Towards a Model of Virtual Proxemics for Wearables

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Abstract. We present a Virtual Proxemics Model inspired by Hall's Proxemics Theory targeting wearable technology design and use. In Virtual Proxemics the degree of data control defines different levels of data spaces personal closeness including: Intimate, Personal, Social and Public in the same way Hall's proxemics defines these for physical distance from a person. This model is important for wearable technology design due to the design characteristics of wearables such as: attention-free, invisibility, closeness to the body, sensory linked, controllability and always-on that may compromise a wearer's ability to adequately control data either coming to them or being sent. We describe an experience with a wearable system, called 'The Cat in the Map.' In this system, when strangers accessed the wearer's Intimate data space, she became uncomfortable, consistent with the model. Likewise, when her intimate relations accessed the same data space, she enjoyed the experience. Thus, we see that Virtual Proxemics Model aligns with wearer's experience of data control that may be suitable for the design of automated data access control mechanisms.

Keywords. Wearables, proxemics, virtual proxemics, control-based spaces

1 Introduction

As wearable technologies promise benefits from invisibly sensing your body's state, providing unobtrusive, attention-free access to your digital world and providing an "always on, always connected" experience [20], these same features exaggerate the range of consequences due to unauthorized data access. The issue arises from the desire to minimize the amount of attention the wearer pays to the technology leading to a potential loss of control of who can send or access data from the wearer [28]. Attentional and use design categories of wearable technology, presented in (§2), include not being visible, close to the body, sensory linked and un-monopolizing and controllability. Some of these conflict with each other, greatly impacting actual and perceived levels of data control [28]. As the data becomes more sensitive, due to the types of application areas for wearables, the potential loss of control can lead to a sense of violation if inappropriate access behaviour occurs.

In the physical world, social and cultural protocol and physical proximity provide cues for appropriate behaviours with respect to a person's personal space [11]. To understand how the physical space around someone defines her/his comfort zones, Hall introduced the theory of proxemics [10]. In Hall's theory physical distance from a person provides comfort categories mapped as distance based zones. These zones then provide a sense of socially and culturally associated acceptable distances for different types of people based on familiarity. For example, from 0-45cm is a person's intimate space reserved for people that are intimate with the person. Someone, say a colleague, who comes within this intimate space, may cause feelings of discomfort and violation due to the lack of control available at that distance.

The virtual world does not have a direct equivalent to physical distance, however we argue that the degree of control a person has over data can serve the same function when defining a *Virtual Proxemics*. Specifically, the *less control* of data a person has, the closer it is to his/her intimate data space, while the *more control* they have, the closer to their pubic data space as shown in figure 3. Then, similar to Hall's proxemics, the virtual proxemics determines the comfort level a person has from someone accessing or sending data into their data spaces depending on their relationship with them. So, data in a person's intimate data space can be comfortably sent to or accessed by a person's intimates, but a violation will be felt if it is from more distant relationships. We also argue, that virtual proxemics can be used in the same way that Greenberg [9] uses Hall's proxemics for technology to function when people (or technology) are physically close. That is, the virtual proxemics can provide cues for how a person's data space may be accessed based on the types of human relationships. Thus, virtual proxemics is a model for defining what level of control to provide for a user over their data space, as well as the possibility to automate this control to better allow attention free properties of wearables to be exploited.

In this paper, we describe how virtual proxemics applies to wearables and why the design criteria for wearables emphasize the need for a model based on Hall's proxemics. We begin with Related Work (§2) discussing wearable technology by describing some of the main factors that have been identified in the literature that impact virtual proxemics. We also present related work on the proxemics theory and how it has been explored in computer science. We present the details of Virtual Proxemics in (§3). We then present a wearable prototype in (§4) where we fixed the level of data control and experience two different community relationships with the wearer. We also discuss the observations from the experience in (§4). Finally we conclude and discuss future work in (§5).

2 Related Work

Wearable technologies have emerged as an important direction for the next wave of sensing, fabrication, computing and communication technologies. As the technologies are intended to be worn, key factors related to adoption and effectiveness of the technology have to be addressed. A number of the factors for each of the design characteristics can compromise a wearer's ability to control data flow. We highlight these particular factors as they relate to virtual proxemics.

2.1 Related Properties for Wearables

Wearable design characteristics, from hardware to software, from appearance to comfort, from body fitting to garment-technology integration, have been presented by: Mann [20] who defines attributes for wearables' behavior, Gemperle et al. [7] who define guidelines for wearability, and Todi and Luyten [27] who present design goals for wearables.

In particular, Mann describes a general framework for comparing and studying wearable technologies with six necessary attributes for a wearable computer in order to better serve wearers. These attributes are: it (a) must be *un-monopolizing* of wearer's attention, it (b) must be *unrestrictive* to the wearer's tasks, it should be (c) *observable* and (d) *controllable* by the wearer, it should be (e) *attentive* to the environment and, it should be (f) *communicative* to others. His framework is focused on how the wearable technology should behave when worn. However, considering the virtual proxemics perspective, some of the attributes conflict with each other when providing necessary data control in the virtual space, e.g. *un-monopolizing* wearer's attention and *controllable* by the wearer. By un-monopolizing the wearer's attention, the user may not be aware of state changes that would require his or her attention; thus, even if the system is controllable, the wearer wouldn't use those controls. Likewise, if the device is controllable, it may require too much attention for the wearer to use effectively. Thus, following these principles may make it more difficult for a wearer to exercise control of their data spaces leading to a higher likelihood that their data space could be violated.

Concerns about aesthetics and interaction are raised based on the design goals presented by Todi and Luyten [27]. Their first two design goals consider aesthetics problems and the last three consider interaction situations: (1) The wearable device can be *integrated* into existing clothing, preventing wearers from having to wear additional accessories to achieve the desired interactions; (2) The technology is *not* readily *visible* to the naked eye, allowing for inconspicuous interactions and does not compromise the aesthetics of the clothing; (3) Interactive elements should be *easily reachable,* and allow for eyes-free interactions; (4) Each entity has its own *dedicated* functions, to avoid mode-switching; and, (5) Individual elements should be *linked* together to form an automated workflow, what would guide us in our design. The inclination to hide the technology, provide an automated workflow and lack of mode switching may impede actively changing data space access; however, having each entity easily reachable may help the wearer; again providing potential design tradeoffs around data control for the wearer. Todi and Luyten included additional missing goals to support designing wearables, hence, Mann's attributes naturally combine with them. Together, these form a useful set of factors to attend to when developing wearables.

Considering the interaction between the wearer's body and the wearable, issues on wearability are brought forth by Gemperle et al. [7] as a concern when designing wearable computers. They describe 13 guidelines that cover wearability by discussing: (i) *Placement* determines where the application should go considering the dynamics of the human body. To guarantee a placement in unobtrusive locations the areas should: be relatively the same size across adults, have low movement/flexibility, and have large surfaces; (ii) *Form language* defines the shape of the application to ensure a comfortable and stable fit; (iii) *Human movement* takes into consideration the dynamic structure of the human body and suggests designing around the more active areas or creating spaces on the wearable to allow movement; (iv) *Proxemics* guideline relates to the human perception of space and dictates that forms should stay within the wearer's intimate space; (v) *Sizing* takes into consideration the different types of body that could use the wearable application; (vi) *Attachment* should also consider the different body sizes on top of offering a comfortable form of fixing the application to the body; (vii) *Containment* remembers the designers about the constraints brought by the components of the wearable application; (viii) *Distribution of the application's weight* and how it should not hinder the body's movement or balance has to be considered; (ix) *Accessibility* suggests testing to verify if the physical access to the wearable-wearer forms is adequate; (x) *Sensory interaction* states that the interaction should be kept simple and intuitive;(xi) *Thermal* issues can arise when placing processing intensive modules close to the body; and (xii) *Aesthetic* means the wearable should be seen as appropriate by the group of people wearing it; (xiii) *Long-term use* guideline is about the effect an application may have on the body and mind.

Gemperle et al. [7] sometimes refer the guidelines as suggestions, states, or definitions, suggesting that some of them have different impact into the design. However, from our perspective all of the guidelines seem relevant enough so that they should be considered for a successful design process for wearables.

Although the discussion of these properties are not stressed in here, they formed the basis for developing the wearable prototype and we are continuously investigating which and how these characteristics impacts the relationship between the wearers and the technology as well as the people they are interacting with, mainly focused on virtual interactions. In this paper, the considered context is the degree of controllability the wearer has and how this impacts his or her feelings of comfort when virtually communicating with a remote group that are either intimate or part of a public related group according to Hall's theory.

2.2 Proxemics Theory

The term *proxemics* is used by Gemperle et al. [7] to name their guideline *iv* in which the distance between the wearer and the wearable is determined as the wearable device being placed in contact with the wearer's body, using the concept of intimate space based on *Proxemics Theory* by Edward Hall [10], shown in Fig 1. Hall's theory includes distance among people, not only between wearer and wearable, and describes a type of nonverbal communication based on distance and level of intimacy considering a body-centric perspective: close to a person is the intimate circle, and away becomes public space. Such terms were coined by Hall to explain the concept of social cohesion, describing how people behave and react in different types of culturally defined personal spaces. According to Hall, proxemics theory was defined as "the study of man's [sic] transactions as he perceives and uses in his *intimate*, *personal*, *social*, and *public* space in various setting" [11] mainly related to other people. Although Hall uses the term 'space' to discuss proxemics, we understand that, in fact, his discussions about spaces are more focused on one single dimension of space: a layer of horizontal distance from the central subject at the height would be as tall as the subject.

In Hall, the *Intimate space* represents the distance for those allowed to touch and be touched by the subject; *Personal space* is reserved for friends and family; *Social space* is used for social and work interactions; and, *Public space* is used for public occasions (e.g.: distance kept from people in a market, plaza or a nightclub). Finally, each of these spaces has variations inside them according to cultural and individual values related to the perception of proximity. These spaces are interpreted and illustrated in figure 1. The image considers 2 axes: distance from the person's body versus degree of intimacy: the bigger the distance, the smaller the degree of intimacy, impacting on our behavior and interaction with others, as people transition from one circle to another. In the work reported here, our model uses the same names from Hall to relate physical space to perceived degree of control as well as the categories of relationship between the wearer and others they encounter. Likewise, we use the same names Hall gives to the level of intimacy between people. We use this mapping to suggest the type of behaviour that the wearable should evoke in the wearer when violations of their data space occur.

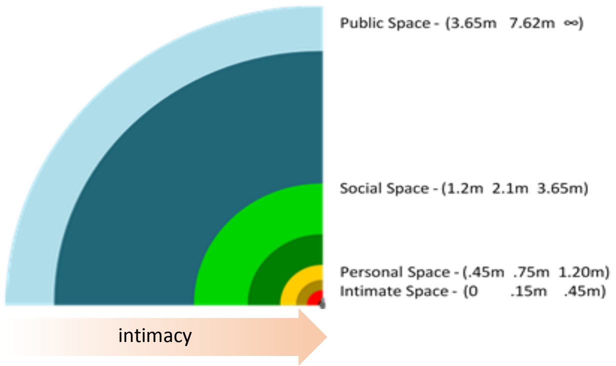

Fig. 1. Four proxemic circles as defined by Hall [10]. In red: Intimate space; in yellow: Personal Space; in green: Social Space; and, in blue: Public Space. First and second numbers of each space represent the interval for the close state and second and third number, the far state.

In our studies, we adapt this Proxemic Theory as a model to represent the concept of Virtual Proxemics for wearables as described in section 3. For this, we interpret the different spaces Hall identified as relating to a person's need for control around their physical space as the distance between other people changes. However, in our adaptation to the virtual data space, we consider the degree of control over a data space to be the correspondence of distance. Thus, we map Intimate space to Intimate Data

Space, Personal space to Personal Data Space and Public space to Public Data Space based on degree of control. In our mapping, the least control over data is considered intimate and the most control over data to be public. Thus, in the same manner as a stranger entering your intimate space is a violation, so would public access to your Intimate Data Space be. However, a close relation, such as a spouse, would have access. Note that we consider data space to be bidirectional where a wearer can be putting data or receiving data into their data spaces.Proxemics in Computer Science
Even though proxemic theory is more commonly associated with disciplines other than computer sciences, such as architecture and social sciences, ubiquitous and pervasive computing made such study useful in the context of Human Computer Interaction (HCI). In Virtual Reality (VR), Hall's proxemic theory has been used to study how behaviors that happen in the physical world translate to the virtual world ([2], [29] and [13]). Human-Robot Interaction (HRI) has used it to better design how people could interact with robots [26], their acceptance [22], trust [12] or even robot's behavioral changes to interact with people from different culture to consider social norms [16].

Greenberg et al. [9] presented the concept of proxemic interactions for ubiquitous computing systems where they explore how to design systems to respond as a person would, adding four variables, besides distance, to correlate the human proxemics to 'smart' information and communication technology (ICT) proxemics, such as orientation, movement, identity and location. By doing so, they provide their ICT systems some human senses to give awareness about proximity beyond only a front camera to capture the presence of a user or other 'smart' technology.

In the ICT context, there are two main relationships involving interactions to which Greenberg applied Hall's proxemic circles in order to determine the technology's behavior: (A) the interaction between technological devices and user and, (B) the interaction between technological devices and technological devices, as shown in figure 2. However, the similarity in both contexts shows that Greenberg's main point is the proxemical behaviour of ICT related to users (with or without a device mobile mediation).


(A) (B)

Fig. 2. Greenberg et al [9] definition for ICT proxemic interaction between (A) located technology and user and (B) located technology and users mediated by a mobile device (from [9]).

In the studies presented here, the proxemic theory and additional variables were combined and used to analyze and better define technology's automatic behavior so that it fits better with the user's expectations based on intimate space. This is particularly evident in Greenberg et al.'s work with proxemic interactions. From the wearable computer perspective, we consider Greenberg et al.'s work may also be applicable to how technology should mediate control of a wearer's data spaces to ensure that appropriate access is provided in situations where the wearer's attention, or the design of the garment, makes it difficult for the wearer to do so.

2.3 Control of Data Spaces and Wearable-based Interactions

Additional complexities in data control with wearables have been identified by Viseu [28]. She makes the point that wearables, through connection with the digital world, augment the physical world where the wearer is the host for the technology. She identifies that some wearable researchers (i.e. Mann [20], Gershenfeld [8], Barfield [5] to name a few) believe that technology gives user more control over the environment while others like Lessig [18] argue it provides less, since the wearer can end up being controlled by the technology, such as an employee being monitored by an employer. She further makes the observation that this aspect of wearables transcends control and power to the realm of cultural biases. Hall's theory acknowledges how critical this aspect is. In adopting a model based on Hall's theory, we also encapsulate the elements of social protocol and cultural norms about what is appropriate for people to access within a person's data space.

In the literature on wearables, there are examples of virtual proxemics at play to support the view that people do have a sense of different levels of comfort based on different elements of how a wearable data is used. For example, Mann's work on a wearable technology allowing him to block out the world [20] is a form of complete control of his visual channel. By doing so, he keeps data outside his intimate data space to extent that people would need to pay him to enter it. Augmented reality with a head's up display that doesn't completely block the wearer's view provides filtering on what the wearer sees. Further along the continuum of control are wearables such as Google Glass that do not block the view, however provide opportunities for interpreting what is seen. In these examples, we can see that wearables provide differing levels of control over visual data that can be placed on the continuum of virtual proxemics.

The model of virtual proxemics can also be applied to establish appropriate access control responses by the technology, much as Greenberg et al [9] uses Hall's theory to determine how technology should behave as discussed in the previous subsection. Even though, they are looking more at technology-human and technology-technology interactions rather than human-human mitigation, we believe their thinking extends to human-human interaction. Angelini et al. [1] proposed a combination of wearable technology to mediate sharing user information when two wearers hug. Using the technology to sense proximity, length of hug and history of hugging allowed the system to infer that those two wearers are intimate, thus, allowing access to each person's intimate data space.

A more direct interpretation of Hall's theory applied to control and wearables within a person's intimate space is the Spider Dress [17]. The dress senses when someone enters a wearer's personal space combined with the wearer's breathing pattern raising menacing spiderlike arms preventing close contact. If the system were to also know whether an approaching person is an intimate from understanding the breathing pattern related to fear or excitement, it could keep its arms lowered. Ideally, for an attention free wearable, the technology would know how to establish this relationship. In a sense, the virtual proxemics model should provide the wearer a sense of the spider arms over their data space when a non-intimate sends data or wants to read the wearer's data.

Puikkonen et al. [23] also represent a similar concept with a performative wearable technology to explore inappropriate attention. Though, Puikkonen et al's also expose how the proximity and intimacy of interaction between the wearer and the wearable can lead to the wearer not always being aware of what is happening, leading to a concern over one's right of privacy and a low level of acceptance of certain wearable devices, as shown in [24] and [30].We argue this design characteristic of wearable technology leads to a lack of control of their data space, implying that all interactions with this data space should be treated as a person's intimate data space.

In contrast to collocated interactions between people, wearables also provide a means for communication between remote participants. Work such as Min and Nam [21] used wearable technology 'to bridge the communication gap between people in close relationships who have to live apart'. They collected one of the partner's bio-signals and reproduced them to their distant partner using wearable prototypes, so that this partner would feel more connected by physically feeling their partner's heartbeat and breathing rate. Differently from the work of Min and Nam, He and Schiphorst [14] explored the concept of mediated communication using wearables and presented a wearable prototype named Patches that allowed for two-way nonverbal communication. In this prototype, the wearer could be poked via a Facebook application by one of his/hers friends and receive the poke on the prototype by simulated feelings of warmth and pressure from one of the patches. In turn, the wearer could return the poke by pressing that patch. When the wearer and observer are physically distant from each other, the wearable becomes the sole channel of communication, effectively mediating the communication between the wearer and observer. In this situation, it may be difficult to know the relationship between the two actors as physical proximity cues are unavailable. Explicit representations are needed, such as using Facebook settings as done in He and Schiphorst [14]. However, these mechanisms then require attention from the wearer, conflicting with some of the desired wearable characteristics brought by Mann. We argue in these situations, where a wearer has not specified explicit control, that the data space has to be treated as their intimate data space.

In summary, many of the related wearable technology explorations have touched upon the challenges of how wearable technology provide channels of data to and from the user and that depending upon the control of the data, can lead to feelings of empowerment, disempowerment, comfort, discomfort. In next section, we describe how virtual proxemics is a suitable model for wearers to think about their data spaces and what degrees of control they have. This model also establishes a means to discuss the socio-cultural biases of power and control over people's data spaces in more structure fashion.

3 Virtual Proxemics

Our model of Virtual Proxemics derives from Hall's theory of physical proxemics. However, we use degree of control as the measure for the different categories of data space in contrast to physical distance for Hall's proxemics (shown in figure 1). In figure 3 we illustrate our mirrored representation of virtual proxemics with data space replacing physical space and the dimension of control replacing distance. As in Hall's proxemics, we envision the virtual proxemics as a continuum with some useful categories that can be identified as related to the type of relationships between people.

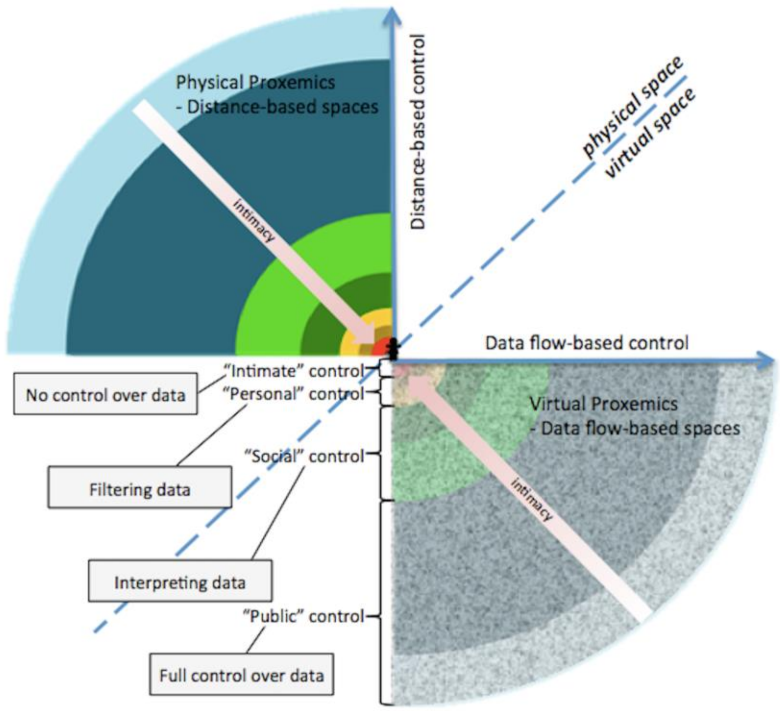

Fig. 3. Representation of virtual proxemics with Hall's physical proxemics from figure 1 included for comparison. In virtual proxemics, the higher the degree of control of the data space (i.e. data coming in or out) the lower the level of intimacy in the data space. For example, for data where the wearer has no control of the data, it would be considered in their Intimate data space.

As shown in figure 3, Intimate data space is one where the wearer has little or no control of the data (or doesn't need/want to have). The data may either be directed towards the wearer such as messages, images, voice etc. or coming from the wearer, such as sensor data, annotation, messages etc. For example, a text message appearing in a head's up display coming from someone that isn't filtered or blocked enters a wearer's intimate data space. Or, a heart rate sensor that sends its data to a third party cloud service is in the wearer's Intimate data space. As the amount of control increases over the data, the data space becomes further out to be Personal data space, then Social data space and finally Pubic data space. In the wearer's Public data space he or she has complete control of the data including being able to completely block all incoming or outgoing data. Social space may include filters or other manipulations that mask or block data such augmented reality glasses that filter out advertisements. The Personal data space is where controls provide interpretation of data but does not completely block or filter it such as aggregate data from sensors being sent to a third party.

Virtual proxemics for a wearer's data space serves two potential roles. First, for wearers, by providing this model they may more easily understand the type of exposure they will have to data coming to them or from them allowing them to make better choices about the technology. While wearable technology can be taken off or left in a drawer to block all data, implying that everything is in wearer's Public data space, this does not address the issue of when people want to use a wearable technology. The desire for always on, attention-free, and an invisible form factor imply that manual data controls that do exist may be difficult to attend to or need to be pre-specified and then forgotten about. However, this may compromise wearers' comfort when something unanticipated happen and wearers are not aware or do not want to stop what they are doing to address it. Virtual proxemics categories provide an explicit way to understand any prespecified settings and also communicate when anyone is entering a certain data space so the wearer will know what to do. The second role, much like Greenberg applies Hall's proxemics is that the categories can be used for having the technology automatically managing someone access to wearers' data space and attempting to provide access only to the appropriate data space. Thus, if a cloud service provider attempts to store a wearer's heart rate data, the system could infer that the cloud service provider is a Public member so would not have access to any data in the wearer's Intimate, Personal or Social data spaces, which would include the heart rate data as the wearer was not exerting any data control of that sensing data. Thus, such privacy policy provided by the Virtual Proxemics model would avoid a potential feeling of being violated, what guarantees wearers' empowerment and data control. Alternately, the wearable can evoke an awareness response from the wearer so they have a visceral sensation that a breach is happening.

As to this second role, a number of wearable technology researchers, such as, [6], [14], [15], and [21], use study participants with known close social relationships. For example, Cercos & Muller [3] avoid privacy concerns by having participants who knew each other and worked closely together on a daily basis, i.e. would likely have been in the wearer's Personal or Social circle. Min & Nam [21] provide some insight that the sense of virtual proxemics is understood with their participants, as they noted that some users commented that they would feel considerably different depending on their relationship with the connected partner.

Finally, for this second role, we have not specified access control policies that could be applied to facilitate automatic mechanisms to alert wearers about potential transgressions, much like the spider dress tries to with real proxemics. With respect to confidentiality of data being read by members from different levels of intimacy, access policies such as Bell-Lapadula model [3], fit with the intuition for access we propose for virtual proxemics. The approach of "no read up, no write down" is consistent with the notion that if someone from a given comfort circle of the wearer tries to read data from a closer data space the wearer would be made aware of the transgression. Likewise, if data is being written from a close data space to a farther one, the wearer would be notified; but would not be for the other way around. In this way, only potential data confidentiality breaches require attention from the wearer. With respect to integrity of the data, models such as Biba's [4] could also be applied. In this case, the "no read down, no write up" can be applied to alert the wearer of potential data integrity problems. The Cat in the Map Experience

The Cat in the Map is a wearable-based functional prototype designed to provide communication between the wearer and her community when she is out of the community, as shown in figure 4.

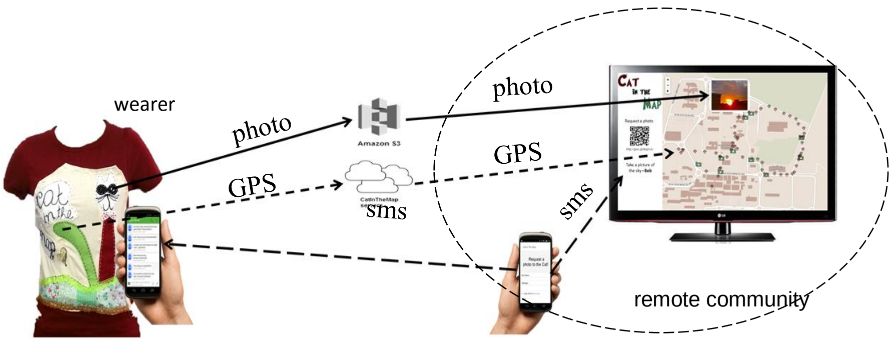

Fig. 4. 'The Cat in the Map' system with the three primary data paths: SMS, photo and GPS. The system has three main parts: (1) the wearable prototype that collects position data of the wearer and allows her to take pictures; (2) a REST API that creates the bridge between these two parts; and (3) the community shared display showing where the wearer has been, photos taken, messages sent and the send message widget.

The wearable was designed to extend the wearer's senses by allowing her to send her location and photos taken while she walks. The location and photos she takes are presented on a shared display for the remote community. The community could also send real time messages or photo requests to the wearer; the wearer could then choose to do so or not. Together the wearer and community had bidirectional communication so that the community could see what she sees and where she is and send messages and requests.

Our wearable prototype had three main functionalities: taking a picture, collecting GPS data and uploading such information to the servers. These functionalities used the camera module and a push button; GPS module; and, Wi-Fi dongle, respectively; with the Raspberry Pi as the processing unit. In terms of controlling the data channels, the wearer could choose when to take a photo. However, she did not control sending GPS data to the shared display so anyone watching could see where she was. Using the phone, anyone in the remote community could send an SMS to the wearer. These messages would appear on her phone and she could choose to ignore or not after she read it; thus, she was not able to filter messages prior to receiving them, nor could she delete them. Figure 5 shows the hardware built in the wearable.

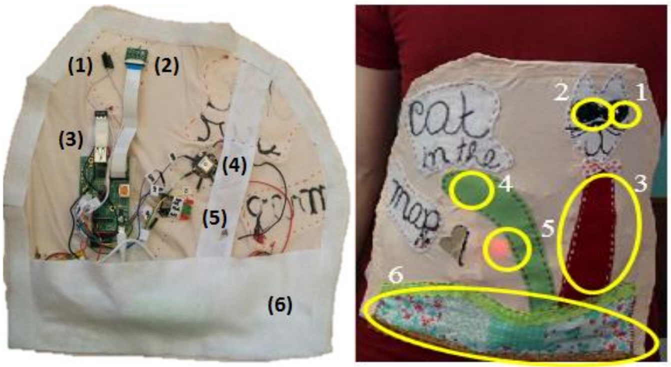

Fig. 5. Wearable hardware (1) push button; (2) camera; (3) Raspberry Pi B and Wi-Fi; (4) GPS; (5) LEDs for feedback; (6) battery pouch with two 1500mAh batteries (GPS and Wi-Fi) and a USB charger (Raspberry Pi).

To see the effect of the data control on her feelings with respect to the data spaces created in this prototype, we had one wearer (female graduate student) and two communities in different relationships to her, i.e., co-workers and partner.

In the co-worker condition the wearer walked around a university campus for 4 hours. During this period, she went about her regular activities (e.g. walked around the campus, stayed at the laboratory, had lunch, etc.). The shared display was put in the entrance lobby of her department at the university. Many observers stopped to watch the photos and the path she was taking. She received ten messages: four were requests for photos (e.g. 'Take a picture of my house' – Ant Man), two were comments (e.g. 'Where's the cat now?' – V.), and four were jokes (e.g. 'A neutron walks into a bar […]' - Dr. Sheldon Cooper). The comments and anonymous jokes sometimes had content classified by the wearer as 'insulting', like 'Fresh meat – Hannibal'. These situations made the wearer feel uncomfortable and 'invaded by strangers'. She also commented that she didn't want them to know where she was. This observation suggests that the lack of control of the GPS data appearing on the shared display and the messages coming from the remote community make her uncomfortable. The violation made her feel powerless and 'deeply unmotivated' to continue the interaction, as reported.

In contrast, for the second condition with her partner at the shared display in his home, she used the Cat in the Map for a period of 2 hours. During this period, twelve messages were received such as: comments (e.g. 'Wow, it's huge'), expressions of concern (e.g. Seems windy, did you bring your coat sweetie?) and requests (e.g. '[…] take some pictures of that World of Science place. […]'). Unlike in the co-worker case, the sender identity was known. The wearer reported to have a 'more pleasant experience' on sharing the photos and receiving requests of photos, comments and advice from her partner.

The prototype was designed to have the GPS and messages in the wearer's Intimate data space. Though, the photos were in her Public data space in that she could choose when to take a photo. As expected, her partner, being intimate, did not cause discomfort when he either sent or watched her moving on the shared display. In contrast, co-workers, not being intimates, caused discomfort accessing her Intimate data space. This is consistent with our view of Virtual Proxemics.

4 Conclusion

We presented a model of Virtual Proxemics derived from Hall's proxemic theory. In Virtual Proxemics the degree of control defines different levels of intimate data spaces from Intimate, Personal, Social and Public in the same way Hall's proxemics defines these for distance from a person. We argue that this model is important for wearable technology design due to the design characteristics of wearables often interfering with the ability for people to control data coming and going from their wearable device. Specifically, attention-free, invisibility, sensory linked, controllability and always-on characteristics in wearable design compromise a wearer's ability to control the data channels. Yet, people understand the social and culturally biased physical space around them as Hall pointed out. Thus, these same understandings can be applied to their data spaces as well. By doing this, it is easier for wearers to understand the complexities of data access policies. This is particularly important once data often associated with wearables is quite sensitive. The other advantage derived from this model is the possibility that technology can be used to infer a wearer's relationship to people that are entering different parts of their data spaces and can provide appropriate protection. We presented an example wearable system where we constructed an Intimate data space to see whether access to it by people in the wearer's Social circle made her uncomfortable, which it did. Likewise, we saw that people in her Intimate space did not make her uncomfortable, thus, suggesting that our approach is promising.

Future work entails exploring the continuum of control and how that relates to the different categories of Virtual Proxemics in the same way that Hall established ranges of distance. As well, if these become established, it will be possible to investigate how technology can use these rules in the same way as Greenberg et al. demonstrated how Hall's proxemics can be used to mitigate human-technology and technology-technology interactions. Though, as Hall noted, proxemics depends upon social and culturally constructed norms, thus, exploring how virtual proxemics are impacted by social and cultural norms seems appropriate as well.

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