 seconds as the time window to sufficiently assess the data. Hence, the SCL value was defined as an average over 60 seconds, and the SCRs frequency (Hz) was calculated within this time window. We used these values at the end of task periods to indicate the basic work stress level of participants and the values at the end of rest periods to represent the stress level after the intervention. We used non-parametric paired Wilcoxon tests for the processed data to identify the significance after detecting the unnormal distribution.

The collected questionnaire data was analysed by SPSS software. We first checked the distribution by the Shapiro-Wilk test. For data with normality, we conducted paired-sample t-tests. For data that was not normally distributed, we conducted non-parametric paired Wilcoxon tests.

All the interview transcripts were processed through NVivo ("Nvivo", 2023) software for thematic analysis. We set 35 initial codes and extracted three themes. The codes with the highest number of references were extracted and analyzed.

4 Results

4.1 Quantitative findings

4.1.1 Acute benefits on stress coping

We used the obtained EDA data and participants' responses to SAM as two indices for the effects of our design for work-related stress coping. As shown in Table 2, the non-parametric paired Wilcoxon test results indicated that interacting with both plants and Plant Playmate significantly reduced the user's stress during breaks. There were significant differences both in the SCL value ($Z=2.949$, $p<0.01$) and SCRs frequency ($Z=2.309$, $p<0.05$) when interacting with Plant Playmate, and the same effect was also observed in SCL ($Z=2.427$, $p<0.05$) and SCRs frequency ($Z=2.488$, $p<0.05$) under the intervention of plants. Despite the significant difference in SCL baseline values ($Z=2.091$, $p<0.05$) between the two states, the improvement achieved was not different both in SCL ($Z=0.561$, $p=0.575$) and SCRs frequency ($Z=0.545$, $p=0.586$).

Table 2. Median (lower quartile, upper quartile), and Wilcoxon tests for EDA data

Conditions M (P_{25}, P_{75})	**SCL (μS)**				**SCRs frequency (Hz)**			
	Pre	Post	Z, p	Improv. *	Pre	Post	Z, p	Improv. *
Plant Playmate	0.13	0.06	2.949	-0.0286	0.08	0.06	2.309	-0.0306
	(.04, .58)	(.03, .24)	.003**	(-.22, 0)	(.01, .22)	(.02, .12)	.021*	(-.11, 0)
Plant	0.29	0.21	2.427	-0.0314	0.16	0.07	2.488	-0.0306
	(.07, .64)	(.06, .62)	.015*	(-.28, 0)	(.02, .20)	(.02, .11)	.013*	(-.11, .01)
Z, p	2.091			0.561	0.544			0.545
	.037*			.575	0.587			0.586

** 'Improve. *' represents Median (lower quartile, upper quartile) for the differences in SCL value and SCRs frequency between pre- and post-conditions.*

SAM scale (see Figure 6) shows that the experimental condition in pleasure (M=7.3, SE=0.44), arousal (M=6.55, SE=0.46), and dominance (M=6.7, SE=0.49), were all outperformed the control condition (pleasure (M=5.95, SE=0.30), arousal (M=4.5, SE=0.34), dominance (M=4.65, SE=0.43)). We conducted the non-parametric paired Wilcoxon test. The results are shown in Figure 6, demonstrating that the differences between the experimental and control conditions were significant, with pleasure at Z=1.95, p=0.05, arousal at Z=3.17, p<0.01, and dominance at Z=2.50, p<0.05.

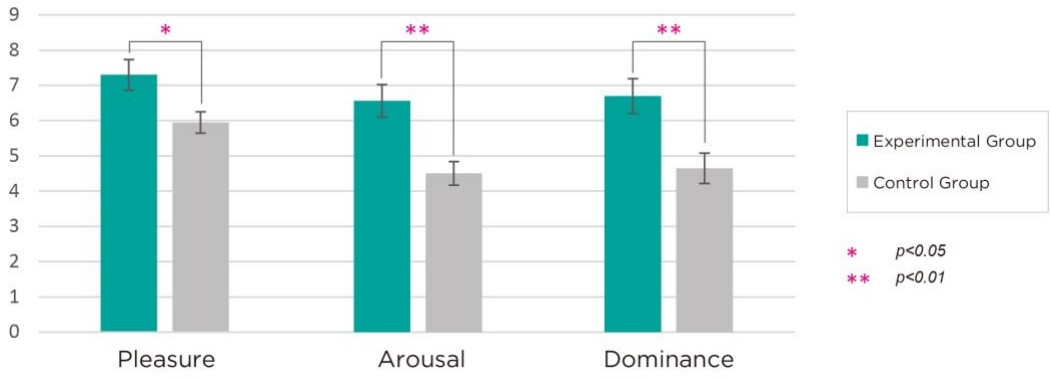

Figure 6. The scores of the SAM scale in pleasure, arousal, and dominance, with the comparison between the experimental and the control group.

4.1.2 Results of user experience questionnaire

We found that Plant Playmate can positively increase participants' user experience, especially in attractiveness, efficiency, stimulation, and novelty. As shown in Figure 7, the experimental condition scored higher in all six dimensions than the control condition. The differences between the scores of the experimental and control conditions in these six areas were obtained by subtracting the scores of the experimental and control conditions. They were generally distributed after the Shapiro-Wilk test (p>0.05). After the t-test, the results of the UEQ scale showed that our experimental condition had significantly improved the user experience in terms of stimulation (M = 1.78 vs. 0.36, SE = 0.28 vs.0.24) and novelty (M = 1.76 vs. -0.64, SE = 0.27 vs. 0.22), with p<0.001. The experimental condition data of efficiency (M = 1.35 vs. 0.24, SE = 0.24 vs. 0.20) and attractiveness (M = 1.95 vs. 1.16, SE = 0.28 vs. 0.18) had also risen with p<0.01 and p<0.05. Although the improvements in the data of the perspicuity (M = 1.78 vs. 1.69, SE = 0.21 vs. 0.27) and dependability (M = 1.50 vs. 1.34, SE = 0.19 vs. 0.19) were also shown in the results, there was no statistical significance.

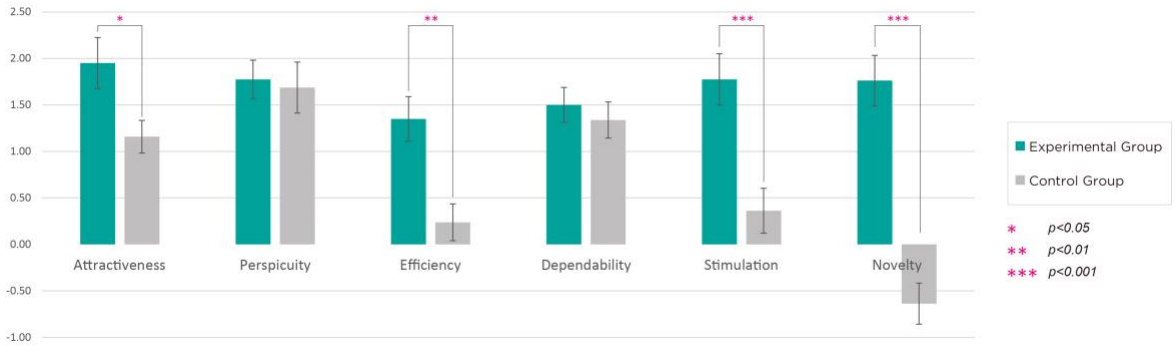

Figure 7. The transformed values of the UEQ scale in attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty, with the comparison between the experimental and the control group.

4.1.3 Summary

From the questionnaire, in the aspect of stress relief, it can be found that participants generally showed positive attitudes towards Plant Playmate according to SAM results, which indicates that Plant Playmate is more effective in relieving work stress than ordinary plants. Besides, although similar stress-relieving effects were observed in interactions with both Plant Playmate and the ordinary plant, the EDA results showed that when the Plant Playmate was placed in the workplace, participants experienced less work pressure. This might be attributed to the Plant Playmate's better ability to alleviate plant blindness. Regarding user experience, participants tend to consider that Plant Playmate is more novel, attractive, and motivating in their use. Next, we present interview results to provide qualitative insights and reasons for this discrepancy between subjective perceptions and physiological data.

4.2 Qualitative findings

4.2.1 Overall experiences

Most participants described their experiences in both conditions as "relaxing, calming, and comfortable." They appreciated the living and green media interface for stress relief. For instance, *"The green plant is symbolic of nature and vitality, which allows me to relax and feel comfortable." (P01).* Participants were impressed by the compatibility of the augmented plant to the working environment, as well as the visual experience and stress-relieving effect it brought. For example, *"The succulent plant is cute, and I would like to have a plant in the workplace. Interventions based on living plants rather than screen or application will not cause distraction." (P13).*

Additionally, most participants described their experience with Plant Playmate as "novel, interesting and pleasure". Compared with ordinary plants, this augmented plant with interactivity could obviously capture participants 'curiosity. As one of the participants stated, *"I watered it constantly to check if it can actually react to my behaviours. It is fascinating to me." (P21).* Participants considered the interaction process as playful games with the living plants. Gamification provided by plants could create new and exciting experiences.

4.2.2 Perceived effect on stress relief

One element that seemed to be greatly appreciated was the ability of the Plant Playmate to create an immersive break. Most participants indicated that non-work-related elements in the workplace could separate them from intense work and help relieve stress, especially the ones in relation to nature,

such as green plants, flowers, and windows. Thus, participants perceived the effects of stress relief caused by distraction in two conditions. Moreover, based on the ordinary plants, Plant Playmate was more appealing to our participants due to its interactivity. Compared with simple breaks, the guidance integrated into the human-plant interaction could effectively engage users in relaxing. For example, as one of the participants stated, *"When it provided some guidance, I could devote myself to relaxing rather than constantly considering too much work-related matters." (P11).* Interacting with Plant Playmate contributes to the immersive refreshing process and high-quality microbreak.

Participants expressed that Plant Playmate provided a more natural and healthy approach to engaging them with microbreak. Some participants would compare Plant Playmate with mobile phones when discussing microbreaks in the workplace. Furthermore, they indicated that this ambient technology performs better in stress relief. In addition to some physiological reasons, for example, asthenopia caused by using phones over time, social factors are equally worth considering. Interacting with plants would not result in misunderstandings and bias, e.g., *"Mobile phones during work would be considered untimely and inappropriate. However, interacting with plants would not." (P13).* The results of the interviews revealed a high acceptance of using living and green media interfaces for stress relief in office settings.

Additionally, some participants appreciated the positive and immediate feedback provided by Plant Playmate. For instance, *"I watered and touched the plants, seeing the increased scores and the smiling face on the screen. These positive rewards were encouraging and contributed to stress relief." (P16).* Compared with the slow-growing process of static plants, Plant Playmate is always dynamic due to its screen-based feedback. Participants could obviously observe the effects of what they had done on the plants. It is not easy to get positive feedback constantly in a formal working process. Therefore, obtaining visible rewards and a real sense of fulfilment through these simple tasks during microbreaks has excellent potential for stress relief.

4.2.3 Challenges and opportunities

Anthropomorphic plants. Most people would consider Plant Playmate as augmented plants with sensors and actuators. They could associate the digital output with the plant's emotion, giving them empathy and intimacy. For instance, one participant stated, "*It could create many different facial expressions in respond to different forces of touch, which seems to be plant's inner perception*." (P12). However, due to these added sensors, some participants regarded Plant Playmate as an artificial product rather than a living plant interface. In that case, they hoped to make the sensors on the plant-based interface invisible, "*It would be better if the hardware was hidden and the function could still be realized*." (P07). Moreover, participants prefer plants' natural response to the output rather than external digital and mechanical elements. "*I want to see changes in the plants themselves more than the feedback on those electronic components*" (P08).

Playful interaction. Most participants appreciate using touching and watering to interact with the plants. However, they proposed to enrich the interactions, such as audio conversations or text messages. Some participants also expressed their expectations of the interactions initiated by plants actively. For example, the plants could express their needs, such as being watered or sitting in the sunshine. Participants indicated that this living media could evoke empathy and motivate them to take a break.

The personality of the plants. Plant Playmate does not have exact and apparent personalities at present. Its response is homogeneous towards users' input, which is a challenge for the long-term use of Plant Playmate in the workplace. Therefore, the participants thought the feedback could be further improved, such as presenting different contents at random whenever users interact with it or changing their personalities according to how users treat it normally. Participants argued that this kind of mechanism could help maintain novelty in long-term use and facilitate emotional attachments.

5 Discussion

In this paper, we intend to design and evaluate interactive plants to facilitate mental wellness during microbreaks in office settings. With Plant Playmate, people can water and touch the green plants, receiving screen-based feedback. We conducted a within-study to investigate whether it can help relieve stress and explore the user experience to inspire future work. The results confirmed our design concept and enlightened a few directions for mental wellness in office settings.

During the study, we found that although interacting with Plant Playmate and the plant can both significantly reduce stress physiologically, there is no significant difference in the stress-relieving effect between both conditions. However, nearly every participant expressed that they had felt more relaxed when using Plant Playmate. According to the results of scales and interviews, we propose three possible reasons for this conflict as follows. Firstly, the playfulness of Plant Playmate draws participants' attention when they rest, which means they can transfer users' moods from work in a short time and make them perceive that the Plant Playmate has a better effect than an ordinary plant. Secondly, its novelty and the complex hardware system that represents technology may lead the participants subjectively believe that it can release their pressure. Besides, affected by the indirection of oriental culture, participants may answer this way out of courtesy.

Furthermore, we believe there is a prospect to enhance the stress-reducing effect of Plant Playmate further. On the one hand, the physiological data under the control condition exhibited significantly higher work pressure compared to the experimental condition, indicating the potential companion effect of the Plant Playmate. Previous work also proposed that communicating with tangible interfaces benefits emotion and activity (Jingar & Lindgren, 2019). On the other hand, the attractiveness and effectiveness of Plant Playmate were highly recognized in the interview and questionnaire. Based on their comments, we further derived several implications for the design and research for promoting mental wellness in workplaces.

Firstly, human-plant bonds can be leveraged to help alleviate fatigue and stress. According to Wilson's biophilia hypothesis, people are biologically drawn to nature (Wilson, 1986). Extensive projects have established close relationships between the presence of green plants in the workplace with increased working performance and office well-being (Gray & Birrell, 2014). A growing body of HCI projects applied interactive plants in health promotion (Zhou et al., 2021) and emotion regulation (Seo et al., 2015). Based on this, our design concept utilized plants as the media interface and invited sensory interaction and gardening play. The quantitative and qualitative analysis results provide evidence that the aesthetic, dominionistic, and humanistic values of nature, which have been identified in the theory of biophilia (Meltzer, 2014), play a positive role in promoting mental wellness in the workplace. Moreover, according to participants' suggestions, it is worth considering how to strengthen the

natural and energetic feelings of the living species, such as enlarging the scale of plants, making the sensors invisible, employing organic output, and multisensory interaction.

Based on previous studies, we made further explorations on anthropomorphizing plants. The results revealed that a few participants could actively establish a connection between the interactive expressions and plants' internal feelings and emotions. Furthermore, the special bond made it easier for users to shift their attention from stressful work to a game-like interaction, relieving the stress caused by prolonged and monotonous work tasks. Previous research has highlighted the potential of experiencing symbiotic relationships and actively engaging in caring for plants (Nam et al., 2023) in enhancing human-plant bonds and facilitating healthier lifestyles for both. In our study, similarly, many participants suggested further enriching the personalities of the plants and providing personalized feedback to strengthen connectedness and promote emotional attachment. For instance, the plant can adjust its personalities and behaviours dynamically according to users' interaction in the long term. When the users care for the plant regularly, it will react mildly and positively to the users' interaction. Conversely, it would be rebellious and ignore users' input. The symbiotic interactive relationships could further enhance the attractiveness of the anthropomorphic plants and serve as a persuasive strategy to promote health behaviours.

Additionally, people can derive fulfilment from the lightweight task and real-time feedback Plant Playmate provides. In prior studies, gamification has been proven effective in energizing users and prompting active breaks (Cambo et al., 2017). Combined with green plants, this mechanism has proven helpful in stress relief. However, rather than merely using plants as controllers (Park et al., 2016), we stressed the reaction and feeling of plants. With Plant Playmate, we could directly observe how our behaviours positively affect other living species. Moreover, it was widely acknowledged among participants. Thus, this is a notable aspect of providing easy tasks and real-time feedback through the living media interface.

Prior study has revealed the importance of social norms in creating break-taking habits in the working environment. Furthermore, it is necessary to provide visible signals that taking a break is socially acceptable (Rudnicka et al., 2022). Our study aligns with this. Plant Playmate could provide appropriate prompts and tasks to support active microbreaks because caring for plants could be considered an accepted or even encouraged activity in the workplace.

6 Limitations and future work

The experiment has its limitations. Firstly, the experiment environment kept changing during the study since our experiment took place at different workplaces instead of a specific and fixed room. Some relevant environmental elements like lighting, furniture, and noise might affect participants' states differently. Also, technological limits, such as the low sensitivity of the ultrasonic sensor, affected the user experience, reducing the reliability of the Plant Playmate to some degree. There is also an error in the accuracy and lower sampling rate of the E4 wristband compared to the laboratory-grade Refa system, which can interfere with the data (Borrego et al., 2019). We come to the conclusion by combining quantitative and qualitative results. That can reduce the error caused by the wristband. To further verify Plant Playmate's impact on workers' mental wellness, long-term experiments and field studies need to be conducted to obtain more accurate results in the natural context. Furthermore, the issue of better-representing changes in the plant itself through hardware-based devices needs

further exploration. We plan to explore more essential ways of interaction between human and plants from a technical perspective to enhance the critical role of plants during the interaction.

The well-being of mental workers is vital for the development of both enterprises and society. With the help of Plant Playmate, we hope to integrate ecological concepts into the office environment to improve employees' work status and enhance society's care for mental workers.

7 Conclusion

This paper presents the design and evaluation of Plant Playmate, an anthropomorphic smart plant placed in the workplace, aiming at relieving work pressure during microbreaks through multimodal interactions such as visual and tactile feedback. Through a within-subject study with 22 participants, we learned that compared with ordinary plants, the Plant Playmate has more significant potential in improving interactive and relaxation experiences, as well as alleviating workload. The quantitative and qualitative findings also revealed that as a friend and playmate, the intelligent interactive plant could establish emotional connections with humans, thereby enhancing their intimacy with nature while benefiting office vitality and people's mental being. Based on the results, we give further suggestions for building human-plant interaction in office environments.

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