Pediluma: Motivating Physical Activity Through Contextual Information and Social Influence

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ABSTRACT
We present Pediluma, a shoe accessory that tracks and visualizes the wearer's physical activity by varying the intensity of a lighted enclosure. In particular, the more physically active the wearer is, the more the device glows. We hoped the desire to maintain a positive, "glowing" state would encourage users to engage in more physical activity. We describe our two-week, four-condition, 18-participant deployment and user study. Results indicate participants wearing our device were more physically active than participants in our three control groups (each isolating different design and experimental factors). We share the many lessons we learned from our iterative design, post-deployment data analysis and interviewers with participants.

Author Keywords
Wearable computing, persuasion, captology, smart clothes, visualization, ambient information, behavior change.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: Graphical User Interfaces. C.5.3 [Microcomputers]: Portable devices.

General terms: Human Factors

INTRODUCTION
Motivating behavior change is a considerable challenge. People find comfort in familiar routines and attitudes, and naturally resist change, even if to their benefit. Computing technology is increasingly being applied in persuasive ways in order to promote behavioral change [10,20]. Previous efforts have primarily relied on two methods to motivate users: 1) displaying timely and relevant information, 2) and leveraging social influence.

One approach to promoting behavior change is to target the point-of-decision. This is the point when people consult their memories for relevant information, and attempt to make informed choices about how to proceed. Any pertinent information injected into the environment at this moment will be salient. This salience often makes the information highly influential. This strategy has been leveraged in numerous domains, including physical activity [2,31], diet [15], energy conservation [1,13], recycling [14], and water usage [5]. Furthermore, although some recommendations have universal applicability (e.g. consuming less sugary drinks), many systems tailor the information they present to a particular user. Doing so allows the information to be far more relevant, and ultimately more effective.

A second approach to promoting behavioral change is to use social influence. The desire to project a positive image to other people is often at the root of behavioral changes [7]. Technology can amplify this effect by enhancing the communication and interaction between users and the people they interact with. For example, social networking can be used to stimulate competition or facilitate support groups (see e.g., [1,20,32,36]), both of which motivate behavioral change. Additionally, public commitment has been shown to significantly improve the likelihood the associated behavior change will be achieved [17,23].

DEMONSTRATION DOMAIN: PHYSICAL ACTIVITY
We capitalize and extend on the aforementioned effects by designing a new persuasive technology to support behavior change, specifically in the physical health domain. Lack of physical activity is regarded as a "public health crisis," leading to a wide range of health problems, including coronary heart disease, type II diabetes, cancer of the colon, and many other ailments [22]. It has been shown that as little as 30 minutes of moderate physical activity four or more days a week can provide substantial health benefits [22,28]. In particular, walking can be easily incorporated into everyday life and sustained into old age [26], thus offering the best opportunity to impact personal health [21].

PEDILUMA
We developed Pediluma, a shoe accessory designed to encourage opportunistic physical activity (Figure 1). It features a light that brightens the more the wearer walks and slowly dims when the wearer remains stationary. This interaction was purposely simple so as to remain lightweight, both visually and cognitively. Even simple, personal pedometers have been shown to promote walking [6]. Pediluma takes this a step further, attempting to engage people around the wearer to elicit social effects. It should be noted that lights have been previously incorporated into shoes

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Figure 1. Pediluma strapped to a shoe and fully lit. Inset: The covered Omron HJ-112 pedometer that all participants would wear to log their step counts.

(e.g., UFOS [8], L.A. Lights [12]). However, this is the first time they have been used to display motivational information. We also draw upon decades of research into the larger field of wearable computers.

Design

Pediluma expresses *personal* information about the wearer's walking to motivate physical activity. Mounted on the top (as opposed to, e.g. the heel) of the shoe, Pediluma is visible to the wearer, serving as a *personal* display, and to other people, serving as a *public* display, alerting them to the wearer's recent physical activity. This, in turn, might promote discussion, encouragement, and/or other social pressures. Pediluma also acts as a *persistent* display that can continually remind users of their walking behavior. Located on the shoe, the information is *peripheral*, allowing users to engage in other tasks without excessive distraction or discomfort. Furthermore, the light only brightens when users are walking (i.e., making progress), coupling the visual response with their *present* activities. This brightening, which occurs during walking may serve as a *positive* reinforcement. Lastly, we hypothesize the desire to maintain a *positive* state could encourage the wearer to engage in more physical activity [30].

The decision to place Pediluma on the shoe was motivated by several factors. Foremost, this location provided the highest accuracy to sense walking [16]. Additionally, the weight and size of our prototype device, complete with sensors, microprocessor and batteries, was less obtrusive here, both to the wearer and onlookers. Moreover, feet are generally located in the periphery of one's vision during most physical activities, and often entirely hidden when working (e.g., in a seated position or tucked under a desk). Finally, unlike other articles of clothing, shoes have an obvious conceptual connection with walking and other physical activities, unlike, for example, the waist.

To refine the design and increase utility and appeal, we employed a user-centered strategy to design the hardware, software, housing and harness. The authors wore the earliest prototypes, allowing for major issues to be identified. This was followed by iterative pilot presentations of the device to potential users. Feedback collected during these sessions was used for further refinement. This process led to the creation of five distinct designs, each with a unique circuit board, lighting array, control logic, housing, and harnessing (Figure 2 illustrates three major revisions).

Early prototypes featured a longitudinal electroluminescent wire, which provided excellent visibility from all angles. However, the high power consumption would have limited battery life to three days. Focusing on improving battery life, they were substituted with low-power LEDs. The housing had to be adapted to diffuse the light from a point source. Durability was also crucial to successful deployment. To ensure proper operation and to test the robustness of the hardware and harnessing, the authors wore each version for several days. We learned of the need for a secure harness to prevent the devices from flying off the shoe from vigorous activity.

Implementation

The final prototype is small: measuring 4.5x6x3cm, weighs 50g with batteries, and boasts roughly 500 hours of run time on three AAA batteries (Figure 2, right). Substantial effort was invested in making the units energy efficient, small and robust – all units had to survive real world deployment without the ability to recharge or reset for more than a week (all units did). We now briefly discuss implementation specifics.

Various sensors were considered for step detection. Although many advanced pedometers use accelerometers, they were unnecessarily complex for our needs. Piezo films are

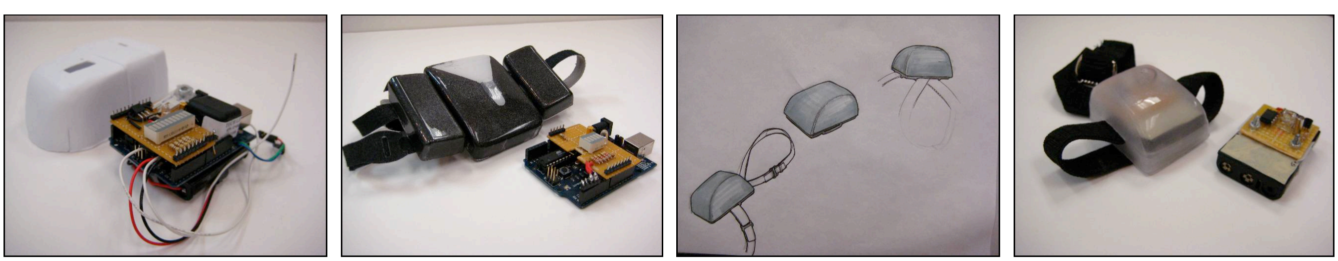

Figure 2. From left to right: 1) First prototype using an Arduino and electroluminescent wire. 2) Second prototype using "wings" for batteries to achieve a flatter profile. 3) Sketch of final design. 4) Photo of final PIC-based Pediluma platform.

simpler, but require calibration to reduce false positives to an acceptable level. A tilt switch proved to be a simple and robust solution. When oriented vertically, the sensor trips whenever an impact (acceleration) of 1g or greater occurs. In addition to capturing walking steps, this sensor also reliably captured motion in a variety of other contexts, including dancing and bicycling.

Our prototype uses light to convey the wearer's current and recent walking activity. If the wearer has remained stationary for a length of time, no light will be emitted. As the wearer begins to walk, the light will quickly brighten to indicate increasing levels of activity. When the wearer stops walking, the light will slowly decay in brightness until it returns to an inactive state. The growth and decay of brightness has been designed to change linearly with step accumulation and time, respectively. We utilized Stevens' power law [33] to linearize the perceptual brightness.

The rate of brightness change was calibrated such that walking was quickly rewarded to motivate even brief actions, while decay was calibrated to be slow to leave a lingering impact of recent walking activity. For a comfortable walking speed of 3mph, Pediluma would light up to maximum brightness in 5 minutes, and when stationary, it would take 15 minutes to decay fully. If the wearer walks for more than 5 minutes, internal points for walking effort were accumulated to a threshold such that the light would remain at maximum brightness for sometime before decaying.

Initial prototypes were developed on the Arduino platform [4]. Our final prototype utilizes a diminutive, down-clocked (for greater energy efficiency), PIC processor. The electronics were housed in a custom enclosure vacuum formed from frosted PETG plastic (Figure 2). Various shapes and sizes for the housing were tested — the final shape being a compromise between a stylized, aerodynamic look and volume minimization. The housing comprises two tightly fitting pieces that form a strong and tight seal. This is water resistant to protect from rain and sufficiently rigid to protect the electronics from shocks and drops.

Experiences with several mounting techniques (e.g., clips, Velcro, nylon) led to the use of rubberized straps to secure the device to the foot. We developed a double-looped design, with one strap going around the bottom of the foot and the other around the ankle. This harness is secure enough such that the user can engage in vigorous activity (e.g. running, jumping, and biking) without Pediluma shifting position or slipping off.

RELATED WORK

B.J. Fogg has established seven strategies of persuasive technology tools: *reduction*, simplification of a complex task; *tunneling*, expert guided persuasion; *tailoring*, presentation of personally relevant information; *suggestion*, point of need intervention with compelling suggestion; *self-monitoring*, automatically tracking desired behavior; *surveillance*, observing one's behavior publicly, and *conditioning*, or the reinforcement of desired behaviors [10]. Given the appropriate cultural background, these strategies for persuasion may be more effective than suggestion.

Kahled proposed that collectivist cultures are more receptive to suggestion while individualist cultures are not. This theory reasons that while collectivists are already used to "acting upon the suggestions of others," individualists focus on their personal values and priorities to determine their choice of action [18]. Considering this, collectivists in an established group may be more receptive to a suggestion in the context of other's perceptions and progress, where as individualists may be more responsive to the strategies of personal feedback established by Fogg [10]. In many ways, western culture can be classified as individualist, calling demand to the exploration and implementation of these persuasive tactics.

Persuasively influencing behavior [7,19] through point-of-decision displays and ambient visualizations has been explored in a variety of prior projects. Our work builds on this by exploring the highly personalized experience inherent in a wearable point-of-decision display with a personal and public ambient component.

Consolvo et al. developed Houston [9], a software application for the mobile phone that allows users to track and share their progress toward a physical activity goal. Two versions of the software were created: a personal version for reviewing personal history, and a sharing version, which allowed groups of people to view each other's progress and communicate. Results from a user study showed that participants using the sharing version were significantly more likely to meet their physical activity goals. The authors discuss numerous qualitative effects they observed, which they use to make a set of design requirements.

An extensive literature review by Andrew et al. [3] produced a comprehensive mapping of the design tactic space of persuasive technologies in the health domain. Their paper identifies three exemplary technologies: ViTo, a point of need system for monitoring and influencing TV watching [24], MPTrain, an augmented music system that detects heart-rate as the wearer is running and selects the next song by either higher or lower beats per minute in order to influence the target heart rate [27], and the Nike+iPod [25]. These systems are compared on both technological dimensions (subtleness, display, notification modality, context source, timeliness, and interactivity) and content dimensions (specificity, affect, adaptive affect, argumentation strategy, overtness, explicitness, and social components).

IMPACT is a system for monitoring personal health while providing the context for a specific activity [11]. The objective is to bridge the gap between perceived and actual behavior by informing wearers about which daily activities have the greatest impact on their health. With this knowledge, the user is able to make healthier activity decisions. Instead of providing the information in a reflective context, as IMPACT does, Pediluma displays impact of daily activities in real time.

Bridging the domains of health and conservation, Waterbot provides information at the point-of decision when people are using a sink [5]. Waterbot utilizes light and sound to indicate water usage for hygiene and water conservation. Through this lighting display, users gain information about the temperature of the water, the duration they have been washing, and a comparative indication of their water use in relation to the other members of the household. Although similar in some ways, Pediluma differs in its user-centric rather than household-centric focus and application to the physical activity domain. Also, Waterbot is a solitary experience, whereas Pediluma is designed for social settings.

USER STUDY

Eighteen participants were recruited using an email campaign (7 female, 11 male) for a two-week study, for which they received a small payment. The participants had a mean age of 30 (min=21, max=53) and represented a diverse range of physical fitness levels.

Following the methodology employed in [9], to better ensure our sample sufficiently represented the population at large, a preliminary survey was given that incorporated the *Sample Physical Activity Questionnaire to Determine Stage of Change* [34] to measure people's Transtheoretical Model (TTM) stage of behavioral change [29]. Our assessment indicated that participants were at a variety of motivation stages regarding their physical activity: 2 contemplation, 3 preparation, 1 action, 11 maintenance (of which 5 had no intention to change). Previous research efforts have tended to recruit only motivated participants. However, using participants with a strong predisposition to wanting to increase their physical activity introduces a significant experimental bias. Although harder to achieve motivational effects with potentially unmotivated participants, we believe this choice yielded a more real-world study outcome.

For a baseline, at the commencement of the study, all participants were asked to wear an Omron HJ-112 pedometer for one week (see Figure 1 inset). This served only as a sensor, recording participants' daily step counts. The pedometer's buttons and display were covered so participants could not tamper with their data. This also prevented wearers from viewing their step counts and setting personal goals — an effect we were not measuring. Participants were given no instructions other than to wear the pedometer whenever possible. At the conclusion of the first week, the experimenters met with each participant and recorded the step counts from the pedometers for the past seven days. Participants were not told what their step counts were. This initial period was used to establish each participant's base level of physical activity.

In the second week, participants continued to wear the covered pedometers. However, they were also randomly assigned to one of four conditions, balancing for their TTM motivation stages. For each TTM stage, participants were randomly assigned to each condition until the conditions were each populated with four participants. By week two, one participant dropped out, leaving 17 participants. The extra participant was assigned to the *Pediluma condition*.

The four conditions were as follows:

Control - Four participants continued to wear only the pedometers given to them in the first week. They were given no new instructions or devices to wear.

Pediluma - Five participants were given full-featured Pedilumas. Each featured a light that grew in intensity in response to a user's physical activity.

Random Light - Four participants were given devices that looked identical to the full-featured Pediluma. However, the lighting behavior was random and was not associated with the participants' physical activity. This condition was included to test whether the mere presence of a lighted, but non-informational shoe-mounted device would increase physical activity. The behavior of the lighting display was programmed to mimic a full-featured Pediluma, including frequency, duration and intensity.

No Light - Four participants were given devices that looked identical to the full-featured Pediluma, but did not utilize lights or sensors. This condition acted as an additional comparison, testing to see whether the mere presence of a shoe-mounted device would increase physical activity.

Participants were not given any new instructions or hints that the objective was to increase their physical activity. For the two conditions with lights, participants were simply told, "here is the device you are going to wear on your shoe. You will notice that it has a light that varies. The light is related to the unit's operation." For the non-lighted condition, only the first sentence was spoken. This was necessary to minimize any demand effects. At the conclusion of the second week, data from the pedometers was recorded. Similar to week one, participants were not told their step counts.

We aimed to investigate if participants in the *Pediluma condition* would benefit in several aspects when compared to the *Control condition*. We also hypothesized that the other two intermediate conditions (*No Light* and *Random Light*) would perform no worse than the *Control condition*.

Over the course of the two-week study, three surveys were administered — one in the beginning, middle, and end. The first survey measured participants' initial state, including their TTM motivation stage towards physical activity. This information was used to ensure a balanced distribution of participants in different stages into the four conditions introduced in week two. These questions were also included in the following two surveys to detect if there were any subsequent motivational changes, though no significant changes were detected. The second survey was administered at the conclusion of week one, but before participants were given the shoe-mounted devices that they would wear for the next week (all conditions except *Control*). This survey captured participants' experiences with the covered pedometers and posed several scale questions to measure their awareness and attitudes towards physical activity.

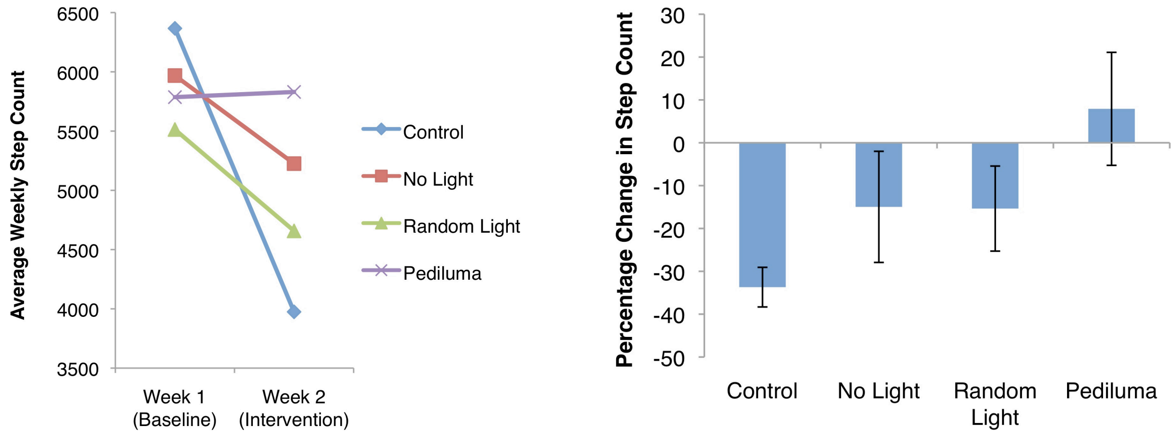

Figure 3. Left: Change in step count from first to second week. Notice that all conditions except Pediluma decreased. Right: Mean of percentage difference of each participant by group. The Control condition decreased the most, the No Light and Random Light conditions saw similar, although less dramatic decreases, while Pediluma condition step counts increased.

Additionally, a social confidence scale from the Jackson Personality Inventory (JPI, 1994) [34] was included to learn if the devices influenced peoples' behavior or attitudes. The concluding survey once again captured participant's awareness and attitudes towards physical activity for comparison.

At the conclusion of the study, questions were posed to gauge participants' experiences with the shoe-mounted devices: how much the devices were noticed, who noticed and remarked about them and how much, and whether participants found the devices useful and liked them. Additionally, participants were interviewed for approximately half an hour. This covered a variety of topics, mostly qualitative in nature, including how they felt about the device (if they wore one), if and how others reacted to it, and other body locations for the device that might be preferable to the shoe.

RESULTS

We collected two weeks (baseline and intervention) of pedometer readings, and three survey responses from each of the 17 participants. Due to a pedometer setup error, data from one participant in the *Pediluma condition* had to be discarded (leaving four participants' data in that condition). Anomalies in pedometer step count were noted and dropped when verified through interviews as abnormal behavior (e.g. some participants had days with particularly low count, due to forgetting to wear the pedometers; some pedometers recorded zero count on some days possibly due to resetting by accidentally pressing a covered button; one participant was sick for two days). Even though there were fluctuations in the TTM motivation stages through the repeated surveys, the changes were statistically insignificant and not unique to any condition. As such, there remained no significant imbalance in TTM motivation stages across the conditions. As an additional reliability check, social confidence scores were computed. This also revealed no significant differences amongst the conditions.

Of immediate note is that participants in all *non-Pediluma conditions* decreased in step count from week one to week two, while participants in the *Pediluma condition* did not (Figure 3). This is likely attributable to the Hawthorne and novelty effects wearing off, as well as varying environmental conditions that could have hindered walking. We found a significantly greater number of steps taken by those in the *Pediluma condition* when compared to the *Control condition* ($M=7.9\%$ vs. $M=-33.7\%$, $t[6]=2.98$, $p<.05$). Although only a preliminary finding, it does suggest Pediluma has some motivational effect. Moreover, Figure 3 shows that the *No Light* and *Random Light conditions* slightly outperformed the *Control condition*, revealing the magnitude of the novelty effect of introducing a device in week two. However, this difference is not significant, indicating that novelty was not a major effect.

During the study, there were no significant changes in attitudes towards physical activity and health. This suggests that the change in walking behavior for *Pediluma condition* may had been a subconscious decision. Similarly, we did not detect significant differences in how participants perceived other people influencing their physical activity, or vice versa. However, our data suggest that wearers were reminded of the device by catching it in their peripheral vision, and through social interaction when other people noticed the devices.

As shown in Figure 4, participants in each condition noticed their shoe-mounted device at significantly different levels of frequency ($F[3,13]=14.7$, $p<.01$). As expected, participants in the *No Light condition* noticed their device fewer times a day when compared to the *light-enabled conditions* ($F[1,13]=7.48$, $p<.05$). Interestingly, participants in the *Random Light condition* noticed their device the most (although not significantly so). This could be due to illumination occurring at unexpected times, thus catching the wearer's attention. In the *Pediluma condition*, users are unlikely to be surprised because the light is coupled with their physical activity.

While Figure 4 illustrates how effective lighting is at providing wearers with a regular reminder of the device's presence, Figure 3 indicates that a random light (i.e., non-

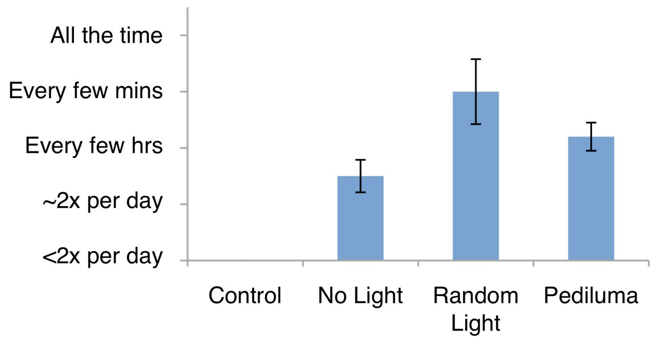

Figure 4. Participants in the *No Light condition* noticed the device less than *the light-enabled conditions*. The *Control condition* (no device) is the theoretical minimum.

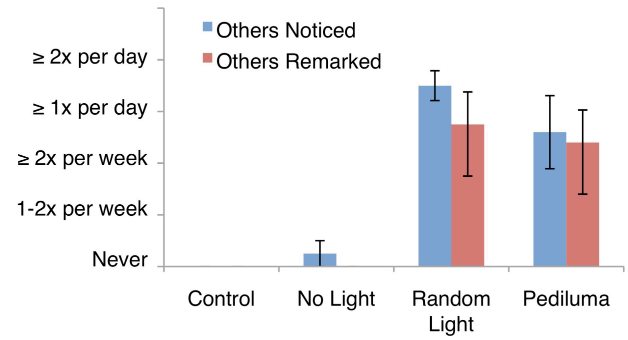

Figure 5. Participants in the *No Light condition* experienced almost no social interaction in contrast to the two *light-enabled conditions*.

contextual light) did not increase walking. We hypothesize this is due to people not associating the light with their walking, instead viewing it as an unrelated distraction, and thus not explicitly reminded about their physical activity. On the other hand, by leveraging a timely presentation of the light with positive reinforcement, the full-featured Pediluma allowed users to develop a comfortable mental model of how the device related to their walking. Through the change in display as the participant walks, the participant is made more conscious of his or her walking. This awareness of their walking allows them to make the conscious activity choice to walk rather than, for example, unconsciously choosing the habit of driving.

The public visibility of the shoe-mounted devices led to other people noticing and remarking to the participants. The frequency of such events was estimated from survey questions. Figure 5 indicates that participants wearing light-enabled devices (*Random Light* and *Pediluma conditions*) experienced significantly more social interaction than those wearing the unlit device (*No Light condition*), (Others noticed: $F[1,13]=25.7$, $p<.01$; Others remarked: $F[1,13]=19.9$, $p<.01$). Participants in the *No Light condition* reported almost no one noticing their devices and never talked to others about the item on their shoe. This difference in social interaction is correlated to how much participants noticed the devices they wore (Others noticed vs. Self notice: $r=.67$; Others remarked vs. Self-notice: $r=.49$). Both the wearer and others were able to notice the lighted devices significantly more than the unlit versions.

Figure 6 provides a breakdown of the types of people that noticed the devices. This data illustrates that participants tended to talk to people they are more comfortable with (family, friends, and colleagues) than a random stranger in public ($M=23.6$ vs. $M=5.4$).

DISCUSSION

Encouragingly, the initial results suggest that Pediluma induces wearers to increase their walking. We believe there are several factors that contributed to t

ahis successful outcome, which, overall, mirror the literature [7,19]. Foremost, wearing a *personal* information display of this nature provides a *persistent* reminder. Additionally, we believe the *positive* reinforcement provided by Pediluma was vital to remind and induce the wearer to walk both longer and more frequently. As we hoped, some participants enjoyed showing the lit device to others, and sought to maintain a positive state with sustained physical activity. Pediluma was somewhat successful in demonstrating the value of the *present* design property. Although the lighting display was received favorably, participants noted that it would have been more rewarding (and perhaps more effective) if the light remained on longer to acknowledge their walking effort (a careful balance to strike).

Bar a few unavoidable distractions, Pediluma generally allowed people to concentrate on their primary activity, remaining in the *periphery* of their vision. However, the devices did interfere with one participant's driving, drew unnecessary attention from security personnel, and was considered to be inappropriate in certain social or office settings. Potentially, many of these effects lie more in the particular implementation of Pediluma, a prototype, than Personal-Public Displays in general.

In regard to the *public* nature of the devices, we found that positive and direct encouragement did not occur, contrary

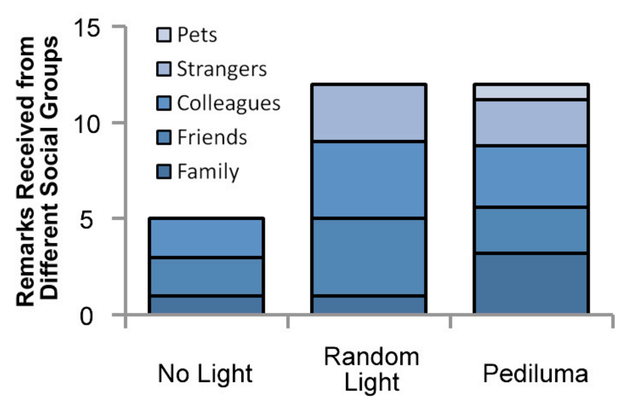

Figure 6. Types of people who remarked to participants as they wore their devices. Note that participants tended to socially engage with closer contacts. One participant favorably explained her cat noticed the light.

to our hypothesis. Instead, for some participants, Pediluma appeared to create a negative social pressure. Participants felt more self-aware, and sufficiently embarrassed to the extent of wanting to hide or take off the device. Though opposite to the effect we intended, this negative pressure may have provided an even more potent reminder to participants. We believe through careful design, the same benefits could be realized, but in a more palatable manner.

Although most of our participants were apprehensive of the devices, two of our participants (both in the *Pediluma condition*) did react positively. Both individuals felt that Pediluma provided an interesting social "ice-breaker" and allowed them to stand out in a crowd. They enjoyed talking about Pediluma and welcomed questions. People in this demographic, who enjoy sharing their state and the added attention that comes from it, may be stronger candidates for this type of social influence. Furthermore, several participants indicated that Pediluma would be more acceptable in certain settings, such as a gym. In these scenarios, where there is a pretext for use, it would be less socially awkward to wear a device like Pediluma. Participants also suggested more natural placements for the display, most notably the arm, which is more common for wearable devices and generally more socially acceptable.

DESIGN IMPLICATIONS

Through a combination of quantitative findings and qualitative feedback, we have compiled a list of design implications can be applied to our future research and aid in the creation of similar technologies.

Aesthetic to Others, Important to Self

While participants saw great value in the ability to monitor their progress in real time, they felt somewhat uncomfortable about sharing their personal information with the public. One participant remarked, "I would never purchase a device that would give my friends a reason to tell me I'm fat. I don't want to hear, hey, it looks like you haven't been walking today." This suggests that the display needs to be sufficiently ambiguous in order to provide adequate privacy; the device should appear decorative or meaningless to others. However, to leverage social effects, we believe it should be sufficiently unique and prominent to spur people to inquire. The wearer can then share the meaning to trusted friends and family if desired.

Adapting for Pace and Peripheral Vision

Although the pace at which the light brightened or dimmed in reaction to walking (or the lack thereof) is reasonable (5 and 15 minutes, respectively) when calibrated for a walking speed of 3 mph, it seems that participants did not appreciate the gradual changes in brightness, and only recognized whether it was either fully lit or off. One participant remarked that "it seemed like it really only had two states, walking or not walking, and I already knew when I was walking." This is probably because people tend to walk faster than 3mph, so the light would reach maximum brightness too soon. They would end up missing the intermediate steps in brightness and only see it in the two states. In addition to using variable luminance, the design could also be improved by employing multiple colors.

Appropriate Visual Attention

Few participants were comfortable with the additional attention they drew due to Pediluma. Many felt the light was too bright, and suggested a more subdued appearance. This was especially problematic at night when the light was visible for more than a city block. One participant felt unsafe and "like a target" walking through a parking garage late at night with the light on. Given their uncommon design and placement, the devices also posed security concerns with guards approaching two participants to enquire of them. Moreover, the lighting display used in Pediluma caused concern among participants that others perceived the device as "attention getting," "juvenile," or "unprofessional." Participants stated that they would feel more comfortable in public if the device did not appear to be so bright, (though only a problem at night). These factors led us to conclude that 1) the information display needs to sensitive to a variety of social and environmental conditions, and 2) be able to adjust the light magnitude to appropriate levels.

Sensitivity to Established Associations

Displays need to consider various pre-existing associations; color, shape, size, location and other factors may have unwanted connotations. For example, although many people associate green objects with concepts like progress, environmentalism, and life, some participants viewed the green LED light used in Pediluma as "creepy" and "weird."

Clear Mapping of Functionality to User

The display of the device must match the expectations and mental models of the user. Failure to do so may not simply lead to confusion or lack of attention, but distrust, anger, and ultimately discontinuation of use. Participants in the random light condition had a negative reaction to the light, describing it as "out of control," and remarking "it seemed like only lit up when I didn't want it to... like I was in a dark parking garage alone late at night," but not when they wanted. These experiences led to distrust in the device, and a wariness of its usefulness.

Blend Form With Wearer Lifestyle

The form must not interfere with personal habits and blend with the personal style and identity of the wearer. Ideally the wearable device should be of a size and weight that are virtually imperceptible, and not interfere with personal habits such as crossing legs or sitting styles. Even inadvertently causing a participant to cross their legs in a manner they are not accustomed to may cause annoyance and physical discomfort. Also the aesthetics of the device must not make the wearer feel strange or out-of-character.

Goal Setting

Several people wanted the ability to set goals, which if achieved, would reward them with a special display state, such as a change in color or light pattern. This begins to morph the experience into that of a game, with objectives and rewards - an approach that has been successful in the past. We avoided goal setting as that added a confound to our study. However, it could prove useful in future systems.

CONCLUSION

We presented a simple shoe-mounted device designed to motivate physical activity through positive reinforcement at the point-of-decision, and social influence through public exposure. The results from our preliminary two-week deployment indicate Pediluma has the potential to increase physical activity, awareness and social interaction. From post-hoc analysis, reflections and interviews, we learned that our Pediluma prototype could be improved in several ways. Chief among them is designing the device to be more appealing and socially acceptable. Overall, we believe our positive result with some users is not limited to Pediluma, but likely extends to a variety of domains and device types.

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