Open Research Online

The Open University's repository of research publications and other research outputs

Wearables for Physical Privacy

Conference or Workshop Item

How to cite:

Mehta, Vikram; Price, Blaine; Bandara, Arosha and Nuseibeh, Bashar (2016). Wearables for Physical Privacy. In: UbiComp 2016, 12-16 Sep 2016, Heidelberg, Germany.

For guidance on citations see [FAQs](#).

© [not recorded]

<https://creativecommons.org/licenses/by-nc-nd/4.0/>

Version: Accepted Manuscript

Link(s) to article on publisher's website:

<http://dx.doi.org/doi:10.1145/2968219.2979138>

Copyright and Moral Rights for the articles on this site are retained by the individual authors and/or other copyright owners. For more information on Open Research Online's data [policy](#) on reuse of materials please consult the policies page.

oro.open.ac.uk

Wearables for Physical Privacy

Figure 1: Types of privacy breaches in physical environments: [a] Recording through CCTV camera, [b] Eavesdropping a private conversation, [c] A stranger trying to touch/grab users' body.

Vikram Mehta

The Open University, UK
vikram.mehta@open.ac.uk

Arosha K. Bandara

The Open University, UK
aroshha.bandara@open.ac.uk

Blaine A. Price

The Open University, UK
b.a.price@open.ac.uk

Bashar Nuseibeh

The Open University, UK
Lero, Ireland
bashar.nuseibeh@open.ac.uk

Abstract

Physical or bodily privacy is an innate need that drives a variety of human behaviours. However, in a highly dynamic, crowded and context dependent world with rapidly changing technology, other humans or technological devices can pose threats to the physical privacy of an individual in many ways. This short paper explores the use of wearable devices to tackle this multi-faceted problem.

Author Keywords

Physical privacy; User privacy management; Haptic warnings; Wearable computing; On-body interfaces.

ACM Classification Keywords

H.5.2. Information interfaces and presentation:
Haptic I/O; K.4.1 Computers and Society: Privacy

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from Permissions@acm.org.
Ubicomp/ISWC'16 Adjunct, September 12 - 16, 2016, Heidelberg, Germany. Copyright is held by the owner/author(s). Publication rights licensed to ACM. ACM 978-1-4503-4462-3/16/09...\$15.00
<http://dx.doi.org/10.1145/2968219.2979138>

(i) Environment Sensing Waist Belt

(ii) Haptic Arm Band

Figure 2: Wearable system for Physical Privacy

Introduction

Privacy is the ability of an individual, or group, to control access to themselves, either by physically separating themselves from others or controlling how others view information about them. This enables people to express themselves selectively. User information privacy has become a significant research challenge in recent years [5], particularly with the growth in ubiquitous computing, with variety of novel privacy management interfaces proposed (e.g., [4,6,13]). Physical or bodily privacy on the other hand, has been comparatively less clearly defined and researched. We understand it as a sensory interference [7]: the intruder senses you against your wishes by watching/video recording, listening to, or touching you, which potentially leads to discomfort or even harassment. For example, the user may be unaware of the privacy threat (e.g., Figure 1a and b), or the user (aware or otherwise) may be unable to take mitigating action due to fear, shock, physical and mental weakness, or embarrassment [2] (e.g., Figure 1 c).

In this paper we introduce the problem of physical privacy in users' immediate physical environment. A privacy interference or breach may arise through technological devices, or directly by other humans physically present around the user. One way to address these privacy threats is to augment human senses with technology that (1) quickly senses such situations around a user, (2) empathetically and actively warns them in real time, (3) enables them to take immediate action when informed or automatically responds appropriately on the users' behalf, and (4) learns continuously from user responses to understand their context and needs. In terms of usability, the interfaces of these technologies need to be fast, direct, easy and intuitive to operate, available at all times to the user (potentially hands free), and usable in a social setting. We argue that new on-body devices and interactions for privacy management could provide a means to address these requirements, and begin by presenting two example usage scenarios.

Scenario 1:

Eavesdropping private conversations in public places:

Adam is on a tour with his wife, Alice, and shares many private conversations with her along the way in public places such as airports, bars, cafes and shopping centres. He wears a *Privacy Wearable*. While discussing a private matter with Alice, and unaware of his surroundings, as soon as a stranger, Anna, physically enters his predefined *safety zone*, he is notified haptically by his Privacy Wearable of a potential threat to his physical privacy. As a result he becomes more aware and careful about what he is saying to Alice, and for that moment chooses to whisper, use hand gestures, and then moves to more secluded location.

Scenario 2:

Sexual harassment via human contact in public places:

Neha's route home from work involves walking through a poorly lit and deserted area of town. However, she uses a *Privacy Wearable* that increases her awareness of the physical environment around her. When an assailant, Ranjit, approaches her from behind, enters and continues to be in her predefined *safety zone*, Neha receives a haptic notification of this intrusion into her private physical space. The intensity of this warning increases continuously as Ranjit moves closer to her. She is scared and immediately interacts with the Privacy Wearable to provide an emergency input, upon which a loud alarm sounds and a help message is sent to a nearby police station, friends and family, along with the coordinates of her location.

Related Work

Throughout history, humans have used different forms of physical barriers such as walls, curtains, clothes, makeup and their own body to protect their physical privacy. Technology too, in many forms has also played a part in helping users to protect their physical privacy. For example, bright infrared LED devices, such as the hat developed by URA/FILOART [11], offer protection from video surveillance. Similarly, the Privacy Visor

[10] prevents unauthorized facial image identification from unintentional capture of such facial images, through wearable glasses with infrared LEDs. The No-Contact Jacket [9] repels a potential assailant with a powerful but non-lethal electric shock, while the Spike Away [12] vest, plastic armour fitted with long flexible plastic spikes, prevents fellow commuters from invading the personal space of the wearer in a public setting.

For improved usability, factors such as culture, gender, and age should be considered when designing privacy wearables. A number of changing factors in the users' immediate physical environment also need to be considered, such as context, social modes (e.g., party, meeting, with friends vs. strangers, etc), locations (e.g., public vs. private places), number of people in the vicinity (e.g., secluded vs. crowded), lighting conditions (e.g., bright vs. dark), and possible intrusion agents such as devices (e.g., CCTV) or people (e.g., friends, strangers, etc). Appropriate body locations for such devices and corresponding interactions should also be considered. In the next section, we explore the design of one such wearable device for physical privacy management.

Example Physical Privacy Wearable Device

To manage physical privacy threats, we propose a pair of wirelessly connected wearables: a waist belt to sense the environment around and allow user interactions, and an armband for haptic notifications. Unlike other form factors, belts tend to be physically discreet and a common type of everyday clothing in many cultures and both genders. Vibrotactile waist belts have been proven effective in increasing users' situation awareness [3]. Due to its' central location on a human body, a waist belt that is augmented with sensors, could effectively perform 360 degree sensing of the immediate physical environment around a user. Figure 2(i) shows a sample implementation of such a Physical Privacy Belt. It consists of 4 real time vision processing cameras such as CMUcam [14] (sensors

a(i), a(ii), a(iii), and a(iv)) can detect objects that it is taught). In addition to motion detection, it can identify people through face recognition, and detect the number of people around and their distance from the user. The detection *range* can be programmatically controlled to vary *sensitivity*, which can create different virtual and mobile *safety zones* for the user in different social modes (e.g., in a crowded urban transport environment, having confidential discussion in a meeting/phone, or while walking in a deserted area at night). The buckle also consists of a light sensor (b) and a powerful speaker (c). The flexible part of the belt that goes beyond the buckle (e) could be used for subtle interaction purposes. We derive some of the relevant input modalities from on-skin input [8] such as touch, grab, pull, press, scratch and twist. This allows for eyes free *coarse user interactions* such as changing sensitivity, social modes, etc. on the fly. The belt is connected to users' smartphone, which allows for *finer user control*. The control box (d) is right above a(iii).

The circular geometry of users' arms can be used to give subtle but strong directional haptic warnings of incoming physical privacy breaches. The arm band consists of 4 vibration motors [f(i), f(ii), f(iii), and f(iv)], and the control box (g) as shown in Figure 2(ii).

Privacy intrusion in situations similar to scenario 2, can lead to increased user anxiety, resulting in several physiological changes such as heart rate, respiration and galvanic skin response. These could be sensed through wearable bio-toolkits [15] on the skin and also used to detect privacy breaches. Recent advances [1] can detect people behind the walls through radio frequency signals and even distinguish them. These when miniaturised, could replace the vision sensors in our prototype and cover more complex scenarios. Similarly, sensors that could detect hidden cameras, microphones or drones, when integrated in the belt, could also enable users to manage privacy threats from devices in their immediate vicinity.

Conclusions and Future Work

In this paper we introduced the problem of managing physical privacy in users' immediate physical environment. An example wearable device for physical privacy management was discussed along with possible sensing and notification capabilities, user scenarios and interaction control. Further work is required to address other concerns, such as providing effective mechanisms for achieving privacy, whether by alternative communication modalities to prevent eavesdropping, or using additional sensing technologies to assess the level of the privacy threats in a given context. This will require research into the *human factors and usability* of devices for physical privacy management as well advances in techniques for *engineering adaptive software* that will drive the functionality of these devices. We plan to explore such technologies through further prototype development and user studies.

Acknowledgments

We acknowledge ERC Advanced Grant 291652 (ASAP) EPSRC Grant EP/K033522/1 (Privacy Dynamics), and SFI grant 13/RC/2094 (Lero).

References

- [1] Adib, F., Hsu, C.Y., Mao, H., Katabi, D. and Durand, F., 2015. Capturing the human figure through a wall. *ACM Transactions on Graphics (TOG)*, 34(6), p.219.
- [2] Ahmed, N., 2016, May. Discussing about Sexual Harassment (Breaking Silence): The Role of Technology. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 459-472). ACM.
- [3] Hao, F. and Song, A.G., 2010, July. Design of a wearable vibrotactile display waist belt. In *Intelligent Control and Automation (WCICA), 2010 8th World Congress on* (pp. 5014-5017). IEEE.
- [4] Jedrzejczyk, L., Price, B.A., Bandara, A. and Nuseibeh, B., 2010, September. Privacy-shake: a haptic interface for managing privacy settings in mobile location sharing applications. In *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services* (pp. 411-412). ACM.
- [5] Langheinrich, M., 2002, October. Privacy invasions in ubiquitous computing. In *Workshop on Socially-informed Design of Privacy-enhancing Solutions in Ubiquitous Computing. UbiComp*.
- [6] Mehta, V., Bandara, A.K., Price, B.A. and Nuseibeh, B., 2016, May. Privacy Itch and Scratch: On Body Privacy Warnings and Controls. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 2417-2424). ACM.
- [7] Moreham, N.A., 2014. Beyond information: physical privacy in English law. *The Cambridge Law Journal*, 73(02), pp.350-377.
- [8] Weigel, M., Mehta, V. and Steimle, J., 2014, April. More than touch: understanding how people use skin as an input surface for mobile computing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 179-188). ACM.
- [9] Whiton, A. and Nugent, Y., 2005. *Electrically charged self-defense wearable*. U.S. Patent 6,961,227.
- [10] Yamada, T., Gohshi, S. and Echizen, I., 2012, October. Use of invisible noise signals to prevent privacy invasion through face recognition from camera images. In *Proceedings of the 20th ACM international conference on Multimedia* (pp. 1315-1316). ACM.
- [11] <http://www.oberwelt.de/projects/2008/Filo%20art.htm>
- [12] <https://www.behance.net/gallery/12573867/Spike-Away>
- [13] <http://www.dezeen.com/2014/06/16/coop-himmelblau-jammer-coat/>
- [14] http://cmucam.org/projects/cmucam5/wiki/Introduction_and_Background
- [15] <http://www.bitalino.com>