Exploring Acceptability and Utility of Deformable Interactive Garment Buttons

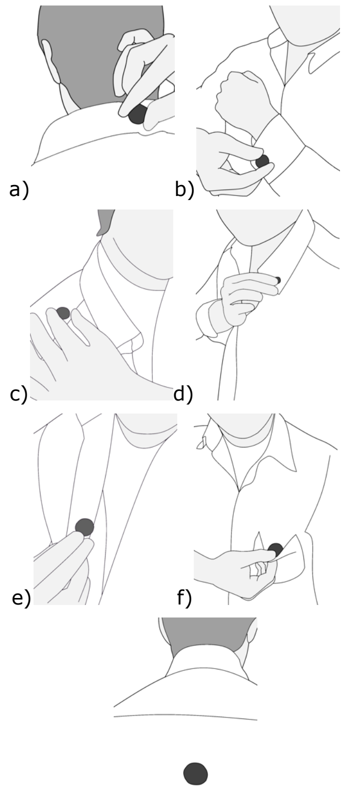

Figure 1. We explored interaction types, possible input and output locations, preference in sizes, and comfort levels in various actions/locations using mock-up interactive garment buttons. Examples from left to right: a) back of collar, b) sleeve, c) shoulder, d) collar, e) inside of placket, f) inside of front pocket, and g) back.

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Abstract
Wearable devices have received tremendous interest in fitness and personal assistance sectors. Yet most are still worn as auxiliary hardware; falling short in ubiquity and convenience. We examine the potential of a novel deformable wearable device that embeds interactive technologies into garment buttons, and seek to enhance the form factor of buttons to incorporate deformation and motion as inputs. We surveyed garment buttons in everyday clothing to inform an exploratory study, where we investigated social acceptance and elicited interaction gestures using mockups. Our results indicate people mostly prefer smaller sizes, and regard sleeves as the most comfortable area to operate and look at when seen by others. Based on our findings, we discuss potential context of use, possible applications, and future work.

Author Keywords
Wearables; smart clothing; buttons; ubiquitous computing; deformable user interfaces.

CSS Concepts
• **Human-centered computing~Human computer interaction (HCI)**; *Haptic devices*; User studies.

Purpose	Task
Types of interaction	List actions performed with button mockups at pre-defined locations: chest middle, front pocket, L/R collar, L/R sleeve
Types of application	List applications that are most suitable for deformation- and motion-sensing buttons
Preference of location	Mark locations of buttons and types of interaction anywhere on the shirt template
Display of public information	Mark locations and appearances of buttons anywhere on the shirt template to broadcast information (e.g., mood, steps taken)
Display of personal information	Mark locations and appearances of buttons anywhere on the shirt template to show personal information for oneself

Table 1. Five tasks carried out by every participant pair, focusing on various contexts in which deformation- and motion-sensing buttons and wearable devices are operated.

Figure 2. Deformable button mockups with diameters 1 to 4cm. We provided pins (top) for participants to attach the mockups to their own clothing (or the mannequin).

Introduction

Wearable devices, or simply wearables, have become a pervasive commodity, from simple step counters to more sophisticated smart objects that mediate information between their wearer and other connected digital devices. Many wearables are modeled after familiar wrist-worn accessories, for example, watches and bracelets, as this part of the body is an easily accessible and socially acceptable site of interaction [18, 19]. Others mimic jewelry or accessories, aiming to meet our social, emotional, and aesthetic needs, going beyond functional requirements [8, 10, 13, 15]. Yet, in most cases they are still additional pieces of hardware to the wearer's attire, which might not be ideal for a ubiquitous computing device in terms of portability, and integration with clothing style.

Garment buttons, on the other hand, are an inseparable part of most clothing, and have served purposes beyond just fastening garment pieces, including decoration and displaying social status [17]. We look at augmenting garment buttons with computing capabilities, as opposed to adding extra buttons [e.g., 6, 11], and extend the input vocabulary to include deformation such as bend and squeeze.

To this end, our work contributes to research in wearables by exploring the acceptability and utility of wearables as buttons, with the inclusion of novel sensing capabilities such as deformation and motion to widen the input vocabulary. We are interested in the following research questions: (RQ1) *how do people think about using these buttons in a daily and social context?* and (RQ2) *what kind of applications do people think would be useful with these buttons?*

Interactive Buttons & Social Acceptance

Some of the early works in button-shaped wearables involved exploring their utility and possible applications. Todi & Luyten [22] proposed iButton, an initial design space for integrating interactive elements, such as push-buttons and displays, into outdoor clothing in the form of buttons. The authors mentioned four types of interaction (i.e., secretive, embodied, contextual, and glance), and presented a few prototypes with some example uses (e.g., a four-way button functioning as a d-pad). Hännikäinen et al. [7] implemented a button component that encases wearable technologies while maintaining its appearance and usability. The authors used temperature measurement as an illustrative example by embedding a digital thermometer into a button, and sewing it to the clothing using electrically conductive fibers. In a recent work called SensorSnaps, Dementyev et al. [2] investigated integrating wireless sensor nodes into fabric snap buttons and showed their utility and feasibility, taking one step closer to our envisioned embedded interactive garment buttons.

Besides technical challenges [2, 21] and design considerations [4, 16], social acceptability [23] is also an important factor for the adoption of interactive buttons. Profita et al. [20] explored third-party attitudes towards users' interactions with a wearable controller placed at various body locations (e.g., collarbone, torso, and forearm), and found wrist and forearm received the most positive interaction and placement ratings. Their findings also corroborate Oakley & Park's [18] discussion of the wrist being an appropriate body site for a wearable computing device, who also highlighted "easy to access" as an important consideration in designing wearables. Karrer et al. [9] evaluated the ideal placement of their Pinstripe textile

Figure 3. Participants could attach and experiment with the button mockups on a mannequin or on their own clothes.

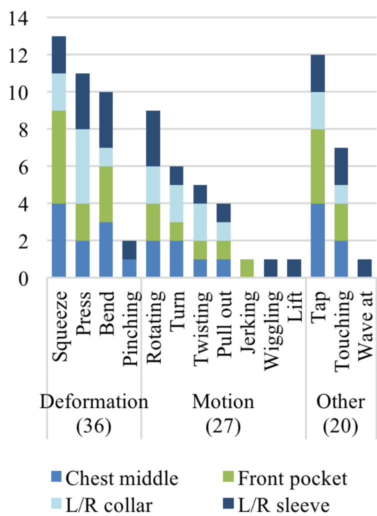

Figure 4. Count of actions listed by participant pairs at pre-defined locations, grouped into three forms based on effect on the button's physical state: Deformation, Motion, and Other.

user interface element and found similar results for appropriate body sites. They further reported that the sternum, and lower parts of the body (e.g., thighs and waist) were the least favoured areas due to lack of social acceptance. Others have looked at the acceptability of having non-wearers touch wearables in public [1], different poses [5], and social comfort [12].

Our work is inspired by prior work and existing products (e.g., Flic [3] & Misfit Flash [14]) showing feasibility and utility of button-shaped wearables, and those that investigated social acceptability. We believe that wearables resembling garment buttons will enjoy greater freedom in the social acceptance of their placement and handling in public, and hence more likely to be adopted for daily use.

Study Exploring Social Acceptance & Utility

We aimed at investigating how interactive buttons' placement and interaction impact each other, and people's preference in terms of size, location, and context. Our work differs from prior work that focused on devices that are added to garments, and instead focuses on the gestures on those that replace garment buttons. This focus allowed us to directly use common buttons locations as potential interaction areas, instead of solely investigating preferred locations (cf. [9, 20]).

Study Design & Procedures

We recruited and paired our participants in an exploratory, co-discovery design session to identify the best locations and potential uses of deformable interactive buttons. After acquiring their consent to participate in the study, we started with individual demographic questionnaires to understand their experience, preferences, and concerns with wearables.

We then asked our pairs to explore together possible gestures, locations, and uses using our deformable button mockups (made as flat round buttons using Alumilite 70A flexible silicone with 1, 2, 3 and 4cm diameters and 2.5mm thickness, see Figure 2). We provided each pair one worksheet to direct the exploration through five tasks with buttons on shirts (Table 1). Our decision on only using buttons from shirts (upper body) was based on the findings from Karrer et al. [9] that the lower body was a less favoured place for on-body interaction.

The first three tasks were associated with the buttons as inputs, whereas the last two tasks were associated with the buttons as displays, so as to let participants explore/comment on the output features as a possibility. In the first task, we used four of the most common locations of buttons on shirts as pre-defined locations: chest middle, front pocket, left/right collar and left/right sleeve. Besides their commonality in everyday clothing, the chest and pocket placements allow bi-manual reachability, while the collar and sleeve placements align our study with prior work on acceptability [9, 20]. For the last three tasks where we asked the pairs to mark locations of buttons, we let them freely choose the locations of buttons and mark them on provided drawings of the front and back of a shirt template (similar to those shown in Figure 5).

During the session, we encouraged our pairs to try out the mockups and asked them to verbally discuss where they would place a button and interact with it. We recorded their discussions using a camcorder and asked them to elaborate their designs by filling out the worksheet. We also took notes on-site to capture important observations.

Domain	Application/task (number of pairs)
Well-being	heart rate monitor (3), medical (1), body monitoring (1), pain sensor (1)
Sports	sport/measure movements (3)
Communication	cell phone (4), send messages (1)
Control	camera (4), microphone (3), bluetooth (2), home appliances (2), head piece (2), volume (2), smartwatch (1), lighting (1), media (1), TV remote (1), temperature (1)
Other	disguise/undercover (2), surveillance (1), instant assistance/activation (1), assistance for blind people (1), calculation (1), indication for shirt on (1), education (1)

Table 2. Summary of applications listed by participant pairs (one answer is removed for inappropriateness).

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To facilitate experimentation with the buttons, we encouraged our participants to attach the buttons using a pin onto either a provided male mannequin or their own clothing (Figure 3). We included a mannequin to allow participants to see and manipulate the deformable buttons as 3rd-person, and to standardize their answers in cases where they did not wear a long-sleeve shirt or did not want to attach the buttons to their clothes. We believe that through experiencing both 1st- and 3rd-person views and working as a team would enable a more comprehensive perspective and view of the surroundings, and thus greater creativity.

On completion, we asked each participant to complete an exit questionnaire (a mix of 7-point Likert-scale and open-end questions) to detail their preferences regarding location and size of deformable buttons as wearables. The study session took approximately 60 minutes. Each participant was compensated $15 for their time. The study protocol was approved by Carleton University Research Ethics Board (#107016).

Results

We recruited 20 participants from our local community (13M, 7F, average age 26.7), yielding 10 groups (8 groups knew each other prior to the study; 3 mixed-gender). We analyzed our data both qualitatively and quantitatively, and report our findings following the tasks structure in Table 1. We kept the tasks in separate sections because our smaller sample size did not provide enough power to identify interactions.

Three participants had some experience with deformable devices (those that can measure degree of deformation) before; 13 had used wearable devices, including RFID bracelets, wrist-worn fitness trackers, on-body action cameras, and wireless headphones. When asked about their concerns towards wearables, 12 expressed concerns including chance of losing the device, discomfort due to straps or weight, difficulty in operating, safety of emitted signals, and privacy.

Types of Interaction in Pre-Defined Locations

Figure 4 shows the types of input and interactions generated by our participant pairs in pre-defined locations. The exploratory nature of the study meant that participants used their own vocabulary, rather than from any standardized terminology. Thus, some actions were almost indistinguishable from each other, for example, participants described the rotating action in a very similar way as the turn action. We kept the words used by our participant pairs to present their answers more faithfully and grouped their actions into three forms (deformation, motion, and other) based on how the triggering action affected the button's physical state (e.g., a squeeze compresses the button from two opposing edges, causing a deformation).

- **Deformation** — compressing the button at its edges (squeeze/pinch, Figure 1a-c) or sides (press, Figure 1d-f), or folding it into an angle near an edge (fold).
- **Motion** — moving the button like a dial (rotation/turn), tilting or shaking it (twisting/jerking/wiggling), or elevating it from the shirt (pull out/lift).
- **Other** — contacting the surface of the button (tap/touch) or gesturing near it (wave at).

We did not observe any discernable difference in gender in listing number or types of actions around the chest and breast areas (all participant pairs listed actions around those areas). Nevertheless, during the

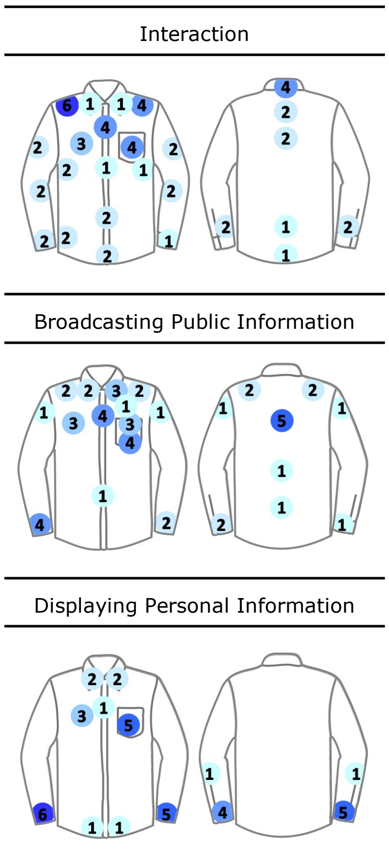

Figure 5. Heat maps of preference in location for interacting (top), broadcasting public information (middle), or displaying personal information (bottom) with a wearable device. Each value indicates number of pairs marking that location.

study session, both genders verbally expressed concerns with this body region. For example, when attaching the button to the chest middle location, a female participant said, "*as a woman I would never put a button in the middle of my chest*" (G6); and when attaching the button to the front pocket location, a male participant (from another group) said, "*I would just generally avoid the whole nipple area.*" (G10)

Types of Application

Table 2 summarizes 25 kinds of applications our participant pairs deemed suitable for the buttons, covering various domains (e.g., sports, communication) and tasks (e.g., monitoring, device control).

While many applications are related to inputs that control other devices (e.g., music players and mobile phones), many pairs suggested inputs that would augment the wearer's senses. These inputs included cameras, and microphones (that could "*enhance your hearing behind you*"). On the other hand, though unprompted, some also listed applications related to output, for instance, showing distinct colours to indicate health status, and sending vibrations as notification.

Preference of Location

Our survey on garment button usage has revealed that they can move beyond standard fastening locations, thus later in our study we opened this aspect up and probed participants' location preference anywhere on the shirt. Many participant pairs marked the shoulders and the back of the collar as their preferred locations, in addition to the four initial locations (Figure 5, top). These locations, while not easy (or even impossible) for the wearer to see, can be reached easily, suggesting potential uses in eyes-free interaction.

While not integrated in the button mockups, and not the primary focus of our study, we were also interested in participants' ideas on the interactive buttons having some form of display to potentially increase their utility. Thus, in the next two tasks, we expanded our query to general wearable devices that have display functionality, focusing on how they might display information for the public or for wearers themselves. Because of the low-fidelity nature of the mockups, participants envisioned a variety of display formats including colours, LED screens for notifications and messages and, most creatively, holograms.

Display of Public and Personal Information

When asked to consider a scenario in which the wearable device can display any information the wearer wants to broadcast, such as mood, or steps taken, participant pairs indicated 23 possible locations (Figure 5, middle). The upper part of the shirt (shoulders, chest, and back) received the highest number of markings, and was supported by comments stating that these areas were at "*eye level*" and allowed people to be "*able to see it more*". Interestingly, many pairs (five) marked the back of the shirt as a potential area for displaying information for others to see.

On the other hand, when asked to consider a scenario in which the wearable device displays personal information that one might not want others to see, such as health information, participants narrowed down the locations to only 13 (Figure 5, bottom). As expected, all the indicated locations are viewable by the wearer. In addition, some pairs explicitly commented that the device must be "*inside*" or "*underneath*" at those locations, "*look as a part of accessories* [sic]" (G4), or should "*only turn on when lifted*" (G10).

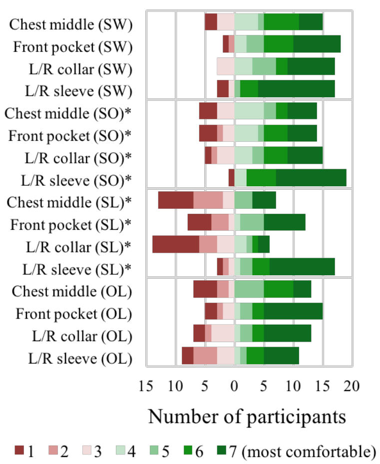

Figure 6. Comfort level in wearable locations (chest middle, front pocket, L/R collar, and L/R sleeve, grouped by activity: SW-seen to be wearing, SO-seen to be operating, SL-seen to be looking, OL-have others looking. (* indicates significant difference between locations)

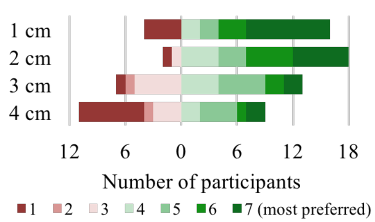

Figure 7. Preference in button sizes. We found a statistically significance in preferring smaller sizes.

Comfort Levels in Pre-Defined Locations

Figure 6 shows the results regarding each participants' comfort level for each of the four pre-defined locations. We ran a separate Kruskal-Wallis test on wearable device locations for each of the four activity types (SW-seen to be wearing, SO-seen to be operating, SL-seen to be looking, and OL-have others looking), and found significant differences for SO ($\chi2(3)=9.471$, $p<0.05$) and SL ($\chi2(3)=15.864$, $p<0.05$), with L/R sleeve having the highest median (7) on the Likert-scale (1-least comfortable, 7-most comfortable) for both cases.

Preference on Sizes

Regarding button sizes, a Kruskal-Wallis test revealed a significant difference in preference ($\chi2(3)=12.409$, $p<0.05$), with sizes of 1 and 2cm having the highest median (6) on the Likert-scale (1-least preferred, 7-most preferred). The 2cm size has the highest skew towards being the most preferred size, whereas the 4cm size has the opposite (Figure 7).

Comments from participants also revealed that the higher preference on smaller sizes was mostly due to ease of concealment and discreet interaction they afford. Some expressed concerns that smaller sizes would be difficult to activate via deformation. As for larger sizes, their perceived ease of operation and potential to display information were outweighed by the concern that they are too big in most locations.

Some participants did, however, point out that their preference was related to the button's location. For example, the 1cm button was suitable in most locations because it would not stand out, but the 3-4cm buttons were only suitable on the chest or wrist due to their resemblance in sizes with broches or watches.

Discussion

Overall our participants were excited to use deformation and motion to devise a wider range of input modalities on buttons beyond simple tap/touch.

Regarding RQ1, they found the idea of buttons as wearables interesting and identified possible utility in many application areas. Our results also pointed to the need of reachability [23] for input, as evidenced by the frequent selections at the front side of the provided shirt template. For social acceptability, as an input device, there were concerns on operating the buttons near the chest area, corroborating similar studies [9, 20]. As an output device, however, there was less concern. We believe this was due to the common use of display chest pieces (e.g., broches, name tags).

As for RQ2, besides associating functionality with the physical location of the wearer, there was a desire to have the buttons' purpose associated to specific body locations. For example, buttons with health-related purposes being closer to the heart, while buttons with smartwatch-like purposes being closer to the wrist. Also, for buttons that show personal information, our results showed the need for explicit activation.

Conclusion & Future Work

Our exploratory study on interactive garment buttons has revealed concerns and preferences in their positions and sizes, as well as comfort levels of wearing and using them, thus provides insights in designing wearables that are socially acceptable and useful. We hope to extend this work by developing a functional prototype for more in-depth user studies and examining the relationship between preferences and location/context in a greater detail.

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