Make Me Move at Work! An Ambient Light Display to Increase Physical Activity

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***Abstract*—Physical inactivity has become a normal condition for many people today, and in the long run accounts for 1 out of 10 deaths world-wide. Long sitting periods have been shown to increase the risk of diabetes and cardiovascular disease. In this paper we propose MoveLamp, a system which helps to integrate physical activity into a person's workplace. An ambient light display in the office indicates a person's recent physical activity. While sitting at the desk, typically in front of a computer, the light display helps the person to keep track of his or her activity and encourages them to integrate a little physical activity into the day. Through a user study in which we measured the participants' physical activity by counting their steps, we show that MoveLamp can help office workers to both, increase their number of steps taken during a typical working day and move more frequently.**

I. Introduction

Physical activity is good for human health – too little activity can lead to serious illnesses, overweight or even obesity [1]. However, physical inactivity has become a normal condition for many people today, for several reasons, and in the long run accounts for 1 out of 10 deaths world-wide [2]. Physical inactivity does not only refer to the lack of the weekly sports exercise but the fact that physical activities are disappearing more and more from our private and working life [3]. Inactivity such as long sitting periods have been shown to increase the risk of diabetes and cardiovascular disease [4]. According to [4] this effect is even valid for people who meet typical daily physical activity recommendations. Another recent study supports the positive impact of active breaks during prolonged sitting on cardiovascular health [5].

If time at work is not combined with high physical activity, the questions arise: how might awareness for the lack of activity be raised, and how can physical activity be integrated into daily work routine? A way to increase physical activity would be to include activities like walking to colleagues instead of phoning them, using the stairs instead of the lift, or going to the kitchen for each glass of water instead of putting a filled bottle on the desk. However, office workers rarely take these opportunities.

We want to motivate office workers to take more steps overall and to move more frequently during their office day by presenting feedback on their current activity level in a motivational way. With MoveLamp, shown in Figure 1, we designed an ambient light display, serving as both an unobtrusive reminder to move, and as a feedback system on a person's recent activity during office occupation. We show, on the basis of the step count per day, that the physical activity during office hours significantly increased. In this paper, we present the related work, the presentation design of MoveLamp, and our user study with the evaluation results.

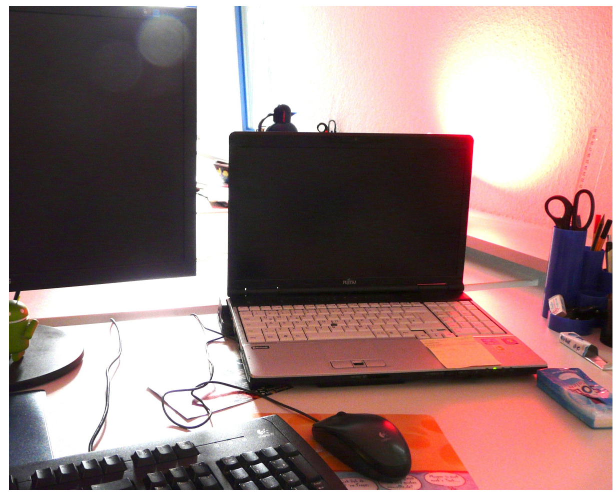

Fig. 1. MoveLamp in the office

II. Related Work

In this section, we discuss recent work which investigated the use of abstract displays to encourage physical activity. Jafarinaimi et al. proposed an ambient information system to motivate people to take regular breaks during desk work. They presented Breakaway [6], an ambient display which encourages its user to get up more frequently during desk work by imitating his or her posture through a small aesthetic sculpture placed on his or her desk. Sensors in the chair of the user measure his or her continuous sitting period and adjust the posture of the sculpture accordingly. The system Fish'n'Steps by Lin et al. [7] pursues the goal to increase the user's daily step count and presents feedback on the user's activity via a graphical ambient display. A virtual fish represents the user's daily step count and is presented on a common public display in the user's workplace. The fish's growth and facial expression is affected by the step count of the user. A similar, also metaphoric approach, but designed for mobile use was proposed by Consolvo et al.. They presented UbiFit Garden [8], a system which aims at supporting the user's overall physical activity by using the background screen of his or her mobile phone as an ambient information display. The user's weekly physical activity behaviour is displayed in terms of a blooming garden. Different types of flowers represent different, predefined types of single activities which the user has performed during the ongoing week. Butterflies indicate if s/he has reached his or her weekly activity goal.

Rogers et al. [9] explored more in general how ambient displays in an office space can influence people of one community to change their behaviour. They installed different types of ambient displays, like twinkly lights embedded in the carpet, in a large common area in an office building with the aim to entice people to use the stairs instead of the lift. In a user study they found that people changed their behaviour in that they used the stairs more often even though they were not aware of doing so.

However, to the best of our knowledge no research has yet considered to combine the support of both goals to (1) move more frequently and (2) take more steps overall. But investigations ([4], [5], [1]) show that both of these goals have to be considered in order to decrease the risk of serious non-communicable diseases. The work we present here is novel as it analyses the use of an ambient display which supports both goals. Fish'n' Steps and UbiFit do not support goal 1 in that they do not provide feedback on recent activity and do not challenge the user to move at a certain time. Breakaway does not actively support goal 2 as it does not track the activities which have been done.

III. Design

Considering our problem space and target group, we pursue three main design goals: the system should (1) support the user's awareness of his or her continuous sitting duration, (2) give feedback on the amount of activity the user has done recently, and (3) present the information in a motivational and unobtrusive way. We were inspired by the proposed design strategies to support behaviour change of Consolvo et al. [10], especially *Abstract & Reflective* (present reflective data in an abstract manner), *Unobtrusive* (present and collect data unobtrusively), *Public* (present and collect data in a way that does not make the user feel uncomfortable in public) and *Aesthetic* (device and display need to be aesthetic and comfortable).

As the use of pedometers to count steps is a prevalent, successful and *unobtrusive* method to measure physical activity in daily life [11], pedometers seem to be well suited to assess the office worker's level of activity. According to Tudor-Locke [11], the number of steps can be used to classify physical activity for healthy adults ranging from a sedentary lifestyle (<5000 steps/day) to a highly active lifestyle (>12500 steps/day).

Ambient light is suitable for displaying important, but non-critical information in an *aesthetic* way [12]. Unlike alerts, it is *unobtrusive* and can be presented over a certain period of time and is not restricted to discrete alerts as typical reminders. Additionally, it is easy to install in an office and should be inoffensive in office context [13]. MoveLamp (see Figure 1) shows the user's recent physical activity, which is aggregated from his or her number of steps taken recently and the time passed since his or her last movement, by means of a certain colour value (*Abstract & Reflective*).

MoveLamp (see Figure 2) consists of a pedometer application running on an Android smartphone (1), a stationary light display (5) and a desktop application to process the pedometer data and to control the lamp (3). While the user carries the smartphone, the pedometer counts his or her steps. Every 10 steps the smartphone transmits the current step count via Bluetooth (2) to the desktop application, which calculates a new colour value for the light display. The new colour value is based on the current colour of the display and the transmitted step count. The resulting colour is transmitted to the light display via radio (4), where it is displayed immediately.

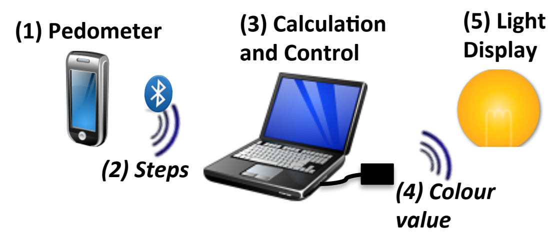

Fig. 2. Components of MoveLamp

Inspired by a preceding user study, our system uses the light pattern "linear gradient from green to red with increasing brightness", which proved to be a workable compromise between caused distraction and perceptibility, emphasises the critical phase (see below), and was as well favoured by the participants. In the user study we evaluated six different light patterns, regarding their applicability for the use in an office. These six patterns included variations of brightness, colour, gradients and blinking. We installed the light display of MoveLamp in the participants' office for two days and asked them to assess the felt *distraction from primary task* by the light, and their *awareness* of the light during their usual office work. The participants were not undeceived about the intended purpose of neither the light patterns nor the light display.

MoveLamp follows the idea of the state of a rechargeable battery: it discharges over time if the user is not walking and recharges if the user starts walking again. The light display shows the state of charge by changing from green (fully charged) to red (fully discharged) while additionally increasing brightness and vice versa (see Figure 3). The increasing brightness pattern enhances the challenge to move and was chosen because the preceding user study revealed

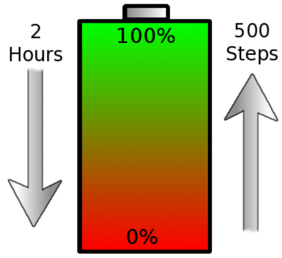

Fig. 3. The Battery Metaphor: Charging Behaviour

that increasing brightness has a strong effect on the user's awareness of the light. The complete light pattern runs for an interval of two hours. If the user has not been walking at all for two hours or longer, the display will shine red. If the user starts walking, the light will slightly change along the gradient from red to green according to the number of steps taken. To change the colour from red to green, the user needs to make 500 steps overall. If MoveLamp is completely charged, additional steps taken will be forfeited. If it is completely discharged, no further regression is rated until the user starts walking again. Overall, after a typical 8 hours working day, a user will have made 2000 (8/2*500) steps, if – when he started walking – he always walked just enough steps to make the display shine green. We calculated this value as follows: Following Tudor-Locke [11], 5000 steps can be taken as the lower threshold value for an at least reasonable daily activity. Considering an average sleeping time and a typical office day lasting 8 hours each, we define 2000 steps as the minimum daily step goal during office work.

IV. Experimental Method

We evaluated MoveLamp in a user study with 10 participants to investigate if office workers firstly, increase their number of steps taken and secondly, increase the frequency of single walking activities when using MoveLamp, compared to when using a common step count display only.

For the study, we used a recent Android smartphone (HTC Desire, Android 2.2) with the installed pedometer application. The smartphone was placed in the trouser pocket of the participant and sent the measured sensor data via Bluetooth to the laptop which controlled a Philips LivingColors lamp standing in the office in the lateral peripheral view of the participant. Additionally, the smartphone displayed the user's step count numerically. For the control condition, we only provided the smartphone. 10 participants (2 female) from different offices in the area of Oldenburg volunteered to take part in the study. Their average age was 29.6 (SD = 11.9). They all stated themselves as not being colour-blind and as typically sitting and working in front of a computer for at least 6 hours a day. None of the participants was paid for taking part in the study.

We used a repeated measures design, i.e., all participants contributed to both conditions, and alternated the order of conditions to cancel out sequence effects. The displayed colour value of the ambient display served as independent variable. In the experimental condition, the ambient light display provided visual feedback and the current step count was displayed numerically on the smartphone's display. In the control condition, no ambient light display was provided. To measure the number of steps taken and the walking frequency for each condition, we counted the number of steps and the number of single walking activities as the dependent variables. To assess the walking frequency, we divided each study day into periods of 20 minutes each and investigated whether the participant made at least 20 steps during a period. If he did, we defined and counted this as an activity.

Participants took individually part in the study. Each study session included a short introduction, the study itself lasting for two non-subsequent days, and concluded with a post-hoc interview after each study day. During the introduction, the participants learned about the procedure of the study. After they signed an informed consent, they were equipped with the smartphone. For the experimental condition, the ambient light display was installed in their office. Then, the participants engaged in their usual office activity for 6 to 8 hours, depending on their working hours. The participants were instructed to follow their normal daily office routine, which was defined as "preponderantly sitting", and to avoid unusual activities. We logged the number of steps taken with the appendant timestamp. In the experimental condition, the light display continuously showed visual feedback. At the end of each study day, we conducted a post-hoc interview in which we asked for the experience and general acceptance regarding the system, and for the subjective assessment of the user's physical activity. One week later, the participants took part in the second study day, whose procedure was the same as for the first study day.

V. Results

Per participant we logged step data for averagely 434.6 minutes (control condition, SD = 73.9) and 438.5 minutes (experimental condition, SD = 66.2). Thus, the typical working day we investigated lasted for about 7 hours in average. As we gathered data from different time periods, we use relative values for the analysis.

Figure 4 shows the average number of steps per minute per participant for both conditions. Participant 2 did only keep the concerted daily routine on one of the two study days, as we found out from the analysis of her step data and the post-hoc interview. She admitted that she went shopping on the day of the control condition. Regarding this, we do not consider a comparison to be valid and excluded her dataset from the analysis of the number of steps.

The mean number of steps per minute was 3.24 (SD = 2.51) in the control condition and 5.10 (SD = 3.47) in the experimental condition, which yields an average increase of 57.48%. This difference was statistically significant ($p < 0.01$, two-tailed t-test). Thus, these results support our hypothesis that participants take more steps when using MoveLamp.

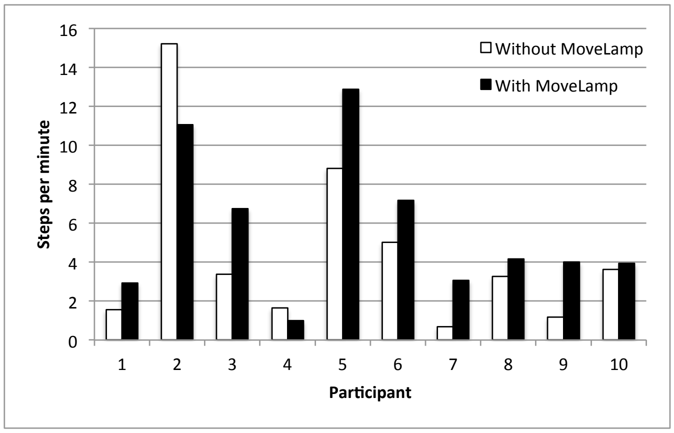

Fig. 4. Average number of steps per minute per participant with and without MoveLamp

The mean number of single walking activities per hour was 1.07 (SD = 0.05) in the control condition and 1.30 (SD = 0.06) in the experimental condition. Thus, participants increased their average walking frequency by 21.64%. This difference was statistically significant ($p < 0.05$, two-tailed t-test). Hence, also our second hypothesis, that participants move more frequently when using MoveLamp was supported.

From the post-hoc interviews, we gathered further, qualitative feedback on MoveLamp. In the control condition, nine participants controlled their step count via the displayed numerical value on the smartphone, but in doing so, none of them felt positively influenced in his or her activity performance. The measuring data confirms this. In contrast, in the experimental condition, eight participants reckoned that MoveLamp had a positive effect on their activity, whereas only participant 2 and 10 negated this. As the measuring data shows, participant 10 was wrong and actually, MoveLamp had a slightly positive effect on his activity. In general, MoveLamp was found to be pleasant. Nine participants stated that MoveLamp was not or negligibly distracting them from their primary task. Two participants felt disturbed by the smartphone in their trouser pocket. Four participants explicitly stated green and one yellow as a pleasant phase. Five participants mentioned red as the light phase which was particularly sticking out and three of them explicitly termed it as obtrusive. Participant 3 did not like MoveLamp. He found it obtrusive and felt pressurised by the light. Six participants stated they could imagine to use MoveLamp also during meetings in their office, thanks to its ambient character.

VI. Conclusions

This work contributes to the field of pervasive healthcare technologies in that it shows, for activity-supportive technologies there is value in presenting time-referenced data into feedback about physical activity. The work we presented is novel as it analyses the use of an ambient display, MoveLamp, which supports both goals to (1) move more frequently and (2) take more steps each day overall. Our study results show participants increased their number of steps taken during a typical working day by averaged 57.48% and moved by averaged 21.64% more frequently. In addition, the results indicate that a combined ambient light pattern, in particular a gradient from green to red with increasing brightness, which simultaneously provides feedback on both goals works well in a system designed for encouraging physical activity. However, due to the short duration of the study, it cannot be ruled out that MoveLamp's novelty effect was the cause of the activity improvement. Our light design is limited to people who are not colour-blind. Also, pedometers allow only a limited view on the user's physical activity as they can not measure other popular activities like cycling or swimming.

In the future, we need to analyse long-term effects, i.e. if MoveLamp's positive effect will remain even after a long period of use. Furthermore, the privacy concerns of such public displays should be investigated.

Acknowledgment

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