Smart Handbag as a Wearable Public Display - Exploring Concepts and User Perceptions

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ABSTRACT
Wearable computing has so far focused mostly on systems employing small displays, or no displays at all. In contrast, we explore the possibilities of a smart handbag that functions as a wearable public display, focusing on user perceptions of different design concepts. Our prototype smart handbag explores functionalities such as: changing the bag's appearance to match clothing, displaying textual information, creating a see-though perception enabling items inside the bag to be seen, and enabling interaction with items inside the bag. We report on the findings from a wizard-of-Oz based user study, which included the users walking in public with the smart handbag. The smart handbag concepts were positively received, especially from the utilitarian point of view, but issues related to privacy were raised. Key insights are e.g. the creation of a 'handbag mode' for smartphones placed within the smart handbag and the importance of evaluating such wearables in real-world contexts.

CCS Concepts
• Human-centered computing - Human Computer interaction

Keywords
Handbag; Wearable displays; Wearable computing; Design; User Studies; Wizard of Oz

1. INTRODUCTION
Wearable computers have become more and more common especially in the form of smart watches, wellness bracelets and armbands, which are today available as off-the-shelf devices in large numbers. These devices typically employ sensors and connectivity features, but are limited in adopting displays - the device-integrated screen elements are typically very small or non-existent, and the interaction may rely e.g. on a graphical user interface on a smart phone application. Wearable displays have so far received much lesser attention from both research and industry.

Whereas public displays are invading the urban landscape in many different forms [24], wearable public displays are still scarcely seen. In our research, we are interested in exploring the user perceptions of a public display integrated to a personal item, which the user carries around in their everyday life context. More specifically, we investigate an underexplored form factor in the area of wearable, or portable, computing – the handbag (Figure 1).

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Figure 1: A test participant walking with the public display handbag. Inset: The handbag display shows the content items contained within the handbag.

Handbags as physical items can be positioned on the periphery of wearable computing. They are accessories, which are strictly speaking not wearables, however they are often considered as part of a clothing outfit and coordinated with clothes. Handbags are interesting objects as they combine the functionality of carrying important items, with a fashion and appearance conscious form factor. They are at the same time very visible, but still personal and intimate objects. The importance of handbags, in particular to women, is summarized by [6], highlighting that handbags are both items of fashion, and indicators of public identity and status. Additionally handbags are also intensely private. The privacy of objects held within the handbag has been studied by [28], who reported that objects defined as more personally meaningful were also considered more private.

These underlying socio-cultural factor and functional design give an interesting background for a design exploration that augments the traditional design of a handbag. The physical size of handbags makes them an appealing platform for a small public display. In our research, we sought to create a 'smart handbag' with the aim of exploring different design directions that integrate a public display to a handbag, and to chart user perceptions on different concepts. As a contribution our work provides,

- several novel concepts on integrating a public display to a handbag, and

- to the best of our knowledge, a first user study focusing on user perceptions on the concepts.

2. RELATED WORK

2.1 Wearable Displays

Whereas wearable public displays represent still a minority in the design space of wearable computing, earlier design and study examples in the area exist. Wearable public displays integrated into clothing have been demonstrated and tested with selected concepts e.g. [14][18]. Research so far has explored wearable public displays integrated into runners' shirts at sporting events [27], and Puikkonen et al. [29] tested a Tic-Tac-Toe T-shirt in-the-wild, integrating the game on the front-side of a t-shirt by using single coloured LEDs. Focusing on more functional aspects, seven different locations of wearable display have been explored by [19], who quantified the reaction times of users to notifications appearing on the displays.

Considering social aspects of wearable public displays [32] explored the use of a semi-public ambient wristband display device. Here, highlighting that friends or strangers may interpret the meaning of the displayed ambient information differently. In their CueSense project, where information from a users' social media accounts is shown on a display carried around the neck, [22] report concerns about the privacy of information shown. Puikkonen et al. also report on social acceptability concerns related to staring and touching clothing-integrated wearable displays [29].

2.2 See-through User Interfaces

When exploring the role of handbags as a container, the possibility to see the content of the bag without opening it is an interesting direction. Thus, see-through design concepts are relevant prior art for our handbag design exploration. In [17], when considering interaction with see-through technologies, defined as technologies that *utilize transparent materials for displays or create the illusion of transparency*. See-through interfaces have been studied in contexts other than wearables, and for example, concepts that view objects inside a fridge [5], through a wall [10], and inside a box [30] have been studied. Similarly, [11] explore a see through public display in a supermarket. Here, both the visual information as well as the perception, even based on illusion, of transparency contributes to the holistic user experience. Utilizing transparency for interaction has been demonstrated in several computing concepts. For instance, HoloDesk [20] shows the user's hands below the screen, and the small handheld nanoTouch prototype presented in [3] shows the user's fingers on the back of the device by simulating transparency.

Dynamically changing the level of transparency is an interesting research direction in see-through user interfaces. This aspect has been considered especially in designs where the transparent UI creates a space that connects or reveals people. Lindlbauer et al. [26] have presented a dual-sided see-through display, where the areas of transparency can be controlled. In [16] a virtual see-through window between two spaces is presented. Here, the transparency gradually fades as the gesture controlled window 'freezes' and is covered with a layer of ice. Transparency using an X-ray visual style has been illustrated in playful applications such as [33], which imitate showing the human skeleton when a mobile phone is placed on top of the hand.

2.3 Interactive Handbags and Digital Jewelry

Prior art specifically considering interactive or display handbags is rather limited. In their concept for an interactive handbag [4] focus only on the use case of handling an incoming call to a mobile phone contained within the handbag. Here, the handbag indicates the incoming call using led lighting and tangible feedback, whilst a squeezable ball hanging from the bag enables call rejection without taking the phone from the bag. LadyBag [25] used RFID tagged items and a reader within the bag to provide a visual notification, via leds on the bags surface, if items are missing from the bag. The use of a handbag as an environmental monitoring device for city commuters is proposed by [13]. Here, the bag includes a display, which e.g. changes color if a high degree of pollution is detected. In their Gemini handbag concept, [8] explore social aspects of using a handbag as a social communication device. In Gemini, the handbag has a 12x20 led matrix display, which the user can customize using a smartphone app. Here one Gemini user commented that using the bag was, "like… tweeting to the public in (the) real world". The mirror bag, by Cute Circuit productizes a Gemini type concept [12].

Taking a wider view of the fashion accessory space, findings from the domain of digital jewelry may also be extendable to that of the handbag. In this respect [15] reports that general high quality aesthetic appearance is more important than customizability. As pointed out by [23] there is an overlap between the spaces occupied by wearable devices and fashion items, for example a wristband device occupying the same physical space as a shirt cuff, and a mobile phone being located in a handbag.

Users develop strategies to handle Mobile Essentials (MEs) such as keys, cash and phone [9]. The handbag is noted as one strategy that enables the containment and handing of mobile essential items. Thus, our approach of utilising technology solutions in the handbag space to further improve the handling the mobile essentials is a logical progression.

3. INTERACTIVE HANDBAG CONCEPT

3.1 General Concept

Inspired by the prior art in the area, we aimed to study 3 different aspects of the interactive handbag domain:

- **Outfit and context matching.** Here we target to use the dynamic visual output possibilities of the smart handbag to match with other items being worn. For example matching the handbag to the color of the wearer's shoes or jacket. Additionally, we were interested to experiment with matching the handbag to other surfaces on which it is placed i.e. a chameleon effect.
- **See-though interface.** To aid the user in identifying which objects are contained within the bag, we explored the creation of a virtual see-through window to the contents of the bag. Additionally we explored the possibility to interact with items within the bag without needing to remove them from the bag. Here, we were also interested to find users' responses to different visualization styles, varying the way the content items were shown on the display.
- **Information display.** The smart handbag provides possibilities for its wearer to interact socially, in public in a more ad hoc way than is possible with traditional printed designs. For example the user may select a personal motto or statement to display on their handbag.

Considering the see-through interface and the public display, we were particularly interested to explore privacy aspect raised by the concept.

3.2 Handbag and Content Design

3.2.1 Handbag Design

As a proof of concept, we chose to use a commercially available Android tablet (Samsung Galaxy Tab 10.1") as the core element in our smart handbag. Two existing handbags were selected and modified to include a tablet as an integrated display, see Figure 4. The handbags were chosen as they were simple in design, and hence would not distract from the added functionality. A cut-out window was made in the handbag's outer skin and the tablet was fixed in place using a frame of wire and thick cardboard.

For the outfit matching, we selected sets of clothes with a variety of textures and colors to demonstrate the range of effects that could be achieved by changing the handbag's display to match the garments (Figure 2, Left). As a core function of handbags is to carry personal items, we selected typical items for the content of the handbag. The items selected were, a smartphone, a hairbrush, a bottle of perfume, nail polish, a condom and a tampon (Figure 3). Six different visualization styles were created, that showed the content items in various degrees of detail (see results section, Figure 8). In addition we prepared a set of personal statements or motto texts that users could choose to show on the handbag's display (Figure 2, Right).

Figure 2: Left: Clothes and accessories used in the user test. Right: An example of one of the statements that the test participants could select to be shown on the handbag.

Figure 3: The items that could be placed in and removed from the handbag during the user test.

3.3 Technical Implementation

As our focus was fully on user experience aspects, we chose to use a Wizard-of-Oz [31] approach to the study. This approach enabled us to more accurately present a close to product level experience to test participants without being restricted by the limitations of a prototype technical implementation. Thus our set-up included a remote control device operated by a hidden operator, which was used to select the image shown on the handbag's display, see Figure 4. The remote control device was a Samsung S5 smartphone.

We chose to base our approach on RFID tagging technology. Thus, objects that the bag interacts with, either to control its surface appearance or to sense them being inside the bag, should have an RFID tag attached to them. To create the illusion of reality in our simulated approach, we fitted fake RFID tags to all the objects to be sensed by the handbag. Additionally, we created 2 fake tag readers and fitted them to the inside and outside of the handbag, illustrated in Figure 5.

Figure 4: The remote control device (left) and an interactive handbag showing content inside it (right).

Figure 5: The fake tag reader on the handbag and fake RFID tag attached to a scarf. Here, the bag display matches the pattern of the scarf.

To produce our Wizard-of-Oz based experience, we implemented a test application that allowed an operator to control what was shown on the handbag display. The test application was implemented in Android and installed on both the handbag tablets and the remote control smartphone. The test application utilized a Bluetooth link between the two devices. When an image was selected on the remote control app, it was then shown full screen on the handbag situated tablet. The application included two modes:

- **Full view mode.** In this mode, one of 9 images could be selected on the remote control device and was shown full screen on the handbag tablet. Additionally, a fully black screen could be selected.
- **Overlay mode**. This mode included 6 images, multiple of which could be selected simultaneously. In this case the source images used included transparency, such that the images were overlaid on the handbag display. Clicking each image on the controller toggled its visibility on the handbag. This mode was used in the cases where objects could be placed in, and removed from the handbag.

Additionally, for the mobile phone and perfume images, textual popups were added activated when the images on the screen were tapped.

4. USER STUDY

4.1 User Study Process

To explore user perceptions and anticipated experiences of the interactive handbag concept we conducted a Wizard-of-Oz study. The test was conducted by a moderator and a cameraman videoed the test participant's interactions. An operator sitting in an adjacent room viewed the live video feed from the camera on a monitor, and used the remote control to control the handbag display accordingly. This setup was chosen such that participants would be unaware of the operator and believe the handbag to be autonomously functional. As an introduction to the test, the functionality of the handbag was described to participants as being based on RFID tags placed on items and an RFID reader inside the handbag. The location of the fake tags and reader was shown to the participants to support the story, and guide the interactions during the test.

The main data collection method was a semi-structured interview with a laddering technique, which was complemented by an AttrakDiff 7-point scale [2] with ten statements related to the overall concept idea.

At the beginning of the evaluation, participants completed a background questionnaire giving their demographic information and prior experience with handbags and wearable technology. The purpose of the study was then briefly explained to the participants. The main part of the study consisted of seven tasks, which were completed by participants:

1) Match the handbag with clothing
2) Match the handbag with context
3) Place items in and remove items from the handbag. Tap the images of the phone and the perfume bottle on the display to show info popups
4) Walk in a public context while the handbag display shows items inside the handbag
5) Select a preferred visual style to display the content of the handbag
6) Selected a 'motto' image from a predefined set and walk in a public context with it displayed on the handbag

During and after completing the tasks, participants were asked additional questions on the concept ideas. The data analysis followed general qualitative coding principles [7]. The analysis was started from observations notes, which were first grouped and then emerging themes were marked with different colors. Here, the focus was on gaining understanding of the participants' needs and wishes for the handbag design, thus both comments that were expressed by many subjects and by one subject were held as equally important.

For the walking parts of the test, a route of approximately 50 meters in length around an open café area was defined. During the test times there were between 20 and 100 people in the café, depending on the time of day. Walking the route took a few minutes to complete, depending on walking speed.

4.2 Test Participants

Test participants were recruited from the university of Lapland campus at the time of test. We aimed to recruit women with a range of different ages, as women are the typical users of handbags and thus understand the issues faced when using one. Altogether 20 participants took part in the test. All were women with ages between 22 and 63 years (M = 33 years). All participants owned a touchscreen phone and more than one handbag. Most of the participants had used some sort of wearable electronics, such as heart rate monitors, GPS trackers and pedometers. Three of the participants owned 2-3 handbags, 7 participants had 4-5, 7 participants had 5-10 and 3 owned more than ten handbags.

The total test session time per participant varied from 40 minutes to 60 minutes. Participants were rewarded with candy for participating in the user study.

5. RESULTS

5.1 Current Handbag Usage

Participants commented that the appearance and color of the bag were important selection criteria, as well as the target use context for the handbag. Some participants mentioned the handbag size as a major factor when selecting handbags for certain situations, e.g. a large bag for going to lectures and a small one for parties. Comments related to the cost and material of the bag were also considered important by some when selecting a new handbag.

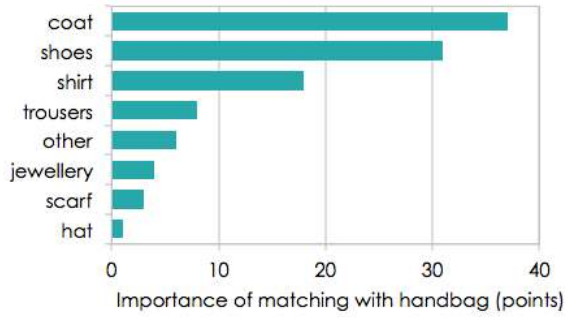

Figure 6: Importance of matching handbag with other items (1st choice: 3 points, 2nd choice: 2 points, 3rd choice: 1 point)

Participants' reported importance of matching handbags with other clothing items is shown in Figure 6. A large amount of the participants found it very important to match their handbag with their coat or shoes, while only one user wanted to match their bag with their hat. The majority of participants commented that they had one 'every day handbag' which they use daily, while they use their other 'party handbags' only once per month or less.

5.2 Matching the Handbag to Clothing and Surroundings

5.2.1 Matching Clothing

Initially participants did not expect that the smart handbag prototype could dynamically change to match clothing. Thus nearly all participants began by describing how they would physically modify the handbag to make it match the sample clothing outfits, for example by changing the strap or adding elements, such as colored ribbons to make the bag coordinate with the clothes. After participants had successfully set the first material to the handbag, by pointing the handbags' sensor to the tag in the shoe, it was clear how to change the bag's outlook to match the other example outfits as well. A majority or participants (15/20) described the concept as 'fun'. It was also commented to be 'exciting', 'interesting', and 'useful'. Matching the bag with clothes this easily was perceived to work well especially for party outfits, as it is difficult and expensive to find matching bags for them. As one subject stated: *"Wow, I could finalize my outfit and make other women jealous…It is frustrating to purchase a bag for one event only"* (#2). Additionally, it was perceived to be beneficial as it could decrease the amount of handbags owned, as the same bag could be used in different events and situations.

To improve the design of the bag, participants suggested that the size and capacity of the bag should be changeable according to the use context. Also durability, weight, feeling, quality, and flexibility of the material were listed as important things related to the handbag design. A few of the participants saw this feature as a gimmick (#9, #19), whilst others the suggested the handbag could be used for self-expression. For example, pictures of favourite cartoon or anime characters (#12), other graphical patterns (#13, #17), or animated/video content could be displayed on the handbag - *"Could I have it with aquarium, universe, or disco ball videos displayed on it?"* (#9). Related to the prototype itself, participants commented e.g. the screen being was too fragile (#18), inability to mimic the material feeling or texture well (#9, #12), and need for it to be waterproof (#6). Similarly, some recommended that the material itself should function as the display (#16) and that the whole surface area of the bag should change color (#8).

5.2.2 Matching Surroundings

Matching the handbag with its surroundings to reduce its visibility was considered a handy, interesting and useful feature. On the other hand people were not comfortable leaving their bags in public places even when it was camouflaged with its surroundings. However, the use case presented as an example, leaving the handbag exposed in a locked car, was perceived to be a suitable use context for this kind of feature. Participants liked that the handbag could be easily camouflaged to the floor of the car. Other suitable use contexts suggested were trains, airports, and cafeterias: *"In a train it would be useful when you have to leave from your place to go to use the toilets, you could use this chameleon feature on your suitcase"* (#8), and *"In international business trips, your luggage identifies you as a walking cash machine, making you a target for pickpockets… thus, this kind of feature would be ok and could prevent robberies"* (#3).

5.3 Visualizing Items inside the Handbag

5.3.1 General Perceptions

The idea that objects appear on the display when they are placed in the bag was liked by more than half of the participants (12/20). They perceived this function as fun, but even more as handy, especially with larger bags, as items can easily get lost inside the bag quite easily: *"Women's handbags are like the Bermuda triangle, all the content items mystically disappear."* (#19). Participants noted that this would be particularly helpful in the morning rush, as it aids in checking that all the necessary items are in the bag. To ease locating items inside the handbag when searching for an item in on-the-go situations, it was wished that the items could be seen in their realistic positions inside the bag. This would remove the need to rummage around in the handbag and having to remove all the items from the bag when searching for one item.

On the other hand participants perceived that when their own items would be in the bag, the outlook might be less aesthetic. It was commented that handbags contain also unwanted items that were not attractive, such as receipts and small items of trash. An example comment on this was stated: *"It could look quite chaotic, as when you pack in a hurry there is all kinds of stuff in the bag, such as receipts and other small papers, and you rarely clean those items out from the bag."* (#20).

Displaying items perceived as more personal, such as condoms and tampons was not liked, and was perceived as embarrassing. Thus, it was suggested that private things could be *"covered with overlay images"* (#9), or the items could be presented in a more *"symbolic manner"* (#1), or even as a textual *"checklist"* (#2, #10). Also a few participants voiced concerns of lost privacy and the danger of being robbed if items are visible on the display in public contexts. It was also suggested that the screen part of the bag could be located under the opening cover flap on the handbag, to prevent others seeing the content.

5.3.2 Interacting with Items inside the Handbag

Participants found the feature that the mobile phone could be used via the handbag as handy and good. Especially in situations when mobile phone usage would be difficult and not safe. Whilst in on-the-go situations, it would be easier to check if messages have arrived to the phone via the bag, as it would remove the need to rummage in the bag. As one participant stated: "*A good feature, you can see what happens inside of the bag and you don't have to search for items"* (#6). Another factor was security, as subjects stated that it would be more secure to check mobile phone messages and other content via the bag for example when travelling and being in situations where there might be pickpockets.

Advertisements that were displayed when user taps an item on the bag were not much liked. Half of the participants were against advertisement on the bag, and commented for instance, *"A handbag is too personal an item and it feels like someone is breaking in to my house, this is sacrilege!"* (#1). On the other hand, some participants stated that if they can control the advertisements shown on the bag, then it is not that bad an idea. For example, it was mentioned that discount prices in nearby grocery store and other user related advertisements would be ok. Here, similarities may be found with prior art related to the use of advertisements on the surface of cars [1].

Participants also gave proposals to improve the overall design of the handbag. It was commented that the whole exterior surface of the bag should present the content. Also there should be many pockets instead of a one, then a graphical marker should be used to indicate which pocket an item is in. Also different kinds of visual popups and notifications were suggested, such as library book return dates, amount of money in wallet, balance of bank account, time to take medicine, danger of breakage of an item, end of lunch break, and calendar alerts: *"It could notify about events marked in the calendar that are connected to the things inside of the bag for example a hairbrush could indicate a hairdressers appointment"* (#6).

Figure 7: The handbag's display showing the pop ups.

5.3.3 See-Through Handbag in Public

In general, most of the participants did not like walking in the public context when personal items were displayed on the bag, and 12/20 described it as an unpleasant experience. Participants

were observed whilst undertaking the task, and it was noted that they were observing other people's reactions to the handbag. After the walk was completed, half (10/20) commented that people did not pay attention to the bag at all. Still, the participants did not like the idea and felt awkward and ashamed when walking in public – "*Walk of shame"* as stated by participant #9.

5.3.4 Alternative Visualization Styles

The participants' preferences for visualization style are shown in Figure 8. Generally participants preferred the alternatives that presented the content more abstractly, as they did not want other people to recognize the items that they were carrying in their handbag. Thus, options C and D were most preferred. Based on first place votes, the best option was visualization C (Figure 8, C). It was perceived as presenting the content in the simplest and most unnoticeable manner. The majority of participants' comments focused on the public presentation of the content, such as *"Even though recognizability of the objects will suffer, I will recognize them"* (#6) and *"I will know what there is, but others will not"* (#2).

The second best option based on first place votes was visualization D (Figure 8, D). It was selected for the similar reasons as option C, that it did not reveal the handbag's content too noticeable a manner and it was simple, as commented by one participant: *"It is clearer (than C), you can tell if it (an item) is a box of mints or a condom"* (#12). But the differences with this option were the use of colors and the graphical style, which was perceived to look nice, funny and pretty. The third best option was visualization B (Figure 8, B). It was selected because it was perceived to be a graphical and pattern like visualization. However, participants noted that, if the content of the handbag would be viewable only by its owner, then the photographic presentation (Figure 8, E) would be preferred, as it makes it easy to recognize the content items. Also colors were liked. The most disliked options were those that used textual descriptions of objects (Figure 8, F). Participants explained that it reduces the glanceability of the handbag display, as the texts need to be read. It was also perceived that text is the least descriptive manner of presenting the content. For example one subject stated: *"It does not tell enough, for example the color of the* nail *polish"* (#12).

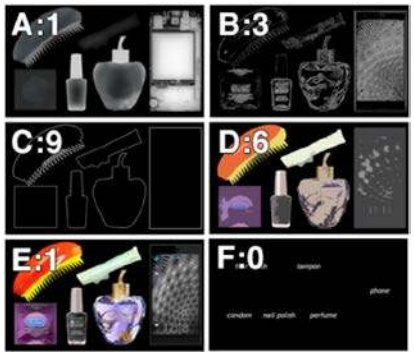

Figure 8: Preferred visualization styles. The number indicates the number of participants that selected each style as their preferred style.

5.4 Using the Handbag for Self-Expression

This task used the second, smaller handbag prototype. During this task participants were less embarrassed and self-conscious with the handbag than in the previous content showing case. Some were even proud of the message they could display to others around them. This was not only because the user had more control over messages or images on the screen, but also because the second handbag was physically smaller and less noticeable, even though the display size was the same as the larger bag.

Participants commented that the 'Busy!' message was useful, provocative and even rude. Commenting e.g. that this could work in big, crowded places like in bars or other public spaces, where you're in a hurry. The 'Save the Arctic!' was also noted as provocative, but also useful in certain situations like conventions, parades, protests and events with large crowds. Participants felt that the handbag would initiate conversations in favour and against the topic displayed on the handbag.

Participants proposed ideas such as displaying personal messages, how the user was feeling in that moment, or photographs of loved ones. This would give the handbag new meaning and situations where it could be used. Displaying reminder notes was considered useful and discreet. Compared to a physical note, the handbag displayed note would never get lost and e.g. could be used in a supermarket shopping cart by placing the handbag in the right place in the cart. In general participants wanted to personalise what was shown on the handbag. Many would have chosen a photograph they had taken themselves, i.e. a photograph of family, kids or pets. Other ideas were seasonal greetings, themed images, awareness day or content related to a convention or conference the user is currently attending. With this the user could meet new people who share their interests. On the other hand, some felt that the handbag would give out more information than they would have intended.

5.5 Overall Evaluation of the Concept

Participants' subjective rating of the overall smart handbag concept across ten word-pair categories is shown in Figure 9. It can be seen that participants scored the concept highly positively in forward-looking aspects (interesting, innovative, creative and novel). However the concept was rated somewhat neutrally in areas related to its practical usage (challenging, unpredictable, practical, complex).

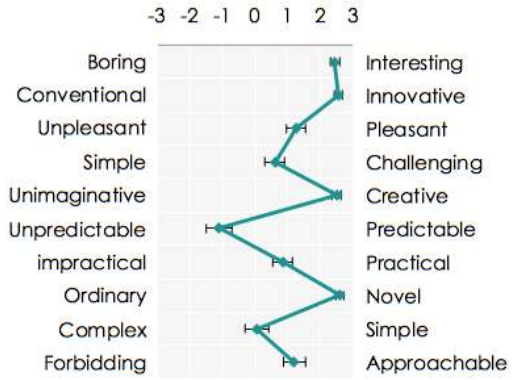

Figure 9: Antonym word pair evaluation of the overall concept. Error bars show standard error of mean.

6. DISCUSSION

6.1.1 The Smart Handbag Concept

Overall the smart handbag concept captivated the interest of the majority of our test participants. This was apparent not only in the positive adjectives used to describe the presented concepts, but also in the wealth of ideas that the participants provided for iterating the concepts. This high level of interest also highlights the special status of the handbag for many users, beyond its practical role of a functional accessory to simply carry personal items.

In particular the possibility to dynamically customize the handbag to match the wearer's current outfit was considered interesting, driven by both fashion and economic considerations. The general wish in this area was for a wider scope of customization, beyond that provided by an embedded display. The participants' desire to change the whole surface of the bag, not only visually but also in terms of its texture, informs to the future directions of work in this area. The idea of making the bag 'invisible' by changing its appearance to match that of its surroundings raised rather less interest. Here, the main issues noted related to personal security and the possibility to hide the handbag to avoid attracting the attention of thieves.

Compared to related work that has largely addressed novelty cases e.g. [27][28], our concept creates a wearable display that has potential to be an integral part of its user's daily life. Comparing our findings with that of [8], who utilized a lower resolution display, we found that our test participants were rather more focused on privacy and would be less willing to carry such a display in public. Here, cultural issues may also play a strong role.

Looking at the participants' subjective ratings on antonym pairs, Figure 9, we can conclude that the general concept is perceived desirable, but it still requires some iteration in terms of its detailed functionality and interaction. The strong feeling of unpredictability is somewhat difficult to explain. Here, we speculate that this may relate to the participants concerns about the reactions of others to the concept, when it is used in public spaces.

6.1.2 See-Through Handbag

The possibility to easily see items inside the bag was considered to address a current pain point by many participants. However, the visualization style was found to be a critical issue, both in terms of its effect on the aesthetic appearance of the handbag and in its invasion of the users' privacy. Here our work may be compared against the more focused functional approach in [25], which indicates only when pre-configured items are missing from the handbag, and makes no aim towards forming part of the overall aesthetic design of the handbag.

Similarly to [22] our findings related to privacy indicate that users were particularly conscious of being observed when walking in public with embarrassing objects visible inside the handbag. In this respect our choice of content for our test was purposefully controversial (i.e. a condom and tampon), aiming to extract the broadest range of insights from our test group. To address this issue, approaches such as those employed by [16][26] to control the translucency of the see-through effect would be interesting to apply to our handbag context.

6.1.3 Smartphone 'Handbag Mode'

The possibility to interact with items inside the handbag without having to remove them was felt to be both efficient and reduce the risk of theft of removed items. Although we presented this concept largely in the context of simple interaction with a mobile phone, test participants proposed extending this scope, particularly towards issues related to calendar, notifications and schedule management. Here, it may be interesting to draw parallels with smartphone usage in the car context, where a 'car mode' provides a context appropriate view to the smartphones functionality, viewed on a display embedded in the car's dashboard. Similarly, we envision the potential for the creation of a 'handbag mode' for smartphones, where the handbag surface provides an optimized interface to a smartphone and other devices contained within it.

6.1.4 Methodological Notes

Overall the Wizard-of-Oz approach used in the prototype worked extremely well. All participants fully believed that the handbag was interactive and autonomously responded to their interactions. Even following the completion of the test, participants were not informed that the functionality was moderated by a human operator, to avoid the possibility of the information spreading to future test participants.

A key finding was that, when developing wearable devices, they should be evaluated in real-world contexts, as issues such as privacy and user embarrassment are critical in creating usable devices with engaging user experiences.

We acknowledge that our work is limited by the sample size and short-term duration of the study. Also, even though we sought to expose the handbag users to the public by including walking tasks in a café, a proper in-the-wild study would be required to assess the concepts more thoroughly. As a future work, we plan to continue towards a more mature prototype development both for the implementation and design.

7. CONCLUSION

We have presented a practical wearable display, in the form of a smart handbag concept. Its evaluation in a user study (n=20) revealed that the concepts were generally positively received, especially from the utilitarian point of view, as well as for their novelty and creativity. The need for user control and the privacy of the publicly displayed content and visualizations was identified, highlighting that wearable computing user studies should include tasks where the concept usage is exposed to social and public contexts. Particularly, identified privacy concerns suggest that a mechanism to control the visibility of items within the handbag is required. Positive feedback was given on the possibility of matching the handbag's appearance with clothing and to interact with devices inside the handbag without removing them.

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