The Social Comfort of Wearable Technology and Gestural Interaction

Lucy E. Dunne-*IEEE and EMBS Member*, Halley Profita, Clint Zeagler, James Clawson, Scott Gilliland, Ellen Yi-Luen Do-*IEEE member,* and Jim Budd

***Abstract*— The "wearability" of wearable technology addresses the factors that affect the degree of comfort the wearer experiences while wearing a device, including physical, psychological, and social aspects. While the physical and psychological aspects of wearing technology have been investigated since early in the development of the field of wearable computing, the social aspects of wearability have been less fully-explored. As wearable technology becomes increasingly common on the commercial market, social wearability is becoming an ever-more-important variable contributing to the success or failure of new products. Here we present an analysis of social aspects of wearability within the context of the greater understanding of wearability in wearable technology, and focus on selected theoretical frameworks for understanding how wearable products are perceived and evaluated in a social context. Qualitative results from a study of social acceptability of on-body interactions are presented as a case study of social wearability.**

I. Introduction

Wearability of body-worn devices and technologies is often characterized in terms of how the device is physically perceived by the wearer. Several key studies of wearability have investigated the device-centric variables that contribute to "wearability" such as the physical shape (volume and contour), and body location of the device [1], as well as user-centric variables that reflect and assess aspects of wearability such as ability to move freely and feelings of pain or pressure [2]. The cognitive aspects of wearability of wearable technology often fall into the category of usability or human-computer interaction, although the interaction between sensory perception of wearability variables and cognition through the bottleneck of attention has also been explored [3].

Most approaches to understanding wearability have focused on the physical experience of the wearer, concentrating attention on the size, shape, weight, and body location of the device, as related to the wearer's tactile perception of the device and ability to perform everyday movements and tasks. However, the design of other forms of wearable artifacts (such as clothing and accessories) instead concentrate primarily on the aesthetic aspects of the artifact, with physical attributes considered as a secondary emphasis.

L. E. Dunne is with the University of Minnesota, St. Paul, MN 55108 USA (phone: 612-626-5901; e-mail: ldunne@umn.edu).

H. Profita was with Georgia Institute of Technology, Atlanta, GA 30332 USA. She is now with the University of Colorado - Boulder, CO 80309 USA (e-mail: hprofita@gmail.com).

C. Zeagler, J. Clawson, S. Gilliland, E.Y.L. Do, and J. Budd are with the Georgia Institute of Technology, Atlanta, GA 30332 USA (e-mails: {clintzeagler; jamer; scott.gilliland; ellendo; jbudd}@gatech.edu).

As wearable devices become increasingly common in the consumer market and in everyday use, the aesthetic aspects of wearing technology become more pronounced. Further, aesthetics may in fact become key variables in the consumer adoption decision. Therefore, we find that it is necessary to expand the designer/engineer's definition of "wearability" to include the influence of the device on the comfort of the wearer's social experience and identity.

The history and theory of design of other forms of wearable artifacts offer useful frameworks for understanding the variables that influence social wearability. Here, we explore existing theories and discuss their relevance for wearable technologies.

II. Visual Processing of Aesthetics

While physical wearability is perceived mainly by the wearer, aesthetics are perceived by the wearer and by external viewers. Significantly, the wearer's perception (or assumptions) of aesthetic interpretation by others is often the key experiential variable influencing aesthetic wearability. Body adornments communicate on two levels: through their "expressive" characteristics such as color, texture, and form; and through their "referential" characteristics, which are interpreted by the wearer or another viewer as relating to something outside of the form (such as a brand, trend, social role, or other concept) [4].

DeLong [4] describes the combination of these characteristics of the worn artifacts and the characteristics of the wearer's body as the Apparel-Body Construct. In this relationship, the garment or worn artifact can change the body, be changed by the body, or both – and vice versa. Further, artifacts within the apparel-body construct (particularly accessory-like artifacts) can also influence the visual properties of other artifacts. Wearable devices can have a dramatically different effect on the apparel-body construct depending on whether they are worn under the garment or over the garment. When the device is on the exterior of the apparel-body construct, it can become a high-contrast visual focal point, dominating the aesthetic of the outfit. However, when worn beneath the garment, it can distort the surface of the garment and the silhouette of the body. Depending on the viewer's assignment of referential characteristics, this distortion could be interpreted in any number of ways: perhaps as deformity of the body, or as a deliberate concealment of an object (along with perhaps an interpretation of the reasoning behind the concealment).

The expressive and referential characteristics of the apparel-body construct are selected by the wearer usually to

978-1-4244-7929-0/14/$26.00 ©2014 IEEE

express some combination of individual and group identity. In some cases (such as uniforms, for example) these identities may be very explicit. However, in most cases the interpretation of identity is full of subtle variations and indicators. Even within a group wearing a uniform, individuals find ways to express unique aspects of their individual and sub-group identities [5]. Expression of identity visually through worn artifacts can also have a reflexive effect on the individual's understanding of self, even in terms of skills and abilities. Adam and Galinsky [6] found that different understanding of the role portrayed by a white coat in a laboratory experiment significantly influenced participants' cognitive abilities. In wearable devices, this effect has also been documented in the form of device wearers decreasing their physical activity when wearing a perceptible wearable device [7].

III. Social Aspects of Gesture and Interaction

For wearable devices, the social perception and comfort of worn artifacts often extends beyond the "static" aesthetic variables of the artifact (worn on the body, but not interacted with) into the social aesthetics of interacting with a body-worn device. As a case study, gestural interaction provides an interesting lens through which to explore these variables.

Gestural input can be provided in one of two ways: either through passive interactions, wherein the device "listens" for activities or movements that are used to trigger or inform a device function without conscious intention on the part of the user, or through active interactions, wherein the user consciously performs a movement or action in order to provide instruction to the device.

Because passive input is inherently focused on naturally-occurring movements and gestures, it has far less social impact than active input, and therefore we will focus here on active input. For the designer of a device that uses active gestural input, a tradeoff exists between the clarity of the input and the visual distinction of the input. Gestures that are markedly different from everyday actions are much less likely to be "accidentally" performed (e.g., for an everyday movement to be misinterpreted as an input gesture). However, gestures similar to everyday movement are less conspicuous and have less social impact. Toney et al. discuss the "social weight" of interacting with a device as the negative impact that a device interaction has on a parallel social interaction [8]. This is reinforced by Karrer et al., who observed users appropriating trouser pockets for more inconspicuous or naturalistic interactions with a textile-based wearable device [9]. Rico et al. explored social acceptability of gesture usage with respect to mobile devices and found that audience and location directly influence one's willingness to perform certain gestures [10].

An additional complication for gestural interactions is the current novelty of the input method. Because there does not currently exist a standard "vocabulary" of gesture, it is correspondingly more difficult for viewers to match a perceived gesture with a previously-understood meaning. This not only increases the likelihood of erroneous conclusions, but also increases the distraction of perceiving the interaction (as the viewer must devote more attention to building a mental model of what is taking place, vs. matching the gesture easily to a previous experience.) Starner et al. [11] describe a similar contextual situation with respect to the "static" (non-interactive) aesthetic properties of wearable computers in the late 1990s. They found that certain colors were associated with certain assumed functions (black for consumer products, white or beige for medical devices). Today, as body-worn technologies such as Bluetooth headsets and activity monitors become more commonplace, the static aesthetic qualities of a device have become easier for viewers to understand and make sense of. However, gesture remains more socially ambiguous.

A. Case Study: On-Body Gestural Input

In previous work [12], we conducted an evaluation of the social impact of body location on the social acceptability of an on-body gesture interaction. A badge-type mock interface was attached to the clothing of an on-screen actor in different body locations. In video recordings, the badge was swiped to silence a ringing phone, and participants from the United States were asked to evaluate the social acceptability of the interaction when placed in different body areas on a male and a female actor. The quantitative results of this study are published in [12], and here we will explore the qualitative results of open-ended survey questions, which illuminate some of the key themes of social acceptability that emerged from the study.

Three open-ended questions were asked (n=63 responses, 38% male): 1) Please describe why you would wear the wearable controller in the body locations (identified in the preceding question); 2) Please describe why you would *not* wear the wearable controller in these body locations (identified in the preceding question); and 3) Please describe the concerns you would have about using a wearable controller such as this one.

Qualitative data were evaluated using a grounded theory approach, and an open-coding process. Codes were grouped into concepts, which are shown in Figures 1-3.

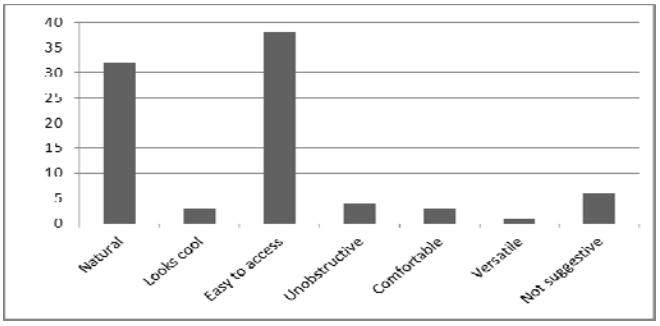

Figure 1. Reported reasoning for preferred body locations for the wearable controller (categories)

Figure 1 shows the data categories that emerged from the open-coding process for question 1, concerning the reasoning behind selecting the body locations in which participants *would* be willing to wear the controller (identified predominantly as the wrist and forearm in [12]). The strongest themes were around usability (ease of access, low level of difficulty in physical interactions) and around

avoiding social discomfort (looking natural, blending in, not being obvious, not being awkward). Less frequently-identified were other aspects of physical wearability (physical comfort, obstruction of other activities), or positive aspects of social wearability (looking cool/futuristic, coordinating with a variety of garments). The theme of sexual suggestivity (feelings of social awkwardness around interacting with body areas proximal to genitalia) was less prominent in this question, and always expressed as the absence of suggestivity relative to other options for on-body placement.

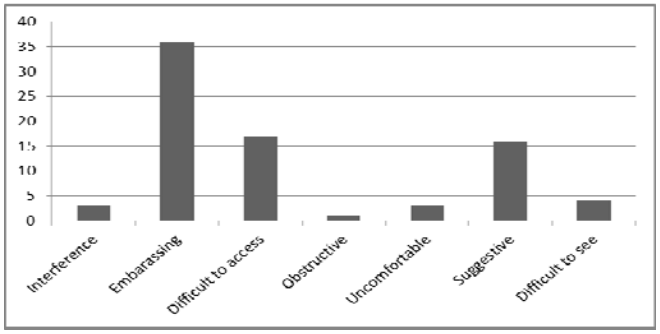

Figure 2. Reported reasoning for averse body locations for the wearable controller (categories)

Figure 2 shows the data categories for open-coded responses to question 2, regarding participants' reasoning behind selecting the areas in which they would *not* wear the controller (identified predominantly as the torso and collar bone in [12]). Here, there were many parallels with the positively-framed version of this question in terms of the categories that emerged, but a much stronger emphasis on social/emotional variables. Feelings of awkwardness or embarrassment were by far the most common theme. While it was much less common that a participant would fully illuminate the source of these feelings, the strongest sub-category that emerged was that of sexual suggestivity. Usability was also a secondary variable here, including related categories of accessing the device (physically and visually), the device interfering with other garments or obstructing actions, and physical discomfort in wearing the device.

By contrast, Holleis et al. [13] in evaluating body locations for capacitive touch-input in clothing found that users prioritized the thighs and hands. This in some ways contradicts our results, which found that pocket locations (close to the thigh/hip) and mid-garment locations were socially weighty and visually conspicuous, respectively. As gloves are not commonly worn in everyday environments, we have elected to exclude the hands from the available body real-estate under consideration.

Finally, Figure 3 shows participants' reported sources of concern with wearing the wearable controller, a question that deals generally with wearing an on-body gestural control (rather than specific body locations for the controller). Eight participants reported having no concerns with wearing the controller. Of the remaining 55 responses, the strongest theme was around questions of how the device worked, how durable and reliable it was, what it would be used for, how securely it would be attached to clothing, and how it would be integrated into clothing. Outside of those un-answered questions, the second most common source of concern was with the visual properties of the device. These comments were predominantly negative (concerns with the device being visually obvious in a negative way), but two respondents cited "cool" aspects of wearing the device, and the novelty of the interaction also emerged as a positive aspect encouraging adoption. Finally, six participants identified concerns relating to electro-magnetic radiation and the health risks of wearing technology on the body.

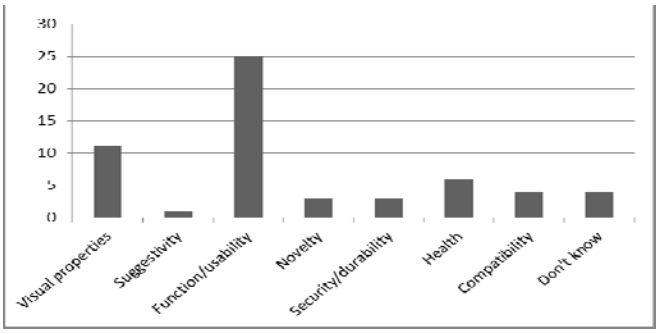

Figure 3. Sources of concern about wearing the wearable controller (categories)

From these results, it is clear that the visual properties of an on-body interaction are a key source of discomfort and aversion to adoption of on-body interactive technologies. The relationship between perceived "awkwardness" of the interaction and proximity to genitalia reflects results of the quantitative evaluation, where they were also found to vary depending on the gender of the actor using the interface.

B. Natural Interactions with Clothing

On-body interactions can potentially be made less explicit by embedding interfaces that are designed to leverage existing interactions with clothing. We find that garment features (pockets, decorations, fasteners) and edges afford interaction more than mid-garment locations, which were often cited by participants in our study as visually conspicuous and awkward. However, while the "vocabulary" of everyday tangible interactions with garments may be more established, it is nonetheless not well-codified. What might be the scope of "natural gestures" that individuals currently perform with everyday clothing? Could such natural interactions be successfully adopted for the pursuit of wearable technology interaction design? What concerns might arise with respect to accidental triggering or false positives? While many of these questions are still open-ended, preliminary assessment of the social "wearability" of on-body interaction can serve as a guide for the design of future wearables.

Figure 4 shows a speculative map of body locations in which natural garment interactions are likely to currently

exist. Lines indicate common locations for garment "edges", locations that are more commonly interacted with to don, doff, or adjust clothing. Shaded areas indicate easily-accessed body areas, as well as those areas that (as indicated in the previous section) are socially problematic due to proximity to genitalia. Socially awkward locations can differ with respect to gender, and the area as well as significance or degree of unacceptability can drastically fluctuate based on the cultural lens. Thus, while wearable interface design can explore the opportunities of natural clothing interaction provided by distinct garment design specific to different cultural regions and segments of society, it may still remain significantly influenced by the societal perceptions that dictate socially acceptable forms of presentation and interaction.

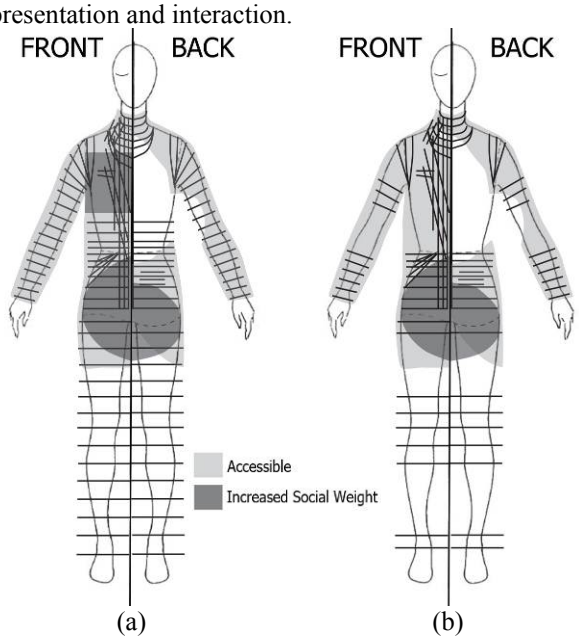

Figure 4. Body map of garment edges, features, and zones of accessibility and social weight for women (a) and men (b)

While such a map offers a broad view of potential interaction areas, the available real-estate must also be subject to analysis according to social conventions (in context) associated with garment interaction areas. Is a manual interaction with the hem of a garment more or less socially weighty than interacting with a pocket or front opening? Does this change depending on whether the opening is on top of another garment, or whether the opening is closed or open? While successful implementation must also consider subtle influencing variables, an underlying framework for interaction which takes into account existing sensitivities may ease the transition into a new vocabulary of on-body gesture.

IV. Conclusion

As outlined in Maslow's classic hierarchy of human needs, as basic needs are met, attention shifts to higher-order needs. In the case of wearable technologies, the field has matured to the point where basic needs like physical comfort, accessibility, and usability are met, higher-order needs for social acceptance and self-actualization become increasingly imperative. The theory and case-study outlined here support both the subtlety and importance of addressing social needs as they relate to visual properties and aesthetic expression in wearable technology. Success in wearable products increasingly approaches the standards set by other, more established products like garments and accessories, rather than those of personal electronics.

Acknowledgment

We would like to extend our acknowledgments to Dr. Thad Starner for contributing to the initial concept and development of this research direction.

References

[1] F. Gemperle, C. Kasabach, J. Stivoric, M. Bauer, and R. Martin, "Design for wearability," in *Proceedings of the Second International Symposium on Wearable Computers*, Pittsburgh, PA, USA, 1998, pp. 116–122.

[2] J. F. Knight, C. Baber, A. Schwirtz, and H. W. Bristow, "The comfort assessment of wearable computers," *Proc. IEEE Int. Symp. Wearable Comput.*, pp. 65–72, 2002.

[3] L. E. Dunne and B. Smyth, "Psychophysical elements of wearability," in *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, San Jose, California, USA, 2007, pp. 299–302.

[4] M. R. Delong, *The Way We Look: Dress and Aesthetics*, 2nd ed. Fairchild Pubns, 1998.

[5] J. Swain, "The Right Stuff: Fashioning an identity through clothing in a junior school," *Gend. Educ.*, vol. 14, no. 1, pp. 53–69, 2002.

[6] H. Adam and A. D. Galinsky, "Enclothed cognition," *J. Exp. Soc. Psychol.*, vol. 48, no. 4, pp. 918–925, Jul. 2012.

[7] M. Costa, M. Cropley, J. Griffith, and A. Steptoe, "Ambulatory Blood Pressure Monitoring Is Associated With Reduced Physical Activity During Everyday Life," *Psychosom. Med.*, vol. 61, no. 6, pp. 806 –811, Nov. 1999.

[8] A. Toney, B. Mulley, B. H. Thomas, and W. Piekarski, "Social weight: designing to minimise the social consequences arising from technology use by the mobile professional," *Pers. Ubiquitous Comput*, vol. 7, no. 5, pp. 309–320, Oct. 2003.

[9] T. Karrer, M. Wittenhagen, L. Lichtschlag, F. Heller, and J. Borchers, "Pinstripe: Eyes-free Continuous Input on Interactive Clothing," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, New York, NY, USA, 2011, pp. 1313–1322.

[10] J. Rico and S. Brewster, "Usable Gestures for Mobile Interfaces: Evaluating Social Acceptability," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, New York, NY, USA, 2010, pp. 887–896.

[11] T. Starner, B. Rhodes, and J. Weaver, "Everyday-use Wearable Computers," Georgia Tech Technical Report Georgia Tech Technical Report, 1999.

[12] H. P. Profita, J. Clawson, S. Gilliland, C. Zeagler, T. Starner, J. Budd, and E. Y.-L. Do, "Don't mind me touching my wrist: a case study of interacting with on-body technology in public," in *Proceedings of the 17th annual international symposium on International symposium on wearable computers*, New York, NY, USA, 2013, pp. 89–96.

[13] P. Holleis, A. Schmidt, S. Paasovaara, A. Puikkonen, and J. Häkkilä, "Evaluating Capacitive Touch Input on Clothes," in *Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services*, New York, NY, USA, 2008, pp. 81–90.