Designing Ambient Notification Devices to Mitigate Stress

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Summary

World Health Organisation predicts that stress will be one of the largest health issues in 2020. Due to the size of the issue concerning technology's impact on stress, this project focuses on reducing stress induced by notifications from mobile instant messages, received on mobile devices. With the aim of designing notification devices able to create awareness without inducing unnecessary stress, we present, in this paper, the design and deployment of four ambient notification devices; *Polaris*, *Monsoon*, *Framify*, and *Blossom*.

The design choices of the prototypes were informed by our pre-thesis in which five notification modalities and their effect on stress was studied. The study results indicated that different modalities induced different levels of stress as well as momentary notifications induced more stress than prolonged. Furthermore, a design workshop with six interaction designers was conducted to explore ideas on how to design ambient notification systems. Together with the participating designers a condensed list of design guidelines was created to guide the design of the Ambient Notification Devices.

An exploratory field study was conducted in which the ambient notification devices were evaluated with seven participants, who were asked to use the ambient notification device in a four-day device deployment. Each participant was given an ambient notification device which was set up in their home.

We found they successfully created awareness, albeit less than mobile devices when delivering notifications. By creating less awareness, the participants perceived our ambient notification devices as less obtrusive than their mobile devices. Furthermore, we observed a tendency that the participants found ambient notifications to be less urgent than mobile device notifications. However, the effect our ambient notification devices have on users' stress, is only suggestive. To verify whether ambient notification devices affect stress, a longitudinal study in which physiological measure are made, should be conducted.

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ABSTRACT
Stress is a global health issue. Technology, and in particular mobile instant messaging notifications, is actively contributing to the increase of stress. We designed and prototyped four ambient notification devices, the purpose of which are to create awareness while mitigating stress induced by notifications. A qualitative exploratory field study was conducted to evaluate our prototypes' ability to create awareness without inducing unnecessary stress. We found they successfully created awareness, albeit less than mobile devices when delivering notifications. By creating less awareness, the participants perceived our ambient notification devices as less obtrusive than their mobile devices. Furthermore, we observed a tendency that the participants found ambient notifications to be less urgent than mobile device notifications. However, the effect our ambient notification devices have on users' stress is only suggestive. To verify whether ambient notification devices affect stress, a longitudinal study in which physiological measures are made should be conducted.

INTRODUCTION

The term stress is often used to describe various busy situations and contexts. Stress, from a health perspective, is induced by *stressors*, which create a response affecting most of the body physically and mentally [27]. The World Health Organisation predicts stress will be one of the most significant global health issues in 2020 [26]. Maier et al. [30] analysed technology-related stressors' effect on people, concluding IT can be considered a cause of stress. Similarly, [29] report the negative effects of technology-induced stressors on job satisfaction and workplace exhaustion. Furthermore, research shows that mobile instant message notifications induce stress, negatively impacting users [e.g. 5, 6, 10, 17, 20, 21, 24, 28].

Due to the challenges concerning technology's impact on stress, we have, in this paper, focused on stress induced by notifications from mobile instant messages. Our goal is to design a notification device which can create awareness without inducing unnecessary stress. Notifications are defined as auditory signals, visual cues, or haptic alerts generated by an application or service to relay information outside of a user's current focus of attention [9]. Furthermore, mobile device notifications are typically delivered instantly when receiving, e.g. a message or reminder [18]. A simple solution to eliminate stress induced by notifications would appear to be removing notifications entirely. However, [10] showed removing notifications, and therein, the awareness of received messages increase users' stress. We explore the potential of ambient displays as notifications, aiming to balance awareness and stress. To contribute to research into notifications delivered by ambient displays [e.g. 2, 3, 4, 8, 11, 14, 15, 16, 18, 22], we designed, prototyped and deployed four ambient notification devices, to create awareness and mitigate users' stress in the home. We chose to design for the home to assist users in disconnecting with technology while at home. The choice was partly made due to people relying on their mobile devices during work and may, therefore, appreciate being made instantly aware of notifications. Design choices were informed by our previous work [12] in which five modalities and their effect on stress was studied to create design implications for less stressful notifications. The study results indicated different modalities induced different levels of stress, and momentary notifications induced more stress than prolonged.

Each of our ambient notification devices was deployed twice, and we found they successfully created awareness while remaining unobtrusive. Also, our devices' created awareness, combined with an ambiguous representation of received notifications, made the participants unconcerned with notifications delivered during the device deployments. The participants perceived the ambient notifications to be less urgent, as opposed to mobile device notifications, which make each notification appear urgent. We also found that our devices may have had a positive effect on the amount of stress induced by notifications. This can, however, not be verified without conducting more studies which investigate the effects of ambient notification devices on stress.

RELATED WORK

In this section, we present related work on ambient displays and artefacts in relation to notifications. The presented related work will highlight how existing displays and artefacts can be used to create awareness while limiting the amount of induced stress.

Ambient displays are aesthetically pleasing displays aimed at leveraging the attentional scope of people by non-stressfully presenting information in the periphery of a user's attention [2, 16]. We, therefore, focus on *ambient notifications* which [18] define as *"the idea of slowly and gently catching a person's attention towards an upcoming notification over time"*. By slowly making users aware of upcoming events, we allow users to focus on their primary task, which may reduce the amount of stress induced by notifications [18].

Müller et al. [18] present an example of an ambient notification system; *Ambient Timer*. The purpose of which was to continuously remind users in an office space of upcoming events without being obtrusive. It conveyed the information using the user's peripheral vision around a computer monitor in a manner that allowed the user to focus on executing a primary task while being made aware of an upcoming event. The Ambient Timer was an RGB-LED frame mounted on the back of a computer monitor, the purpose of which was to emit light onto a wall which in turn would reflect the light. The light would increase in obtrusiveness over time to switch from pre-attention to divided attention, creating awareness while enabling users to complete their primary tasks sensibly [18]. The authors found Ambient Timer able to compete with traditional reminder notifications. Ambient Timer shows it is possible to use light to unobtrusively create awareness through users' peripheral vision, meaning our ambient notification devices can be designed to operate in users' periphery and still be able to create sufficient awareness.

Another ambient notification system is presented by [4]. The authors created an ambient soundscape which notified users through auditory icons embedded into the soundscape. Soundscapes are defined by [1] as the acoustic counterpart to landscapes. The ambient soundscape is composed as a piece of music to which particular instruments or motifs work as notifications. These instruments are composed in a manner which enables them to be added to the soundscape without deteriorating the quality of the overall composition. The authors could, therefore, make subtle changes to the soundscape, which is only noticed by the users who chose an instrument as their notification prior to a test conducted by the authors [4]. The soundscapes presented in [4] consisted of musical compositions with fixed cores to which several optional elements could be added. The fixed core is the backbone, providing a musical structure in terms of rhythm and melody. These optional elements are instruments or musical elements not present in the fixed core. The musical elements can be additional motifs or rhythmic patterns. The user decides which optional element will work as their notification; for instance, a user can designate a drum fill or the addition of a piano as their notification. After choosing an optional element, the soundscape is played in the user's environment and because only the individual user who chose the optional element has learnt it. The notifications will only be noticeable to this user and remain unobtrusive to other people in the vicinity. Jung et al. [13] evaluated the ambient soundscape and found it could successfully notify participants without becoming obtrusive to other people in the same environment because the notifying elements was an integrated part of the overall composition. Furthermore, [13] found that the effectiveness of the soundscape was equal to or better than normal notifications in terms of identifying them. However, the notifications from the soundscape had an increased reaction time. We should consider designing an ambient soundscape with embedded auditory icons as it may be able to deliver less stressful notifications because the notifications would be prolonged, which [12] indicated was less stressful than momentary notifications.

Seah et al. [22] present the multimodal ambient notification display *Sensabubble* which deliver notifications by generating scented bubbles. These bubbles are produced in specific sizes and filled with fog containing a scent relevant to the notifications. By presenting the notifications multimodally, Sensabubble combines a fast, visual, approach with a slow persistent approach. The visual presentation consists of the bubble and a projection of service (e.g. Facebook's or Bluetooth's logo) lit onto the bubble. This presentation will instantly inform the user of a received notification. However, should the user miss the bubble; the scent will continue notifying the user when the bubble bursts, dispersing the scent and leaving a perceptible trace of the notification which lingers in the air. Sensabubble shows how multiple modalities can be combined into one notification device. This knowledge can be utilised as a tool to adjust the amount of awareness created, in that it is possible to create an ambient notification device which employs both momentary and prolonged notifications.

DESIGN WORKSHOP

We conducted a design workshop based on the related work and the findings of [12] exploring ideas on how to design ambient notification systems. Six interaction designers participated in the design workshop. These were briefed in the findings of our earlier work [12] as well as key points of relevant research. The design workshop consisted of three stages; demonstration of ambient notification prototypes, discussion about delivery of ambient notifications, and creation of design guidelines for ambient notification systems for the home. In the first stage, a series of lo-fi prototypes of ambient notifications were demonstrated; the purpose was to inspire the designers before initiating the second stage. Much of the design workshop was spent the second stage as the discussion created the basis for design guidelines for ambient notification systems created in the third stage. These design guidelines, alongside the related work, became the foundation of our ambient notification designs.

The second stage of the design workshop facilitated an insightful and inspiring discussion in which the main question was; *What is the home, and how do users want to be notified in it?* The initial discussion highlighted the diverse interaction between people and technology in the home; the designers explained how people either put away their phone when they get home or kept it close in case, they would receive anything important. This led the discussion into how the modalities; light, scent, shape-change, and sound could be applied to the home as ambient notification systems. The designers pointed out that using these modalities as ambient notification systems could serve two purposes, mainly notifying users but also as an effect of the ambience help establish an atmosphere or mood in the home. In theory, this could work as [19] showed that scent could invoke feelings, and therein be able to affect the mood of the users. However, while discussing scent as an ambient notification system, some concerns rose. These primarily focused on how external factors would impact scent; for instance, how would cooking or an open window affect them? Cooking often omits strong scents which may obscure or hide the scent notifications. Similarly, a breeze from an open window might disperse the scent notifications. However, an ambient scent notification system may work efficiently, if used in a localised and stationary situation such as a workspace in which an ambient notification device is placed on a desk near the user.

A finding presented to the designers described peoples' stress increase when notifications are turned off opposed to having them turned on [10]. In relation to ambient visual notifications, a designer feared the lack of sound might cause the notifications to appear turned off, having the same effect on users' stress. This prompted a discussion on whether ambient notification devices should replace or supplement the mobile device notifications. It was also discussed whether users wish to be notified in every room of the home, suggesting ambient notification devices should be a mobile supplement to regular mobile device notifications. However, a designer suggested the ambient notification devices should be an integrated part of the home interior, arguing homeowners are aware of their interior and will easily notice change. As an idea, the designer suggested a wall hung picture which changed visual appearance when the user received a notification was presented.

The designers, furthermore, discussed the effect and role of ambient soundscape notification systems in the home, whether they should be nature-based or based on the existing soundscape of the home. Concerns were voiced about a nature-based soundscape may create an *alarm clock effect*. The effect was described as the phenomenon when a melody has been used as an alarm clock for a time and afterwards invokes the feeling of being woken up whenever it is heard. For instance, if a soundscape used chirping birds as a notification, the users may begin to think they received a notification every time a bird chirp. An ambient notification system based on the existing soundscape of a home may create less of an alarm clock effect, as the sounds used would already be familiar to the users. However, notifications integrated into the home interior should strive to be subtle to avoid notifying any other than the receiver as some user find notifications to be a private matter [21].

In the third and final stage, the participating designers were asked to condense a list of design guidelines for ambient notification systems based on the prior two stages. Four design guidelines were created:

- An ambient notification system;
  - should not replace the mobile device but act as a supplement
  - should be an integrated part of the home
  - must not reveal any intimate information about the receiver's notifications
  - should be adaptive to individual user's needs and lifestyle

Figure 1: The four ambient notification devices; (A) Monsoon, (B) Polaris, (C) Framify, and (D) Blossom.

DESIGN AND PROTOTYPING

In this section, we present four prototypes of ambient notification devices; *Polaris, Monsoon, Framify,* and *Blossom* (Figure 1), as well as the choices made during the design and development phase.

The prototypes were developed based on the related work and the design guidelines. In addition to the devices themselves, the necessary software to tunnel mobile notifications through our prototypes has also been developed. Each prototype implements ambiguous design elements, allowing users to interpret received notifications [7]. In doing so, we enable users to make their own decisions concerning whether the received notifications require immediate actions. Our previous work [12] showed the suddenness of a notification induce stress, by implementing ambiguity, we aimed to remove the suddenness and thereby mitigate said stress. Furthermore, we aimed to design the ambient notification devices to be aesthetically pleasing to make them more integrable with existing home décor.

Polaris

Polaris is a prototype of an ambient light notification device, developed to imitate the northern lights and project this onto a wall (Figure 3). As default, Polaris will project nuances of green and blue, as these are often the colours people link to northern lights. The colour of Polaris will turn gradually more yellow and red as the users receive notifications (Figure 2). The yellow and red colouring is dependent on the number of received notifications, the more unread notifications the users have the more yellow/red Polaris will be. The design choice of imitating the northern lights was based on the discussion of the workshop; ambient notification systems may be able to help create an atmosphere of a room. With the imitation of the northern lights, we aim to create a calm and soothing expression.

Figure 2: A graphical representation of Polaris' gradually changing colours; from left (no notifications) to right (maximum number of unregistered notifications).

The choice to project the light onto the wall was inspired by [16] in which an ambient light prototype was presented. This prototype consisted of a floor lamp which increased and decreased its intensity, depending on the amount of sunlight present outside. The users who evaluated the prototype perceived the light as too bright. By projecting Polaris onto the wall, we avoid making it too bright as the users are not directly exposed to the light. Instead, the light from Polaris is reflected by the wall, causing the light to be fainter and less obtrusive. The colour change was similarly designed to be subtle to avoid becoming too attention grabbing in contrast to the purpose of creating less stressful notifications.

Figure 3: Polaris project an imitation of the northern lights onto the wall.

To create the effect of the northern light, we placed an LED ring containing 24 RGB LED inside a 3D printed shell with four slits (Figure 1.B). Due to the displacement of each LED in relation to the slit, the light from each LED exists the shell at four different angels. By doing so,

Polaris effectively project 96 induvial artefacts onto the wall. The LED ring is divided into four sections, each displaying a different colour. When a user receives a notification, Polaris will slowly change the colours one section at a time, creating a morphing effect.

Monsoon

Monsoon is an ambient soundscape notification device (Figure 1.A) designed to play a continuous background track and notify users by playing sounds relating to the background track, inspired by [4]. However, unlike [4], we chose to design Monsoon as a nature-based soundscape. This choice was partly inspired by [32] in which a study showed the participants actively used sound as sonic decoration. Some of the sounds included water features and wind chimes as the participants used these to create desired ambiences. With Monsoon we aimed to create an ambient notification device which users could use as a sonic decoration in the home, creating ambiences as well as notifying. The background track of Monsoon is the sound of rain, and to notify users the sound of thunder is played. We added the rumbling sound of distant thunder, to indicate the number of received notifications. The frequency at which the rumbling is played increases or decreases depending on the number of these. Monsoon consists of a speaker and a Raspberry Pi fitted into a box, the purpose of which was to hide these while giving it a simple aesthetic expression. The users can adjust the volume and turn the device on/off, using a volume knob placed on the front.

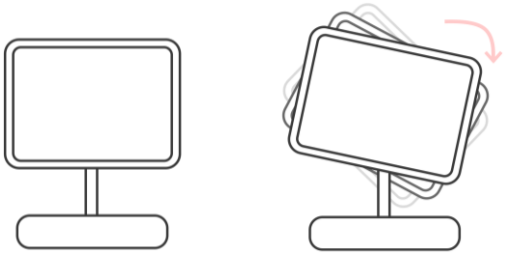

Figure 4: Framify's angle of tilt increases or decreases based on the number of unread notifications.

Framify

Framify is an ambient shape-changing notification device (Figure 1.C), inspired by the idea presented in the design workshop; that notifications could be an integrated part of the home in the form of a changing picture. However, instead of using the picture, we adapted the design to use the frame of the picture to notify users, simply by tilting it. The angle of the tilt increase based on the number of unread notifications received by a user and decreases when notifications are opened (Figure 4). To control the angle of the tilt, we use a servo motor attached to the back of the frame. The choice to tilt the frame was inspired by the ambiguous display presented by [23] in which a picture frame was connected to a table and tilted whenever weight was placed on said table. The original idea presented during the design workshop concerned a wall hung picture, we changed the design to a picture stand which can be placed on any flat surface. This allows users to freely place and move Framify around their home, unlike if it had been a wall hung picture.

Blossom

Blossom is an ambient shape-changing and olfactory notification device, the design of which is heavily inspired by a blooming flower (Figure 1.D). When a user receives a notification, Blossom will open its five petals and diffuse a scent into the air (Figure 5), further enhancing the illusion of a flower. However, the petals do not open completely when a notification has been received, as Blossom indicate the number of unread notifications by 'blooming' more, or less (Figure 5). Blossom is the only ambient notification device which uses a combination of modalities. This decision was based on the concerns raised during the design workshop; that scent may be obscured or disperse, as well as the findings from [12] which discussed similar issues found in scent as a notification. We, therefore, decided to develop a prototype implementing two modalities; shape-change and olfactory, to ensure users would receive their notification even if they do not sense the scent.

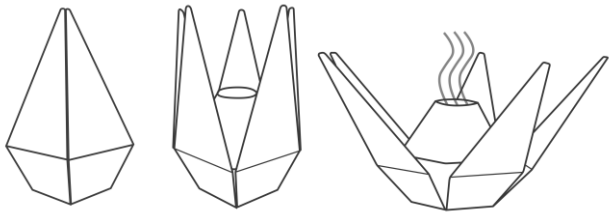

Figure 5: Blossom 'blooms', by moving the petals and diffusing a scent, the degree at which it opens is dependent on the amount of received unread notifications.

Blossom consist of three sections; a core, a water diffuser, and five petals. Each petal has an upper and lower part connected by a joint to better imitate the movement of real flower petals when opening and closing. In closed state, the upper parts of the petals are angled inwards, while the bottom part is angled outwards, causing the petals, by default, to open. This is, however, prevented by a stepper motor placed within the core to which the upper part of each petal is connected. The stepper motor is able to gradually release the petals, providing us with full control. The last section of Blossom consists of a water diffuser and a container

filled with enough scented water to allow Blossom to create scent for five hours continuously.

Mobile Application and App/Device Communication

To tunnel the mobile notifications through our Ambient Notification Devices, we developed a mobile application which implements a notification listener service, able to intercept notifications from various instant messaging services; e.g. Messenger, Snapchat, WhatsApp, Hangouts. Furthermore, the application can identify when received notifications are opened or dismissed. If a user performs either action, the ambient notification device will reset, returning it to its default state. The application is designed to run as a background service, meaning users are not required to use it actively. The application ignores traditional 'silent, sleep, or do not disturb' modes, meaning the ambient notification devices will produce notifications, despite having any of these modes enabled. Providing users with the option to choose whether they want to use our ambient notification devices as their only notification source, it is, however, also possible to turn the ambient notification devices off via the application.

Our mobile application communicates with our ambient notification devices via a cloud-based server, eliminating any network dependency which means the system does not require the user to be connected to the same network as the Ambient notification device. Furthermore, this setup did not require the users to pair their mobile devices to our ambient notification devices. Technically the mobile devices communicate with the ambient notification devices via IoT WI-FI boards [33] implemented in Polaris, Framify and Blossom. Monsoon uses a Raspberry Pi to communicate as it has a sound interface, unlike the IoT boards.

DEPLOYMENT

In this section, we present a qualitative exploratory field study in which four ambient notification device prototypes were deployed and tested with users. The purpose of the study was to gain insight into how ambient notification devices can be designed to induce less stress while creating awareness.

Participants and Setup

We recruited seven participants (aged between 21-28, 2 female and 5 male). All participants regularly used mobile instant messaging for communication. The study was conducted as an exploratory field study. Each participant was given an ambient notification device which was set up in their home and connected to their mobile device. The participants were asked to use the ambient notification device for four days.

Procedure

The study included a four-day prototype deployment in which the participants were asked to use the provided ambient notification device while at home as well as two semi-structured interviews. On the first day of the study, each participant was interviewed about their mobile device habits in relation to mobile instant messaging and notifications as well as looking into how they feel notifications affect them in their daily lives. After concluding the preliminary interview, each participant was given an ambient notification device which they were asked to use the following four days. On the fourth day of the study, another interview would be conducted as part of a debrief, this time looking into the experience of using the ambient notification device, primarily focussing on whether they felt stressed using the notification device opposed to using regular mobile device notifications.

FINDINGS

In this section, we present our findings from the deployment of our four prototypes; Polaris, Monsoon, Framify, and Blossom as well as the interviews conducted before, and after each deployment. The findings mainly fall into two broad categories; Mobile Notification Habits, and Ambient Notification Systems.

Mobile Notification Habits

This section will highlight common themes which became apparent through our interviews.

Important is Personal

A major theme, appearing in the preliminary interviews was the distinction between important and unimportant notifications. When participants explained the frustration of receiving unimportant notifications, they were asked to describe what made notifications important to them, and the general response was; the notification had to have a personal stake. Meaning the notifications had to be a personal message to the receiver, or the receiver had to be personally invested in the content of the notification. A quote highlighting this attitude was expressed by a participant, during a preliminary interview, explaining that a notification from the service Pinterest used the same earcon, as her SMS. *"It's stressful because it uses the same sound as my SMS, and when you hear it, you think 'Wow, I've got an important SMS', but then you look, and it just says 'you probably like this forest too' or something. I only click on it to remove 'Unread'"*. Several participants described

unimportant notifications as emails, one of which said; *"I think it's way too often I check the phone, and then it's just some stupid spam mail. I believe it's only about fifty per cent of the time that I actually receive something I want to see"*. This feeling of important notifications was even distinguished to the point of group chat, not being defined as important by one participant; *"There's too much trivial information because, again, it's not meant for me, it's a group thing. There is nothing directly for me; it's more indirectly"*, furthermore, highlighting the importance of not notifying recipients of non-personal notifications as this often, caused frustration.

Mobile device Usage in the Home

We found participants fitted into two groups based on their mobile device usage in the home; participants who use their mobile devices as entertainment devices, and participants who put their mobile devices away when they get home. A participant of the former group was asked to describe her usage; *"in public, I often use it to listen to music while commuting but mostly just to check the time. At home, I just use it to play on"*. This quote is very representative of this group. When a participant of the latter group was asked, he replied: *"I usually just put the phone on the table somewhere when I get home"*. These groups should be considered when designing notifications as users should be enabled to adjust an ambient notification device to cater to their individuality and differences in daily practices.

Ambient Notification Systems

In this section, we present the findings concerning our ambient notification devices. The section is divided into three themes; awareness, stress, and personalisation.

Awareness

We found that each ambient notification device had successfully created awareness while remaining subtle and passive. The participants generally displayed a positivity towards the ambience as it provided them with notifications without becoming obtrusive. One of the participants using Polaris described the ambient notifications as 'soft' notifications, which he elaborated as not being intrusive or insisting. When asked about what effect he felt Polaris had, he responded: *"you become less aware of notifications, unless you focus on it"*. The feedback Polaris got, generally indicate it creates less awareness in comparison to a mobile device and as an effect makes it less obtrusive, which is emphasised by the following quote *"It isn't obtrusive as it stands there, it's seemingly anonymous. I have to actively seek it out"*.

This quote adds something interesting in that he describes how he actively sought the device in order to be notified. When inquired, he elaborated his comment *"you have to actively check for notifications with this, opposed to the phone which actively approaches and affects you"*. The participant also related this to auditory and olfactory notifications and explained how he found these to be more intrusive because one cannot turn off one's hearing or sense of smell, but one can easily look away. Comments about actively turning attention to the ambient notification devices was a reoccurring theme expressed by several participants. However, not all participants saw it as a positive feature, a participant using Monsoon criticised the visual modalities, explaining visual modalities are like a phone, in that one would actively have to look at them to check for notifications same as how one check their phone. She preferred sound because it allowed her to focus on something while remaining reachable, which made scent intriguing to her because it would furthermore allow her to listen to music while being notified.

Despite the mostly positive feedback given to our ambient notification devices, we found some participants felt the devices did not create sufficient awareness of notifications. This was particularly apparent with Polaris, a participant explained; *"I thought it didn't work at one point, not that I didn't receive anything, I just couldn't see if anything happened"*. When the second participant to use Polaris was asked about his experience relating to the ambience, he replied the colour change was at times too similar, that it had to turn more reddish before it caught his eye. Similar issues were found in Monsoon and Blossom, with a participant using the former stating; *"Either you didn't hear it rumble or you had to concentrate on listening for it"*. Blossom, however, had not one but two issues; the scent was not noticeable, and the shape-change too ambiguous to clearly communicate the number of received notifications. The participant using Blossom saw the latter as a significant issue because she often used the number of notifications to determine whether it was urgent to respond. The uncertainty created by the ambience may have introduced a new issue as a participant stated he might have spent more time looking at his phone during the study, in an attempt to understand how the ambient notification device worked. Indicating an ambient notification system should not become ambient to the degree at which it fails to inform the user without certainty.

Stress

When interviewing the participants, we found that most participants felt the ambient notification devices induced less stress than their mobile devices. The main reason for this was, according to the participants, the less obtrusive

way the notifications were delivered. A participant using Framify stated; *"I think the picture is less stressful than notifications from the phone because the phone vibrates and stress you whereas the picture frame does it discretely"*. Another finding we believe affected the amount of induced stress was an indifferent behaviour towards the notifications which was adopted by many of the participants. The participant using Blossom described an experience which highlights this behaviour very well; *"I think it was very pleasant when it opened […] because you wouldn't stress but instead slowly realise 'oh, something's there', but it was definitely more pleasant than the pling sound Messenger has"*. Most participants explained how they would sort of dismiss the notifications when delivered by the ambient notification devices.

We could argue this behaviour is present because we have managed to eliminate the suddenness of the notifications which our previous work found to prompt immediate action [12], and stress participants. Instead, the ambient notification devices slowly catch the attention of the participants prompting a dilatory action. It is caused by the possibility of getting notified in 'retrospective', meaning the participants can leave the device and return to it later. One of the participants using framify described such interaction; *"One of the better interactions with the frame was when I arrived home and saw it was crooked because it reminds me of messages I've dismissed earlier and forgotten about"*.

However, one participant was more stressed by Monsoon when comparing it to his phone; *"I actually think it was stressful to listen to the rain and then it suddenly rumbles. I would rather just have my phone vibrate on the table"*. Monsoon was interesting in terms of stress as the two participants using it had opposite opinions about it. The other participant described the calming properties of Monsoon, *"It was kind of like white noise, background noise, I think it is nice, it didn't bother me at all. I definitely found it to be relaxing"*. This show the individual preference plays a significant role in the stress induced by different devices, both ambient and mobile.

Personalisation

We found preference and individuality played a central role, in how the participants received our ambient notification devices. One of the best examples of this is the very different opinions about Monsoon, one participant disliked it and found it stressful, and the other thought it to be relaxing. This indicates that soundscapes used as ambient notification systems should be catered to the individual user or provide enough variety of sounds to allow users to adjust the soundscape to their liking. As suggested by a participant; *"It's a bit weird, looking out a window, see the sun shining, and then hear rain, maybe you could change it to a summer sound"*.

The theme of personalisation appeared during most debriefs while discussing how our ambient notification devices could be improved. Mainly two subjects were discussed; integration into the home, and display of service. The former subject was often discussed in relation to Polaris, one participant stated; *"I think there's something to it, using the light and getting some distance to the phone, but in my experience, I doubt green and blue light is the best solution […] it stands out a lot in relation to the rest of the décor, it becomes a lot like a party lamp. I think it would fit much better into a modern home"*.
The participant suggested using a white/yellow glow like natural light lamps rather than the colours, due to the colours feeling out of place in his home. The other participant using Polaris was, however, more interested in making it a more integral part of the home, suggesting it could be built into the backlighting of a TV or a ceiling lamp. He implicitly emphasised the importance of subtlety as he continued this line of thought in relation to a ceiling lamp, *"[Polaris] has that dynamic light, you could make something which changed naturally. Not a flash or disco in the kitchen"*. A participant using Framify also argued that it could genuinely become part of the home if users considered the device while decorating the home, giving it its specific spot.

The second subject concerning the ability to display services was mentioned in relation to Framify and Blossom. A participant using Framify described, how knowing which service notifications stem from, could help in deciding whether the received notification was important *"[…] it would've been nice if it showed which service received a message. […] I don't want to see the message if it's from Whatsapp whereas I'm more prone to check messages from Messenger"*. The subject was also discussed in relation to Blossom, which a participant suggested each petal could become a service, thereby, providing users with more information about received notifications. This could help users make an informed choice regarding the importance and urgency of the received notifications.

Concerning importance and urgency, one participant suggested turning the concept of our ambient notification devices upside down; have our devices receive all the unimportant notifications while the mobile device only received important ones. This could

indicate an ambient notification system may be able to mitigate the frustration experienced when receiving 'spam' notifications, by physically separating unimportant notifications and the mobile device.

DISCUSSION

In this section, we discuss the presented findings and their implications towards designing ambient notification systems which aim to create awareness while mitigating stress. We will discuss this in relation to; mobile device versus ambient notifications, awareness of ambient notification devices, personal preference, and novelty effect.

Unconcerned with Notifications

This section discusses the difference in participants' attitudes shown toward notifications delivered by mobile devices as opposed to notifications delivered by our ambient notification devices.

Our findings indicate our ambient notification systems generally were able to create awareness without inducing unnecessary stress. It was particularly apparent in the different behaviour the participants had towards notifications delivered by our devices, compared to notifications delivered by their mobile devices. During the preliminary interviews, participants expressed their frustration when receiving a notification, believing its important, only to find they have received an unimportant notification. This frustration was caused by participants mostly feeling obligated to check their mobile device notifications. However, we were able to identify a trend in our participants' feedback. They were generally more unconcerned with notifications during the device deployment. This change in behaviour may be due to the way the notifications were delivered. Our previous work [12] found that momentary notifications prompted immediate action, whereas prolonged notifications did not. Most notifications delivered by mobile devices are momentary, whereas our devices are designed to slowly gain the users' attention prompting dilatory action. Furthermore, we found a lack of information can make notifications less important. By ambiguously representing the number of received notifications, we encourage users to interpret the urgency. Opposed to the mobile devices which provide a new momentary notification every time something is received, making every single notification seem urgent and important.

Balanced Awareness

In this section, we discuss where our ambient notification devices fit in terms of awareness. The findings indicated our devices created a balance between a lot of awareness and none. It was pointed out by a participant using Monsoon who described the prototype as counter-intuitive because it was like halfway putting the phone away and using it. She mentioned it as an issue, causing her to doubt the usefulness of Monsoon. However, we argue it is quite the opposite as it supports our goal, which was not to create an alternative to 'do not disturb' mode but to design an ambient notification device capable of creating awareness while mitigating stress. By stating our device is an in-between solution to a phone with notifications turned on and 'do not disturb' mode. The participant's feedback indicates our ambient notification devices are a step in the right direction as they can create awareness but do not equal a phone. It creates a space where users are aware of notifications but not the content, which may be another reason why the participants became unconcerned with notifications delivered by our ambient notification devices.

Personal Preference

This theme highlights the apparent effect personal preference had on the participants' reception of the ambient notification devices as well as how they preferred to receive their notifications. Drawing lines to findings in *Mobile device Usage in the Home.*

Our findings showed that personal preference played a significant role in how our ambient notification devices were perceived as well as how they were used. Particularly when it came to how the participants approached the devices, like the findings presented in *Mobile device Usage in the Home,* participants either wanted to be actively approached by the devices or actively seek them. Furthermore, the response gathered from the debriefs called for added customisation to the devices, which resonate with the design guideline *'An ambient notification system should be adaptive to individual user's needs and lifestyle'*, despite not fulfilling this guideline, the findings validate the importance of the guideline. To successfully integrate an ambient notification device into the home, it should provide sufficient customisation to enable users to make the device personal.

However, personal customisation may introduce an issue as a participant using Framify explained having a more personal picture such as his girlfriend in the frame would have affected him more because he would not want the picture to be crooked. This might become a stressor as seeing the tilted frame could prompt immediate action, similar to a momentary notification, to avoid a tilted picture of his girlfriend.

Novelty Effect

This section discusses the possibility of a novelty effect and learning curve introduced by the ambient notification devices as well as how it might have influenced the participants.

We saw signs of novelty effect in our participants' feedback, as well as an indication; our ambient notification devices may have a learning curve. Many of the participants reported very actively keeping track of the ambient notification device given to them and comparing it to their phone, in an effort to understand the device. This might partly have been due to the ambiguous elements of the devices which encourage interpretation of received notifications by not giving the participants an exact number. Instead, the participants were given ambiguous signals indicating the number of received notifications. A participant commented she wanted the number of notifications to be displayed more obviously as she was the only one commenting on this, we suspect it is a matter of experience in reading and understanding the device rather than an issue of implementation. However, we cannot confirm or dismiss it without conducting a longitudinal study to test whether the ambiguity can be understood as well as see if participants, in time, would keep less actively track of the devices.

LIMITATIONS

We experienced three limitations when conducting our study; the duration of deployment, number participants, and instability of the prototypes. The four-day deployment limited our study as the novelty effect of the prototypes may have influenced the participants' behaviour towards them. Furthermore, the small number of participants only provide us with limited insight into the effect of ambient notification systems on stress. A limitation introduced by Blossom was instability of the prototype as it broke down during the first deployment, limiting our feedback to one participant. However, this was not unexpected as [31] described how shape-changing interfaces are not suitable for long-term use due to their fragility caused by complex hardware.

FUTURE WORK

We have found there is a potential for Ambient Notification Devices in creating awareness while mitigating stress. However, as the deployment period of our study, was only four days with seven participants. Future work calls for a longitudinal study with more participants to verify the effect of ambient notification systems on stress as well as determine the influence of novelty effect. Furthermore, creating and exploring alternative designs of ambient notifications employing the same modality could outline the challenges in designing ambient notification devices. This could also further the exploration of the balance between awareness and stress to help find the find optimal solution.

We found participants did not see one notification as being important. Research into the effects of not notifying users of a single notification but instead waiting till multiple have been received before informing the users could be interesting. As it may highlight the threshold at which the number of notifications is considered important or urgent. Similarly, research into the type of notification and its perceived importance could help determine what makes a notification important or urgent.

CONCLUSION

We have, in this paper, presented four designs of ambient notification devices for the home, aimed at creating awareness while mitigating users' stress. We created prototypes based on a design workshop and previous work. These were evaluated in a 4-day exploratory field study in terms of their ability to create awareness and deliver notifications without inducing unnecessary stress. We found that each ambient notification device successfully created awareness, albeit less than mobile devices. The awareness created by our devices, in combination with an ambiguous representation of the number of received notifications, made participants unconcerned with notifications delivered by our ambient notification devices. Participants found these notifications to be less urgent, prompting dilatory action when receiving them. Opposed mobile device notifications which prompt immediate action, making each notification appear urgent. The findings suggest our ambient notification devices had a positive effect on the amount of stress induced by notifications. However, in order to verify it, we will need to conduct a longitudinal study in which physiological measures are taken to precisely determine the stress induced by notifications delivered via our ambient notification devices.

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