How to Present Information on Wrist-Worn Point-Light Displays

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NordiCHI '14, Oct 26-30 2014, Helsinki, Finland
ACM 978-1-4503-2542-4/14/10.
http://dx.doi.org/10.1145/2639189.2670249

Abstract
In the last years there has been an emerging trend towards wearable devices, such as wristwatches, and wristbands. Common wrist-worn devices often present information visually and in an abstract way. However, little research has been done on the question of how these displays should present information in daily life. In this work we built a point-light bracelet to explore this question. In a user study participants designed light patterns for a hands-on scenario: physical activity feedback. Afterwards, we investigated how the participants experienced the light patterns in their daily life. From the study results we derive implications for the design of light patterns on a wrist-worn display, e.g. how and when to use the light parameters colour and brightness.

Author Keywords
Wearable Computing, Participatory Design, Field Evaluation, Physical Activity

ACM Classification Keywords
H.5.m [Information interfaces and presentation]: Miscellaneous.

Introduction
Mobile technologies need to be well-integrated into everyday life because they are typically carried all-day,

everywhere, and in many different situations. In the last years there has been an emerging trend towards wearable devices, such as wristwatches and wristbands. Typical functions are to notify, remind, or to present personal information, such as physical activity. One of the benefits of wrist-worn devices is that they are fast to access [2]. Further, they are - in most cases - either in a user's viewing angle or in their periphery of sight. Thus, wrist-worn devices often present information visually.

Common wrist-worn devices implement different visual design dimensions. Especially point-light displays (i.e. information tied to an individual light source) are an emerging trend in the market (e.g. FitBit Flex[1], Nike+ FuelBand[2], Misfit Shine[3]) and in research [3, 1]. However, we do not know how well point-light displays perform in everyday life as this has not been thoroughly studied yet. In general, little research has been done on the question of how point-light wearable displays should present information in daily life.

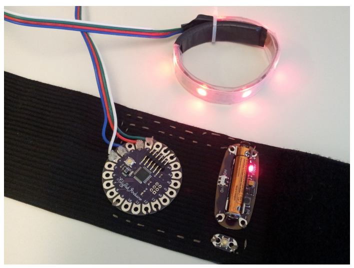

Figure 1: Study prototype consisting of the point-light bracelet and the armlet with the Arduino microcontroller, power supply and button

We have built a prototypical point-light bracelet to explore how information should be presented with point lights. In a user study, participants designed light patterns for a hands-on scenario: we chose physical activity feedback, because it is a common use case and was easy to understand for the participants. After the design session participants tested their light patterns on our prototype in a 3 days in situ study. Results show participants often preferred similar light patterns for specific types of information, such as progress and challenge. Participants in general wished for a customisable bracelet in terms of design and light patterns. From our results we derive preliminary implications for the design of light patterns on wrist-worn displays.

[1]https://www.fitbit.com/flex
[2]http://www.nike.com/us/en_us/lp/nikeplus-fuelband
[3]http://www.misfitwearables.com/

Related Work
Wearable point-light displays have been explored initially. Hansson et al. [4] proposed the Reminder Bracelet, a simple black bracelet with three red LEDs which indicated notifications triggered by a connected PDA. Damage [6] was another, more fashioned point-light bracelet consisting of one white and five coloured LEDs. The author's vision was to connect it to a messenger application on a smartphone to support the communication in a social group. Ahde and Mikkonen [1] describe their vision of communicating spatial proximity of friends by using LED-illuminated bracelets. With ActivMON Burns et al. [3] presented a watch-like device with an LED that shows the user's and the user's friends' physical activity level. Harrison et al. [5] found that in general, wrist and arm as body locations for a wearable visual display were found to be very suitable to present information effectively and efficiently.

What is missing is a thorough investigation of wrist-worn light displays. We need to know how to present information on point-light displays in a way that they are effective and everyday life suitable.

LED Bracelet
To explore how information should be presented with point lights we built an LED bracelet (see Figure 1). We used a 25cm long digital RGB LED stripe with a waterproof casing which we curved to the form of a bracelet and fixed it with cable fixer. The LEDs were covered with semi-transparent film to diffuse the light. In this length the bracelet provided 6 visible LEDs. We chose this length because it could support different wrist sizes.

Pattern	Range						
Colour	white	yellow	orange	red	green	blue	purple
Brightness	dim			bright			
Blinking	off			on			
Colour gradient	off			on[1]			
Brightness gradient	off		bright to dim[2]		dim to bright[2]		

[1] for each combination of colours listed above
[2] for each colour listed above

Table 1: Set of light patterns for the study

The LEDs on the bracelet were controlled by a LilyPad Arduino microcontroller, which we sewed on an elastic armlet. An AAA-battery provided the system with power and a LilyPad Button Board allowed the user to activate the light display. All LilyPad components were sewn on the armlet and connected by conductive thread. The armlet made it possible to keep the size of the plain bracelet minimal and to make the bracelet look as aesthetic and unobtrusive as possible considering its early prototype status.

We connected the LilyPad microcontroller and the LED stripe with a quad cable. To program the microcontroller we used the Arduino IDE.

Study Design

In a user study we firstly, investigated what kinds of light patterns users would design for different types of physical activity feedback. Secondly, we evaluated how participants perceived and experienced the light patterns on the bracelet in daily life. The focus of our investigation was on user experience and everyday life suitability of the light display. Thus, we did not connect the bracelet to an activity tracker, but imitated the user's activity behaviour over the day.

Seven volunteers (four female) took part in the study. Their age group varied between *under 21* and *28 to 34*. Participants were students at the local university (not related to the research team) and employees. None of the participants suffered from dyschromatopsia. None of them had prior experiences in the use of the bracelet. They were paid 25€ each as reimbursement.

Participants took part individually in the study. After they signed an informed consent and filled out a demographic questionnaire they were introduced to the bracelet. In the first part of the study we asked the participants to design light patterns for four different types of physical activity information: (1) daily progress, (2) time elapsed since the last activity, (3) trend with regard to the preceding week, and (4) challenge to move. We demonstrated the available light patterns on the bracelet, which we selected according to good perceptibility, discernibility, and pleasant appearance (see Table 1). After the participants had designed the light patterns using crayons and paper templates we demonstrated these on the bracelet. When the participants were satisfied we interviewed them about inspirations they had with regard to the designs.

In the second study part we programmed the bracelet with the designed patterns and explained all issues regarding the prototype use. Participants were instructed to wear the bracelet while following their daily routine. We asked them to push the button to activate the light display at least once in every new situation they get into, as long as they feel comfortable with it. Activity information 1, 2 and 3 were displayed when the user pushed the button on the armlet once, twice or thrice. As Information 4 should arrest the user's attention it was displayed automatically once per hour. After the first day of usage participants were interviewed about their experiences. They could redesign their light patterns, which we then reprogrammed on the bracelet. After two more days of usage we repeated the interview to learn about experiences from further situations.

Results

Design Sessions
Participants designed light patterns according to a consistent scheme, e.g. some used gradients with same colours or specific colours which they mapped to either a neutral, positive or negative information. Many

participants used a traffic light pattern (red, yellow, green) to encode rating information. However, other colours were interpreted very differently and participants in general wished for customisable colours. All but one participant used blinking patterns only to encode urgent or important information. Four participants wished for a clearly visible distinction between the most positive and all other levels of an information to indicate a reward.

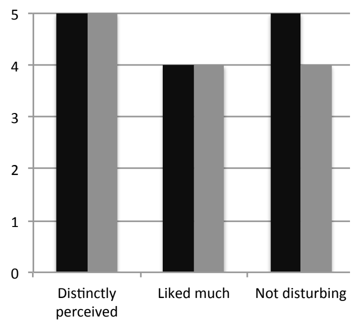

Figure 2: 5-point Likert scale ratings (Mdn) for user-initiated (black) and system-initiated (grey) information

In-Situ Usage

Participants assessed 19 different situations including 7 locations, 5 audiences, and 2 different lighting conditions. No participant was able to reliably distinguish different brightness levels at daylight. Participants perceived the user-initiated information 1,2 and 3 similarly like the system-initiated information 4. On a 5-point Likert scale the system-initiated information 4 was assessed slightly worse in terms of disturbance (see Figure 2). The few situations in which participants rated the light as disturbing were either characterised by a dimly lit environment or by the presence of strangers. One participant said she felt frustrated because the situation did not allow her to react to the challenge to move. In 13 cases participants experienced reactions from bystanders, but only in 2 cases this made participants feel uncomfortable. After the study all participants stated they can imagine to wear a similar bracelet if it was embedded in jewellery such as an aesthetic bracelet or a watch.

Discussion and Conclusion

From the study results we derive six implications for the design of light patterns on a wrist-worn display:

1. Use a consistent pattern mapping,
2. Use colours to differentiate levels of an information, and make the colour mapping configurable,
3. Use blinking for urgent information only,
4. Do not use brightness to encode information, but adapt brightness level to lighting conditions,
5. Clearly encode minimum and maximum levels,
6. Allow "invisible" mode during inappropriate moments.

The study is limited in that it was conducted with an early prototype and for a short period. However, we argue that wrist-worn point-light displays that consider the presented findings and implications - although preliminary - will benefit from an increased user acceptance. In future work we will implement the design implications on a wrist-worn light display. In a field study we will evaluate in how far the new design influences user experience and acceptance.

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