WaterJewel: Design and Evaluation of a Bracelet to Promote a Better Drinking Behaviour

Jutta Fortmann[1], Vanessa Cobus[1], Wilko Heuten[2] and Susanne Boll[1]

[1]University of Oldenburg
Oldenburg, Germany
firstname.lastname@uni-oldenburg.de

[2]OFFIS - Institute for Information Technology
Oldenburg, Germany
wilko.heuten@offis.de

ABSTRACT

A recent study revealed that every fourth German adult drinks less than 1.5 litres a day. Insufficient fluid intake can cause headache, lack of energy and lightheadedness. Signals can be used to be reminded of drinking. However, these are often missed or even deactivated because they are too obvious. On the basis of a participatory design study, we designed the fashionable light bracelet *WaterJewel* as an awareness display and an unobtrusive reminder for a regular fluid intake. In a four-week 12-participant study, we explored the use of *WaterJewel* in daily life and how it compared to a prevalent mobile drinking reminder application. Our results show that with *WaterJewel* participants drank more in total, more often accomplished the daily drinking goal of 2 litres, drank more regularly, and drank more often prior to the reminder event than with the mobile application. Participants rated *WaterJewel* as very usable and appreciated its practical and discreet design.

Author Keywords

Fluid intake, Wearable Light Display, Ambient, Digital Jewellery, Reminder, Prototyping, Arduino, Everyday Life

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation: Miscellaneous

General Terms

Human Factors; Design; Experimentation.

INTRODUCTION

Fluid intake is essential for human health. Insufficient fluid intake can cause discomfort such as headache, lack of energy and lightheadedness [11]. Scientists recommend an intake of *at least* 2 litres of fluid a day [6]. Accordingly, a well-known rule of thumb suggests to drink *at least* eight 8-ounce glasses of fluid a day. However, a recent study revealed that every fourth German adult drinks less than 1.5 litres a day, and only 55% drink evenly distributed servings over the day [19]. This may be because of being busy or just because of not being thirsty.

MUM '14, November 25 - 28 2014, Melbourne, VIC, Australia

ACM 978-1-4503-3304-7/14/11$15.00
http://dx.doi.org/10.1145/2677972.2677976

Figure 1. *WaterJewel*: Single light spots on a bracelet reflect the user's daily drinking behaviour and thus help her to drink 2 litres in 8 evenly distributed servings over the day.

Solution approaches are carrying a bottle of water, checking the watch from time to time, or setting an alarm every few hours. But these approaches are not satisfactory. People easily forget to drink when they have to keep that in mind by themselves. Setting up an alarm every few hours is tedious. Besides, interval-based reminders such as alarms are often triggered only once at a certain point of time, which might be awkward and might not allow the user to go into the matter. In this case, despite the reminder signal, the user might forget the task s/he was reminded of because s/he could not react immediately. Also, reminders typically signal in an obtrusive way, such as an auditory alert, a noisy vibrating phone, or a popup window appearing on the user's screen. This forces the user to interrupt a current task immediately and shift attention to the reminder. This is unnecessarily disruptive and furthermore – in public environments – can cause discomfort by drawing unwanted attention to the user.

We have designed and built *WaterJewel* (see Figure 1), a bracelet with discreetly integrated light spots that reflect the user's actual drinking behaviour via abstract light signals. In a participatory design process, we created two fashionable designs for a masculine and a feminine style of *WaterJewel*. In a field experiment we explored the use of the *WaterJewel* prototypes in daily life, and compared *WaterJewel* to a prevalent mobile drinking reminder application.

The contributions of this paper are as follows:

- We demonstrate the human-centered design process of the interactive bracelet *WaterJewel*.
- We show that *WaterJewel* is more effective in promoting a healthy drinking behaviour than a state-of-the-art mobile application.
- We highlight that *WaterJewel* has been experienced as very usable and pleasing due to its wearable and discreet form factor.
- We indicate that *WaterJewel*'s always perceivable display enables constant awareness of personal drinking behaviour.

In the following, we present related work, design process and implementation of *WaterJewel*, and the field experiment with its results.

RELATED WORK

In the following, we present related work which focuses on requirements for everyday life technologies, abstract light displays, wrist-worn light displays, and tools to improve drinking behaviour.

A system which supports a user in everyday life has to be accessible at any time and at any place in order to be effective. To be socially accepted and emotionally comfortable, everyday life technologies need to be aesthetic [12, 7]. With regard to wearable everyday life technologies, Consolvo et al. [4] stated it is important that users find these acceptable to wear in various scenarios, and that the acceptance is highly influenced by the form factor of the technology. The authors picked up and complemented this aesthetic requirement in their design strategies for everyday life technologies, which include *Abstract & Reflective*, *Unobtrusive*, *Public*, *Aesthetic*, and *Positive* [5]. Aesthetics in wearables was also considered to be important by others, e.g. Knight et al. [13] indirectly included it in the comfort rating scales for wearable technologies (*Emotion* rating). Miner et al. proposed to integrate wearable technologies into jewellery, bearing in mind that wearable technologies need to consider social, emotional and aesthetic needs [15].

Aesthetic visualisations have been valued for higher effectiveness and efficiency than less aesthetic visualisations [3]. For the implementation of aesthetic, abstract visualisations, ambient, low-information rate displays are well suited [17]. Also often referred to as peripheral displays [14], these displays allow unobtrusive information presentation in the periphery of a user's attention. Light as modality offers a huge range of encodings and can easily be displayed in an ambient, aesthetic way [16]. Tarasewich et al. [18] showed that low-information rate displays, which consist of single LEDs, can be useful for supporting information awareness on mobile devices. Harrison et al. [9] emphasised the expressivity of point lights and proposed a set of light behaviours recommended for the presentation of particular types of information on mobile devices, like an incoming call or low battery.

Previous work has investigated the use of wrist-worn light displays as unobtrusive information displays. Hansson et al. [8] proposed the Reminder Bracelet, a simple black bracelet with three red LEDs, which indicate notifications triggered by a connected PDA. Its purpose is to notify the user of scheduled events in a subtle and silent way using light, colour and blinking patterns. Damage [20] is another, more fashioned LED bracelet consisting of one white and five coloured LEDs. The author's vision was to connect it to a messenger application on a smartphone so that it supports the communication in a social group. Ahde and Mikkonen [1] describe their vision of communicating spatial proximity of friends by using LED-illuminated bracelets. Harrison et al. [10] 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.

Several tools can be found on today's market with the purpose to remind the user to drink. Alarm clocks, e.g., are available in various forms and typically remind after a preset time period. Ah!Qua[1] is a fashionable bracelet which vibrates in preset intervals over the day. MyWay[2] is a silicone bracelet on which a bar display and an occasionally flashing LED both indicate the time elapsed since the user's last fluid intake within a fixed timeframe. Carbodroid[3] is a popular Android application which serves as a drinking reminder via sound or vibration, similar to Ah!Qua. Additionally, it visualises the amount of fluid intake and the time of single servings for the day on the graphical display of a smartphone.

Initial evaluations of light bracelets seem promising. However, thorough investigations of wrist-worn light displays beyond the presentation of visions have not been done yet. Also, to our knowledge, wearable drinking reminders such as Ah!Qua and MyWay have not been explored in daily use.

DESIGN OF WATERJEWEL

In the following, we describe the design process of *WaterJewel*. First, we present the conceptual design of *WaterJewel*, and afterwards the presentation design of two different bracelet styles (masculine and femine). From the results of a brainstorming session, we created three different presentation designs per style. In a user study, participants evaluated and redesigned these designs. From the results, we derived our final designs which we present at the end of this section.

Conceptual Design

A wearable display is suitable to support a person's drinking behaviour in everyday life as it is ever-present. It needs to be aesthetic, unobtrusive, practical and convenient [13, 4, 5]. A piece of jewellery is able to fulfil all of these requirements. Therefore, the discreet integration of a fluid intake display into jewellery seems promising. Having regard to the work of Tarasewich et al. [18] and Harrison et al. [9], and due to their applicability for abstract information presentation, we decided to use light spots for the information presentation. A bracelet is a common piece of jewellery, clearly visible from the wearer's viewing angle, and worn on a well suited body location for information presentation [10]. So, we integrated a light display in terms of single light spots into a bracelet.

[1] http://ahqua.at/index_e.html

[2] http://trinkuhr.com/myway.en.html

[3] https://play.google.com/store/apps/details?id=de.jooce.water&hl=de

In order to implement the requirement of supporting the user to drink 2 litres a day in 8 evenly distributed servings, we chose the following design concept: *WaterJewel* displays the amount of fluid intake for the day ("volume display"). This allows a user to reflect on the daily fluid intake and thus supports him/her in accomplishing the recommended fluid intake of 2 litres. To support the user in drinking roughly evenly distributed servings over the day, *WaterJewel* uses an ambient reminder ("reminder display"), which reminds the user to drink in an continuously perceivable and yet unobtrusive way.

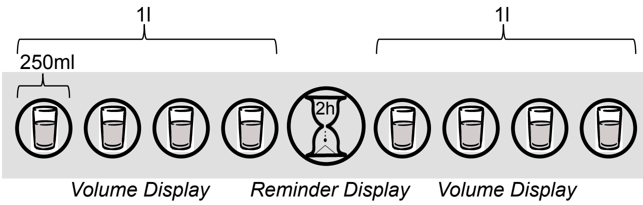

Figure 2. Illustration of the display concept of *WaterJewel*: 8 light spots represent 8 glasses of fluid which add up to 2 litres. A central light spot indicates the time elapsed since the last intake.

The volume display consists of eight single light spots, each representing a glass of fluid of 250ml (see Figure 2). These add up to the daily recommendation of 2 litres. As this information does not necessarily have to be ever-present, and to ensure an unobtrusive display, the light spots light up on demand only. A drink entry is made through the long push of a button on the bracelet. This activates another light spot in the volume display. If the same button is pushed for only a short moment, all activated light spots of the volume display are illuminated for some seconds. The reminder display is represented as a central light spot which indicates the time elapsed since the last intake and is always illuminated to support constant awareness of the recent drinking behaviour and to remind the user to drink regularly. We assume a person is awake for 16 hours a day in which s/he needs to drink two litres, i.e. 250ml every two hours. So, the reminder display needs to indicate the period between 0 and 2 hours. The reminder display is supported by a vibration display which is integrated into the inner surface of the bracelet. It will vibrate for 500ms if the user has not drunk for two hours. If the user did not react, it would vibrate again twice after one minute for 500ms each, and again for 1s after another 30 minutes. If the user still did not react, the procedure would not start again until after another two hours.

Presentation Design

The conceptual design served as the basis for the presentation design. As we wanted to design a smart piece of jewellery, the bracelet design should suit the fashionable taste of potential users. Therefore, we involved users in a participatory design process.

Our initial ideas for the presentation design were inspired by current trends in jewellery design, and by a brainstorming session. During the brainstorming session, we asked six volunteers (3 female; age: M = 24, SD = 1.55), which we recruited form personal contacts and who were interested in fashion and jewellery, about the jewellery styles they preferred for themselves and for the other gender as well. We found that the preferences of male participants differed considerably from those of female participants. Women preferred charm bracelets made of metal, as well as thin and wide bangles. Men preferred wide wristbands made of rubber or leather. All in all, these findings corresponded to our trend research. As the form factor of a wearable object is critical for its acceptance [4], we decided to design two different bracelet styles: femine and masculine. On the basis of the results we created sketches for three different bracelet designs per style.

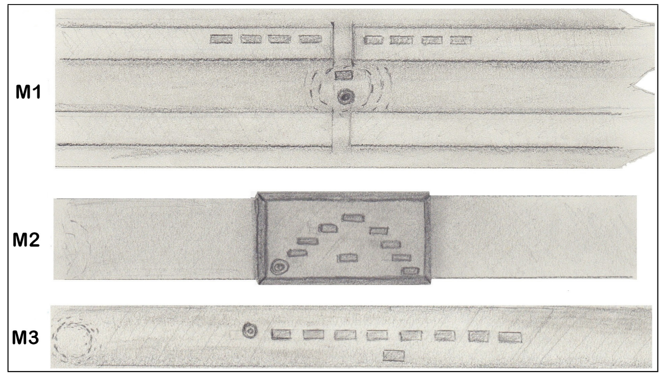

Figure 3. The masculine bracelet designs looked similar to plain leather wristbands and varied in width and the orientation of light spots.

Figure 3 shows the masculine designs, beginning with M1, a wide bracelet, e.g. made of leather, with horizontally arranged light spots. The button and the reminder display are placed centrally. The second bracelet, M2, is smaller than M1 and similar to a watch. In the middle of the bracelet is a wider central section which could be made of metal. The light spots are arranged pyramidally on this central section. The button is, in contrast to M1, positioned next to the light spots. M3 is a small, plain and very artless bracelet, e.g. made of plastic or leather. The light spots are arranged in the same way like for M1, except for the button, which is positioned on the left of the light spots.

Figure 4 shows the feminine bracelet designs. The first bracelet, F1, is a charm bracelet, with each light spot and the button integrated into a charm. These charms hang on the bracelet in line. F2 is a conspicuous, wide bracelet. It consists of thin

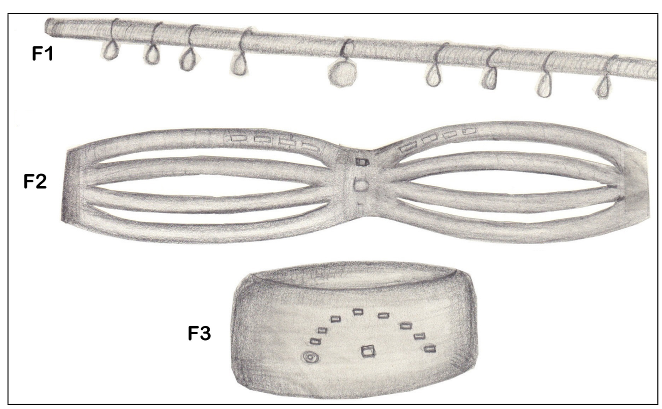

Figure 4. The feminine bracelet designs included a charm bracelet, a conspicuous bracelet with several thin bangles, and a wide plain bangle.

bangles coupled together at two sides so they cannot move and cover the light spots. These light spots are positioned on the uppermost bangle, also in a row. The button is arranged centrally, below the reminder display. The third design (F3) shows a wide, plain bangle. The light spots are arranged in a semi circle in the centre, similar to M2, as well as the button, which is located at the left end of the semi circle. This arrangement is supposed to be reminiscent of a petrol gauge.

Evaluation of the Bracelet Designs

To define a final presentation design, we evaluated the sketches of the bracelet designs in a user study with 20 participants. Participants rated the design sketches with particular regard to their aesthetics and were asked about the arrangement and colour of the light spots. During the study, participants were also encouraged to draw entirely new sketches.

Method

20 volunteers (10 female) took part in our study. They were recruited from the local university and personal contacts. The average age was 25.2 (SD = 3.01) for the males, and 26.4 (SD = 7.09) for the females. None of the participants suffered from dyschromatopsia. They stated their interest in jewellery as moderate to strong, i.e. on a 5-point Likert scale from 1 ="Not at all" to 5 = "Very strong", the male participants rated the question "How strong is your interest in jewellery?" as 2.6 in average (SD = 0.97), and the females as averagely 3.7 (SD = 0.82).

None of the participants was paid for taking part in the study. Prior to the study each participant signed an informed consent. Participants took part in the study individually. Each study session included a short introduction, the completion of a demographic questionnaire, the design part, and concluded with a post-hoc interview. For the design part, participants were presented the three style-specific design sketches, and were equipped with blank paper sheets, a ruler, and coloured pencils. Participants were encouraged to comment on the sketches by naming advantages and disadvantages, to name their preferred sketch, and also to modify the sketches or to draw entirely new sketches if they had own ideas. In addition, they were asked to think and comment on the arrangement and colour of the light spots. In interviews we asked for e.g. the preferred jewellery styles, the desired light pattern for the reminder display, and if there are colours which should be avoided in general.

Results

The generally preferred jewellery styles of female participants were artless (9 votes) and elegant (6 votes), followed by conspicuous (2 votes), sporty, and glamorous (1 vote each). Male participants clearly preferred an artless style (9 votes), followed by sporty (4 votes), elegant, and conspicuous (1 vote each).

This distribution fits the design votes. 4 male participants preferred design M1, 3 chose M2, 2 chose M3. One participant preferred his self-drawn bracelet sketch, which was similar to M1, but more conspicuous as it winded itself round the arm. Apart from that, this participant preferred design M1. 3 male participants who did not choose M1 said the only reason was that it was too wide. The horizontal arrangement of the light spots and the button as in M1 and M3 was positively emphasised by 8 male participants. The vote for the feminine designs was more clearly: 7 female participants preferred design F1, 2 chose F2 and one chose F3. Several female participants positively emphasised that F1 is artless and elegant at the same time, as well as narrower and more delicate than the other designs. In addition, the female participants liked the arrangement of light spots in line and appreciated the possibility of individualising the shape of the charms.

For the reminder display, all participants preferred a light pattern in terms of a colour gradient for which most of them preferred the colours green (just drank) to red (drank long ago). Regarding the colour of the volume display, 7 participants (4 male) chose blue. Other choices varied distinctly: 3 participants (2 male) chose green and 3 participants (2 male) chose red. Other colours mentioned by female participants were purple and pink, where these colours were explicitly mentioned as ugly by male participants. The distribution varied more for the female participants, who said that their choice reflected their favourite colour. Besides, several male participants suggested to clearly distinct the last light spot from all others to indicate the daily goal is accomplished.

Final Design of WaterJewel

From the study results we derived our final design for the feminine and the masculine styles of WaterJewel which we describe in the following.

The masculine bracelet is based on M1 but narrower, as most of the male participants preferred M1. The main point of critique of those who did not was that M1 was too wide. Thereby the reminder display is arranged in line with the light spots of the volume display and the button is placed left of the light spots. The feminine bracelet is like F1, as most of the female participants preferred and fancied this design. The button is integrated into another charm arranged left of the light spots.

The first seven light spots of the volume display are coloured blue because most participants chose this colour and the last light spot is green to distinct it as the "goal accomplished" light spot. With respect to the study results, the reminder display shows a colour gradient from green to red over a period of two hours. If the user has not drunk for two hours, the reminder display will illuminate in red. If a new light spot is activated, it will be reset to green.

IMPLEMENTATION OF WATERJEWEL

According to the final design, we built two bracelet prototypes. Each bracelet (see Figure 5) consists of eight LEDs for the volume display, one button to activate these LEDs, one RGB-LED for the reminder display in terms of a colour gradient from red to green and vice versa, one vibration display for an additional signal and a microcontroller board to control the bracelet. Because of its simple programmability and its low weight we decided to use the *Arduino LilyPad* microcontroller board with some of its hardware components. The *LilyPad* and also a *LilyPad* battery holder for an AAA-battery were fixed on an additional armlet to keep the size of

Figure 5. Masculine (left) and feminine prototype (right)

the plain bracelet minimal. The components on the armlet and on the bracelet were connected by coated wires. To hide the electronics on the armlet we whipped the whole armlet with black felt.

For the masculine bracelet we used eight *LilyPad* Micro LED boards with a size of 3 x 9mm and a *LilyPad* RGB-LED board with a diameter of 20mm. These LEDs were fixed on a plain leather bracelet. A *LilyPad* button board (8 x 16mm) was mounted next to the row of LEDs and allows to activate the LEDs. A *LilyPad* vibe board with a diameter of 20mm served as a vibration display and was positioned on the inner surface of the bracelet. Due to design reasons we did not use the *LilyPad* LEDs for the feminine bracelet. Instead, we used eight leaded LEDs with a diameter of 3mm, of which we bent the pins to use them as charms. Because the smallest leaded RGB-LED has a diameter of 5mm, which is too big, we used a green-red Duo-LED with a diameter of 3mm, which can display green, red, and all gradient colours. To make the LEDs look more like charms, we modelled a cover from translucent bakeable modelling clay and hot glue for each LED. A positive effect of this cover is a softer light of the LEDs. Wires and soldering joints that connected the LEDs were wrapped with black satin ribbon to make the bracelet more aesthetic. The button board was glued on the back of a fashionable charm attached in line with the LEDs. The vibe board was positioned on the inner surface of the bracelet.

EXPERIMENTAL METHOD

In a four-week field experiment, we explored the use of the *WaterJewel* prototypes in daily life and compared them to the drinking reminder application *Carbodroid*. We chose *Carbodroid* as it is a state-of-the-art and prevalent drinking reminder, rated best of all currently available mobile drinking reminder applications in the Google Play Store[4], and because its design concept is similar to the one of *WaterJewel*. The intention of this experiment was to get beyond potential novelty effects that may be present in shorter field studies. We wanted to investigate the everyday life suitability of *WaterJewel* and its effectiveness compared to *Carbodroid*. To assess the effectiveness, we measured how much participants would drink, how often they accomplished the daily drinking goal, how regularly and in which intervals they drank. To assess how usable *WaterJewel* and *Carbodroid* are, we asked participants to rate their usability after they used the systems. Participants also rated how they perceived the emotional and wearing comfort of *WaterJewel*.

Regularity of drinking To analyse how regularly participants drank, we measured the timeframe between two drink entries and calculated the standard deviation over all of these timeframes. The more the timeframe varies, the higher the standard deviation gets. Thus, the lower the standard deviation, the more regularly the participant drank.

Interval of drinking To analyse the interval when participants drank, we measured the timeframe between two drink entries per day. We counted a value as *prior* to the reminder event when $120Min > value > 0Min$ and a value as *after* the reminder event when $value > 120Min$. For the analysis we compared *prior* with *after* counts per condition. As the recommendation is to drink *at least* 2 litres of fluid a day, we interpret *prior* counts as generally positive, because, if recurrent, they lead to more fluid intake. We interpret *after* counts as negative, because when a drink is taken after the 2 hours interval it is less likely that the user will accomplish the daily goal.

Our hypotheses are:

H1) participants drink more with *WaterJewel* than with *Carbodroid*.

H2) participants more often meet the recommendation of drinking 2 litres fluid a day with *WaterJewel* than with *Carbodroid*,

H3) participants drink more regularly with *WaterJewel* than with *Carbodroid*, and

H4) participants drink more often prior to the reminder event with *WaterJewel* than with *Carbodroid*.

Material

For the study we used the masculine and the feminine versions of *WaterJewel*. Participants used their own Android smartphones with the installed *Carbodroid* application. *Carbodroid* reminds to drink via vibration every two hours. The main view of the application shows the app character (see screenshots shown in Figure 6). This character indicates the water intake of the user. It is filled with water more and more and the character's facial expression becomes happier whenever the user makes another drink entry. The user enters a glass of water by selecting the glass icon below the character. The daily drinking goal is set to 2000ml. Another view ("list view") shows an overview of the drinks of the day in terms of a list showing serving size and time of drinking. This view as well as the main view are always reset automatically at midnight.

Figure 6 shows four different types of information and how they have been displayed on *Carbodroid* and *WaterJewel* during the experiment. In the upper left the initial status is shown. *Carbodroid* shows an empty and therefore sad character. The reminder display of *WaterJewel* illuminates in red

[4] https://play.google.com/store

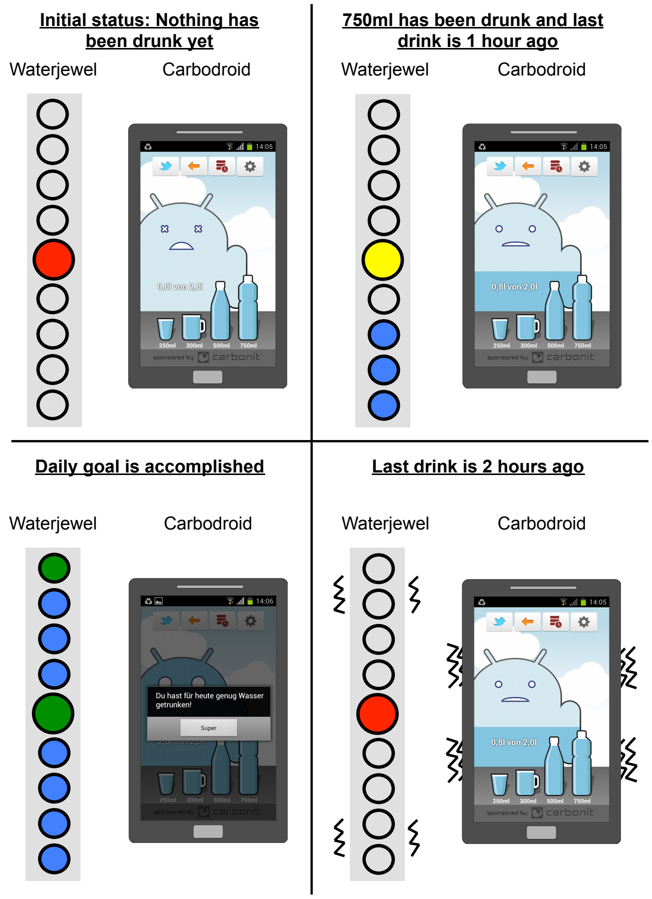

Figure 6. Examples of different types of information and their display on *WaterJewel* and *Carbodroid*

and the light spots of the volume display are deactivated. The upper right illustration shows both systems when the user has drunk his third glass of water one hour ago, that makes 750ml in total. The character is filled up with water up to his upper body and looks slightly happier. *WaterJewel* illuminates the first three light spots of the volume display in blue and the reminder display in yellow. In the lower left the goal status is shown, i.e. the user has just reached his daily drinking goal of two litres. *Carbodroid* shows a popup saying that one has drunk enough water for today. The character in the background looks happy and is completely filled up with water. *WaterJewel* illuminates the first seven light spots of the volume display in blue and the last light spot in green. The reminder display lights up in green. The lower right illustration shows the display of the information that the last intake was two hours ago. *Carbodroid* makes the smartphone vibrate, and *WaterJewel* illuminates the reminder display in red and, in addition, also vibrates.

Participants

12 participants (6 female) volunteered to take part in the study. They were recruited from the local university, personal contacts, and through public announcements. 5 participants were students, 1 was an apprentice, 4 were (self-)employed, 1 was job-seeking, and 1 was a housewife. The participants mapped their age to the following ranges: *under 21* (n = 1), *21 to 27* (n = 6), *28 to 34* (n = 4), and *42 to 48* (n = 1). None of them suffered from dyschromatopsia, and none of them had already used neither *WaterJewel* nor *Carbodroid*. They all stated that they in general have problems to fulfil the recommendation to take in at least 2 litres of fluid each day. The participants were paid 25€ each as reimbursement.

Study Design

We used a repeated measures design and alternated the order of conditions to cancel out sequence effects. The type of drinking reminder (*WaterJewel* or *Carbodroid*) served as independent variable. In the experimental condition, *WaterJewel* was worn on the wrist and provided feedback on the drinking behaviour. In the control condition, *Carbodroid* was provided on the participants' smartphones for the same purpose. The dependent variables were the drinking volume per day, the number of days on which at least 2 litres consumed liquid had been entered, the standard deviation of the timeframe between two drink entries (regularity of drinking), and the timeframe between two drink entries (interval of drinking). We measured the values by logging the participants' drink entries on the corresponding device.

Participants took part individually in the study. Each study session included a short introduction, the study itself lasting for four subsequent weeks, two post-hoc interviews, one after the first two weeks and the other on the last study day, and concluded with the completion of a System Usability Scale (SUS) [2]. After the experimental condition, participants also completed a Comfort Rating Scale (CRS) [13] to rate the comfort of *WaterJewel*. During the introduction, the participants learned about the procedure of the study, and the operation of *Carbodroid* and *WaterJewel*. After they signed an informed consent, they assessed their personal drinking behaviour by means of a questionnaire. Afterwards, they were equipped with *WaterJewel*, i.e. female participants received the feminine version and male participants the masculine version of *WaterJewel*. Then, the participants engaged in their usual daily routine for two weeks. Afterwards, they exchanged *Carbodroid* for *WaterJewel* or vice versa, and continued their daily routine for another two weeks. In between, we shortly met the participants once a week to read the logged data on their bracelet or smartphone. At the end of the second and the fourth study week, we conducted a post-hoc interview in which we asked for the situations in which the participants had worn the bracelet and carried the smartphone and where they had carried the smartphone and how visible they had worn the bracelet. On the last study day we also asked for the participants' general preference regarding *Carbodroid* and *WaterJewel* and which system supported them better in taking in fluids regularly and sufficiently.

RESULTS

Our results show that with *WaterJewel* participants drank more in total, more often accomplished the daily drinking goal, drank more regularly, and drank more often prior to the reminder event than with *Carbodroid*. Participants found *WaterJewel* usable, appreciated its aesthetic appearance, felt comfortable with it in general, and most of them preferred *WaterJewel* to *Carbodroid*.

Quantitative Results

In total, we logged 1341 drink entries on *WaterJewel* (ca. 335.25l), and 1225 drink entries on *Carbodroid* (ca. 245l). 12 participants used *WaterJewel* for a total of 168 days and *Carbodroid* for a total of 159 days. *Carbodroid* was used for a total of 9 days less, because 4 participants did not use *Carbodroid* on single days.

Personal drinking behaviour

To assess the personal drinking behaviour of the participants in a natural way before the study, we asked for the number of glasses (200-250ml) the participants usually drink for breakfast, lunch, dinner, and inbetween. Participants stated they drink on average 5.96 (SD = 1.94) glasses of liquid per day. If we assume that a glass contains 200-250ml, this makes approx. 1192-1490ml. With regard to the recommendation of drinking at least 2 litres a day, these values indicate that the participants had difficulties to drink sufficiently.

Before the study, we also asked the participants from which container they usually take their drinks. 3 participants named a bottle, 1 named a big glass, and another one stated a small glass. 4 participants named a big glass and a bottle, and 3 participants named a small glass and a bottle.

Drinking volume per day

On average, participants made drink entries for a total of 1995.54ml per day with WaterJewel (SD = 11.1, Mdn = 2000, Min = 1500, Max = 2000), and for a total of 1528.7ml per day with *Carbodroid* (SD = 345.22, Mdn = 1700, Min = 400, Max = 2000). To keep the results comparable, we excluded the totalling 9 days from these calculations on which *Carbodroid* was not used. Figure 7 shows a bar chart for the entered drinking volume per day per participant for *WaterJewel* and *Carbodroid*. A two-tailed t-test showed that this difference was significant ($p < 0.001$). Thus, hypothesis H1 is supported.

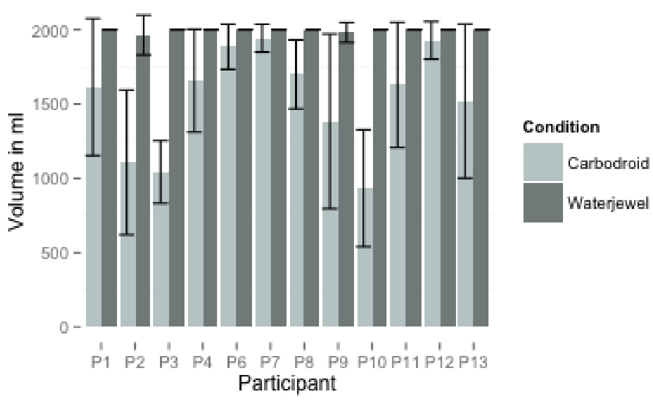

Figure 7. Average entered drinking volume per day per participant

Accomplishment to drink 2 litres a day

On average, the daily drinking goal of two litres was accomplished on 14/14 days (Mdn, Min = 13) in the experimental condition, and on 4.5/14 days (Mdn, Min = 0, Max = 10) in the control condition. A chi-square test showed that this difference was significant ($\chi^2 = 17.14$, df = 1, $p < 0.001$) and therefore supports hypothesis H2. When these results are interpreted it should be considered that 4 participants did not use *Carbodroid* on single days, i.e. altogether they did not use it for 9 days out of 168 days, on which these participants theoretically could have accomplished the daily goal. Participants also assessed this subjectively after the study. 6 participants thought *WaterJewel* was more successful in making them drink at least 2 litres a day, and 6 participants thought that there was no difference in their amount of drinks with regard to *WaterJewel* and *Carbodroid*.

Regularity of drinking

On average, participants drank more regularly in the experimental condition (SD = 19.23), than in the control condition (SD = 103.53). Figure 8 shows the regularity of drinking for each participant in terms of the standard deviation for all timeframes between two drink entries. A two-tailed t-test showed that this difference was significant ($p < 0.001$). Therefore, hypothesis H3 is supported. This result is supported by the subjective assessment by the participants themselves after the study. 10 participants thought they drank more regular with *WaterJewel*, and 2 participants thought that there was no difference in their drinking regularity with regard to *WaterJewel* and *Carbodroid*.

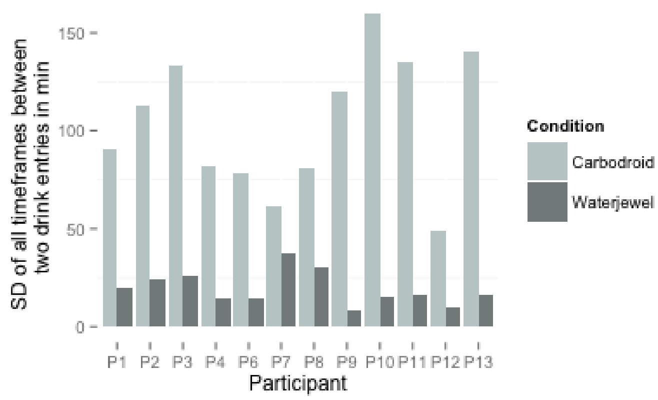

Figure 8. Regularity of drinking per participant

Interval of drinking

On average, participants drank every 94.01 minutes (SD = 11.52) in the experimental condition, and every 140.03 minutes (SD = 36.74) in the control condition. A two-tailed t-test showed that this difference was significant ($p < 0.01$). With regard to the colour of the reminder display of *WaterJewel*, 94 minutes that elapsed since the last drink entry were displayed as a mid orange.

Of all the drinks participants entered in the experimental condition, they made 95.63% prior and 4.37% after the reminder event. Of all drinks they entered in the control condition, participants made 60.1% prior and 39.9% after the reminder event (see Figure 9). A chi-square test showed that this difference was significant ($\chi^2 = 335.35$, df = 1, $p < 0.001$) and therefore supports hypothesis H4.

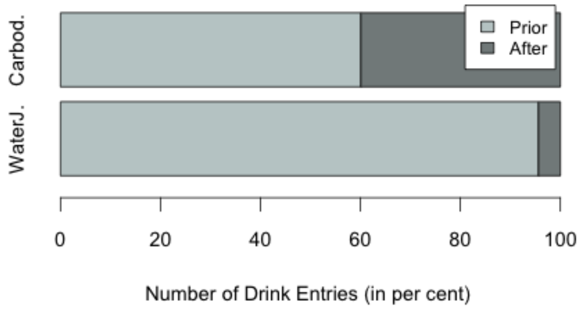

Figure 9. Drink entries that were made prior and after the reminder event with *WaterJewel* (bottom) and with *Carbodroid* (top)

Usability Rating with the SUS

The SUS scores were averagely 91.88 (SD = 6.84, Mdn = 93.75) for *WaterJewel* and 91.04 (SD = 5.69, Mdn = 90) for *Carbodroid*, i.e. both systems were rated very good in usability with only a very small difference for the benefit of *WaterJewel*. A two-tailed t-test could not show that this difference is significant ($p = 0.71$).

Comfort Rating of WaterJewel with the CRS

The comfort of *WaterJewel* was rated with the CRS. Participants rated how they perceived each of the six dimensions *Emotion*, *Attachment*, *Harm*, *Perceived change*, *Movement*, and *Anxiety* on a 20-point scale from *low* (= 1) to *high* (= 20). The CRS were analysed individually. The lower the rating for a dimension, the more comfortable *WaterJewel* was perceived with regard to this dimension. Figure 10 illustrates the ratings of the single dimensions as boxplots. In general, the CRS received very low ratings, i.e. no major comfort issues have been identified. Whereas *Harm* and *Anxiety* were rated extremely low (for both Mdn = 1, Min = 1, Max = 4), *Emotion* (Mdn = 3, Min = 1, Max = 14), *Movement* (Mdn = 3, Min = 1, Max = 14), *Perceived Change* (Mdn = 3.5, Min = 1, Max = 16), and *Attachment* (Mdn = 5, Min = 3, Max = 18) received slightly higher ratings.

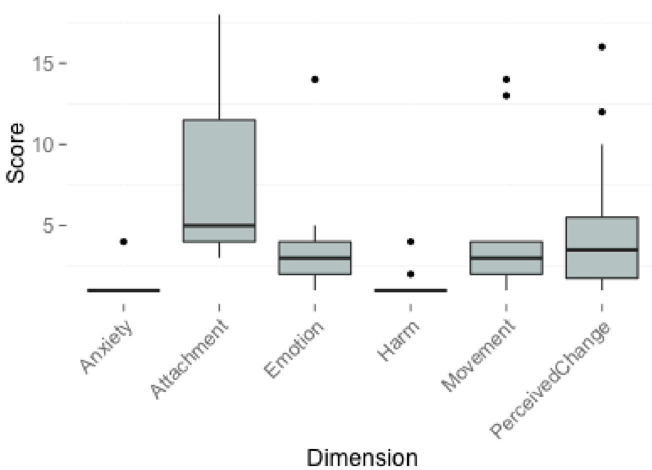

Figure 10. Individual ratings of the CRS for *WaterJewel*

Qualitative Results

Situations which participants experienced during the study

We asked the participants in which situations they carried the smartphone and wore *WaterJewel*. These situations were classified by locations, such as the office, in a lecture, the library, at home, in the street, in a medical practice, the cinema, a restaurant, at the zoo, or in the train. Participants also named various audiences, such as family and friends, colleagues, acquaintances, and public, as well as different activities they performed, such as working, meeting friends, partying, eating, watching TV, doing housework, doing handiworks, shopping, or cycling. Participants did not wear the devices during sports, or when they came in contact with water.

Location of the participants' smartphones

During the study, participants carried their smartphones in various places. We identified two wearing patterns, i.e. participants who carried their phones directly on their body and participants who carried their phones in bags. Concretely, 7 participants (5 male) carried their smartphone either in their trousers or jacket pocket or put it on a table next to them. 5 participants (4 female) carried their smartphone either in a bag or kept it close by on the table.

Visibility of WaterJewel *during the study*

We asked the participants how visible they had worn *WaterJewel* during the study. In general, participants wore *WaterJewel* in a clearly visible way on their wrist. Some participants mentioned that the bracelet was not visible outdoors when they wore a jacket which covered the bracelet. One participant said she intentionally covered the bracelet on the wrist during a cinema show because the bracelet's light was too bright and obtrusive. Most participants stated they hid the additional armlet under their clothes, particularly when they were in public environments. Reasons were the apparent and prototypical appearance of the technical components. Participants said they did not want to unsettle other people who might have thought they were ill or dangerous.

Reasons for difficulties in drinking regularly and sufficiently

Participants reported they had difficulties in drinking sufficiently and regularly when they were on the way or experienced a stressful working day. This was due to the absence of drinks or because participants were short of time. With regard to *Carbodroid*, participants mentioned situations in which they forgot to carry their smartphone, were not motivated to fetch the phone from another room, in which the smartphone battery was flat, and in which the triggered vibration was inappropriate in a way that they could not react to it. Several participants reported they sometimes did not notice the vibration of the phone. Thus, they forgot to drink, or added a drink belatedly. One participant stated she had difficulties to drink regularly at school and at work, where she was not allowed to use a smartphone.

Preference and Comfort

On the precondition that *WaterJewel* was a real product with less prototypical appearance and all components integrated into the bracelet, 8 participants preferred *WaterJewel* to *Carbodroid*, 3 preferred *Carbodroid*, and 1 liked both systems. As the reason for the perceived impact on movement, perceived change, and for the sensing of the attachment, that participants rated using the CRS, they gave the armlet and the cable which connected the bracelet with the hardware components on the armlet. In addition, some participants stated they worried about that they could demolish the prototype. As the main reason for the perceived worry about their appearance (= *Emotion*), participants named the overall prototypical appearance of *WaterJewel*.

Carbodroid was experienced as easy to handle and intuitive. A participant was especially motivated by the illustration of the app character. He said he liked to fill up the character and thus drank more than usually. A female participant experienced *Carbodroid* as unnecessarily playful. As a big drawback of the application participants mentioned that *Carbodroid* reminded to drink every two hours, no matter if the user drank in the meantime. Besides, participants criticised that *Carbodroid* automatically reset all input values at midnight, no matter how the circadian rhythm of the user was.

All participants liked the appearance of *WaterJewel* in terms of an aesthetic bracelet and especially mentioned the advantage that it was always in the view, did not need to be fetched or could not be forgotten like a smartphone and was very intuitively to use. The green light spot of the volume display was experienced as a motivating sense of achievement. All participants commended that the reminder display allowed continuous awareness of the time elapsed since the last intake and thus helped to drink proactively. Several participants added they would not need the additional vibration signal. E.g. a participant reported that she drank in an orange lighting phase because she knew the upcoming appointment would overlap the red lighting phase. However, one participant experienced *WaterJewel* as pushing because he felt stressed by the red light of the reminder display. Furthermore, participants appreciated that – in contrast to *Carbodroid* – the countdown for the drinking reminder of *WaterJewel* was reset when the user had entered a drink.

DISCUSSION

In summary, the results show that *WaterJewel* helps to improve the drinking behaviour with respect to the presented study conditions. *WaterJewel* performed significantly better in drinking volume (H1), accomplishment of the daily drinking goal (H2), drinking regularity (H3), and drinking interval (H4) compared to *Carbodroid*. The participants found *WaterJewel* usable, appreciated its aesthetic appearance, and in general felt comfortable with it due to its unobtrusive character. Most participants preferred *WaterJewel* to *Carbodroid* for daily drinking support.

The study revealed that *WaterJewel* in particular impressed by its convenience in terms of a wearable technology which is ever-present, unobtrusive, aesthetic, and integrated into an object which is often worn anyway in everyday life. Especially the reasons participants named for not performing well while using *Carbodroid*, such as not being motivated to fetch the device, having forgotten the device, or having missed the phone's vibration, plead for the use of a wearable device with an always perceivable display, such as *WaterJewel*. A central finding was that a continuously illuminated light display such as *WaterJewel* is well-suited to serve as a reminder in daily life, and to support drinking more regularly. Furthermore, it allowed drinking proactively. We found participants averagely drank when the reminder of *WaterJewel* displayed a mid-orange, i.e. they drank every 94 minutes. Overall, with *WaterJewel* they typically drank prior to the reminder event. It may thus be concluded that participants actively made use of the continuous information presentation. With regard to drinking reminders, the study showed these should factor in the user's circadian rhythm, his/her actual drinks and a selectable drinking unit, e.g. from different glass sizes. Reminders based on onetime signals should repeat or encourage the signal if the user does not react.

Our study results reflect the participants' drinking behaviour on the basis of drink entries that participants made independently. We assume, participants made the entries to the best of their knowledge, but still this cannot be guaranteed. Besides, some results have to be interpreted carefully. The measures "drinking regularity" and "drinking interval" might be influenced by belatedly added drinks in the *Carbodroid* condition, for the benefit of *WaterJewel* (see section on qualitative results). Although our study was reasonably long compared to the related work, we cannot be sure that we were successful in overcoming the novelty effect. However, a potential novelty effect would have been present for both conditions, albeit less intense in the *Carbodroid* condition because all participants were used to a smartphone.

The current approach is limited in that intakes have to be entered manually. Also, drinking unit and daily goal are fixed to standard values. In a practical setting, serving sizes may vary and daily goals might differ due to age, illness or physical activity. However, having a look at current developments we think that, in future, wearable activity recognition applications and physiological sensors such as sticking hydration sensors will be used to automatically detect fluid intake needs and thus make user input unnecessarily.

Our current *WaterJewel* prototypes do not yet fulfil all requirements, in particular with regard to aesthetics and unobtrusiveness. Although we designed two fashionable bracelets, we could not implement them with a sufficiently aesthetic and unobtrusive appearance that is required for a piece of jewellery. E.g. the discreet integration of all hardware components into the bracelet itself would allow a much more convenient use in everyday life. These limitations are due to the bracelet's prototypical status. Further worthwhile improvements seem to be the adjustment of the display's brightness due to lighting conditions in the environment.

CONCLUSION

In this work we found a lighting-up bracelet to be an effective tool to promote a better drinking behaviour in everyday life. We demonstrated the design process of the interactive, fashionable bracelet *WaterJewel*. A four weeks field experiment showed that with *WaterJewel*, participants drank more in total, more often accomplished the daily drinking goal of 2 litres, drank more regularly, and drank more often prior to the reminder event than with a prevalent mobile drinking reminder application. Participants rated *WaterJewel* as very usable, and especially highlighted it as pleasing thanks to its form factor. Our results indicate that the always perceivable reminder display of *WaterJewel* enables constant awareness of the personal drinking behaviour. We argue that the implementation of motivational and reminder applications in terms of a presentable and always-in-the-view wearable technology is very promising. We think that such wearable technologies could be a useful complement of mobile applications or could even replace them, according to the desired information depth. Our qualitative study results provide concrete suggestions for a useful and appealing design of drinking reminders and wearable light displays.

This work contributes to the field of wearable informational displays, quantified self and motivational technologies. By means of the concrete use case of a drinking reminder, we have shown that its implementation in terms of digital jewellery is a promising approach to integrate wearable technologies unobtrusively into everyday life. Furthermore, we have shown that this technology is usable for self-tracking in everyday life and inspired participants to perform a specific behaviour. In the next step, we will research the influence of particular everyday life situations on the acceptance of *WaterJewel*. Besides, we want to investigate other form factors of jewellery-based displays.

A drinking reminder is one use case for a personal reminder in everyday life. We assume, *WaterJewel* and similar wearables can also be appropriate for other everyday life activities for which the regularity of actions is important, like being physically active, eating, or medication. Also, onetime reminders which remind of e.g. closing the window, removing the tea bag from the water, or taking the cake out of the oven seem to be potential use cases for a continuous light-based information display, such as *WaterJewel's* reminder.

ACKNOWLEDGEMENTS
We thank all participants for taking part in our studies. We thank the developers of *Carbodroid* for providing a modified version which allowed us to log user input.

REFERENCES
1. Ahde, P., and Mikkonen, J. Hello: bracelets communicating nearby presence of friends. In *Proc. of PDC '08*, Indiana University (2008), 324–325.
2. Brooke, J. SUS - A quick and dirty usability scale. In *Usability Evaluation in Industry*, P. W. Jordan, B. Thomas, I. L. McClelland, and B. Weerdmeester, Eds. CRC Press, 1996.
3. Cawthon, N., and Moere, A. The effect of aesthetic on the usability of data visualization. In *Information Visualization, IV'07.*, IEEE (2007), 637–648.
4. Consolvo, S., Everitt, K., Smith, I., and Landay, J. A. Design requirements for technologies that encourage physical activity. In *Proc. of CHI '06*, ACM (2006), 457–466.
5. Consolvo, S., McDonald, D. W., and Landay, J. A. Theory-driven design strategies for technologies that support behavior change in everyday life. In *Proc. of CHI '09*, ACM (2009), 405–414.
6. EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). Scientific opinion on the substantiation of health claims related to water and maintenance of normal physical and cognitive functions, maintenance of normal thermoregulation and basic requirement of all living things. *EFSA Journal 9*, 4 (2011), 2075.
7. Fogarty, J., Forlizzi, J., and Hudson, S. E. Aesthetic information collages: generating decorative displays that contain information. In *Proc. of UIST '01*, ACM (2001), 141–150.
8. Hansson, R., and Ljungstrand, P. The reminder bracelet: subtle notification cues for mobile devices. In *Proc. of CHI EA '00*, ACM (2000), 323–324.
9. Harrison, C., Horstman, J., Hsieh, G., and Hudson, S. Unlocking the expressivity of point lights. In *Proc. of CHI '12*, ACM (2012), 1683–1692.
10. Harrison, C., Lim, B. Y., Shick, A., and Hudson, S. E. Where to locate wearable displays? reaction time performance of visual alerts from tip to toe. In *Proc. of CHI '09*, ACM (2009), 941–944.
11. Hoggmann, P., and Gehring, W. G. *Richtig trinken - Vom Wasser bis zum grünen Tee: Alles über Trinken und Getränke für Gesunde und Kranke*. Trophos GmbH, 1998.
12. Holmquist, L. E., and Skog, T. Informative art: information visualization in everyday environments. In *Proc. of GRAPHITE '03*, ACM (2003), 229–235.
13. Knight, J., Baber, C., Schwirtz, A., and Bristow, H. The comfort assessment of wearable computers. In *Proc. of ISWC 2002* (2002), 65–72.
14. Matthews, T., Dey, A. K., Mankoff, J., Carter, S., and Rattenbury, T. A toolkit for managing user attention in peripheral displays. In *Proc. of UIST '04*, ACM (2004), 247–256.
15. Miner, C. S., Chan, D. M., and Campbell, C. Digital jewelry: wearable technology for everyday life. In *Proc. of CHI EA '01*, ACM (2001), 45–46.
16. Müller, H., Fortmann, J., Pielot, M., Hesselmann, T., Poppinga, B., Henze, N., Heuten, W., and Boll, S. Ambix: Designing ambient light information displays. In *Designing Interactive Lighting Workshop in conjunction with DIS '12* (2012).
17. Pousman, Z., and Stasko, J. A taxonomy of ambient information systems: four patterns of design. In *Proc. of AVI '06*, ACM (2006), 67–74.
18. Tarasewich, P., Campbell, C., Xia, T., and Dideles, M. Evaluation of visual notification cues for ubiquitous computing. In *Proc. of UbiComp 2003*. Springer Berlin Heidelberg, 2003, 349–366.
19. Techniker Krankenkasse. TK-Medienservice "Wasser Quell des Lebens" , 2010.
20. Williams, A., Farnham, S., and Counts, S. Exploring wearable ambient displays for social awareness. In *Proc. of CHI EA '06*, ACM (2006), 1529–1534.