IdleStripes Shirt - Wearable Display of Sedentary Time

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ABSTRACT

Prior work on clothing with integrated displays has typically presented catwalk-style garments, with light output from hundreds of LEDs. In contrast, we present the IdleStripes shirt, a garment for normal daily office wear, that encourages the wearer to avoid long sedentary periods through an integrated ambient display. Rather than adding the display functionality to an existing shirt, we present a process where a clothing designer designed the smart garment from scratch, in this way creating a more aesthetic and comfortable garment. A display element in the upper chest area of the shirt utilises cloth with embedded optical fibers, stripes of which illuminate based on the wearer's inactivity. Taking a short walk then resets the display. Participants in an in-the-wild user study wore the shirt during their normal working day, and, e.g., report positively on the design of the garment and their willingness to wear it. Those that were not already frequently active during their working day, reported that the shirt encouraged them to break their sedentary behaviour and take short walks.

Author Keywords

Ambient Displays, Wearable Displays, Activity Tracking, Wellness, Sitting, Design

INTRODUCTION

Wellness tracking technologies are increasingly being adopted, and today, people commonly use step-counters, activity bracelets and various mobile applications to monitor their physical activity. Especially, there are vast amounts of smartphone apps targeted to people aiming to change their habits towards a more active lifestyle. The smartphone user interface is not optimal for the purpose of creating awareness of the current activity level, as the habit of checking it can easily create a longer distraction from other tasks [26]. More pervasive and subtle means for creating awareness are needed, such as ambient displays at the periphery of the user's attention [20]. Ambient displays present the information in an unobtrusive manner, and can maintain privacy better than explicit visualization techniques. When presented in an ambient way, the activity tracking data visualization carries meaning for the user, but may not be directly interpreted by others.

Figure 1. The IdleStripes shirt

Technology development has enabled everyday objects to be enhanced with integrated technical solutions, and clothing offers an interesting platform for mobile ambient displays. Clothes are personal items, through which the wearer can express themselves. Utilizing clothes as a wearable ambient display provides interesting opportunities, where the data visualization can be entwined with the aesthetics and style of the garment. The traditionally rather static clothes then adopt a new design dimension with a dynamically changing outlook.

In this paper, we present the design, prototype and in-the-wild evaluation of the IdleStripes shirt, which integrates an ambient display to increase awareness of the wearer's sedentary sitting time during a typical office work day (Figure 1). Reducing sedentary time at work has been highlighted as an important factor in wellbeing [4], and products such as the

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PerDis '20 June 4–5, 2020, Manchester, United Kingdom

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ISBN 978-1-4503-7986-1/20/06…$15.00

https://doi.org/10.1145/3393712.3395340

Apple watch have included features specifically aimed at reducing sitting time. As a contribution, we present a smart garment designed from scratch, following a clothing design approach, to incorporate an ambient display. We report on the in-the-wild evaluation of the shirt during a normal office work day, highlighting issues related to acceptance and motivation. This work extends our previous introduction of the concept [14] with an in-the-wild user study.

RELATED WORK

Relevant prior work comes from the areas of clothing-integrated wearable displays and activity tracking. Concepts incorporating publicly-visible wearable displays and exploring the public/private boundaries of sharing of activity and physiological data are of particular relevance.

Clothing-Integrated Displays

The most common output mechanism employed in clothing-integrated displays is through LEDs, e.g. [23, 29, 30, 32]. Well known examples being catwalk or stage pieces such as the Cute Circuit Galaxy Dress [1], that includes 24000 LEDs. Such pieces are driven by aesthetic design goals, rather than information presentation. Bigger et al. explored the incorporation of optical fibers in cloth as an aesthetic output, reporting that the approach has potential for daily-wear apparel [3]. Other approaches have utilised a non-illuminating electrochromic display [31], and thermochromic dyed fibers and heating elements to create fully garment-integrated displays [9, 35]. Kan et al. have proposed social textiles to support social interaction, and presented a prototype of a shirt which dynamically displays letters and words [17].

Displays on outfit accessories have been demonstrated in handbags [7, 18]. Wearable displays with functional, rather than aesthetic, purposes have primarily focused on accessory form factors such as watches and bracelets, e.g. [11, 36]. Exceptionally, Juhlin et al. [16] presented a fashion wearable watch face, which matches its colours to match the user's outfit. The dynamicity of electronics eases the possibility to update the outlooks of the outfit, which could be attractive feature for fashion designers [18, 37].

Sharing Activity Data

The majority of research and commercial concepts for display of activity or physiological data have primarily been targeted to the wearer themselves, for instance Gouveia et al. exploring design for wearer glancability [13]. Several studies have shown that sharing activity related data can increase motivation for being physically more active [25]. For instance, benefits have been reported related to sharing activity data within a group of peers [34], where the sharing initiated discussion in the group on a wider range of health and wellbeing topics. Focusing on outdoor sports, Fedsov et al. discuss the goals of sharing different types of performance data within a social group [10]. In a study of activity tracker users [2] 36% shared their data online, whilst a larger 72% reported sharing their data verbally, to those around them. Choi and Jiang [6] report social sharing improved the performance of a health tracking intervention, and that the improvement did not diminished over time. Sharing activity data on social media with a like-minded group of friends has been identified as correlating with long-term engagement [27].

Wearable Public Display of Wellness and Activity Data

There are a limited number of works on clothing-integrated displays that present personal performance information for others e.g. [22, 32]. Mauriello et al. demonstrated a running shirt-integrated display showing information for other runners [22]. The wearer's heart rate is displayed on a shirt in Schneegass et al.'s study [32]. Both of the previous examples display information in an explicit format, rather than aiming towards ambient aesthetic visualisation. More ambient approaches have been taken e.g. in MacLean et al.'s MoodWings, where a wearable butterfly displays the wearer's stress level, encouraging self refection [19]. Focusing on wearable display of personal activity data, Colley et al. present a model, highlighting the different motivational criteria for wearer visible vs. public visible data [8].

Summary

From prior work in the area we learn that sharing activity data with a close social group can have motivational effects. Whilst there has been research on wearable display of activity and physiological data, this has so far either been displayed exclusively for the wearer, or has been explicit in format. With the IdleStripes shirt concept, we we aim to explore the domain of a wearable public display of activity data, using ambient visualisation.

THE IDLESTRIPES SHIRT

The Idle Stripes shirt is a office business-wear shirt, which integrates an ambient display in the bodice area. The display consists of stripes of fiber optic material, which create a subtle effect when illuminated. The display gradually illuminates based on the wearer's sitting time, so that all the stripes are lit after 60 minutes inactivity, which is the recommended maximum time for continuous sitting [4]. After the wearer gets up and walks 10 steps, the inactivity time is reset and the stripes illumination turned off. This visualization approach leverages the finding of prior work on peripheral displays e.g. [24, 21, 15].

The design seeks to take into account the sociocultural aspects of the use context, by utilizing materials and forms familiar to typical office wear. The aesthetics of the design as well as a business casual wear look were considered important drivers for the social acceptability of the garment. The style is informal and a common style in offices where is no specified dress code.

THE DESIGN

Design Process

We began the clothing design process by sketching different scenarios for the garment and identifying the design space. In addition we used a day-in-the-life storyboard to visualize typical day of an office worker. The shirt format was chosen because it usually contains patterns and is a typical element in the business casual style outfit containing e.g. a shirt with jacket or cardigan and trousers or a mid/knee length skirt. The

silhouette of the shirt with loose fit and drop shoulder sleeves was designed to fit diverse body types. It also contains fake pockets in the side seams for housing a power source and an elastic tape in the hem, which keeps the fabric loose and away from the body. As we were aiming for an ambient, low light output display, we selected to use a fiber optic fabric for its subtle luminous effect [1]. To create side-glow light output from the chosen fabric, required the surface of the fibers to be carefully sandpapered.

Rather than adding a display to an existing garment, our target was to design the garment from scratch to include the fiber optic display as part of the garment structure and aesthetic. Thus, the display element, even in its non-illuminated state was considered as a design detail of the garment. From the clothing design viewpoint the focus was how to utilize the lighting effect and where to place the display elements. After exploring different possibilities for the placement and detailing, we selected to place the fiber optic panel in the upper chest area, where it was both visible to the wearer (in peripheral vision) and to others. From the clothing design point of view, the emphasized body part should be carefully chosen so it would be flattering to different body types. The bodice was chosen because people are used to showy collars and necklaces in the same area, and hence an display area would not be out of place. The pattern of the illuminated elements were chosen after a lot of sketches to be simple vertical stripes, which are also considered to be slimming elements.

For the final prototype material we chose to use silk. As a natural material, this created a contrast with the the synthetic fiber optic fabric and embedded technology. The selected material has a natural shine which we considered to complement and reflect the light output from the optical fiber element . It can also kept clean by ventilating. The design of the shirt followed the Spring/Summer 2019 season fashion forecasts, aiming for a timeless and sophisticated design.

Satin weave fabric has a smooth and lustrous surface and it is a good choice for blouses. However, silk satin is challenging material to sew because it snags easily. It requires e.g. very sharp needle and nonstick sewing machine foot to avoid snagging. The sewing of the shirt was considered in the design phase by simplifying the cutting. In the pattern making phase the inclined lines were reduced. The most difficult part in the sewing phase was to attach the LED panel's bottom and fabric together into a nice looking horizontal seam in the bodice.

Technical Implementation

Each set of fiber optic threads in the fiber optic fabric was illuminated with a high intensity LED. The connection between the LED and the fiber bundle of approximately 8 fibers was made using a custom designed and 3D printed connection piece [2], see Figure 2. The LEDs illumination was controlled using an Arduino microcontroller, which was powered by a small 5V powerbank located in the shirt's pocket (see Figure 3). The wearer's activity level was in measured by an

[1]https://www.sparkfun.com/products/12712, accessed March 2020

[2]https://https://www.thingiverse.com/thing:3202966, accessed: March 2020

Figure 2. The connectors for an LED and fiber.

Figure 3. Assembling and sewing the technology to the shirt.

Android smartphone running a custom developed application, which connected to the microcontroller via low energy Bluetooth. The application utilised the Google Fit step count API [3]. (Figure 4). The final prototype is shown in Figure 5).

Thus, for the shirt to display correct data, the wearer is required to carry the step-counting smartphone with them. This approach was chosen as, at the prototype stage, it was considered to be more reliable than implementing a standalone step counter in the shirt itself, and additionally enabled a settings user interface (UI) in the smartphone. Through this UI the user could set the amount of inactive time required to illuminate each stripe on the shirt, from 10 seconds to 15 minutes. When 10 steps walking were recorded, the sitting count was reset and all the display stripes were switched to the off state.

USER TEST

Method

To investigate perceptions of the IdleStripes shirt, we conducted an in-the-wild user study with six office workers, where

[3]https://developers.google.com/fit/scenarios/read-daily-step-total, accessed: March 2020

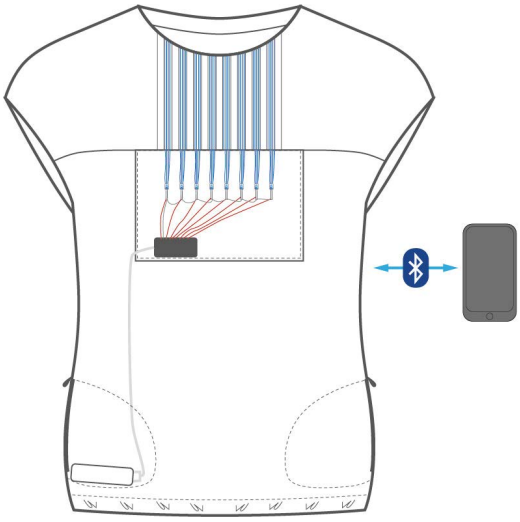

Figure 4. Sketch of the integrated technology. The LEDs are attached to fiber ends with 3D printed holders. The pockets includes power supply and mobile phone which communicates with the microcontroller via Bluetooth

Figure 5. The final prototype.

participants wore the shirt during their normal work day. After completing a consent form, the background for the study and the functionality of the shirt and connected mobile app were explained to the participants. For the study, the participants were provided with a smartphone with the step counting application already installed. Participants then completed a background questionnaire and put the shirt on. At the end of the test period, participants completed an end questionnaire and were interviewed about their perceptions of the concept. Participants were also photographed in their work-space doing their usual work tasks (Figure 6).

Participants

Participants were chosen as office workers, for whom the size EU 38 prototype shirt was suitable. Size EU 38 is the usual size for garment samples in the clothing design process. Participants were sourced from the administration, teaching and research staff at the University of Lapland, Finland. They filled the background questionnaire which included questions about their age, gender, prior use of activity tracking devices or applications and what were their first impressions of the IdleStripes Shirt.

One participant was in the age group 26-35 years, three 36-45 years, one 46-55 years and one 56-65 years. All but one of the participants described their daily work time as mostly or completely sitting. 2/6 considered they did not sit too much, whilst 4/6 reported sometimes sitting too much, noting that their work requires meeting people or that they forget the time when in a work flow. One participant stating, *"Taking breaks interrupts tasks that require concentration, but on the other hand taking breaks would prevent sitting for too long" (P2)*. Five of the six participants had or have previously had activity measuring equipment e.g. mobile apps, step counter or a heart rate monitor.

Participants described their usual office clothing as neat, casual and relaxed. To allow participants to select other clothing to match with the shirt, they were shown the shirt on the day before their test. All wore jeans or trousers and most (5/6) selected to wear a long sleeved shirt under the test shirt and/or a cardigan on top of the shirt. The participants were instructed to wear the shirt and carry the test phone with them for the duration of the study. Although the target was that participants would wear the shirt for the majority of their work day, flexibility was allowed if for individual reasons a participant needed to cut short the study.

Results

Experiences Wearing the IdleStripes Shirt

Participants wore the shirt for between 4.5 and 6 hours during the day. However, one participant only wore the shirt for 2.5 hours (P1). While wearing the shirt, participants continued their usual daily work tasks e.g. computer work, attending meetings, coffee breaks and lunch.

After the test period participants filled the end questionnaire where they reported the time of usage and where they used the shirt. In addition they described work tasks of the work day, what kind of clothing ensemble they wore and what they

Figure 6. The six participants in the user study wearing the IdleStripes shirt during their normal daily work

thought about the appearance of the shirt. Participants could also freely write their own comments.

All the participants reported positive first impressions about the shirt e.g. *"The material is very pleasant and for a shirt with embedded technology it is stylish"* (P5). All the participants considered that the shirt fit them well, was comfortable and nice to wear, commenting e.g. that it was indistinguishable from normal office wear. For instance, it was commented that *"As a technical shirt it was really beautifully made, and that was nice"* (P5). On the negative side, one participant commented that the electronics in the chest area pulled the garment down in the front, and another that the pocket for the powerbank was too loose. Most of the participants noted that the shirt worked well with their own clothes.

After the test period, participants were interviewed in their own offices. They were asked about using the IdleStripes shirt: how does it felt, how it worked with their own clothes and what they thought about the placing of the LEDs. We asked them to reflect does the shirt affected to their activity, how it affected and did they change their daily routines. All the participants thought the placement of the fiber optic light display panel was good. It wasn't a distraction while working, but could be easily seen with a glance, *"... you can see it, but not all the time so you have to look at it, so it isn't disturbing"* (P1). The subtle lighting effect was also noted as a suitable gentle activity reminder, *"It slightly started to remind that it would be time to move"* (P6). Half of the participants (3/6), reported that the shirt affected their activity, e.g., *"When I started look at the lights and if there was quite many lights lit it I felt that I should start moving"* (P5). Another commenting, *"... there came the feeling, that damn, I'm, sitting too much, and when there were people in the meeting with me, it was a even a little bit irritating that do I have to be here this long, I should be able to start moving already and not just sit here"* (P5). The main reason noted by the 3 participants that reported no effects from wearing the shirt, were that they already frequently move whilst working, e.g. changing posture, or moving their desk from sitting to standing mode.

In the end interview, we also asked participants if the IdleStripes shirt drew attention, did anyone comment it and if so what kind of comments did they get. They were also asked to ponder how they felt about the got comments or lack of the comments. All the participants stated that wearing the shirt was like wearing any other shirt and they did not receive any unusual attention or comments whilst wearing it. One participant speculated, *"The technology was well hidden and didn't draw attention, but maybe in a long meeting people would notice it"* (P6).

Participants' Design Suggestions

To guide further developments we also wanted to know what kind of suggestions would participants had. The end interview included questions about alternative design choices. Participants were asked their opinion about the illimination working in the opposite sense, i.e. the more you move the more light stripes illuminate and when sitting the lights would gradually go off, and would they want to set the timing parameters themselves. In addition participants were asked if they could imagine the lights placed somewhere else on the clothing or accessories. We showed them reference pictures and asked if the light would be embedded differently to the fabric e.g. LEDs as dots or rows , electroluminescent wire, or backlit collars or hems. In the end we asked what they would estimate that the price of the shirt would be and how much they would be willing to pay for such a product.

Participants gave many suggestions on the functionality and design of the shirt. Two participants (2/6) stated that they would prefer if the display worked in the opposite sense, i.e. activity illuminates light stripes and sitting switches them off. Other suggestions were relatively minor, e.g., enabling changing the brightness level of the display or its colour to match different clothing. When prompted to consider alternative locations for the display, all six participants proposed the sleeve or, if the shirt was long sleeved, at the cuff. The motivation for this location being improved display visibility for the wearer.

Participants' reflections on clothing-integrated technology in general were positive, preferring the approach to "plastic-looking activity tracker wristbands". Example comments being, *"Maybe you wouldn't remember to put on a wristband, but a garment would be nice to occasionally to wear and to see how much I'm sitting during the day. and because it is so nice looking and doesn't stand out"* (P5), and *"It would maybe lower the bar for use when everything is in the garment"* (P6). Maintenance requirements were also noted, particularly washing, to which two participants proposed modular technology that could be moved between clothes, *"It should be washable, and maybe (the technology) should be able to be transferred to another garment"* (P5).

DISCUSSION

In the following we discuss findings from our approach of holistic smart-clothing design, the perceived effectiveness of the garment in reducing sitting time, and highlight the limitations and next steps of our work.

Holistic Smart-Clothing Design

The common view of our test participants was that the IdleStripes shirt, regardless of any functionality it might have, was an attractive and comfortable garment that they would wear as their normal work attire. Here, our approach to the design clearly differed from the majority of presented garments with integrated displays, which have tended to be either technology focused [32] or catwalk/exhibition pieces [1]. This was enabled by a holistic approach to the design process, involving a clothing designer, and designing the overall garment from scratch, rather than simply adding active elements to an off the shelf garment. As a result, all the participants in our in-the-wild study were willing to wear the garment whilst going about all their normal work activities, including meetings etc.

Compared to many presented interactive clothing pieces, often involving large amounts of LEDs, embedded displays or even shape changing, our final garment and functionality may appear at first modest. However, aligning with the targets of Google's project Jacquard [28], this is precisely the contribution of the piece, to demonstrate the future direction clothing with invisibly embedded functionality.

Motivational Aspects

The target of the IdleStripes shirt was to improve the wearer's wellness though encouraging them to take short walks after a recommend maximum period of sitting [4]. Based on our user study the garment was successful in this respect, with all participants either noting that they were already sufficiently active, or that the shirt display encouraged their activity. As the shirt's display elements are situated on the outer surface of the garment, it potentially informs both the wearer and those around them, acting as a wearable public display (see e.g.[33]). Whilst related work has suggested that sharing activity data with friends and family is generally not motivational [12], we were interested to explore this from the context of a wearable public display with an ambient output visualisation. Our study findings suggest that the subtle ambient display was not perceived by the wearer as a public display, and hence their behavior was not strongly influenced by its visibility to third parties.

The issue of glancability [13], was raised by the majority of our participants, who found the current upper chest placement of the display sufficiently supported this requirement. The participants' suggestion for display placement in the sleeves or cuff of the shirt may create over-visibility, as, in computer based office work, the cuffs are continuously visible. Hence, alternative display placement will be interesting future work.

The 'polarity' of the information display, i.e. does it indicate active or inactive time was also raised by our study participants. Whilst prior work has highlighted the importance of information visualisation in wearable displays for encouraging activity [5], the issue of polarity is not specifically discussed. Interestingly, the Apple watch presents the sedentary time in the form of 'stand time'. The issue of display polarity is thus something that should be addressed in future works.

Limitations and Future Work

We acknowledge that our study was limited by the small number of participants (n = 6) and limited test time (*Med* = 5.5 hours). However, we consider our findings have validity as participants wore the shirt throughout their normal full daily work activities.

CONCLUSION

Designing the IdleStripes shirt fully from scratch, including clothing design and cloth selection as well as functional elements, resulted in a garment that was comfortable and attractive to wear during a normal office work day. For the shirt wearer, the fiber optic cloth based ambient display design, did not raise strong concerns based on its visibility to those around them. However, the display was considered aesthetic and glancable by the wearer. All our test participants reported positively on the shirt design and would be willing to wear it as part of their normal work wardrobe. Wearing the shirt motivated sedentary wearers to be more active e.g. to take short walks from their desk.

ACKNOWLEDGEMENTS

This research has been supported by a grant from the Academy of Finland as part of the TechFashion - Design of Future Wearable Computing project.

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