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Exploration of Electrochromics for Calm Reminder: A Customizable Bracelet

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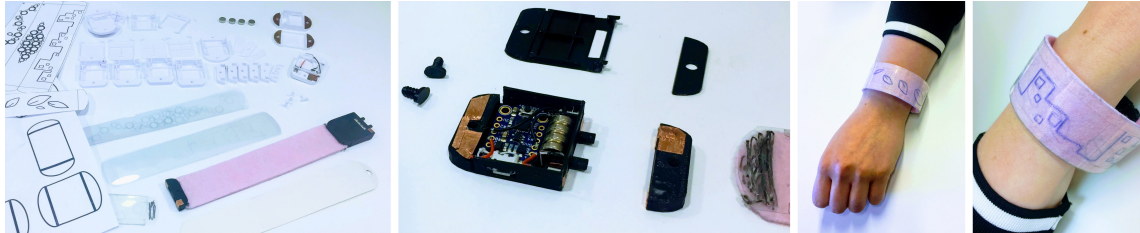


Fig. 1. Prototype implementation: set of previous iterations and various components (left), close-up inside the base (center-left), and two different states of the bracelet while being worn with an optional pink felt background (center-right and right).

At the crossroad of calm computing and personalization technology, we present a calm reminder, taking the form of a customizable bracelet. The concept is based on a perpetual and automatic slow switching between two graphical states, only reminding personal values or actions to the user when fortuitously noticed. Switching and customization of the graphical states increases the reminding personal signification, aesthetics, and noticeability by providing a visual change to the user's periphery. We report on building an actual prototype as well as a survey study ($n = 62$) and a workshop inspired by co-design practices ($n = 17$) to understand why and how this concept of calm reminder could be used.

CCS Concepts: • **Human-centered computing** → **Mobile devices**; *Displays and imagers*; Ubiquitous computing.

Additional Key Words and Phrases: calm computing, electrochromic display, customization, reminder, bracelet

1 INTRODUCTION

Since the introduction of calm computing by Weiser and Brown [15], the research has addressed this concept from various viewpoints. However, calm computing has almost always been explored to provide information without being intrusive.

For instance, in the closest related work, Hansson and Ljungstrand presented The Reminder Bracelet [4], connected to a PDA, it aimed to very subtly notify users of scheduled events using only three light-emitting diodes. Ludden and Meekhof [8] presented personal pebbles softly emitting light to calmly induce social break at work. When the

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light was completely dimmed, the users were invited to place their pebble on a specific table to recharge it. However, acknowledged by the authors, light-emitting sources can be too subtle in a bright environment and, on the contrary, highly intrusive in the dark. Besides, with such simple light sources the meaning was limited, for example, by hardly informing about the ongoing events.

Peterson classified different calm technologies and provided guidelines to design them [9], summarized in four points: (1) easily perceived at a quick glance, (2) integrated in the environment and aesthetic, (3) let the users reflect on the content and (4) natural interaction with the content.

In this context, we present a calm reminder leveraging on the technical possibilities of interactive free-form graphics that can be manufactured with electrochromic (EC) inks, providing thin, transparent, flexible and low-power consuming displays. More importantly for calmness, the EC displays can be visually subtle and naturally integrated to their environments since (1) they are non light-emissive, unlike traditional LED and electroluminescent displays, and (2) they can be created in a wide variety of shapes, going further the simple rectangular or circular form factor. Electrochromics has predominantly been used to dynamically change optical characteristics (tint) of windows [12], but have recently received more attention from HCI research, partly due to the simplification of their fabrication [5, 14], and thus, design exploration. For instance, while exploiting its *slowness* (in switching between states) [6] or by being envisioned and prototyped as a subtle interactive wallpaper [1].

The concept of the calm reminder hereby is based on multiple fortuitous encounters of the user's gaze to the display. Such reminders should be used for constant activities, such as learning a lesson, taking medicine, or just relaxing. Despite being agnostic of the form factor, the concept was implemented as a bracelet (Figure 1) based on the results from a survey study and to remain in the vicinity of the user's gaze and thus, increase the chance of being noticed along the day, for instance while cleaning hands.

As a wearable, this bracelet fully exploits the flexibility of EC displays, in this case, by providing graphical elements all around the wrist. However, the EC displays have a limited number of colors and predefined states. Therefore, the bracelet was designed with the aim to easily change the display in order to (1) aesthetically better fit with the overall outfit, (2) offer numerous personal meaning, and (3) increase its noticeability by providing a slight visual change in the user's periphery. In regard to the last two points, for the same reason, the display shows a perpetual automatic slow switching of two graphical states at a short, fixed interval (arbitrarily 20 seconds). Lastly, to enhance personalization, an optional background can be added, not only to provide different colors, but also patterns and textures from different materials (Figure 2).



Fig. 2. Different flexible background materials, e.g., straw, leather, cardboard, wool, silk, cotton, plastic.

In the next sections, we present the survey study, an actual prototype implementation of the concept (including more details about EC displays) and a workshop inspired by co-design practice to understand why and how this concept of calm reminder could be used.

2 SURVEY STUDY

The preliminary survey study was conducted with the aim to not only elicit different potential form factors of the calm reminder concept using an electrochromic display but also to know the actual reminder values or actions desired by the users. Both information would have direct implications on future design and implementations of the calm reminder.

The survey study was sent online to other university members, as well as relatives and friends from four different countries (Canada, Finland, France and Turkey). Besides two demographic questions (age and gender), the online survey included a short description to help participants imagine an object as a calm reminder, then followed two open-ended questions, asking what would they want to be reminded of, and if the object has to be worn, where? Multiple answers were allowed. Since electrochromic displays are unconventional, we used an analogy of the switching states by describing an example with a subtle light indefinitely slowly going ON and OFF. The exact description and questions are given in the Appendix A. The results of 62 participants (38 women; age mean = 37.4, SD = 12.0) are reported in Figure 3.

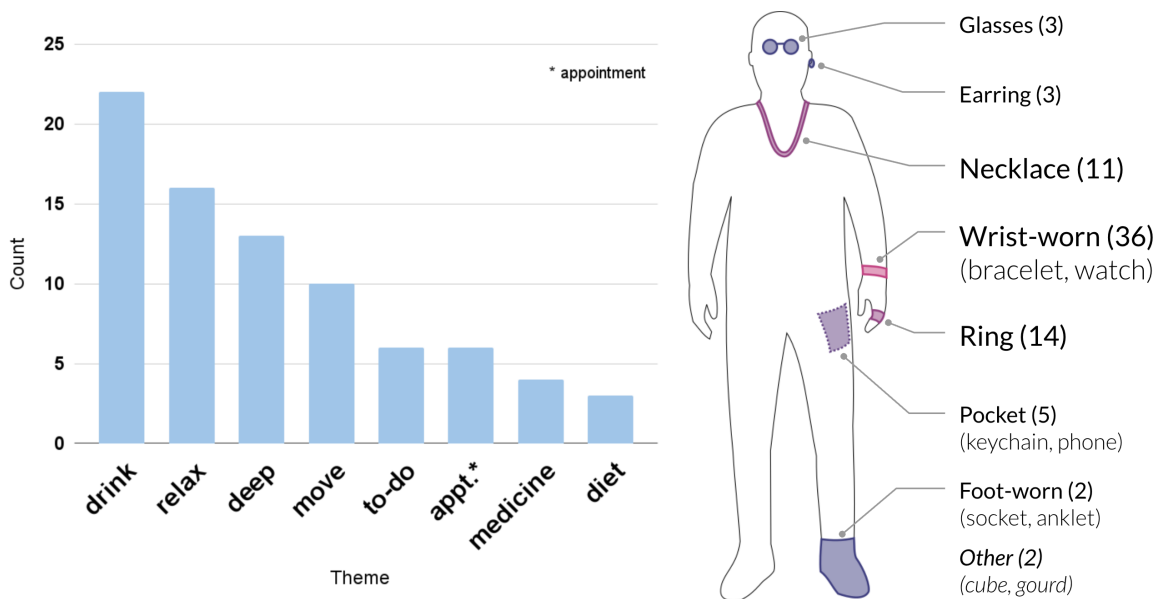


Fig. 3. Main themes (on the left) and desired locations (with their count) of the calm reminder concept (on the right).

The results were analyzed following an open coding approach [3], the aim of the calm reminder, and its location if worn, were identified, compared, and grouped into different themes. This process was conducted by two researchers, first independently and then discussed.

Regarding the first question, a third of the participants ($n = 22$) wanted a calm reminder to drink (water), a fourth ($n = 16$) to relax or, on the opposite, to move ($n = 10$). Interestingly, a large number of participants ($n = 13$) wanted to be reminded of *deep* and abstract meanings, such as relativism, awareness, happiness, "*that every day is unique...*"

First, only the *appointment* theme is timely-constrained; therefore, we assume the participants understood that the concept of having a perpetual switching of states as a reminder is seemingly less appropriate for such use cases. Yet, it remains interesting to explore the use and effectiveness of fortuitous encounters to remind timely-constraint events or actions. Second, it shows that the users want to be reminded of different values or actions. It implies that if a single form

factor should be adopted, it should be more abstract or in a sense, not too specific toward one theme. For instance, this concept of calm reminder could be implemented to a bottle and perhaps better fulfill the calm reminder of *drinking*, but perhaps degrading the meaning or reminding impact *to move* or *to relax*. Yet, the exploration of multiple form factors, or having one that adapts to different artifacts of everyday life should not be dismissed.

Regarding the second question (*where*), participants answered an average of 1.3 locations, with the top three being respectively: wrist (with either a bracelet or watch, $n = 36$), fingers (with a ring, $n = 14$) and chest (with a necklace, $n = 11$). This result led us to adopt a bracelet for this calm reminder concept; in addition to being the most selected location, we considered (1) the chest as less visible than hands to induce fortuitous encounter, and (2) the available area of a finger lower than the wrist, thus giving less freedom of design to the graphical states with the EC display.

3 PROTOTYPE IMPLEMENTATION

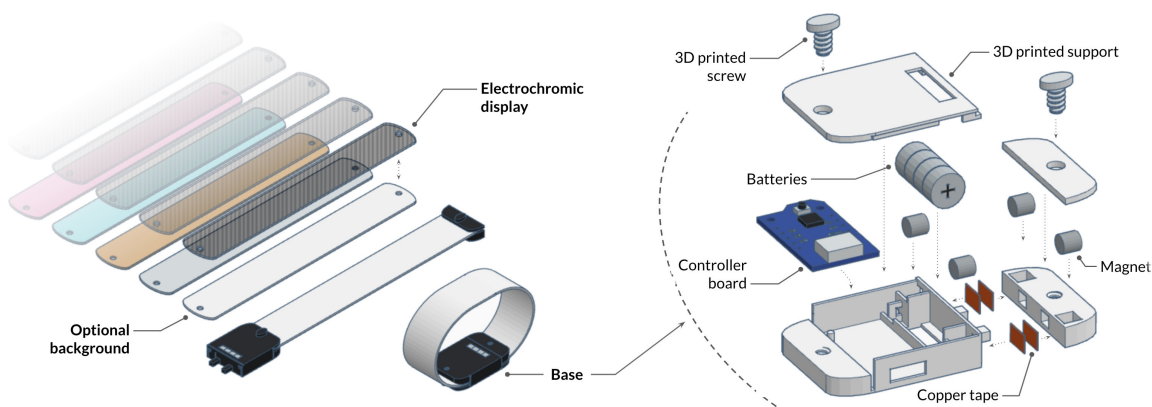


Fig. 4. 3D models of the calm reminder as a bracelet, overall (on the left) and detailed view of its base (on the right).

The bracelet (Figure 4 and 1) comprises three parts: a base, an electrochromic (EC) display and an optional flexible background to improve customization. The EC display and the background are attached to the base with a screw that can be manually operated in order to easily remove and change either one or both parts.

The base comprises two parts joined by a magnet and fork mechanism so the bracelet can be easily worn and taken out, both parts include a conductive surface connected from either side of the EC display. The main part of the base includes power supply (4 x 1.5v coin batteries) and a microcontroller board (Trinket with ATtiny85 for low consumption while keeping prototyping advantage) with its USB connector accessible on one side (to update the software on the go). When the two parts of the base are joined, the microcontroller, and thus the EC display, are automatically powered, to simplify the usage of the bracelet and save the batteries when not worn. The total size of the base is 42 mm x 28 mm x 8 mm. Several iterations have been done to implement the prototype. First starting, with paper and cardboard design to define the size, and finally by 3D printing its structure, including the screws.

Electrochromic displays with simple graphics and shape (strip at 170 mm x 30 mm) to test the bracelet functionality were made with traditional screen-printing equipment following the DIY TransPrint method explained in detail by Jensen et al. [5]. These displays are graphical segment-based in which predefined shapes can be switched with 1.5 V and require power only during the switching period. The shape and size of the display are free and can be adapted to the needs of either the use cases or the wearer. However, the bigger the display, the longer is the switching time, and

more energy consumption is required. From [5], a display with area of 50 x 50 mm needs around 2.4 seconds to switch and requires around 3.8 mW.

Lastly, when the bracelet is fully assembled and active (worn), the microcontroller software alternates the polarity of the voltage to the EC display for only 3 seconds, every 20 seconds. However, being in exploration, the cyclic pattern can be modified and adapted to the display or use cases, for instance only starting the loop a couple of hours after wearing the bracelet or switching states only for a short period of time every hour.

4 WORKSHOP

At this point, the prototype implementation used an EC display with simple graphics irrelevant to any meaning of a calm reminder. Therefore, inspired by co-design practices where potential users can actively take part in early exploration and prototyping of a technology [7, 11], a workshop was conducted with the aim to explore graphical elements dedicated to reminder events or actions. The workshop has been conducted online with 17 participants, none of them answered the previous online survey and all of them were students from the Faculty of Art and Design at the University of Lapland, with diverse levels of competency regarding creativity and graphical design.

The workshop started with a presentation of the bracelet's characteristics, including details about the EC display technology. As an example, a use case was described about someone trying to learn a new language with an app, thus, using the bracelet to be reminded to take a lesson during the day. One researcher, acting as a presenter, made sure participants could ask questions and understood the concept. Finally, two tasks were given: (1) to design two graphical states (and optional background) for a personal use case of their choice, following a defined strip band display, and (2) same process but with a free-form display. A brief explanation of their chosen use cases was also required. Participants received by mail (and email) templates to draw and write on it. Around 20 minutes was given per task, and the presenter wrapped up the workshop session with a short group discussion.

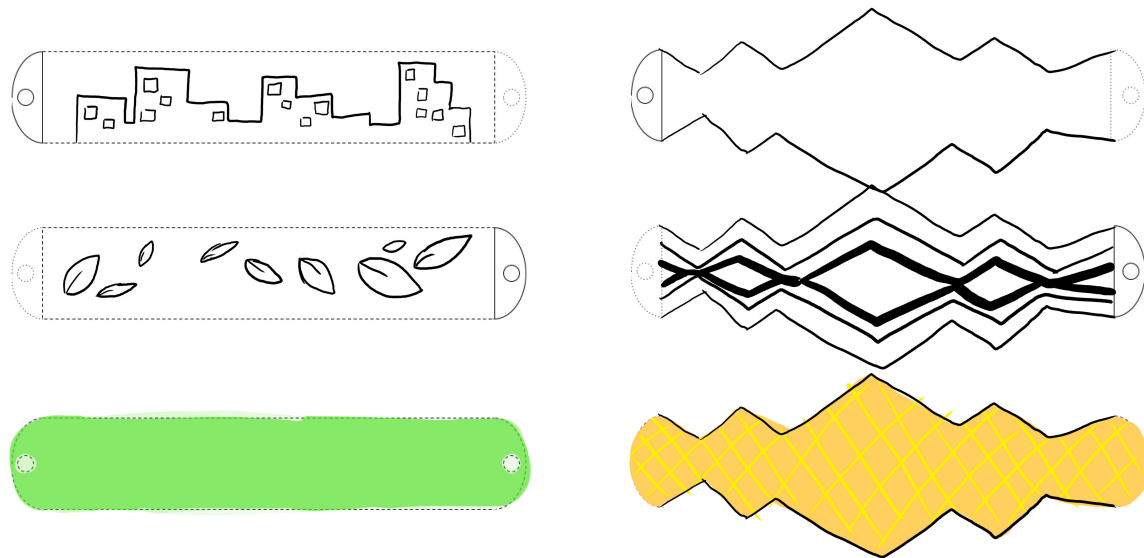


Fig. 5. Strip band (up) and free form (bottom) design to be reminded to take a break. Courtesy of Santeri Hirsikangas.

All drawings were collected afterward (either scanned or physically), an example of feedback is shown on Figure 5. The results were analyzed through the same open coding approach followed for the online survey, in which theme, but also graphical style, were identified, compared and grouped.

The use cases collected reflect those of the survey, with redundant themes, such as drink (n = 6), relax (n = 10), move (n = 5), to-do (n = 8) and medicine (n = 1). In regard to the graphical style of the two states, most of them were considered abstract (n = 19), such as Figure 5, on the right. The others, considered as concrete (n = 9) were either low fidelity (n = 5, such as Figure 5, on the left) or high-fidelity graphics (n = 4) with more detail. Few of them (n = 3) mixed abstract and concrete graphics, switching from one state to the other. Besides these categories, the contents were very disparate among the participants, subjective to the personal significance of their use cases, life experience and creativity; increasing the incentive to offer a customizable calm reminder, with easily interchangeable EC displays and backgrounds. Some design feedback has been reproduced as actual EC displays (Figure 1, right), they are functional and are yet to be tested in subsequent user studies.

5 DISCUSSION AND FUTURE WORK

In this paper, we presented (1) a concept of calm reminder based on fortuitous encounter to an electrochromic display perpetually switching graphics between its states, (2) a survey study leading to (3) an actual prototype implementation taking the form of a customizable bracelet and (4) a workshop inspired by co-design practices dedicated to the design of the bracelet's graphical states.

The concept has been well received by the participants; despite the fact that it goes against the current works aiming for calmness by being context-sensitive on time, providing information presumably only at the right moment [10]. Yet, this concept of calm reminder with its implementation as a bracelet, closely follows the four points of the guidelines for designing a calm technology proposed by Peterson [9]. First, by being present around the wrist, the calm reminder is easily perceived at quick glance. Second, by using a non light-emissive and transparent electrochromic display with different material as a background, the calm reminder is integrated in the environment and aesthetic. Third, by providing a customization mechanism, easing the change of both display and background, the calm reminder offers numerous personal meanings and lets the users reflect on the content of the graphical states. Fourth, by only relying on fortuitous visual encounters with the bracelet and its electrochromic display continuously and slowly transitioning from one state to another, this calm reminder provides a natural interaction, by preserving immediacy and minimizing the complexity to its content as well as having an analogy to the nature sensed by humans: devoid of sudden and unexpected changes [13].

Thus, beyond this initial work, we intend to conduct two user studies. A first one, with participants wearing the actual prototype of the bracelet for a couple of days, mostly to refine the implementation and measure its usability. Then, over a longitudinal study to measure the reminding and calmness impact with formal and dedicated protocols [2, 10]. Finally, we believe such concepts and technology, while keeping the proposed form factor of a bracelet, could be integrated into a watch band including its own power supply, such as a flexible battery.

6 AUTHOR STATEMENT

Following ethical guidelines of the authors' institution, for both studies (the online survey and the workshop), participants were informed beforehand about their consent, the entirely voluntary nature of their participation, the possibility of withdrawing at any time without any penalty, the compensation (in these cases, none) and anonymity of the data collected, secured, confidentially treated, aggregated and published.

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A SURVEY

A.1 Description

A calm reminder. Here, it is considered that a calm reminder must have a supposedly low level of distraction, to be naturally integrated in the ambient environment, while remaining noticeable.

First, imagine a simple object having only two different states, automatically and indefinitely switching from one state to another. Just as an example, it could be an object that includes a very subtle light, slowly going ON and OFF at a fixed interval, every minute or so. Now, imagine you decided to associate a meaning to this object. Each time the object will change its state along the day, it might be slightly noticeable to you, so that it will gently remind its meaning.

A.2 Questions

- What meaning would you choose? In other words, what would you like to be calmly reminded along your day? (It could be literally anything. You can write as many as you want.)
- If you had to wear the object, where (or at least, in what form) would it be?