It's About Time: Smartwatches as Public Displays

Jennifer Pearson, Simon Robinson, Matt Jones
Future Interaction Technology Lab, Swansea University, SA2 8PP, UK
{ j.pearson, s.n.w.robinson, matt.jones } @swansea.ac.uk

ABSTRACT
Current uses of smartwatches are focused solely around the wearer's content, viewed by the wearer alone. When worn on a wrist, however, watches are often visible to many other people, making it easy to quickly glance at their displays. We explore the possibility of extending smartwatch interactions to turn personal wearables into more public displays. We begin opening up this area by investigating fundamental aspects of this interaction form, such as the social acceptability and noticeability of looking at someone else's watch, as well as the likelihood of a watch face being visible to others. We then sketch out interaction dimensions as a design space, evaluating each aspect via a web-based study and a deployment of three potential designs. We conclude with a discussion of the findings, implications of the approach and ways in which designers in this space can approach public wrist-worn wearables.

Author Keywords
Smartwatches; public displays; wearables; mobiles.

ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies; Interaction styles; Screen design.

INTRODUCTION
In addition to being precise timekeeping devices, wristwatches have long been regarded as anything from high-end status symbols to must-have, colour-matched fashion accessories. Despite their personal nature, however, watches have also historically acted as a useful public information resource. For example, someone not wearing a watch might ask a passerby for the time, or even just discreetly glance at another person's wrist when in a room without a visible clock.

After a trend of consumers increasingly discarding watches in favour of phones or other mobile devices [7], we now see a potential reversal with the growing focus on the smartwatch. Consumers already have the ability to link their mobile phone with wearables such as the various Android Wear, Galaxy Gear, Apple or Pebble devices, and recent estimates suggest the overall smartwatch market could expand to several hundred million units by 2020 [16]. The functionality of these devices—with content and apps often just as feature-rich as on modern smartphones—now means we have access to a vast and rich set of information and services directly from our own wrists.

So far, these devices have been marketed as an extension of our personal information spaces – that is, the watch will display a condensed version of content that is available in full on a paired phone. Consider, for example, the promotional material for the Apple Watch, which focuses around terms such as *"personal," "intimate"* and *"discreet"* to describe its capabilities.[1] Unlike the displays on more private screens, however, information given on a wrist-worn device may often be in public view. We feel that this offers a great opportunity to create a new interaction space for the presentation of content to others in close proximity to the wearer. In this research, then, we introduce the novel possibility of designing such wearables for spectators [21], turning the once inherently personal watch face into a wrist-worn public display. We imagine the display showing a range of content from the web, from the wearer, or from (and to) other people who are standing close by.

In the rest of this paper we set out our conceptualisation for this new area of personal-to-public wearables. As a first step, we explore whether the act of looking at other people's watches is socially acceptable, and whether this interaction is noticeable or disruptive in comparison to looking at one's own watch. We then investigate watch deportment via an observation study of postures and visibilities. These results are used to sketch a design space for this field, systematising five factors that will determine the way such displays are designed. We evaluate this design space in a further study that helps select the factors with the most value for current displays. We then describe three example use-case probes, which we prototype and assess in naturalistic user evaluations. Finally, we conclude with a discussion of the rich future of public personal displays.

BACKGROUND
The focus of this paper is around turning personal screens into publicly accessible information displays. While there has been much research into collaborative sharing of media by appropriating personal screens (e.g., [11, 12]), there has been surprisingly little in the area of private displays becoming public displays without direct user input. Existing research has focused around topics such as using private devices to control or place content on public displays (e.g., [4, 28]). Cheverst et al. [2], for example, allowed users who did not want their personal information placed online to leave awareness information on public screens outside their office doors. Schwarz et al. [24] moved closer to our aim with their work to automatically create large tiled displays from a collection of smaller devices. While their technology cannot be used on a single device, it is an

[1] See: apple.com/watch/technology (accessed 6th Jan. 2015).

example of how personal screens can be used to create publicly accessible information displays. More related to our work, perhaps, is that of Harper and Taylor [8], whose Glancephone design let callers remotely "glance" at the person being called to see if they were available, via the camera of their phone. Similarly, in our design, the smartwatch of another person is adopted for a glancer's use, but in our case it becomes a display for any content, not just that of the wearer.

Wearable displays

A significant amount of research effort has been dedicated to personal wearable displays, with much of the focus being on providing information and services to the wearer themselves. Harrison et al. [9], for example, investigated wearable placement to ensure the quickest reaction time to visual stimuli. Of the seven different body locations evaluated, they concluded that, at least for personal use, the wrist is not only the fastest location, but also the most accurate (i.e., gave fewest errors).

The use of subtle cues on wearables to display information to the wearer has been seen in several forms for some time. Eye-q [3], for example, used peripheral LEDs mounted in eyewear to deliver discreet notifications. Other work has hinted at the possibility for more publicly visible wearables such as rings to display low-resolution information (using just three pixels) that only the wearer is able to interpret [1]. In our view, the combination of smartwatches and careful design could provide displays that are understandable by people other than the wearer in ways that are useful to both parties.

Wearable displays to provide information to others

The use of wearable displays to provide information to those other than the wearer has been touched upon previously, but usually in a more explicit manner. An early example of this is Falk and Björk [5]'s BubbleBadge, in the form of a brooch. The BubbleBadge was designed specifically to be a public wearable display, in full view of any others in the area. Falk and Björk also discuss three categories for the information provider: the wearer, the viewer, and the environment. We are interested in similar types of information source (as described later in our design space), but our approach differs to BubbleBadge's "in-your-face" scenario – our intention is to turn a personal wearable into a discreet form of public information access for those around the wearer.

Outside of HCI, public expressiveness has been studied in a range of areas, including fashion, performance and body art (see [10] for a survey), though primarily in the form of abstract and ambient displays, rather than the distinct types we explore. The value of publicly visible wearable displays for the benefit of spectators has also been explored in sport. Page and Moere [18], for example, developed a wearable system which aimed to enhance awareness and understanding of game-related data while engaging in group activities. Their TeamAwear jerseys were equipped with remotely controlled electroluminescent wires to display information such as individual fouls, scores and time alerts. Similar work on the use of wearables during group fitness activity includes Mauriello et al. [13]'s Social Fabric Fitness interface, which used eTextile screens on the back of runners' t-shirts to display information such as average pace, distance or duration to fellow runners in an attempt to increase awareness and motivate group fitness performance. Lastly, the LunarHelm [27] was an LED equipped bicycle helmet designed to provide bystanders with sensor data from the rider (e.g., for communication, expression or play). Its creators describe how wearable displays afford unique information access opportunities for those in close proximity to the wearer – a benefit we take advantage of in this work.

These sport-related examples, and other public wearables such as Waldemeyer [26]'s Twitter dress, make use of specially designed hardware (e.g., augmented helmets; eTextile displays etc.) to facilitate the behaviour they achieve. Our approach makes use of a form factor that many users already wear, however – the wristwatch. It is also worth noting here that none of these previous examples are intended for use by the wearer, as in all cases the screen is not physically visible to them. In contrast, our approach allows both public displays as well as personal displays to be offered by the same device.

How many people actually wear watches?

While media reports have regularly discussed the decline of wristwatches since the introduction of multi-function personal devices such as mobile phones,[2] market research suggests that the number of watch owners has actually remained static in recent years [15]. One study in particular, conducted by market research firm YouGov in 2011 [7], surveyed 1200 Americans about watch use, finding that 78 % owned one or more watches, and 41 % were wearing one at the time of asking. Now, with smartwatch sales increasing, it is reasonable to assume that the number of people wearing watches will either continue to remain static, as smartwatches replace or augment regular watches; or, their prevalence will increase as people resume wearing a watch with new capabilities beyond timekeeping.

The effects of personal technology on social interaction

Our focus in this paper is on the use of wearables as public, rather than private displays. It is important, therefore, to understand the extent to which such technology affects social interaction. The rise of digital wearables has generated a surge of research on the topic of social acceptability around their use. Przybylski and Weinstein [20] studied how personal mobile communication technology influences face-to-face interaction quality, demonstrating that its mere presence can interfere with social interaction, inhibiting the development of interpersonal closeness. Other investigations have focused primarily on visual appearances, such as attractiveness and comfort [6]; and, of course, on worries over how people will react to a new and possibly odd-looking wearable. It will take time for new designs and interaction methods to become socially acceptable (consider, for example, how Bluetooth headsets, now common, made wearers seem like they were talking to themselves [23]).

Some have opted to approach this issue by hiding interactions with wearables, attempting to convince passersby that the user is acting conventionally. The e-SUIT [25], for example, aimed to allow covert interactions with wearables without informing those nearby (e.g., via discreet watch notifications). Profita et al. [19] studied public wearable interactions from both social and cultural angles. With a focus on third-party attitudes

[2] E.g., bbc.co.uk/news/magazine-11634105 (accessed 6th Jan. 2015).

towards these interactions, they found that, culturally, Koreans had a higher preference for wearables that *"avoided making the user look weird or awkward"* than Americans, whose preference was for the devices to be easy to operate. Social acceptability implications of on-body actions and gestures have also been studied. Rico and Brewster [22], for example, investigated phone gestures, discovering that location and audience type had a significant impact on willingness to gesture. Similarly, McAtamney and Parker [14] studied the impact of a large head-mounted display on the conversation between two people. Non-active displays showed no effect, while active screens had a detrimental effect on the eye contact of the users in the study. While a head-mounted display is likely to be seen as more directly noticeable than a wrist-worn watch, the noticeability and perceived social impact of glancing at another person's watch during conversation are questions we investigate and report on later in this paper.

STUDY 1: THE IMPACT OF GLANCING

As a first step in assessing the viability of this new interaction area, we conducted a study to measure people's awareness of interactions with watches. Our prime focus was on whether looking at another person's watch during a conversation with them interrupted the flow of that conversation. We explored this via measuring both the perceived social acceptability of glancing at other people's watches, and also whether this action was actually noticeable or disruptive to conversation.

Primary group: public wearables

We recruited 18 participants (12F, 6M; aged 18–55) for nine 30 min paired sessions, during which one participant (the *glancer*) was prompted to look at a watch worn by the other (the *wearer*) several times without their knowledge.

Procedure

At the start of the study, participants were met separately, and led through an ethically-approved informed consent procedure. In each pair, one participant was randomly assigned to be the *glancer* and the other the *wearer*. The *wearer* was given a smartwatch to wear on their wrist (their choice of left or right), and told that the purpose of the study was to explore people's behaviours during everyday conversation, captured using the watch. They were then asked to sit at a table opposite the other participant, positioning their arm so that the watch face was visible. The *wearer* was intentionally *not* informed that the other participant would be looking at their watch.

The *glancer* was also given a smartwatch to wear on their left or right wrist, and was informed that our interest was around the impact of looking at watches during conversation. This participant was told that their secondary objective (after making conversation) was to look at the face of the other participant's watch whenever they felt their own watch vibrate. The *glancer* was asked not to mention their glancing task during the conversation unless the *wearer* asked them directly.

The primary task in the study was a short (5 min) conversation, observed by the researchers. We provided a list of example topics for participants to discuss during the study (including recent travel, work, study and news items), based on those used in [14]. Apart from the *glancer*'s instruction not to talk about their glancing task, there were no restrictions on conversation topic – participants were told that the example topics were merely suggestions and need not be followed if the conversation naturally diverged during the session. Two researchers observed the conversation from positions diagonally opposite each participant in order to record when the *glancer* looked at the other participant's watch, and note reactions and behaviours of each participant during the discussion. The vibration cue was sent automatically to the *glancer*'s watch at six intervals throughout the five-minute discussion session, and reactions were monitored by the observing researchers using an app linked to the smartwatch vibration trigger times. These intervals were randomly generated prior to the study, but were the same for every pair of participants. Both watches displayed only the current time for the duration of the conversation.

At the end of the discussion task, we performed a short semi-structured interview with the two participants. Each interview began by asking about the conversation flow, and whether anything had interrupted the discussion. The *wearer* was then directly asked whether they had noticed the *glancer* looking at the watch they were wearing. Intentionally not informing the *wearer* about the real purpose of the investigation was necessary to ensure an unbiased answer to this question (e.g., avoiding the *wearer* actively looking for watch glances from the other participant). Following this, the *wearer* was asked whether this action affected or interrupted the conversation, and the *glancer* for their perspective, such as whether they felt uncomfortable or embarrassed about checking the watch.

Participants were then asked to rate the extent to which they felt it is socially acceptable to look at (a) another person's watch; or, (b) their own watch, during a one-to-one conversation. Participants answered on a 5-point Likert-like scale from 1 (*"completely unacceptable"*) to 5 (*"completely acceptable"*). Finally, participants were asked whether they wore a watch themselves; if they had ever looked at other people's watches rather than their own; and, whether they had ever noticed other people looking at their watch. At the end of the study, each participant was compensated with £5 in return for their time.

Comparison group: personal wearables

To calibrate, we conducted a variant of the experiment to compare the effect of looking at another person's watch to the effect of looking at your own watch. We recruited 16 further participants (9F, 7M; aged 18–55) to follow a modified version of the procedure described above. In this study, only one participant wore a watch. When given a vibration cue, this participant looked at the watch on their own wrist, rather than that of the person they were talking to. As before, the other participant was told that we were investigating people's behaviours during everyday conversation, but no mention was made of the watch that their conversation partner would be wearing. All other aspects of the experiment followed the same procedure as described above.

Results

Of the 34 participants in both groups, 17 (50 %) said that they usually wore a watch, with 7 (20 %) wearing one occasionally, and the remaining 10 (30 %) never wearing a watch. 24

participants (71 %) said that they had looked at other people's watches to get the time, but only three participants (13 % of watch wearers) had noticed other people looking at their watch.

Turning now to the noticeability results. In the primary group, three participants (33 %) noticed the glancer looking at the watch that they themselves were wearing. In the comparison group, seven participants (88 %) noticed the glancer looking at their own watch. A Fisher's exact test on these values shows a significant result ($p < 0.05$), indicating that it is less noticeable to look at another person's watch than your own. Although ten participants over both groups noticed the other participant's watch glances, there were no noticeable reactions to this action (as measured by the observing researchers), and none of the participants brought up the glancing in their conversation.

The average rating for the social acceptability of looking another person's watch during a conversation was 3.32 out of 5 (s.d. 1.17), compared to 2.85 (s.d. 0.99) for looking at one's own watch. The difference between the two cases was not statistically significant (Wilcoxon signed-rank test, $p = 0.06$). However, looking at the differences between participants' ratings in more detail, it becomes apparent that in general participants felt that looking at another person's watch was more socially acceptable. That is, 15 participants (44 %) rated the acceptability of looking at another person's watch higher than looking at their own, while only 7 (21 %) said it was more acceptable to look at their own. 12 participants (35 %) saw no difference between the two cases.

This indication was supported by participants' comments. Several participants indicated that the implication of a glance at your own watch would depend on the situation (e.g., social vs. professional), but there were also many remarks about both the ease (*"it's so much easier looking at someone else's than yours"*) and acceptability (*"a quick glance is ok"*; *"I use other people's watches to tell the time instead of taking out my phone"*; *"it's a bit more unobtrusive"*) of looking at other people's watches. We believe—supported by observations, ratings, and participants' comments—these results show that it is a no more noticeable, unacceptable or even unusual practice to look at another person's watch rather than your own.

STUDY 2: WATCH FACE DEPORTMENT

The next aspect necessary in order to be able to define a design space for public watch displays is to understand the degree of visibility of watch faces in current everyday situations. We conducted a study to assess, in situations when a (non-smart) watch was visible, the degree to which watch faces could be seen by a bystander; and, in addition, to gather information on the most common deportments of these visible watches.

Procedure

We created a simple observation capturing app which was used for logging watch visibilities (as defined in Fig. 1) and positions (as shown in Table 1). Three researchers used the app over a period of seven weeks, classifying situations in which they saw people wearing a watch while engaged with others, either sitting down or standing still. People not wearing a watch were not logged. The places in which observations were captured included a wide range of homes, workplaces, third places and public spaces. For example, observations were logged in train stations, airport lounges, offices, beaches, cafés, meeting rooms, boats, public squares, restaurants, homes, hotels, visitor attractions, theatres and research laboratories. In order to be able to accurately compare visibilities, observations were logged from the perspective of a glancer positioned directly opposite the watch wearer. Each observation was classified as one of the following arm positions: by the side of the wearer; laid on a table; on the wearer's lap; by (or supporting) the wearer's head; folded arms; gesturing; in a pocket; and, any other position. Each observer followed the same classification procedure:

1. Select a visible area (e.g., café, platform concourse, etc.).
2. Systematically look around for people visibly wearing a watch who were engaged with at least one other person.
3. Log the visibility and deportment of the face of each watch.

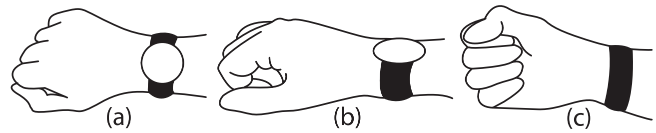

Figure 1. Visibility classifications used in the deportment study. (a) Full visibility: the watch face would be in direct view of a person sitting opposite the wearer, to the point where they would be able to read all the information displayed. (b) Partial visibility: the watch face would be partly visible to a person sitting opposite the wearer, but restricted due to, for example, display angle or clothing cover. A glancer would be able to see information on part of the screen, or distinguish a particular colour. (c) Not visible: a watch is clearly present, but a person sitting directly opposite the wearer will not be able to see any part of its face.

	Arm by side	Arm on table	Arm on lap	Arm by head	Folded arms	Arm gesturing	Hand in pocket	Other position
% Obs.	25	15	15	14	12	10	5	4

Table 1. Percentages of the 300 observations recorded in each position.

Results

Over the 49-day study period, a total of 300 watch observations were captured in four European countries, over a diverse mix of international peoples and cultures. Observations spanned a wide time period (7 a.m. to 9:15 p.m.), and were captured on all seven days of the week. As can be seen from Table 1, which shows the number of observations of each deportment type that was captured, there are many different situations in which watch faces can be visible to others around the wearer.

Turning to visibility, 88 % of observations were of either fully visible (153 obs.; 51 %) or partially visible (112 obs.; 37 %) watches. Only 36 of the 300 people observed were holding the watch in a position where it was not at all visible. We did not notice any differences in positions or visibilities between times of day, days of the week, locations, cultures or countries.

Discussion – Study 2

The deportment results give a strong indication that when a person is wearing a watch that is visible, the face of that watch is likely to be able to be seen by a glancer. This is a valuable finding for the viability of future public watch displays.

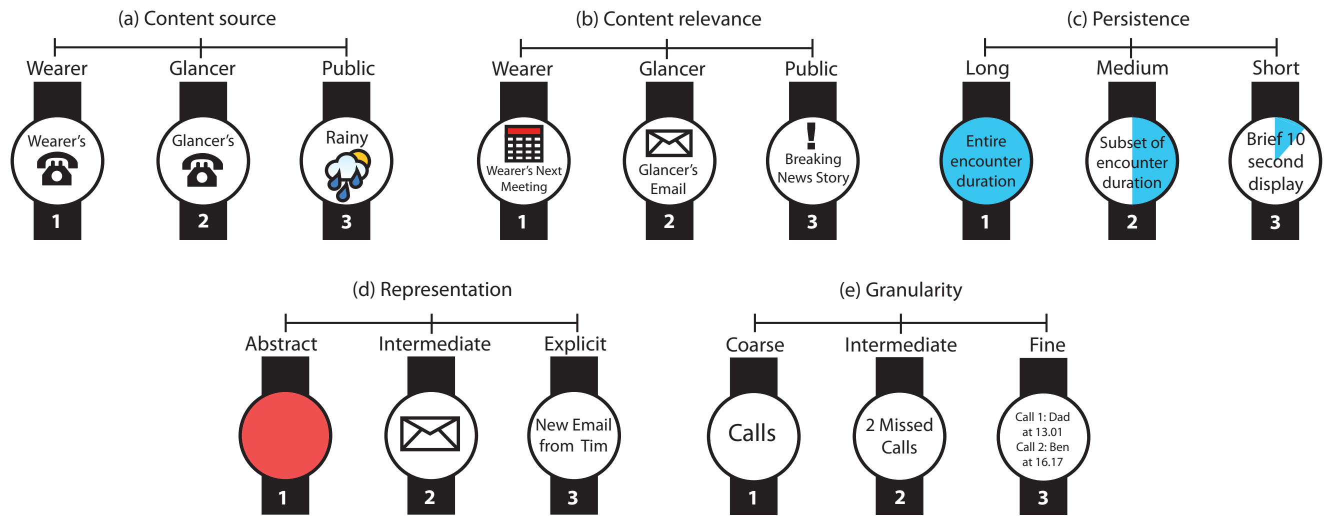

Figure 2. Content-oriented factors of the design space for public watch interactions, showing example displays of each type. Each of the five factors can be characterised on a sliding scale across the given dimension. Each scale is continuous, rather than being restricted to the three key delimiters, and allows any content-oriented aspect of the display to be described, as demonstrated later in Fig. 5. Labels (1, 2, 3) refer to the faces described in Table 2.

The positions that watch wearers' arms are held in will also be important in shaping designs in this space, as in many cases the position of a wearer's arm will directly affect the content that is displayed. While there are clearly many contextual factors that will affect a public watch display, the deportments observed in this study offer some guidance as to where different forms of displays are the most appropriate, and when.

Turning first to deciding where and when to show public watch content, the position, angle and orientation of the display will be important factors in choosing between showing information aimed at glancers or at the watch wearer themselves. When the watch is facing the wearer (supported by posture detection, a face recognition camera on the watch, or simply a tap on the screen) it might be most appropriate to default to showing the time, or other standard smartwatch content.

When the wearer's arm is on a table, by their head, or folded in front of them, there is scope for detailed, precise representations of content to be shown. When their arm is by their side, or on their lap, the screen is most likely to be only partially visible to a glancer, so these positions would perhaps be associated with abstract, iconic forms, or a low level of detail.

Arm positions and watch face visibilities will also influence the choice of display in ways that are less immediately apparent. For example, the length of time content is displayed for may be linked to externally measurable contextual variables, such as the time the watch has been held in a specific orientation (via the watch's accelerometer). Or, the distance of a glancer (via positional information or face recognition) might control the representation that is chosen, with more abstract displays (such as a single colour) used when the glancer is further away.

Other external factors, such as environmental conditions and wearer behaviours (e.g., sleeves entirely covering the display; putting hands in pockets) are clearly beyond a designer's control. However, they will directly affect the choice of both representation and granularity in many cases. For example, a watch that is only semi-visible would perhaps be most useful when displaying a coarse and abstract display, or a pictorial representation of the content. Similarly, a light sensor on the watch could influence both content duration and its representation for ease of interpretation in bright sunlight.

DESIGN SPACE: INTERACTION DIMENSIONS

Before being able to innovate in this novel space there are a number of important design factors to consider. Having explored both the acceptability and noticeability of public watch displays, and measured the real-world visibility and deportment of watches, we used these results to formalise a design space for public watch displays. We approached this by first generating an extensive set of sample design concepts covering all of the visibilities and deportments described in the previous section. These were then analysed to extract technical abstractions that systematise the properties of future designs in this space. Here, then, we present the set of interaction dimensions that we envisage will shape future public smartwatch displays. These factors revolve around the content that is displayed, and can be characterised on a scale across a dimension of its source, relevance, persistence, representation, or granularity, as illustrated in Fig. 2.

Throughout this section, we will be describing two personas (as in study 1). The *wearer* refers to the person who is wearing the smartwatch. The *glancer* refers to the intended recipient of the information displayed on the watch – for example, another person sitting or standing in close proximity to the wearer. In all cases, where specifics are given these are examples of the types of content we see as representing a particular content factor, rather than a restriction to that exact content.

Content source

The content source parameter concerns the owner of the content being displayed, and therefore where it is sourced from (see Fig. 2a). The three key delimiters on this scale are:

– *Wearer:* Information owned by the *wearer*. For example: missed call details; their next meeting time; holiday photographs; health information; contact information;
– *Glancer:* Information owned by the *glancer*. For example: missed call details; appointment times; alerts; and,
– *Public:* General information from public sources. For example: any public information that could easily be retrieved, such as the weather forceast, adverts or news.

Content relevance
This parameter concerns who the content being displayed is relevant to (see Fig. 2b). This may include anyone from the *wearer* to the *glancer* (or an intersection between the two) to the general public:

– *Wearer:* Information that is relevant to the *wearer* (but not viewed by them). For example: information about their schedule; contact details (e.g., when at a conference);
– *Glancer:* Information that is relevant to the *glancer*. For example: email or call notifications; conversation cues; and,
– *Public:* General information relevant to any person (or group of people) able to see the watch. For example: breaking news; the current time; traffic updates; stock prices.

Persistence
The duration (or longevity) of the information that is displayed (see Fig. 2c), ranging from brief alerts to very long displays:

– *Long:* For the entire duration of an encounter. For example: emergency warnings; a countdown timer to a future event;
– *Medium:* For a sub-period of an encounter's duration. For example: agenda details; a rain warning predicting when you need to walk home; and,
– *Short:* As a quick burst of information. For example: standard smartphone event alerts; adverts.

Representation
The type of presentation, ranging from entirely abstract to explicit and precise (see Fig. 2d)

– *Abstract:* Colour-based cues. For example: red for lateness to a meeting; green to indicate an important new email;
– *Intermediate:* An intermediate level of detail (such as an image). For example: an envelope icon to indicate a new email; a message sender's profile picture; and,
– *Explicit:* Clearly understandable and to-the-point, stating the information explicitly (e.g., text). For example: an alert or instruction; a message subject line; a news headline.

Granularity
The granularity of the information presented, ranging from coarse and broad to fine and narrow (see Fig. 2e):

– *Coarse:* Imprecise display of simple cues only. For example: the word "calls" to show missed calls; an email icon;
– *Intermediate:* Some but not all information. For example: number of missed calls only; an email's subject line; and,
– *Fine:* In-depth, detailed description, displaying all relevant information. For example: all missed call information (who called and at what time); an entire email body (scrolling).

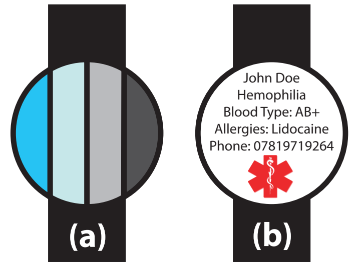

Figure 3. Potential examples of uncommon design parameter combinations. (a) An abstract representation with a fine level of granularity, showing the weather forecast across the day. (b) Content sourced from the wearer that is relevant to the public, showing the wearer's emergency health information.

Illustrative design space uses
Our aim is for these factors to help designers generate potential public watch services. We illustrate this by using them in two perhaps uncommon design parameter combinations, as illustrated in Fig. 3. Figure 3a shows the weather throughout the day, starting with clear blue skies in the morning and ending with a stormy night. This is an abstract representation (Fig. 2d.1) with a fine level of granularity (Fig. 2e.3), using colours alone to show four kinds of weather across different time periods. Figure 3b shows the wearer's emergency health information. This is content sourced from the wearer (Fig. 2a.1) that is relevant to the public (Fig. 2b.3), which could easily be captured with current smartwatches that are already used to monitor chronic health conditions.[3] While these designs are perhaps at first glance unconventional, in theory, any variation of the five design space factors could be combined to provide a type of watch face interaction.

STUDY 3: CONTENT FACTORS
After sketching out the design space of public watch interactions, we felt it valuable to investigate the usefulness of each area of the design space for potential *glancers*. We conducted a web-based study in order to determine which dimensions people find most valuable, given their expectations of current technology, and the ways in watches are currently used. 47 staff and student participants of a UK university (27F, 20M; aged 18–55) took part, completing a 10 min questionnaire.

Procedure
Participants were recruited via email, and offered a £2 gift voucher as an incentive to take part. The study began with ethically-approved informed consent and participation guidance, followed by the same questions regarding current watch use and perceived acceptability as asked in study 1. That is, participants were asked to rate the extent to which they felt it is socially acceptable to look at another person's watch; or, their own watch, during a one-to-one conversation; whether they wore a watch themselves; if they had ever looked at other people's watches rather than their own; and, whether they had ever noticed other people looking at their watch.

Participants then saw, one-by-one, each factor in Fig. 2. They were asked to rate every aspect of each factor (e.g., images Fig. 2a.1–3 through to Fig. 2e.1–3) on a Likert-like scale of 1 to 7 (7 high) for how useful this display would be to them. The three faces of the content source factor (e.g., Fig. 2a.1–3: wearer, glancer and public) were always shown first, as part of the framing and description of the concept of displaying

[3]E.g., bbc.co.uk/news/technology-28776282 (accessed 6th Jan. 2015)

Factor	Face 1	Face 2	Face 3	Significance
Source	3.2	3.2	5.1	$p < 0.0001$
Relevance	3.7	3.8	4.3	$p = 0.25$
Persistence	4.0	3.9	2.9	$p = 0.06$
Representation	2.5	4.3	3.9	$p = 0.0002$
Granularity	3.1	4.6	3.8	$p = 0.0005$

Table 2. Mean scores for each face of each factor in Fig. 2. Significance levels (Friedman tests) indicate that for content source, representation and granularity, there is a significant effect. Pairwise Bonferroni corrected post-hoc Wilcoxon signed-ranks tests on these factors show that darker green values are significant compared to lighter green values in each row (all $p < 0.001$). Unshaded values show no significance to others.

content on other people's watches. Participants were then shown each of the four remaining factors (content relevance, persistence, representation and granularity; Fig. 2b–e) one-by-one in a random order, and asked the same usefulness question about faces 1, 2 and 3 of each factor. The study ended by asking participants to rate the general usefulness of the concept to the watch *wearer*, a *glancer*, or the public.

Results

21 participants (45 %) said that they usually wore a watch, with 11 (23 %) wearing one occasionally, and 15 (32 %) never wearing a watch. 42 participants (89 %) said they had looked at other people's watches to see the time, and 20 (63 % of watch wearers) had noticed other people looking at their watch.

The average rating for the social acceptability of looking at another person's watch during a conversation was 2.40 out of 5 (s.d. 0.97), compared to 2.53 (s.d. 1.10) for looking at one's own watch. These results were not significant (Wilcoxon signed-rank test). As in study 1, however, participants generally felt that looking at another person's watch was more acceptable. 14 participants (30 %) rated the acceptability of looking at another person's watch higher than looking at their own, compared to 7 (15 %) who felt the opposite. 26 (55 %) felt there was no difference between the two actions.

Table 2 shows the average scores given for the usefulness of each design space attribute. A Friedman test shows a significant effect of content source, representation and granularity. Pairwise post-hoc Wilcoxon signed-ranks tests with Bonferroni corrections reveal the differences between each watch face option. For content source, there is a significant difference between faces 3 (public) and 1 (wearer), and also between faces 3 and 2 (glancer): participants felt public content sources were more useful. For representation, there is a significant difference between faces 2 (intermediate) and 1 (abstract), and between faces 3 (explicit) and 1: participants did not feel abstract representations were useful. Finally, for granularity, there is a significant difference between faces 2 (intermediate) and 1 (coarse): participants felt intermediate more useful than coarse granularity. Each of these pairwise comparisons was significant at $p < 0.001$ or lower.

Participants' comments reflected these preferences, particularly regarding the value of public content sources (*"useful to display public information on a watch located in a public place"*) and intermediate levels of abstraction and granularity (*"personally I would prefer an image that hints at the content rather than less or greater detail"*). Many participants were very positive about the general notion (*"I think this sort of thing would be great in a work environment to see when other people have meetings"*), while other comments highlighted the need for careful design (*"don't like colour as [it] seems to indicate danger"*). In general, while participants saw value in the displays, the low level of many of the scores suggests that an appetite for smartwatches is yet to be fired. Participants in this web-based study did not have a smartwatch for illustration of each factor, so might naturally be sceptical. However, their views indicate that the most useful representations for current users would tend towards those scoring highest in Table 2.

STUDY 4: PUBLIC WATCH DISPLAYS DEPLOYMENT

In order to test naturalistic use of public watch displays, we developed and deployed three technology probes. Each probe demonstrates how the design space factors we have described would be used to inform designs in this space.

Technology probes

We constructed three separate technology probe systems, each designed as an Android application for a Sony SmartWatch 2 (see Fig. 4, far left). We chose three different content sources as the primary consideration, and aimed to cover the majority of each of the four further design space factors.

🔴 *Probe 1: Wearer's content*

Probe 1 displayed content sourced from the watch wearer. We designed a simple display showing the time remaining until the wearer's next meeting, automatically extracted from the calendar on their phone. The display started five minutes before a scheduled event, and began by showing a timed reminder (e.g., *"Tim's meeting is in 5 minutes"*) on a green background, as shown in Fig. 4 (far left). The display updated as the time became shorter, cycling through 4, 3, 2 and 1 minutes remaining, and through green to yellow to red for the background colour. Finally, for two minutes after the deadline the display showed a lateness warning.

Our imagined use-case for this probe was to let a glancer know the amount of time remaining before the wearer needs to leave. The factors represented by this probe are illustrated by red circle markers in Fig. 5 In this case, the content source was the wearer, and the content was relevant to some extent to both the glancer and the wearer. The content persistence was of medium length (displayed for a maximum of 7 min), and the representation was explicit, but of relatively coarse granularity.

🟩 *Probe 2: Glancer's content*

Probe 2 displayed content sourced from the glancer's phone. We designed a simple display that showed alert information – that is, any missed calls, emails, SMS or chat messages received by the glancer. Each alert was displayed for 30 seconds, and represented both the type of alert and its source, as shown in Fig. 4 (centre right). Messages from people marked as important were displayed on a green background; other items were displayed on a black background.

Our imagined use-case for this probe was to help a glancer evaluate whether to take out their phone to respond to alerts

Figure 4. Examples of the displays of each of the three probes. Left: the meeting reminder display as shown on a Sony SmartWatch 2. Note that the text is upside-down to the wearer, but upright for the glancer. Other images, from left to right: the wearer's content, showing two further stages of the meeting reminder; a glancer's content, showing a call alert from a person marked as important (top), and a normal email alert (bottom); and, public content, showing a news headline, and an advert.

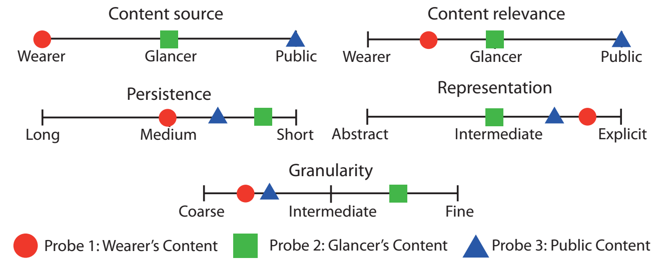

Figure 5. Overview of the design space factors represented by each probe.

(e.g., when expecting an important message). The factors afforded by this scenario are illustrated by green square markers in Fig. 5. In this case, the content source was the glancer, and the content was relevant to the glancer. The content persistence was of relatively short length (30 s), and the display was an intermediate representation (iconic and colour only), but of relatively fine granularity.

▲ *Probe 3: Public content*

Probe 3 displayed content sourced from public sources. We designed a simple display that showed local and national news, weather, and adverts, as shown in Fig. 4 (right). Our imagined use-case for this probe was as a traditional public display, showing timely information that was potentially relevant to anyone reading the screen. The factors afforded by this scenario are illustrated by blue triangle markers in Fig. 5. In this case, the content source was public, and the content was relevant to the public. The content persistence was of relatively short length (1 min), and the display was between intermediate and explicit representation, and of relatively coarse granularity.

Probe deployment

In order to test naturalistic use of the system, we deployed the three probes amongst researchers within our institution. Four participants (one each for probes 1 and 3, and two for probe 2) were asked to use the systems for between 8–12 days.

The participant for probe 1 (M; aged 46) regularly attends scheduled formal meetings with one or more people (approx. 5–10 times per day). This participant is also an author of this paper. We made this decision as it was necessary to have a very busy-scheduled person who was comfortable wearing and using the probe in their day-to-day life. However, our aim was to gather responses from third parties not involved in the deployment (i.e., glancers, rather than the wearer) – we do not focus on responses from the participant themselves. We employed this method of autoethnography—a researcher as a participant—in this probe for similar reasons to O'Kane et al. [17] who suggest that it can *"be considered as an additional method that researchers of interactive technology could employ to understand better non-routine user experiences."*

The participants for probe 2 were a married couple (M and F, aged 27) who both work and live together. Each person's phone was connected to the watch worn by the other person. We chose a close pair of participants to alleviate potential privacy concerns and issues around connecting phones to watches worn by other people, but also maximise the possibility of seeing relevant information on the other person's watch.

The participant for probe 3 (M; aged 29) regularly engages in group encounters in both professional and social capacities. We chose a socially active person to maximise the possibility of others around them seeing the public content.

Procedure

At the start of the study, each participant was given a smartwatch and briefed about the nature of the probe they would be using. All participants were fully informed about the purpose of the study, and were asked to keep the watch in a position that was visible to others (such as friends and colleagues) as much as possible whenever engaged with other people. Each participant was also asked to observe and record any reactions to the content being displayed on the watch. This information was logged via the watch itself – tapping on its screen logged an event, and participants then entered further detail using a companion app on their phone, either at the time of the event or later in the day. Participants were not paid for taking part.

Results

Probe 1: Wearer's content

The participant wore the watch for eight days, during which he had 43 scheduled meetings lasting a minimum of 30 min (45 min average). Meetings were generally one-to-one, but were not always contiguous (i.e., the watch would not necessarily display the next meeting time during each encounter).

The participant saw a correlation between observed glances at the watch and information being displayed. Of the people who were seen glancing at the watch, approximately half commented on the display. Remarks such as *"there's something on your watch"*; or, *"you're late"* were common. The watch was also a useful aid for bringing meetings to a close – pointing to the watch and stating *"as you can see, I have to go"* gave an obvious reason for ending encounters. At times, other people would bring a meeting to a close when they had seen the next meeting time was near, while on two occasions other people, upon being told that the participant needed to leave, remarked *"I know – I saw it on your watch."*

In terms of watch visibility, it was clear that other people noticed the watch screen in situations where its face was not in full view (e.g., while walking in a corridor, or when gesturing during a meeting). Finally, the participant felt that while the watch did not deter from his general working life, he would feel uncomfortable using it in external meetings, particularly in those with strangers. These results are both further evidence that watch faces need not always be in full direct view of potential glancers to be useful, and also a reminder of the need for well thought-out contextual control of the display.

Probe 2: Glancer's content

The couple wore the watches for 12 days. During this time, they tended to be in the same local area during evenings and weekends, but received only a small number of alerts while together. These participants also did not observe anyone else glancing at their watches, making the interaction entirely personal between the two of them. The need for participants to be in the vicinity of each other for messages to be received clearly affected the quantity of messages that were seen.

We designed probe 2 to be able to highlight the importance of the sender of incoming alerts (see Fig. 4), but this feature was rarely used – as one of the participants put it: *"everyone I contact is important to me."* One change in behaviour that was noted by the male participant was that his partner always knew when he was getting a call (as it was displayed on her wrist), and consequently made him answer it, which changed his typical behaviour of letting some calls go to voicemail. The female participant commented that she found herself being quite "nosy" initially, but also that the study made her realise how little she used her own phone.

In the participants' views, the key finding was that the display made each person aware that the other was receiving messages, which usually acted as a mechanism to elaborate on the content (e.g., *"who's that from?"*). The participants also found that knowing when their watch was connected to their partner's phone was helpful: *"I felt like there was an elastic between us, which was useful in the supermarket because if he went out of range I knew I had to go and find him."*

Probe 3: Public content

The participant wore the watch for 9 days, during which he was the main speaker in a two-day course, had several work meetings, sat on an interview panel and attended various social events in places such as pubs, restaurants or coffee shops.

One of the main observations from this probe was that people were far more likely to comment on the watch display in social situations than in work-based settings. For example, during one encounter in a restaurant with his family, the wearer's brother commented *"what on earth is your watch doing?"*, which prompted everyone at the table to look at his wrist, initiating a conversation about the display, and further remarks and conversations when in similar situations. These general comments about content on the watch were not seen in work situations, however. Although the participant often observed others glancing at the watch, very few commented on it. For example, while all of the seven participants in the course he ran were seen to look at the display at some point, none chose to comment at the time. After directly asking about the watch at the end of the course, two students commented that they had seen an advert for a nearby fast-food restaurant, which had sparked a conversation about where they should go for lunch. When asked about the value to him, the participant felt that the discussions generated were interesting, but also made him feel self-conscious at times (e.g., when adverts were displayed in professional situations). He also noted the slight annoyance of not being able to read the content on his own wrist, as it was oriented for glancers rather than him as the wearer. However, he did see value in the technique for those around him, either for providing up-to-date weather reports (which one glancer was particularly interested in) or giving breaking headlines.

Discussion – Study 4

It was clear from all three probes that people around the wearer were able to see and interpret information on the watches. It was particularly encouraging that in probe 1 casual glancers not only saw the information on the watch, but also often acted on it (e.g., telling the wearer he was late for his next meeting). The third probe's finding that social situations generated more remarks than work environments is a useful contextual hint for choosing when to display publicly-sourced watch content.

CONCLUSIONS

With the increasing prevalence of smartwatches, it is certainly timely to investigate their extended use beyond the inevitable "phone-on-your-wrist" scenario. The design space and four studies in this paper have explored the concept of personal watches used as public displays. Glancing at someone else's watch is already a common social practice, with 71 % (study 1) and 89 % (study 3) doing this, often to avoid the potentially negative social signal of looking at one's own watch.

In study 1 we investigated the noticeability and social acceptability of looking at another person's watch. This action was significantly less noticeable than looking at one's own watch. In addition, social acceptability was not seen as a problem (studies 1 and 3). Turning to watch use and deportment, study 2 demonstrated that 88 % of observed watches were either fully (51 %) or partially (37 %) visible to those in close proximity to the wearer, and held in a variety of common postures.

Using the information from these initial studies, we constructed a design space, discussing in detail the different aspects and dimensions designers would need to consider before embarking on turning a personal watch into a public display. Designers wishing to construct a public watch face should consider these factors carefully, and think about any trade-offs that may need to be made across the spectrum. Our third study evaluated each factor's perceived value, then study 4 explored three potential watch displays in a naturalistic setting.

There are many aspects of public watch displays that we have not considered here. For example, setting up connections between watches and content sources may require complex Bluetooth arrangements, or linked trusted web services. There are interesting possibilities around group encounters, where there may be multiple glancers, or multiple wearers becoming glancers themselves. There will also need to be a set of general design norms for the content displayed, to ensure that the glancer is aware of the meanings in these different contexts. Battery life is a potential consideration; however, we believe that with sensible use of sensors, and activating the screen only when needed, our approach will not significantly affect battery life. Finally, as with any public display, there are many considerations around privacy and cultural norms (see Background section). We do not expect to answer all these questions in this paper; rather we have aimed to open up a new research area and highlight its potential for future work.

While previous wearable research has focused either entirely on the wearer (e.g., [3, 9]), or entirely on the glancer (e.g., [5, 18]), we allow an interchangeable approach, laying the groundwork for others to build upon. Our work not only sketches out a design space for the approach, but also investigates many of the issues and concerns over noticeability, visibility and social acceptability, generating many interesting questions and discussions relevant to the community. With the growth of wearable computing, and an expectation that smart watch sales will steadily increase, it is a perfect time to open up a new space surrounding their use.

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