Candid Interaction: Revealing Hidden Mobile and Wearable Computing Activities

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"If I am going to use my devices in the presence of others, I can think of NO situation that I wouldn't share all info with them. If there is any info I'm not willing to share then I need to be in private, not around people."
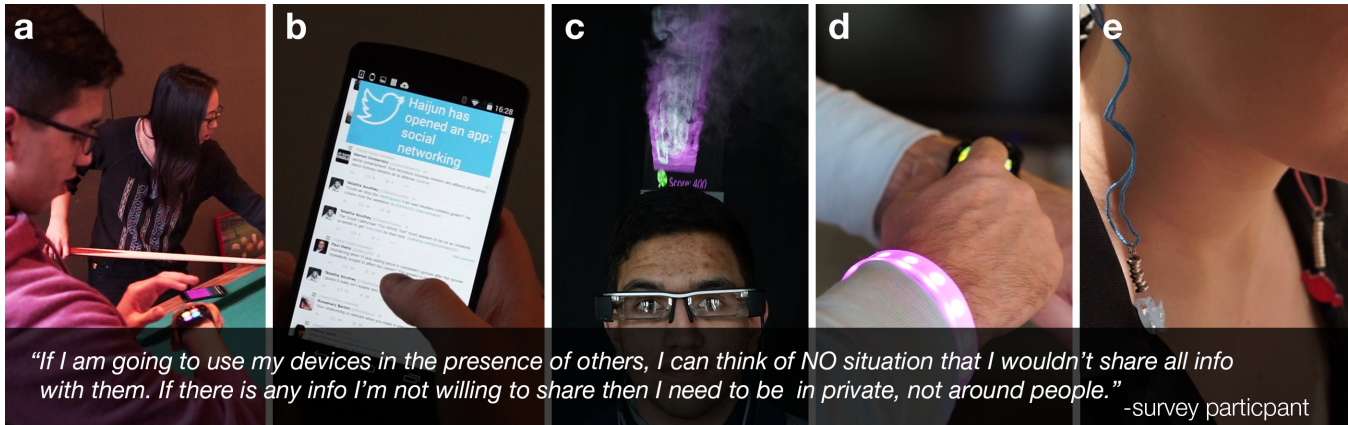-survey particpant

Figure 1. a) People often use mobile and wearable devices in the presence of others. b-e) We explore Candid Interaction through several prototypes for sharing device activity using a range of technologies. b) Grounding Notifications provide common ground through toast notifications. c) The Fog Hat projects wearable device activity onto a physical though cloud. d) A Status Wristband encodes activity into patterns of coloured light. e) Iconic Jewellery communicate app activity through motion.

ABSTRACT

The growth of mobile and wearable technologies has made it often difficult to understand what people in our surroundings are doing with their technology. In this paper, we introduce the concept of *candid interaction*: techniques for providing awareness about our mobile and wearable device usage to others in the vicinity. We motivate and ground this exploration through a survey on current attitudes toward device usage during interpersonal encounters. We then explore a design space for candid interaction through seven prototypes that utilize a wide range of technological enhancements, such as Augmented Reality, shape memory muscle wire, and wearable projection. From a user evaluation of our prototypes we present several findings to encourage further exploration of the trade-offs between the benefits of sharing and the protection of privacy.

INTRODUCTION

The rising prevalence of mobile devices is now echoed by the introduction of wearable devices such as smart watches and smart eyewear. A consequence of our attainment of omnipresent information access is the encroachment of computer interaction into the realm of public, social and workplace encounters. Regardless of perceptions, people are apt to conduct activities, such as checking messages during a meeting or playing a game while lounging with friends (Figure 1a). However, the personal nature of wearable displays makes it increasingly difficult for others nearby to perceive how someone is using their technology.

Researchers have sought ways to promote the transparency of computing activity in collaborative settings. One important strategy of collaborative software designers is to provide users with *awareness* about the state of the shared workspace and their collaborators' activities [9, 13, 14]. This can be accomplished with *feedthrough,* which conveys information about the interaction and its effects to others, analogous to feedback in single-user software [13]. While these concepts have gained traction in the domain of computer-supported cooperative work, they have been applied less in the realm of everyday mobile and wearable device use.

We propose a new class of computing called *candid interaction*, where devices provide feedthrough about a user's interactions to others around them, specifically when that device is difficult to observe (Figure 1). For example, someone wearing smart glasses can make a companion aware that they are taking notes, as opposed to checking email during a conversation; or a meeting participant can subtlety let others know they are not distracted by their smartphone but instead looking up information on a relevant topic. Revealing the nature of our device usage to those in our surroundings could make these interactions more socially acceptable [30]. This approach contrasts prior research which has attempted to facilitate social acceptance by hiding devices [3] or keeping interaction subtle [4, 24, 39].

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There are many conceivable methods of providing awareness about device use. We explore a wide range of designs in this paper, from pragmatic to provocative. In the most basic case we explore how current technology can be leveraged to provide feedthrough, while in other designs we incorporate novel technologies to exceed basic device capabilities, for instance with proxemic-based augmented reality, muscle wire activated motion jewellery and a mobile-projected thought cloud.

This paper makes several contributions: First, we introduce the novel concept of candid interaction for explicitly sharing awareness about mobile and wearable device usage during interpersonal encounters. Second, we present results from a survey of 100 participants to investigate what types of information people might be willing to share, and in what contexts. Third, we propose a design space for candid interaction to assist an exploration of its many possible manifestations. Fourth, we implement seven prototype designs that represent a wide coverage of our design space. Finally, we conduct a preliminary evaluation of our implementations, collecting high-level usability ratings as well as qualitative participant feedback. We conclude by discussing future designs for candid interaction and important issues which should be considered.

RELATED WORK
Our work relies on concepts discovered in the development of multi-user software for collaborative work. In applying these concepts to everyday device interaction, we also draw from work on social acceptability and social interaction.

Awareness in Collaborative Systems
Provision of *awareness* information is a fundamental feature of collaborative software [27] and is theoretically supported by Clark and Brennan's theory of grounding [6]. This theory describes how 'common ground', or a basic set of shared knowledge between participants of a conversation is essential to the conversational efficiency. Monk [27] later used this theory to explain the need for designers to support grounding in electronically mediated communication.

Early pioneers of collaborative software (e.g. [9, 14]) focused on development of features for sharing information about the state of a workspace and the interactions of others therein. Gutwin and Greenberg [12] later formalized a framework for workspace *awareness*. They specify the importance of *feedthrough* as a method of providing awareness about the manipulation of artifacts.

Recent research has also explored methods for signalling information outside of software systems, for instance by using cooperative [16, 31] or large, noticeable gestures [37]. Other work has explored methods for detecting the physical positions and orientations of group members [24] and leveraging this information in device interactions [26].

In our work, we apply the concepts of awareness and feedthrough to device interaction in everyday contexts that may not be explicitly collaborative.

Social Acceptability
As novel mobile interaction techniques were developed, researchers began to notice the importance of observers. Rico and Brewster [36] found willingness to perform mobile device gestures varied by context and audience. Following this work, Reeves et al. [35] developed a framework for designing public interactions which considered observability of both the user's manipulations and the resulting effects. Later study of this categorization [30] found that 'suspenseful' gestures, i.e. observable manipulations with hidden effects, were perceived as less socially acceptable than others. In a similar finding, psychologists [28, 29] proposed a 'need-to-listen' effect when people overhear partial phone conversations; bystanders found conversations more noticeable and intrusive if they could hear only one of the speakers.

Research since Rico and Brewster's study has confirmed that context affects acceptability [2] and found perceptions in public depends on configuration of the surrounding space [12]. Other research has investigated differences in the viewpoints of users and observers [1]. Beyond gestures, studies have also investigated the social acceptability of projection-based interfaces [7, 22]. With the introduction of wearables, researchers are also now interested in acceptability in the context of always-on cameras [8, 17].

In this paper we design our prototypes with social acceptability in mind, in particular users' perceptions about sharing device usage information in various contexts.

Public Displays for Social Interaction
Greenberg et al.'s seminal paper on collaboration describes the complex relationship between personal information and public displays [11]. Since then, a number of concepts have been introduced for promoting social awareness using non-traditional information displays, such as name tags [5], bracelets [20], clothing [19], shoulder bags [23] and even coffee mugs [21]. Recent work by Pearson et al. [33] explores using a smart watch to publicly display a variety of types of information.

We take inspiration from these areas of research, and our design space builds upon this prior literature. However our work specifically focuses on the delivery of information related to activities occurring on mobile and wearable devices that may not be visible to others.

MOTIVATION FOR CANDID INTERACTION
The goal of candid interaction is to provide awareness to others nearby about how someone is using technology. For example, a conversation may be interrupted by a message notification, or one participant of a conversation may consult a search engine and report the results to the other. In such situations, if appropriate contextual information is shared between participants, it can help to ground the interaction and prevent conversational overhead. However, sharing cues about device activities can be challenging when the device has a wearable form factor.

A theoretical grounding of this goal can be deduced from Reeves et al. [35] framework of interactions. This scheme categorizes interactions according to the observability of the user's manipulations and the resulting effects as shown in Figure 2. Typically, interactions on wearable and mobile devices fall within the lower-right corner of this matrix, categorized as 'suspenseful' interactions (i.e. observable manipulations with hidden effects). Research has shown this region is less socially acceptablity than the others [30].

Designers of subtle interaction [3, 4, 24, 39] promote social acceptance by using interaction techniques that draw little attention from those around (making the *manipulations* hidden). Candid interaction uses an alternate strategy; it makes the *effects* of the manipulations *more observable*. Thus, interactions that may be otherwise problematic are moved into more acceptable territory (indicated by the solid arrow in Figure 2). In the following section, we perform a survey to better understand under what scenarios such awareness may be beneficial.
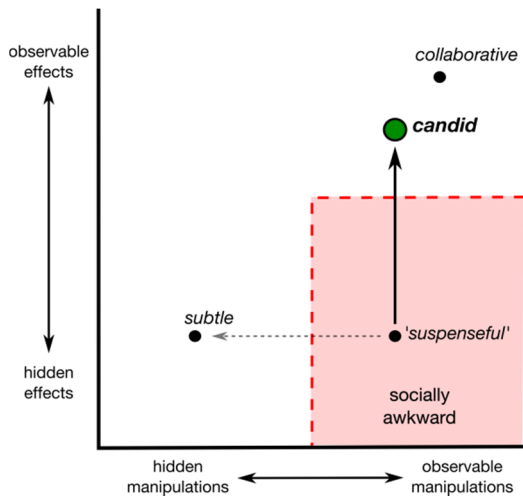

Figure 2. Relationship of candid interaction to other types of social interaction in dimensions of Reeves et al. [35].

SURVEY OF PRACTICES AND PERCEPTIONS
We conducted a survey to help understand how people currently share information about device usage, to learn typical perceptions about different devices and to gauge people's willingness to share information under different contexts. We posted a survey on Mechanical Turk, open to only US participants. It contained a mixture of open-ended and 5-point Likert Scale questions requiring about 20 minutes to complete. We collected responses from 100 participants, 54 female and 46 male, ranging from 18 to 68 years of age (μ=33, SD=9.7). We summarize some interesting outcomes below.

Detecting Device Usage
In alignment with one of our initial motivations, we found that the perceived ability to discern user activity on a device is related to the size and visibility of the device's display (Figure 3). While more traditional form factors such as laptops and smartphones afford observation of the user's

activities, usage of newer devices such as smart watches and smart glasses is perceived as being more difficult to detect. One user noted "*The size of the screen and the location of the screen make a big difference in how to tell if someone is using the device*". Another opinion was based on personal experience: "*I have interacted with people using Google Glass, and it was very disorienting to try and figure out what they were doing.*"
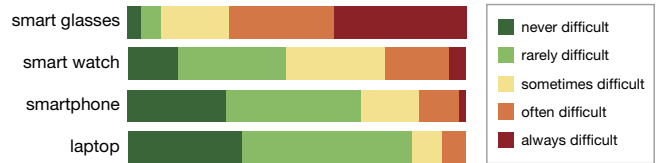

Figure 3. Participant responses on difficulty of determining device activity. According to perceptions, difficulty is related to the size and visibility of the display.

Attitudes about Device Usage
We found a strong diversity of opinions on the appropriateness of using devices during person interactions.

Of all respondents, 47% admitted they often use technology during meetings or conversations, however 51% feel such behaviour is inappropriate. There appears to be a distinct division between two opposing groups, visible in Figure 4: Members of one group use devices during interpersonal discourse, with no qualms about doing so. In the opposing camp are people who refrain from using devices around others because they feel it is inappropriate.
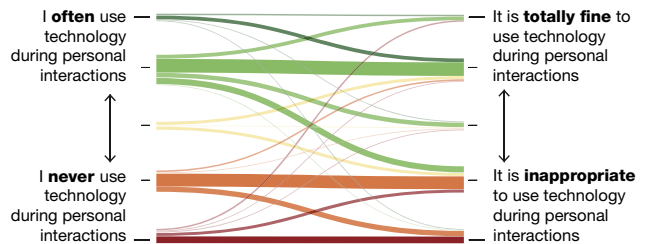

Figure 4. Correlation between Likert Scale responses on how often participants use technology during interpersonal encounters and whether it is appropriate to do so. Colours represent responses on the left scale. Band thickness represents the number of responses in the adjoining path.

Willingness to Share
Similarly, participants were divided on how much information they would care to share or receive from others. In one camp, participants commented: "*only when the information is relevant would I be willing to share it*"; "*I am generally not willing in all situations*"; and, "*It's none of their business and it could cause issues if it were found out that I was recording something*". Contrasting comments included: "*I will be willing to share that information in any situation. I think it's impolite NOT to mention it*"; and, "*I have nothing to hide and I would want my friend or coworker to feel comfortable*". Overall, 84% of participants agreed that they would sometimes be willing to share information with others, and 50% of participants agreed that they would

sometimes prefer to have more information about how people are using technology.

These predilections vary according to context (Figure 5). In general, participants indicated a greater willingness to share information at work or with friends than in a public setting. Also, participants are less interested in sharing application content than minimal knowledge about camera or device use. Responses about interest to receive information about the device usage of others revealed a similar pattern. Although there are clearly contexts where content sharing may be useful, designers must take care to protect user privacy, for example by allowing explicit control over the flow of information.
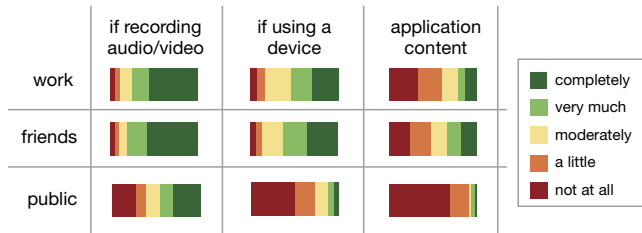

Figure 5. Likert Scale responses about how much information participants are willing to share in various contexts.

Prevalence of Ad-Hoc Sharing

Participants listed many ad-hoc methods they use routinely to provide others with awareness about their usage. These include speaking aloud, placing screens within view or side-by-side, sending messages on social media and connecting to large displays. Several comments indicate people consider the thoughts and feelings of others, noting they might share information with other people "*so they didn't think I was excluding them*", "*just to make them feel more comfortable*" or "*to make it apparent that I wasn't texting.*" One participant mentioned they specifically avoid the use of a soft keyboard when taking notes: "*I usually use the stylus so they know it's for notes.*"

Awareness of Being Recorded

There is growing interest in the social acceptability of camera use [8, 17] and the development of techniques for mitigating concerns [18, 38]. While not our primary focus, improving awareness of recoding status to others is a promising potential use of candid interaction.

A majority (66%) of participants indicated discomfort about people wearing devices with cameras in public. Some were concerned about their personal image ("*I would rather not have any missteps of mine end up as a youtube video*"), while others were worried about malicious use ("*I'd be concerned about criminals say filming my atm pin*").

The majority of participants (79%) agreed they would feel more comfortable if there were a clear indication of whether the camera was turned on or off. Some participants had a total lack of concern. For example, stating that they "*don't mind being recorded by a stranger in public*".

DESIGN SPACE FOR CANDID INTERACTION

Motivated by our survey results, we propose a design space that encapsulates several key concepts that will drive our implementations for candid interaction. These dimensions, which emerged through prior literature and from our survey and analysis, are described below and summarized in Figure 6. Some important terms are defined in Table 1.

Term	Definition
Actor	A person who is interacting with a device
Observer	A person near the actor who is at least partially aware of the actor's interactions
Feedthrough	Information about an actor's manipulation of software artifacts, intentionally provided to observers [13]
Backchannel	From linguistics [41], denotes a secondary communication channel from the observer to the actor.

Table 1. Definitions of terms important to our design space.

Feedthrough Manifestation describes the methods used to convey awareness information to the observer. The *source* of feedthrough may be a device held or accessory worn by either the actor or the observer. Alternatively, feedthrough may originate from the environment, for instance a tabletop display. Feedthrough *modality* can also vary. In our designs we explore sound, motion, light and graphical displays.

Interactivity characterizes additional channels beyond the inherent one-way flow of feedthrough. *Backchannel* makes actors aware that they are being observed. The *operator* of interactive components can be either the actor or observer. Also *control* over information flow, for instance the level of sharing, can be implicit or explicit.

Information Bandwidth describes the flow of feedthrough. This dimension borrows from the terminology of Pearson et al. [33]. *Granularity* is the level of detail provided, which varies from coarse to fine. *Representation* describes how details are presented, ranging from abstract to explicit.

Recency depicts the presence of temporal information in feedthrough. Details are often presented in real-time as they occur. However feedthrough can also contain historical information, such as a user's web search history.
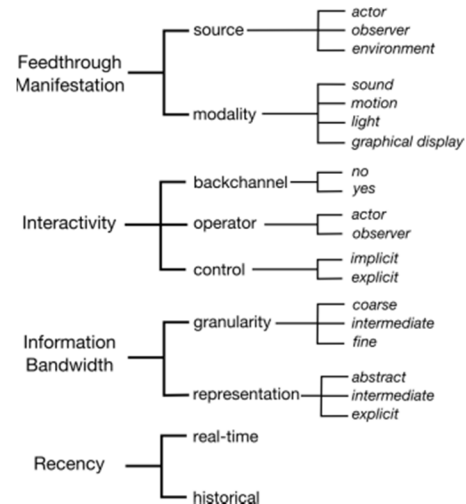

Figure 6. Design space for candid interaction.

CANDID INTERACTION ECOSYSTEM

Our goal is to develop a suite of feedthrough mechanisms that can enable candid interaction while spanning over the above design space dimensions. To provide an environment for prototyping our designs, we built an ecosystem of several interlinked applications. Our ecosystem supports a range of existing mobile and wearable devices: a smart phone (Nexus 5), smartwatch (LG Watch R) and smart glasses unit (Epson Moverio BT-200).

We designed a mock OS to provide a homogeneous platform across these devices, which runs as a standalone Android application. The OS emulates a start screen and set of common mobile applications (Figure 7): a web browser, a social network client, a text editor, an email client, a candy crushing game and a camera app. Each application is interactive, but with only enough functionality to support our primary goal of exploring candid interactions.

Figure 7. Our homogeneous platform has a similar look and feel on the (a) smartphone, (b) smart watch, and (c) smart glasses. (d) Feedthrough sliders control the extent of information sent and received about device usage.

These applications are instrumented with event triggers, described in the following section, that are used to initiate feedthrough. Once triggered, events are forwarded to the other devices through a Bluetooth network (Figure 8). The smartphone acts as a hub and forwards each event to the other devices. The phone also forwards the events to a laptop computer over a closed Wi-Fi network. The laptop is used to drive projectors and to forward events by USB to one of several microcontrollers.

Figure 8. The candid interaction ecosystem links mobile and wearable devices to a laptop, which operates microorocontrollers and projectors in our prototypes.

PROTOTYPE FEEDTHROUGH MECHANISMS

We implemented seven prototype mechanisms for candid interaction, with a goal of maximizing coverage of our proposed design space. Through this exploration, we hope to learn the strengths and weaknesses of different approaches, providing a point of departure for future designs. In the following descriptions, design space dimensions are *italicized* and values are in SMALL CAPS.

Feedthrough Filters

Before describing our prototypes, we present a peripheral feature we call Feedthrough Filters to provide *EXPLICIT CONTROL* over the extent of information shared. This feature consists of two slider controls (Figure 7d). An *ACTOR* can use the sharing filter to control the granularity of information sent, while an *OBSERVER* can use the receiving filter control the extent of information received. Each slider has five levels: *none*, *minimal*, *low*, *moderate* and *full*, which accumulatively allow additional events. The events that are sent at each slider level are listed in Table 2.

Filter Level	Notification Events Sent
none	`No events`
minimal	`photo_taken; capture_started; captured stopped`
low	`application_opened; application_closed`
moderate	`scroll_up; scroll_down` `page_opened; search_query_performed; link_opened`
full	`select_text; edit_text; candy_crushed`

Table 2. Application event triggers increase in granularity with the level of the corresponding Feedthrough Filter.

Prototype #1: Grounding Notifications

Grounding Notifications are toast notifications (terse, short-lived pop-up messages) shown on an observer's device that provide 'common ground' about device activity. Each notification contains the actor's name, a description of the action that occurred, and is encoded with the corresponding application icon and colour (Figure 9). This pragmatic mechanism demonstrates some key principles of candid interaction and covers several design space dimensions.
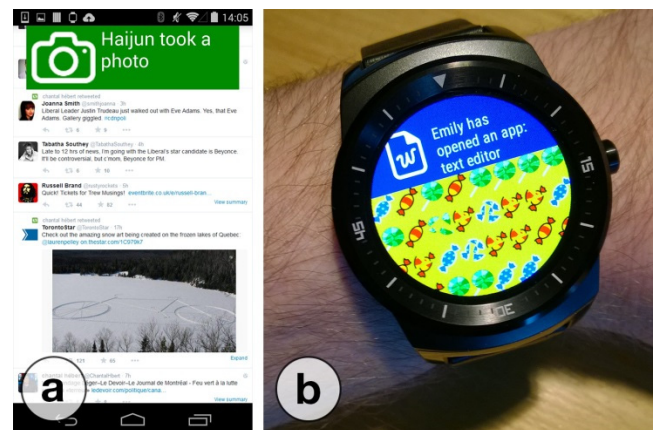

Figure 9. Grounding Notifications show a user's device activity on a (a) smartphone, (b) smartwatch, or smart glasses.

In this design, the *Feedthrough Source* is the OBSERVER'S device. Notifications are accompanied by a distinctive SOUND, which provides *Backchannel* to the actor when information is shared. Furthermore, feedthrough has an EXPLICIT *Representation* given in REAL-TIME.

To demonstrate a practical use case for candid interaction, we implemented an example of information sharing that commonly occurs using current ad-hoc methods: When an actor follows a search link, the observer is presented with an *interactive* page preview. Tapping the preview image open the link, and sends a *backchannel* notification to the actor. Tapping elsewhere discards the notification.

Prototype #2: Lockscreen Stripes
Our Lockscreen Stripes implementation shares app usage history of a smartphone. When the phone's accelerometer detects the device is placed flat on a table (Figure 10a), the screen shows a series of coloured stripes (Figure 10b). Each stripe's colour matches that of the corresponding application icon and its thickness is proportional to the amount of time it was used.

This design is an example of how HISTORICAL information can be shared. This type of mechanism could be useful for helping an actor communicate to others that they were not unduly distracted but that their device activity was related to an ongoing conversation or meeting. The ABSTRACT *representation* allows observers to absorb this information quickly, without interrupting the flow of a conversation. Since users may be wary to share their prior usage, we scale the timeline to show only the last five minutes of activity.
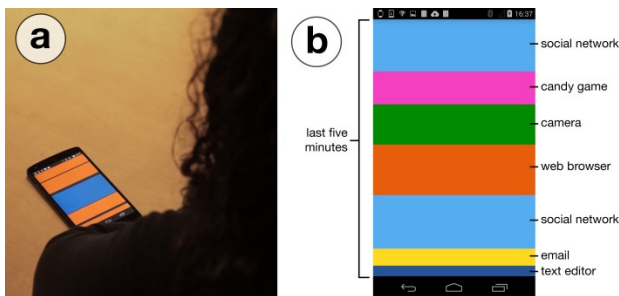

Figure 10. Lockscreen Stripes encode app usage history (a) into stripes displayed when a smartphone is laid at rest (b).

Prototype #3: Semantic Focus
Semantic Focus uses the analogy of a camera's focus control to 'blur' information when privacy is desired. This technique is inspired by the semantic zoom technique [40], which reveals more information as a user zooms in to an object of interest. A physical knob fixed to the back of a laptop computer (Figure 11a) controls an image projected onto the table by a top mounted projector in the ENVIRONMENT (Figure 11b). We demonstrate this technique with a laptop, but similar implementations could be realized on mobile or wearable devices. Future implementations could also use projectors built-into mobile devices. The knob works by sending rotational information from an attached potentiometer to an Arduino Uno microcontroller.

Semantic Focus gives EXPLICIT *control* of *information bandwidth* to the ACTOR. Content can be blurred at two different levels of *granularity*. At the COARSE level, only the current application icon is shown (Figure 11d). At the FINE level, a GRAPHICAL DISPLAY of the full application content is shown (Figure 11f), allowing the actor's interactions to be observed. Since detail in the miniature view may be difficult to make out, we display a marquee [32] to show the most relevant information in the current application. For example, in the text editor, the current line of text being edited is shown. The coarse and fine levels both transition continuously from blurred to focused as the knob is rotated.
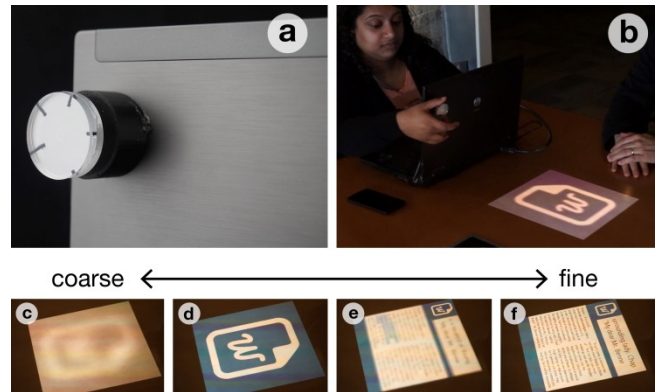

Figure 11. Semantic Focus. a, b) A physical knob controls the clarity of the projected image. c-f) The image gradually transitions from a blurred icon to a clear graphical display.

Prototype #4: Status Band
The Status Band (Figure 12a) communicates application activity through LIGHT patterns [15], from a wrist-worn bracelet [10, 20]. It is made from an off-the-shelf, addressable, RGB LED strip, which we attached to a metal watch clasp and control with an Arduino Lilypad. For comfort and aesthetic appeal we used a waterproof-coated strip covered with a layer of tightly-woven white silk.
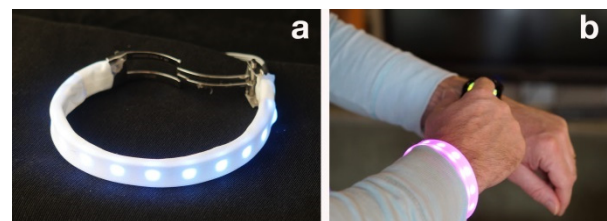

Figure 12. The Status Band apparatus (a) communicates device activity while the hand interacts with a device (b).

The bracelet is worn on the actor's dominant hand, which is typically used for swiping and tapping on a mobile or wearable device (Figure 12b). Thus if the observer cannot see the actor's primary device, they can instead see the band's abstraction of what the user is doing. While the band provides an ABSTRACT *representation,* the information can be presented with FINE *granularity*. For example, individual scroll events and character entries are depicted with distinct patterns. We created patterns for a range of events, which are coded by the application colour (Figure 13).

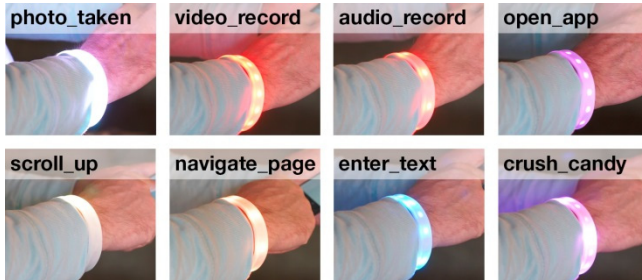| Event	Light Pattern
photo_taken	2 quick bright white flashes with all lights
video_record	2 slow red flashes – on until stopped
audio_record	2 slow red flashes – every 2nd light remains on
open_app	slow brightness, repeated 3 times
	lights remain on low until app closed
scroll_{up/down}	chaser pattern around wrist
navigate page	every 2nd light brightens/dims slowly
enter_text	random twinkling
crush_candy	random twinkling

Figure 13. Light pattern representations of device events. Light colours match the associated app unless specified.

Prototype #5: Iconic Jewellery

To further explore the possible uses of *ABSTRACT representations*, we designed a set of Iconic Jewellery that communicates activity though the *modality* of *MOTION*. Each item in this three-piece set is colour-coded to represent an individual application, with a custom laser-cut acrylic icon attached as a pendant. The set includes a necklace (email app) and a pair of earrings (game and social network apps) (Figure 14a).
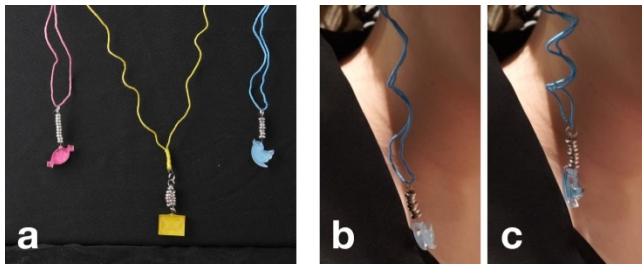

Figure 14. Iconic Jewellery reveals activity in an associated app (a) via motion. When the associated app is used, the jewellery moves from a relaxed (b) to contracted (c) state.

Each piece is constructed from a strand of Muscle Wire (nitinol), which 'remembers' a specific shape when annealed at a high temperature. The wire takes a relaxed form at room temperature (Figure 14b), but reverts to its remembered shape when reheated to roughly 100°C. We use a 12V electrical circuit activated through transistors and an Arduino Uno board. The wires are annealed into helical shapes, causing them to contract when a current is applied (Figure 14c). Embroidery thread wrapped tightly around the wire insulates the wire, making it comfortably wearable.

A long burst of current is applied when an application is initially opened, causing the pendant to contract quickly and noticeably. The jewellery continues to move through more gentle cycles as long as there is ongoing activity in the corresponding app.

Prototype #6: Proxemic AR

Our Proxemic AR prototype uses augmented reality (AR) to reveal an actor's current activity. When an observer points their phone at the actor, or looks at them through their smart glasses, the device's camera detects the actor's face and overlays information on to the observer's view. The extent of information displayed is based on proxemics [25, 26], which applies information about the distance and configuration between participants to facilitate interaction.

Figure 15. Proxemic AR augments the user's image with their device activity on a smartphone (a-c) or smart glasses (d-f). Granularity increases as the observer moves from far (a, d) through intermediate (b, e) to close (c, f) range.

This technique is implemented using Android's face detection library. The actor's distance is estimated based on the width of the first detected face. In the smart glasses, this information is transformed to screen space and the overlay is rendered stereoscopically at the appropriate depth.

In keeping with the fun spirit of many AR applications, information is presented in an *ABSTRACT representation* of a thought cloud and other objects floating above or around the actor's head. To access more detail, the observer is required to enter the actor's personal space. This gives the *OBSERVER IMPLICIT control* over feedthrough, but with a tradeoff of *backchannel* given by the observer's presence.

When observing from afar, information is presented with *COARSE granularity*, revealing only the icon of the actor's current application (Figure 15a, d). As the user approaches (within 3m), the representation changes and observer begins to witness the actor's activity. For example in the social network app, the observer sees a bird circling the user's head, which audibly tweets with each event (Figure 15e). In the game app the observer sees each candy's type and hears it crushed as it appears to fly out of the actor's ears (Figure 15b). Upon entering the actor's personal space (1.5 m) the observer gains access to *FINE granularity* detail, for example recently viewed hashtags or the game's running score (Figure 15c, f).

Prototype #7: Fog Hat

The Fog Hat can be thought of a material version of the proxemic AR prototype, displaying a 'physical thought cloud', with app icons and content projected onto a screen of mist above the actor's head. This whimsical implementation consists of an ultrasonic humidifier, a length of flexible PVC pipe and a custom 3D printed manifold for directing the mist stream (Figure 16a). The image is back-projected from a Microvision SHOWWX+ laser projector (5.1 × 22.9 × 17.8cm, 776g). The Fog Hat provides an interesting property of inherently obfuscating the displayed image, especially at the top region (Figure 16b). Affixed to the Fog Manifold is a 5V fan, (Figure 16a) which can create turbulence to further obfuscate the mist display. An Arduino Leonardo microcontroller operates the fan and a relay switch that turns the mist on or off. The apparatus is tethered to a laptop and carried in a small backpack. However, we imagine that advances in miniaturization will eventually allow a similar device to be built into a more amenable form factor.
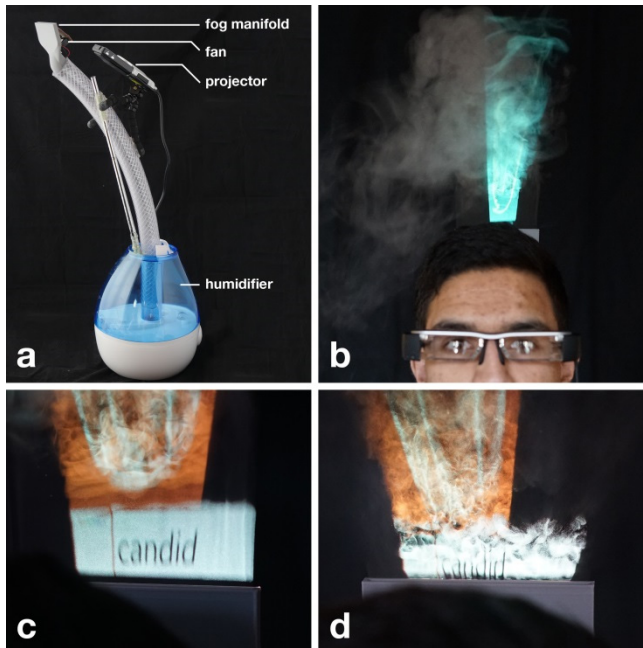

Figure 16. (a, b) The Fog Hat projects a graphical display above the device user's head. (c, d) The content of the display can be further obfuscated by turbulence from a fan.

The Fog Hat incorporates multiple levels of *information bandwidth* with some using a marquee feature for sharing important information. The *granularity* is controlled by the actor's sharing level in the Feedthrough Filters panel. At the 'low' setting, only the icon of the current application is shown. At 'full', the display shows more information including a miniature page view and marquee.

Applications use different layouts to leverage the Fog Manifold's inherent turbulence; apps with low privacy needs, such as the web or game apps, place the marquee at the smooth region at the display's bottom, where text and images remain clearly legible. Apps that require greater privacy, such as the email app, place the marquee higher, in the more turbulent region. In this case typing activity is still conveyed to the observer, but the contents are obscured.

Decreasing the filter setting to *minimal* or *moderate* activates the small fan, which increases privacy further by creating additional turbulence (Figure 16d).

USER EVALUATION

We conducted a small user study to gain initial insights on our prototype designs. The goal of the study was not to formally evaluate the prototypes, but to instead gather initial subjective feedback, and to elicit discussions on the general topic of candid interaction.

Participants

Ten participants were recruited internally from our organization. Participants ranged from 19-42 years of age (μ=26, SD=8.9) and were equally distributed by gender. All participants had at least two years of close experience with smartphones. Only one had minimal experience using a smart watch and two with head-worn displays (both had reported trying an Oculus rift).

Method

We demonstrated our prototypes to five groups of two participants each (10 total). In addition to the experimenter demonstrating the prototypes, participants were encouraged to wear and interact with the prototypes themselves. For efficiency of time and exposition of features, we presented the prototypes in the same order for each group. Also for time efficiency, participants were not asked to wear the fog display due to its weight and form factor. After each prototype was demonstrated, participants gave 5-point Likert rating of usability from the perspective of an actor and an observer. We took notes on participant comments during and after each session.

Results

Usability ratings measured the perceived ease of use from an actor's perspective and the ease of interpreting feedthrough as an observer. Results are shown in Figure 17.

For ease of use (actor), we see a narrow variation between the prototypes, however the Iconic Jewellery and Fog Hat stand out as appearing more difficult to use. This may be due in part to the prototype state of the designs; whereas the Status Band was simple to slip on, the jewellery had to be delicately handled and the Fog Hat was very large.

For ease of interpretation (observer), the prototypes with strictly abstract representations (Lockscreen Stripes, Status Band and Iconic Jewellery) rated among the lowest. We see the Fog Hat also grouped among these, likely due to turbulence in the mist projection surface. In contrast, the Semantic Focus stands out on the positive side for both ease of use and interpretation.
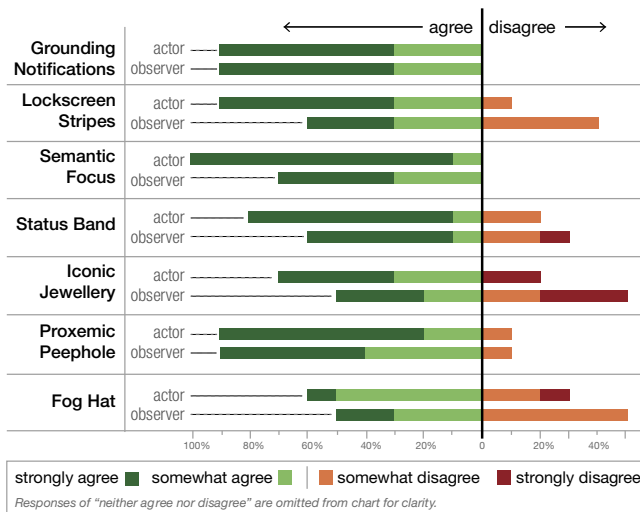
Figure 17. Perceived usability of each prototype. Participants were asked if they could easily use the method as an actor and whether they could interpret information as an observer.

Qualitative Feedback

Overall, participants were generally keen on the concept of candid interaction and admired the variety of concepts we presented. They indicated an understanding of the need to balance the benefits of sharing with the desire for privacy. For instance sharing usage information can potentially "dissolve discomfort about using devices" around others. However, it must be used judiciously to prevent "information overload".

As in the quantitative results, participants expressed greatest interest in sharing with friends or coworkers. Participants seemed to prefer methods that blend into their attire, such as the Status Band and Iconic Jewellery for use in public settings. We also learned that excessive backchannel mechanisms can draw unwanted attention; several participants mentioned that pointing a smartphone screen for extended periods with Proxemic AR may be awkward, however the smart glasses mitigate this issue.

LIMITATIONS AND FUTURE WORK

This paper has introduced the conceptual framework and design space to begin a deeper discussion on candid interaction. Despite our wide foray into the topic, our prototypes have yet only scratched the surface of potential applications of candid interaction. However, we have explored all of the dimensions with one or more of our prototypes. Some of these designs have led to initial outcomes about user preference such as our participants' predilection for abstract feedthrough in public settings. Other dimension values, such as ENVIRONMENT (*feedthrough source*) and HISTORICAL (*recency*) were only covered by one of our designs. Some of these prototypes are visionary in nature and we don't expect to see implemented in the near future, although further work will produce deeper understandings.

The concepts and prototypes we design in this work offer many areas prime for deeper exploration. In particular, we plan to explore a greater variety of interactive features to encourage interplay between actor and observer. We hope this work inspires researchers of social interaction to explore wearable device feedthrough as a potential use case for existing and new social displays.

CONCLUSION

As computing devices continue to emerge in smaller and more personal form factors, device usage will continue to encroach on interpersonal engagement. A survey shows that there are situations when observers are interested in information about such interactions and when actors are willing to share it. Context is a determining factor of when, how and what information should be shared.

Our design space exploration offers several insights into the potential benefits and drawbacks of various approaches: 1) Users are cautious about the information they choose to share thus candid interaction methods must default to sharing minimal information without express consent; 2) Comfort levels about sharing are highly dependent on context, thus information and delivery methods are must be modified according to where interaction takes place and who is present; 3) Participants prefer to remain inconspicuous, particularly in public, where abstract methods are best suitable; likewise, backchannel methods should not call unwanted attention to observers. We hope this work provides a cue for others to openly explore candid interaction methods and leads to greater sharing among mobile and wearable device users.

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