Customizability in Preventing Loss of Interest in Ambient Displays for Behavior Change

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***Abstract*—Ambient displays are effective for behavior change; however, their prolonged use may cause users to lose interest in the content and fail to change to desirable behavior. We investigate two methods of presentation customization to address loss of interest caused primarily by habituation to the system: 1) incremental and ad hoc customization and 2) initial and goal customization. These methods were incorporated into a prototype system designed to avoid a sedentary lifestyle at home. A 36-day user study revealed that effective methods varied depending on users' motivation for using the system. Issues related to customization and user feedback and directions to improve the loss of interest caused by distrust of the system were identified.**

Keywords*—*ambient display; behavior change; customization.

I. Introduction

People are encouraged to change their behaviors in everyday situations, such as behaviors to prevent the spread of CoVID-19, promote health (e.g., dieting and smoking cessation), and save resources to avoid global warming. To positively change their behavior, they must be appropriately motivated according to their current situation. Target behaviors can be quantitatively monitored using sensors installed in wearable devices and the environment. However, this information must be easily accessible, and motivating factors should be communicated for effective behavior change.

Several studies on ambient displays exist [1], intuitively making information understandable by mapping it onto virtual creature illustrations, light and sound patterns, and physical form changes, rather than numerical values or graphs. An ambient display is recognized as a part of an environment, such as an object or a painting, which is always activated as an independent system, rather than being used as an application that is activated each time information is checked. Ambient displays are widely used in behavior change because they can convey information without interrupting other daily tasks, and users can receive information positively through a pleasing design [2]–[6]. Ambient displays' novelty may attract users initially; however, they may gradually lose interest and stop paying attention to the display [2] because of the calm manner of information presentation, causing a reduction in the effectiveness of persuasion [3]. Furthermore, system malfunctions can present results that fail user expectations, resulting in loss of interest and abandonment of the system [4] [7]. To our knowledge, few studies have aimed to solve these problems in the context of behavior change. Studies on user interest estimation and its applications have used eye gaze information [8], head pose [9], user personality [10], and speech information [11]. These studies have dealt with users' temporary interests and preferences. However, ambient displays must handle long-term user interests, which is challenging. Here, based on a model of losing interest over a long period, we investigate two methods of customizing persuasive ambient displays to avoid losing interest in displays' content. The methods were implemented in a persuasive ambient display system that aims to encourage the user to be active at home and were evaluated in a 36-day test.

The remainder of the paper is organized as follows. Section II presents a model of losing interest. A customizable persuasive ambient display is designed and implemented in Section III. Section IV presents a user study, and Section V concludes the paper.

II. A Model of Losing Interest

Referring to previous study that modeled the mental states of children playing with robots [12], we proposed a model that adds the two states of habituation and distrust that occur with the long-term use of ambient displays (Figure 1) [13].

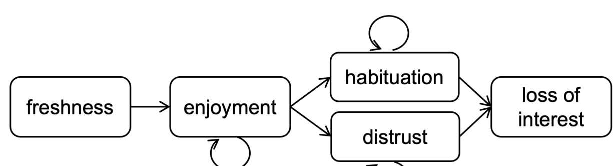

Figure 1. A model of losing interest

In the *fresh* state, the system is unknown to the user. Therefore, the interest level and use frequency are high. Users find their own way of using the system and thus *enjoy* the changes in information at their own pace. This period increases depending on the functionality and variations of the system. With system usage, a state of *habituation* occurs wherein the users gradually lose interest in the system because they feel that all the functions and patterns have been explored. If the system continues to present similar information for an extended period, users will perceive it as "background" information. Thus, users will eventually ignore it. This phenomenon

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has been often noted in previous studies that conducted long-term user evaluation experiments (e.g., Bauer et al. [14]). Additionally, a state of distrust emerges when users feel that the system does not follow their wishes or information and its representation methods are inaccurate. This occurs, for example, when the user's activity information is not accurately reflected on the display [4] [7], or the design is not to the user's liking. We believe that distrust increases the tendency to intentionally avoid using the system. Consequently, the user finally reaches a state of loss of interest and ignores the display. Therefore, we detect the emergence of habituation or distrust as a sign of loss of interest and intervene by returning the user to the enjoyment state. Here, we mainly dealt with the habituation issue.

III. Customizable Ambient Display for Active Living in the Home

A. Overview

A prototype system that motivates the user to be active, for example, moving around and performing exercises to prevent excessive sitting while working at home, and incorporates the above intervention concepts, was developed. The system employs a growth metaphor in which a virtual tree grows when the non-sedentary time per hour exceeds a certain ratio. This is aimed at improving behavior through the aspiration to increase tree growth. Two types of active involvement strategies were introduced to facilitate long-term engagement with the system: 1) incremental and ad hoc customization and 2) initial and goal customization.

B. Major components

Figure 2 illustrates the major functional components of the system, which consist of 1) home activeness calculation, 2) basic feedback, 3) interest level estimation, and 4) customization. The system ran on a Raspberry Pi 4 (RP4) with a 7-inch touch display. An OMRON Human Vision Components (HVC)-P2 [15] was connected to RP4 as a gaze detector to estimate the level of interest. Home activeness is judged by integrating the information from Fitbit Charge 4 worn by the user and a smartphone connected to a WiFi Access Point (AP) in their home.

1) Home activeness calculation: Home Activeness (HA) is defined as the ratio of the active time at home to the time spent at home, which is calculated every hour and is represented by (1). The active time at home in the past hour from time h was obtained as the difference between the time spent at home ($t_{home,h}$) and the inactive time at home ($t_{inactive,h}$). The value of t_{home} is measured by accumulating the duration of the user's smartphone being connected to a home WiFi AP, while we retrieved values using an activity type of "sedentary" in the Fitbit API for $t_{inactive}$. Note that the value of $t_{home,h}$ is 60 min unless the user leaves home between times h and $h+1$.

$$HA_h = \frac{t_{home,h} - t_{inactive,h}}{t_{home,h}} \quad (1)$$

2) Basic feedback: A tree growth metaphor was used. The tree begins to grow from a seed, and HA_h (1) is evaluated every hour (h). *Positive feedback* is when the tree grows by one stage if the value exceeds a certain threshold value (Figure 2 (b1)). In our earlier prototype system [13], the frequency of evaluation was set to once per day; however, the study participants were unmotivated by the lack of changes in the feedback. Thus, we chose once per hour as the evaluation frequency for the new system. Furthermore, to ensure that the growth was not easily completed during the experimental period of 12 days per condition (Section IV-A), images of the grown trees were prepared for approximately 100 stages. Contrarily, the tree becomes thinner by one stage if the evaluated value of HA does not exceed the threshold value, and the tree breaks at the fourth stage (Figure 2 (b2)), which we call *negative feedback*. An early prototype system did not employ negative feedback to ensure that the users did not quit using the system because of sympathy for the weakening virtual creature [16]; however, we found that the motivational elements were not enough with only positive feedback [13]. Thus, we decided to introduce both positive and negative feedback while taking care to ensure that the degree of negative feedback was not too strong; for example, the tree did not suddenly break but gradually thinned before breaking, and the update interval was set to 12 h instead of 1 h.

The threshold for positive/negative feedback was set to 3/60, which assumes at least 1–2 min of movement every 30 min based on the recommendation for interrupting long periods of sedentary behavior every 30 min by light movement [17]. Note that in a full-scale operation for health promotion, the target value should be set appropriately.

3) Interest level estimation: We hypothesized that the frequency of screen viewing would decrease as the level of interest decreased and attempted to model the correlation. In our previous work, we simply used the distance between the user and the display obtained from an infrared distance sensor [13]; however, this method caused frequent misdetections. Thus, we opted to use the frequency of eye gaze falling within the display area using the gaze detector HVC-P2 (Figure 2 (c)). A preliminary experiment, which is briefly described below, was conducted to test this hypothesis.

Nine university students in their twenties used an ambient display set up in their homes, illustrating a tree. The fact that only the background color changed over time was not mentioned to the participants. They indicated the level of habituation and distrust on an 11-point scale from 0 to 10, with a frequency of once per hour. Lower values indicate lower levels of these states. The experiment continued until one of these levels reached the maximum value of 10. Although the individual completion times of the experiment ranged from 1 day to 2 weeks, the results of all nine participants showed the same tendency. Specifically, with the exception of one participant, a negative correlation with an average value of –0.60 and a standard deviation of 0.39 existed between the frequency of viewing and the level of habituation or distrust. The frequency of screen viewing was obtained by averaging

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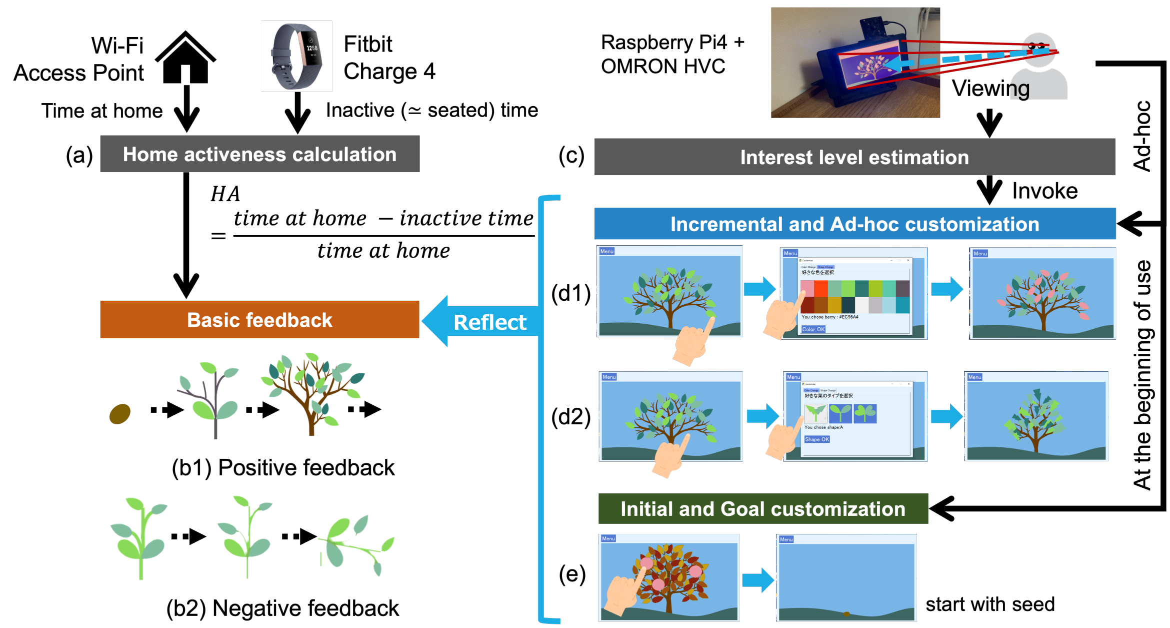


Figure 2. Major Functional Components of of the Prototype System

the number of times the participants viewed the screen at least once per hour over the time they spent in the room per day. For example, the value is 0.5 if a user spends 4 h at home and views the display twice, zero times, three times, and zero times each hour.

4) Customization: In our early prototype system, two types of involvement strategies were proposed: active and passive involvement [13]. Active involvement allows users to customize the appearance of the tree and change their daily goals, which is based on the self-determination theory that the users can be motivated in the long term by increasing their self-determination [18]. Conversely, passive involvement was designed to attract the user's eyes to the display [19] by animation, which changes the speed of swaying the tree according to the distance from the user. A comparative user study showed that active involvement tended to keep users' interests relatively high, whereas a monotonous system was not suitable for maintaining user interest over a long period, even with active involvement. Therefore, we implemented two types of active involvement approaches, which differ in the timing and target of customization.

First, the number of customizable parts increases as the tree grows to give the system an "unknown" element and create a sense of anticipation of what might happen next. For example, only the color and shape of leaves could be changed immediately after sprouting, while the colors of the trunk and fruit could be changed after some stages of growth. This is because the user will quickly become habituated to the functionality and lose interest if everything is customizable from the beginning. The user can change the color at any time by tapping any part of the presented image, such as the ground and background (Figure 2 (d1)). The shape of the leaves and the spread of branches can also be changed (Figure 2 (d2)). Additionally, the system prompts customization if the user's interest falls below a certain level and the user passes in front of the display. Such an approach from the system side is intended to make the user aware of the display even if the user's interest in it declines and to regain their interest by redecoration. The threshold for prompting customization was set to 0.516. The value was obtained as the ratio of the average frequency of viewing by nine participants when the level of either habituation or distrust reached 9 out of 10 to the frequency of viewing on the first day when the interest should be the highest. We call this type of customization *incremental* and *ad hoc customization*, or simply *ad hoc customization*.

Second, the appearance of the final stage was customized at the beginning (Figure 2 (e)). Some people may want to have a sense of "working toward a goal" through customization at the beginning. Once the goal appearance is set, the system starts with a "seed" view, and the user spends time at home toward a tree with the specified appearance. The second approach is designed to motivate the user to grow the tree toward the goal appearance, which we call *initial and goal customization* or simply *goal customization*. In this approach, no suggestions for customization were made by the system.

IV. Experiment

A. Methodology

A user study was conducted to investigate the effectiveness of the proposed behavioral feedback and customization methods with six university students in their 20s (two females and four males). They were each asked to use the system under three conditions for 12 days: 1) with ad hoc customization, 2) with goal customization, and 3) without customization as a baseline. The participants did not receive any specific instructions regarding their time at home, and the order effect was counterbalanced.

Home activeness and frequency of viewing the display were analyzed. As qualitative data, the participants were interviewed at the end of each system condition usage to collect the perceived interest in and distrust of the system. Furthermore, another interview aimed at comparing the three conditions was conducted at the end of the entire experiment.

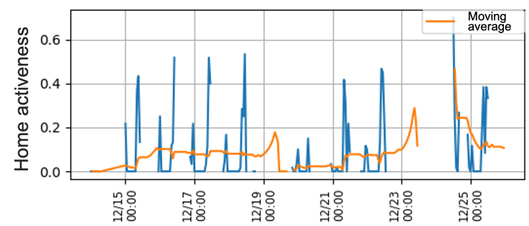
B. Results and Discussion

1) Feedback method: Some participants felt that the measure of activity was well reflected in the growth of the trees, whereas others did not. This contradiction might be because the tree growth rate depended on the participants' daily home time, as tree growth was determined once every hour. For example, if they stayed at home all day, the tree grew by about five stages in one day if the HA reached the threshold every 3 h. However, if they went out in the morning and returned home at 22:00, the tree grew by only about two stages, even if they were active after returning home. Hence, they felt that their efforts were not reflected, which is likely to increase distrust of the system. Thus, various scenarios should be handled by changing the speed of tree growth according to the user's daily rhythm and the amount of time spent at home. That is, the user's preferences and lifestyle and behavior should be considered for more effective feedback.

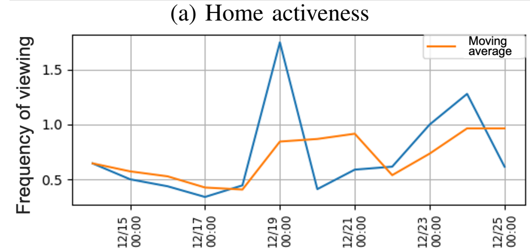
Negative feedback was invoked by three participants. One participant stated that negative feedback made her more aware of the need to improve her behavior, which we confirmed as an increase in HA. However, other two participants stated that they had already lost interest in the system and thus did not feel the need to improve their behaviors. This suggests that negative feedback is ineffective if the user reached the state of loss of interest. Negative feedback is invoked if an HA below a threshold is detected for half a day. Consequently, the user is likely to have lost interest in the system and may abandon the use thereof if the tree breaks under such conditions. Therefore, the use of negative feedback may not be effective, especially for users who lost interest in the system.

2) Effective customization method by user type: The participants used the three types of system conditions consecutively for more than one month, and the degree of loss (or continuation) of interest varied depending on individual characteristics. Therefore, we classified the participants into three types based on the interview results: 1) Highly Motivated (HM), 2) Gradually UnMotivated (GUM), and 3) Poorly Motivated from the beginning (PM).

Three participants fell into the HM type and continued to use the system throughout the experimental period without a significant decrease in the frequency of screen viewing or the duration of their activities, although some differences exist in their tendencies. Figures 3a and 3b present an example of the time trend in home activeness and frequency of viewing, An example of time trend in home activeness and frequency of viewing are shown in Figures 3a and 3b, respectively. All participants in this type preferred ad hoc customization followed by goal customization and then the baseline. They tended to be more motivated by the metaphor of tree growth, suggesting that the presence or absence of a goal did not affect the results. Additionally, because participants regularly checked the display, we considered it a good match with the customization method, allowing them to customize the visualization at any time. They would not use the system if they were not interested in it, because operations were required to customize the display. Therefore, the participants in this category were highly interested in the display, and the nature of the display being customizable at any time may have led to the continuation of their interest.



(a) Home activeness



(b) Frequency of viewing

Figure 3. Time trends of a participant in the HM type who used the system without customization (baseline) for the third option.

Two participants belonged to the GUM type, showing a gradual weakening of their motivation. Figures 4a and 4b show the time trends in the home activeness and frequency of viewing of a participant who first used goal customization. The frequency of viewing gradually declined as days progress 4b, indicating that the level of interest was decreasing. Moreover, home activeness was not as high as in the case of HM. The other participant showed a similar tendency. All GUM-type participants used the ad hoc customization type as the second or third option; however, they never used the customization functionality because they had already lost interest in the system or did not see any tree growth, according to the interview results. Interestingly, they agree that they preferred goal customization, allowing them to set a goal tree first. That is, we consider that GUM-type participants had difficulty maintaining their motivation with only the metaphor of tree growth and customization of visual elements. However, they were facilitated to make efforts to reach the goal since their goals were made more concrete. Therefore, we believe that an approach that encourages voluntary operation is not effective for participants who show a strong tendency to lose interest. Any functionality might be utilized after a complete loss of interest; therefore, this issue should be addressed at an earlier stage.

One participant was classified as the PM type, who had

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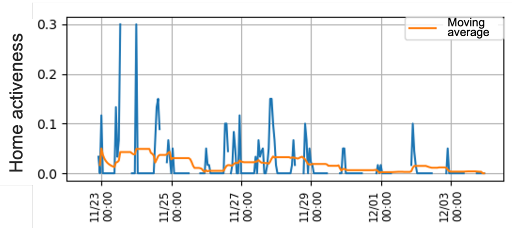
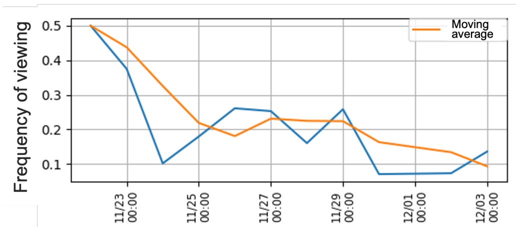


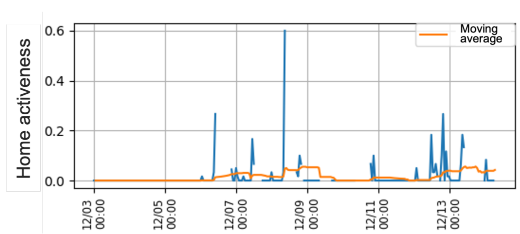
(a) Home activeness



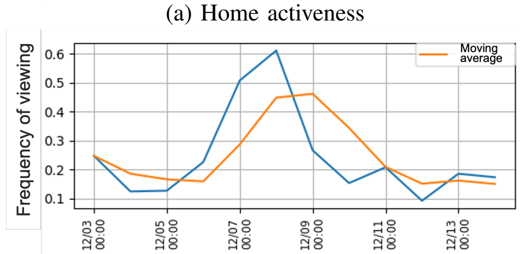
(b) Frequency of viewing

Figure 4. Time trends of a participant in the GUM type who used the system with goal customization as the first option.

low interest in the system and low awareness of behavior change from the beginning and tended not to utilize the system continuously. Figures 5a and 5b show the time trends of home activeness and frequency of viewing for this participant using goal customization as the second option. According to the participant, the confirmation of tree growth did not inspire him to change his behavior, nor did he notice any particular difference between the systems. The possible reason is that the participant was unaware of the risk of being sedentary at home and was not conscious enough to change his behavior through an ambient approach. Thus, for participants who are not interested in changing their activity level, their consciousness are challenging to change through customization, and a stronger approach or information other than activeness is considered necessary. For example, indirectly activating participants' interests by simultaneously displaying their interests and information may be effective.



(a) Home activeness



(b) Frequency of viewing

Figure 5. Time trends of a participant in the PM type who used the system with goal customization as the second option.

Thus, we consider that effective approaches differ depending on the level of motivation that users have to use the system, which is in line with [20] [21]. Previously, our research group has attempted to estimate the stages of behavior change in the transtheoretical model [22] as levels of motivation. We wanted to change motivational strategies according to these stages and apply them to a system for promoting energy-saving behavior [23]. The motivational stages were estimated by a decision tree classifier that used the data on electricity consumption and usage status of an information presentation system as inputs. The results suggest the possibility of a motivation-aware behavior-changing system. If behavioral features representing motivation level and a sufficient number of correct labels are obtained, the motivation level can be estimated through machine learning, and users of GUM and PM can be covered for the type of activity time considered in this study.

3) Customization method: As discussed in Section IV-B2, the ad hoc customization feature tended to be effective in maintaining users' interest who were mainly motivated to increase their activity level. Although the method could prompt users to customize the tree visualization if a decrease in interest was detected, the functionality was only invoked once for one participant during the experiment, making it difficult to evaluate the effectiveness of the recovery process. The determination of the reference value for invoking this process was based on viewing the display on the first day of the ad hoc customization. Users who did not start with the ad hoc customization started with a certain degree of loss of interest initially. Thus, the threshold is quite small, and we consider that HA rarely falls within the thresholds. Therefore, the threshold should be determined based on data from the first day of using any of the systems.

Regarding goal customization, some participants insisted that they would like to see the gap between their current situations and their goals. Others wanted to confirm the goals that were initially set whenever they wanted. These functionalities would be useful because forgetting the goal appearance throughout long-term use is reasonable.

4) Distrust in the system: From the interview results, we confirmed the occurrence of distrust of the system owing to the failure in retrieving data from Fitbit. This is because the data on the Fitbit cloud service sometimes failed to synchronize with the measurement data on the Fitbit wearable device, resulting in delayed or no update of the feedback. However, distrust, to some extent, can be addressed by making the internal status of the system (e.g., communication status and data freshness) naturally transparent on the feedback screen.

V. Conclusion

We investigated two methods of display content customization to prevent loss of interest caused mainly by habituation during prolonged use of ambient displays. A prototype system aiming to motivate people to be active at home was implemented and evaluated in a 36-day user study with six participants. The implications of this study are as follows:

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- The negative feedback in the tree growth metaphor did not work effectively, especially for those who lost interest in the system. Negative feedback's timing or degree should be reconsidered.
- The effective customization methods varied depending on the motivation level of users for the use of the system: highly motivated users preferred ad-hoc customization; goal customization seemed to work for moderately motivated users, but they gradually became unmotivated; and poorly motivated users needed an approach other than customization.
- Although a function for prompting users to customize the display was implemented based on a preliminary experiment, it worked only once because of the inappropriate setting of a threshold value. Thus, the threshold must be redesigned.
- Distrust of the system was found in terms of the feedback rule (i.e., tree growth is only for time spent in the house) and system malfunction (i.e., failure in synchronizing between devices). These issues should be addressed to prevent loss of interest.

We will address these issues with a special focus on the functionalities of prompting the user based on the frequency of display viewing and relaxing distrust.

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