Body-worn controllers and E-Textiles - Interaction and social acceptability

Philipp Ubrich
T6A - AUI - TU-Dresden
Dresden, Germany
s9706290@mail.zih.tu-dresden.de

Fabian Mischke
T6A - AUI - TU-Dresden
Dresden, Germany
s0189852@mail.zih.tu-dresden.de

Andrea Pittaro
T6A - AUI - TU-Dresden
Dresden, Germany
andrea.pittaro@studenti.unipd.it

Philip Vogel
T6A - AUI - TU-Dresden
Dresden, Germany
philip.vogel@mailbox.tu-dresden.de

ABSTRACT

Smart Textiles and body worn controllers (Wearables) have been analyzed, mostly individually, using different technologies and studying different aspects. Although there were some tests concerning everyday life, these controllers are not used very often for several reasons. This paper aims to show some of ~~them~~ these reasons and analyze, instead, the opportunities that may lead to better development and improve the feeling that a user has when interacting ~~in an uncommon way~~ with a device in a way that's not common along the rest of the population. One of the main threats to the adoption of Wearables that this paper will discuss will be the reasons for social unacceptability. Other topics will be the methods to review social acceptability and possible solutions to the problems concerning the usage of Wearables in public, taking into account the technology-related tradeoffs. To illustrate this issue, different Wearables are going to be presented - specifically concentrating on the social aspects of the devices. Finally ~~,~~ this paper discusses further development of social acceptability of Wearables in the future.

INTRODUCTION

Touch gestures are a form of interaction that is used ~~by almost everyone daily~~ a lot in our society.[1] Whether Smartphone, Tablet, or Smartwatch - many mobile devices are nowadays controlled by this input technique to master different tasks. High demands are directly related to the fast and intuitive use of these devices. The combination of different electronic devices can help achieve these requirements to a higher extent. For example, smart watches are already used to control mobile phones or various home electronics (e.g. controlling lamps). The development of innovative input devices, which can be integrated into clothing or even applied to the user's skin, offers the potential to communicate with electronic devices in completely new ways and make interaction even more intuitive. In this paper, we especially focus on touch input devices that are attached to the user's skin or are integrated into clothing. This can be used to control different electronic devices. Because these technologies create new and unusual forms of interaction, we will also look at third-party perceptions of a user's interactions with a wearable ~~E-textile~~ E-Textile interface. Social conventions play an important role in the development of these new forms of interaction. The willingness to make a gesture depends largely on how appropriate these interactions look and feel in public. [11] The usability of these technologies must also be examined: to support the user as efficiently, effectively and satisfactorily as possible, the designers must consider the interaction with the system in addition to the placement of these ~~body-worn controllers~~ wearables.

SHOWCASE OF TECHNOLOGY EXAMPLES

The body worn controllers[2] usually allow to have bigger controlling surfaces ready to be used without needing to take out the main device. Moreover, these controllers allow users to express input gestures, which are comparable to everyday gestures. This allows the user to express emotions while using the device. If on a touchscreen, the feedback of the input is based only on vibration and visual input. With body-worn controllers, the input surface is placed over the skin, which allows direct feedback to the user, including the emotion put into performing a gesture. An example made by Wiegel et

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[1] To date, just counting only Android and iOS devices, more than 3 billion devices are active monthly, https://www.apple.com/newsroom/2018/02/apple-reports-first-quarter-results/ and https://twitter.com/Google/status/864890655906070529

[2] input sources made by joining small electric devices with everyday worn clothing

~~Al~~al. [15, p.185] is "Uncomfortable interactions were chosen for actions that are very important and not reversible", which shows how the gesture chosen to perform an action were related to the consequence that this action may lead to.

Augmented Reality related research is still trying to optimise the input, which interacts with the shown interface, so that it could potentially capitalize on the natural and unobtrusive ways you interact with Wearables. "Belt" [3] is a body-worn controller specifically built to interact with Augmented Reality applications. As the name suggests, the device is worn around the hip like a regular belt, which is touch-sensitive and can differentiate between simple gestures and locate the position of the touch-input [3, p. 2136].One of the main use cases of the device is spatially mapped shortcuts to open apps, like a virtual wallet. [3]

BODY-WORN SENSORS

A current approach deals with the placement of multi-touch sensors directly on the skin. Because the surface of the human body is irregularly curved and deformable, the system must be particularly flexible and adaptable to fit the skin. This is a special requirement for the design of the sensors, as they need to be comfortable to the users wearing them. [8, 14]

Furthermore ~~,~~ the human body has capacitive effects, which must be correctly shielded from an input sensor to ensure reliable touch detection. This places special demands on the technology's material: it must both be insulated from the conductive sweat produced by the skin, but also has to let the same sweat flow outside, to avoid the user to feel uncomfortable due to the impossibility of the the skin to dissipate the heat in that area. [8] To overcome these challenges, the researchers of "Multi-Touch Skin" [8] studied various materials and manufacturing processes. As a result of this research work, a multi-touch sensor was developed, which can be applied directly to the user's skin in the form of a thin layer and is capable of comforming to different body shapes. To counteract the capacitive properties of the human body, the prototype consists of three layers: the transmitting, receiving and shielding layer. The individual layers are produced using a standard printer. Silver ink was used here because silver is a particularly effective electrical conductor and so is perfectly qualified to produce the sensor units. Furthermore, this method is well suited to produce multi-touch sensors in different sizes and therefore for testing on different body regions. [8] A small multi-touch sensor behind the ear could be used to manipulate an audio device. For example, the user could adjust the volume by stroking the sensor or pause playback with a simple tap. A wristband sized sensor could be used to control interactive lamps. Users could place two fingers around the wrist and rotate them to change the color of a light bulb or adjust the brightness of a lamp using swipe gestures. [8]

Another solution is presented by iSkin [14], where a different material is used to allow input to be sensed. ~~The polydimethylsiloxane~~ Polydimethylsiloxane (PDMS), the silicon-based material used, is "fully transparent, elastic, and a highly biocompatible material. [...] Therefore it is widely used on or in the human body, for example in body implants." [14, p. 2994] PDMS is non-conductive, but adding carbon produces
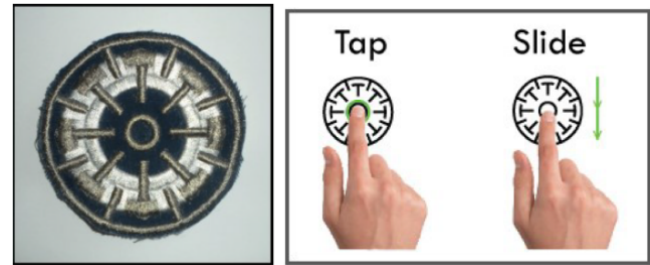

Figure 1. *Jogwheel* **as presented in [11]**

cPDMS, which can create a conductive surface. This allows the creation of a gray-colored sensitive surface that can have a specific shape or design. ~~.~~ This feature can immediately let the user know what to press for an action, but only registers that the ~~are~~ area has been touched, without any information about the gesture made ~~on~~ at that area. The reason for this limitation is the electrical principle used: the RC charge-discharge circuit allows time evaluation only for the whole sensitive surface [3].

E-TEXTILES

E-Textiles, short for electronic textiles, are input devices fitted or integrated into the fabric of a user's clothing. These surfaces allow the user to interact with various electronic devices in their environment, since they integrate both the sensing surface, which processes the physical input like a touch, grab or slide motion, and a control unit, which elaborate the input and sends it to a controlled device. This means that usually an E-Textile is only an input surface, which implies the necessity for the surface itself not to be rigid in order to let the skin act as direct feedback for the user. An example of E-Textiles is "Pinstripe" a project by the Aachen University [7]. This technology is directly integrated in clothing by conductive threads. The threads measure folds, which are created by pinching the fabric with thumb and index finger. When the fold is rolled across the fabric the rolling gesture accompanied by the diameter of the fold acts as an input (smaller folds represent finer inputs). Those inputs can be used for example to manipulate the volume of a music player. Another ~~E-textile~~ E-Textile is the "Jogwheel", which was developed as part of the paper "Don't Mind Me Touching My Wrist[...]" [11] to investigate the social acceptance of on-body technology. The Jogwheel is visually comparable to a fabric patch and is made of conductive yarn. A tactile surface structure should guide the user's fingers, which simplifies eye-free interaction. The developers describe the size of the Jogwheel as twice the size of the iPod click wheel. This size should allow high precision in use and several types of one-handed gestures. Figure 1 shows the Jogwheel and two ways of interacting with ~~them~~ it. The E-Textile can be placed anywhere on the user's clothing for controlling electronic devices. [11]

Another type of ~~E-textile~~ E-Textile is the one presented by SmartSleeve [9], where the fabric is an input surface made

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[3] An RC electronic circuit has a typical charge-discharge time constant τ which is given by the product $R \cdot C$. when pressure is applied, capacitance changes as the distance between the two surfaces ~~it's~~ is reduced. When a different charging time is sensed, the pressure is identified.

of alternating conductive and insulating textile bands. Then another pressure-sensitive fabric is set under the first one, beneath which there is another fabric alternating conductive and non-conductive bands. This layer is positioned orthogonally to the top layer. This allows the fabric to register both the position and the intensity of a touch with a matrix representation. The sensor density is 1.66 sensors per square inch, which allows for a moderate sensing capability. However, since the system is working with the short-circuit principle, and the wires are not insulated, skin moisture can lead to false position sensing. To avoid this, the authors have put SmartSleeve over a long-sleeved running shirt. This solution, however, becomes unsuitable in summer for obvious reasons. Project Jaquard [10], instead, utilizes a capacitive system where the fabric is one layer textile, in which some of the wires in the weft and warp are electrical wires. As the touch sensing is made with capacitance measure, this system is not vulnerable to errors due to the skin moisture. Different materials have been investigated to create the electrical wires, both for simplicity of the creation of the fabric and the necessity of flexibility needed for comfort. The material chosen was copper because it has similar properties to cotton, silk and wool when the wire diameter is 50μm. The Simple Skin [13] is an example of a modular smart textile garment, created for commercially viable multi-purpose garments. It combines multiple sensing modalities, namely capacitive sensing for head and wrist movement, resistive sensing for arm movement [17] and bio-impedance sensing for heart rate. This allows optional smartphone interaction. This placement is intended to detect the angles of the joints to analyse posture, monitor vital signs, and offer input on the socially accepted region of the lower arm with the wrist sensor. Finally, the smartphone grants the options of a regular input device or a supportive device to supply the user with information. This modular design allows for the separation of various components such as sensing, acquisition hardware, processing, and software. This allows the use of various combinations of different technologies on the same garment, and enables modifications of the underlying fabric with detachable hardware. [13]

ADVANTAGES AND DISADVANTAGES OF BODY-WORN CONTROLLERS

Body-worn controllers offer innovative solutions to a host of problems, facilitated by a combination of progressive miniaturization and sophistication of electrical components. Recent miniature controllers in the form of smartwatches and wristbands can complement larger devices by supplying information or act as more limited but less power-consuming alternatives. [16] Although Smartphones are undoubtedly the most ubiquitous form of small computing devices, improvements can be made: Mobile phones are large enough to offer extensive functionality and services, but their use can be distracting due to the length of interactions, or even objectionable, in certain social settings. Phones are usually kept out of sight, retrieved when needed, then returned to their container or receptacle in order to conform to social etiquette. They also demand more concentration from the user, preventing effective use while moving or attempting to execute other tasks that require coordination. Smaller body-worn devices, in the

form of wrist-worn contraptions, can be worn in an unremarkable and acceptable manner and remove the need for retrieval and concealment for their use. The design of new interfaces for these body-worn devices also allows for the development of more concise interaction, reducing the time needed to return to the previous task without interruption, and creating a "micro-interaction" cycle.[4] [1] Yet for all the innovative concepts developed with these technologies, they have not reached the level of ubiquity of their handheld Smartphone counterparts. This is in part due to inherent size restrictions for the sake of user convenience. Controllers are designed to be worn in a fashion conforming to conventional accessories, usually situated on the upper body for manual access. Any unnecessary bulk is trimmed as not to encumber the user, especially in the case of distally attached gadgets. This comes at the cost of display sizes, resulting in diminutive screens operated by basic button controls, which can be unintuitive, or touch input, which is made difficult by "fat-finger" issues[5] with the limited size. Operating conventional graphical interfaces like the QWERTY keyboard on very small screens is not very practical: The input method requires precious screen space to display a touchscreen keyboard and precise positioning of the fingertips to avoid input errors. [5] Research efforts are being made to remedy these problems in circumstances where screen enlargement would contradict concept goals or where redesigning screen real estate[6] use would be deemed ineffective. These efforts are directed towards introducing more natural and expressive user interfaces for existing hardware as well as methods to influence gesture recognition by improving the quality of input. [5, 16]

SOCIAL ACCEPTABILITY OF TOUCH-BASED WEARABLES

When developing body-worn controllers, two things have to be considered: which body part the technology is placed on, and the design of the technology itself so that the system adapts as well as possible to the selected body part. These two parameters are a basic requirement for the most user-friendly system. [11] However, another parameter is crucial and will be discussed in more detail in this section - social acceptability.

Social acceptance includes the social competence and presentation in which people behave in such a way that they feel comfortable in society or do not embarrass themselves or draw attention to themselves. [6] The use of portable technologies is therefore also subject to social conventions. The body-worn controllers listed in the previous sections are associated with new designs, new shapes and, above all, new interactions that might seem unfamiliar to third parties at first glance. An example of this is the Bluetooth headset from the early 2000s. At first, there was less acceptance in society because it looked as if the users were talking to themselves. After a while, however, the Bluetooth headset became established in society. [12] The use of body-worn controllers could initially lead to similar

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[4]Microinteractions: interactions with a device that take less than four seconds to initiate and complete.

[5]A fat-finger error is a human error caused by pressing the wrong key when using a computer to input data.

[6]Screen real estate is the amount of space available on a display for an application to provide output.

effects and acceptance problems, for which reason possible application examples are presented below, evaluated and discussed with the aid of current studies.

The perception of technology use in public spaces can be different in every culture, because the standards of social behaviour vary in many countries. This also should be considered in the development of new interactive systems, which is why it also needs to be part of the research of social acceptance. Campbell et al. [2] have shown in their study on the public use of mobile phones, that there are indeed differences in this field. For example, ~~Campbell et al.~~ the same paper just quoted, discovered that in Japan the use of mobile phones in buses or sidewalks is less accepted by society than in a restaurant. In many other cultures, this is rather the opposite. [2] These results lead to the conclusion that there are also cultural differences in perception when interacting with body-worn controllers which need to be explored.

Social acceptance includes various factors, which is why different methods are used to evaluate them. A handful of these methods will be mentioned and discussed in the next section.

~~Methods to review social acceptability~~

METHODS TO REVIEW SOCIAL ACCEPTABILITY

Since social acceptability is a major issue when it comes to the adaptation of new technology there is also the need to measure it appropriately. Different ~~researches have different~~ research have various approaches to review the social acceptability of their respective research. [11]

~~TESTING - DEMONSTRATING TECHNOLOGY~~

Testing with dummy (without working technology)

One of the first possible ways to study and discuss both comfort and easiness to interact with clothing as an input, is to interview people about what they would do to enact some commands on their skin. This is the main principle adopted by the Paper "More Than Touch" [15, p. 181], where the authors say: "This allowed us to observe participants' unrevised behavior, free of the restrictions of current hardware. This method prove helpful in previous work for deriving implications for future hardware and system designs to accommodate this user behavior." These research types allow to have a common ground, as they help defining areas where the touching is not possible, either because it's a position not easily ~~acceptable~~ accessible or because it's not a social acceptable position. Testing usually is done in a laboratory, like with "Usable Gestures" [12], where the user feels less the social pressure given by the presence of many people. So this type of testing is quite useful when beginning the development of a technology, as it's not related to the current hardware, but has some limitations both because it doesn't consider the necessary tradeoffs that must be made to go from the idea of the device to the actual working device and because the laboratory itself doesn't reflect the everyday situation that a person and a device will encounter on.

Testing in private (lab situation)

Tests in a lab offer special possibilities. On one side the subject is not distracted by other stimuli and is more focused on the presented topic (in this case gesture testing). On the other side researchers can verify more data recorded by the sensor, receive voice feedback by the testing subject, which can include the narration of the task and the reasoning behind the execution. The first prototype shown is "Belt" [3], here users had a visual feedback for the belt-interaction, which was Google Glass. The main result, common to all interactions, is that the area reachable to the dominant hand is preferred. In the Belt case, in particular, the area which had a higher number of shortcuts is the front of the belt on the side of the dominant hand, where users expressed the easiness and comfortability of interacting with a body-worn device. The second case-study taken into account by this paper is "Pinstripe" [7] in which test subjects would perform gestures in three different contexts, which are sitting, standing still and walking, and for each of them they'll try to perform a grabbing gesture in all the sixteen areas of their body defined by the authors. For each of them they expressed the easiness and the personal acceptance of doing that gesture in that context. The most important discovery, found out also by the papers [3, 4, 15], is that the preferred part of the body is the upper side of the body, both for accessibility, which relates to easiness, and the comfort related to the social acceptance. Moreover, as shown by [15] the mind model related to the touchscreen UI influences mostly the types of gestures (i.e. pinch to zoom is transferred from the Smartphone to the textile surface)

Testing in public

When transferring from the private laboratory environment to the public and social environment where the subject meets people who are looking to himself, some different aspects can be noticed: first of all, the area, that was shown as acceptable is reduced considerably and includes only the arm, the pocket area and the sternum [7]. This can be related to "More than Touch" [15] were people felt uncomfortable in areas where they're not used to perform touch gestures. An example that we can make is the fact that ~~in~~ the pocket area is normally accessed to get the Smartphone, the wallet or the keys. In case of the forearm, instead, a person may look at his watch multiple times a day. One remark made in "Pinstripe" [7] ~~, in fact,~~ was that even though the sternum had a high rating. Female testers were underlying that it would not be socially acceptable to interact in that area, so the areas where the input should be placed depends on cultural background, sex and personal attitude. When it comes to testing technology in public the most important factor is the observer. In the research done by Rico et. al. [12] one observation was, that not only the location played an important role, when it came to performing unusual gestures, but also the amount of observers and the degree of acquaintance. So in order to review a technology, which should be used in public situations, one has to test it in public situations to accurately define the degree of social acceptability. "Because we observed differences between the first and second trials, we would recommend completing at least two trials when evaluating for social acceptability because users will develop preferences and change their acceptance rates after multiple trials. Additionally, we suggest that such trials be completed in real world settings, rather than lab ones." [12, p. 9]

Testing with device (working technology)

When reviewing the social acceptability of a product and on a larger scale even the product itself, at last it comes down to testing with the device itself. Tests with a dummy are inherently easy to set up and do not require costly prototypes. They can also yield interesting, insightful results, especially when it comes to reviewing the gestures and overall appearance. On the other hand there are some aspects you can only truly examine while testing with working technology. These aspects include for example the actual amount of distraction the user experiences while using the device. A survey participant might experience some minor distraction while practicing a gesture with a dummy and simultaneously talking to a person. When he now repeats the same gesture with working ~~a working~~ Augmented Reality Wearable he might encounter a stronger level of distraction due to the Augmented Reality Overlays, which are shown to him. To avoid insufficient dummy tests both techniques are often combined to create a time- and cost-efficient solution with satisfactory results.

~~Demo video showing technology~~

Demonstrating a demo video to participants that represents the usage of a technology in a public situation can be a good way to get feedback regarding social acceptance. The paper "Don't Mind Me Touching My Wrist: [...]" [11] deals with this issue and examines which cultural differences of perception can arise during interaction with an E-Textile. [11] The USA and South Korea were chosen as reference countries for this purpose. In order to investigate perception, the "Jogwheel" was used, which we have already discussed above. The use case was the control of a mobile phone, to be exact, muting it after an incoming call, during a four eye conversation in an elevator. The scenario was simulated twice in each of the two countries - once the interaction with the Jogwheel was done by a woman and once by a man. This was recorded by camera and then the video was presented to the participants in an online-survey. This allows evaluation of the scenarios in public context. The video was shown to the participants once with a view from a distance (1.2-1.5 meters) and once with a focus on the interaction (distance 30-45 centimeters)). After the video, the participants were asked various questions about the interaction shown with the Jogwheel and its body placement. The questions were answered by using the Likert scale, given values and personal opinions of the participants. [11] In combination with an online survey, this test method offers the advantage of evaluating the scenarios in a public context. Furthermore, larger numbers of participants can be achieved through easier sharing of the videos/survey. [11]

Interviews

When conducting a research based on interviews the first approach is often to offer the subjects a multiple choice style answer sheet. This technique yields a few very obvious advantages. The results are very comparable and the answers are always very clear. The interviews are also faster - so a larger number of subjects can be interviewed in less time. One major disadvantage is that the answers are always represented in thresholds. A participant might not feel that he "strongly agrees" with an aspect of the survey, but since there is often no other choice than "strongly agrees" and "somewhat agrees" he might feel inclined to still pick the first choice. Also the researching party only gets very limited feedback, since the participants often cannot express their detailed opinion on the matter, because they are limited to the given questions and multiple choice answers. On the other hand there are survey techniques which try to structure the interview more like a loose conversation. This allows the subjects to express there detailed opinions and feelings on the survey matter. The disadvantages can be derived from the above mentioned advantages of multiple choice interviews. Briefly summarized the disadvantages are worse comparability, more time consuming interviews and the inability to give any or a very clear answer by the virtue of lacking options.

Conclusion on methods

When comparing the different methods of testing Wearables, especially concerning the social acceptability there is no ~~cleary~~ clearly preferred method. There is a small trend to testing with dummies (not working technology) rather than testing with working devices or prototypes. Furthermore testing in controlled environments (private settings - like a laboratory) is more common[7] than testing technology in public situations. Both of these trends seem reasonable. Testing with working prototypes needs more refined production to allow robust testing and public spaces are harder to control and monitor than controlled settings. These methods for testing technology are inherently more ~~time- and cost-consuming~~ time and cost consuming than the previously mentioned counterparts and might go beyond the ~~space~~ scope of some projects. Another interesting observation regarding the testing is, that oftentimes different methods are combined (for example in the case of Belt [3] and Pinstripe [7]). This approach seems to be an efficient ~~compromis~~compromise. With the combination of both methods and an iterative approach on testing, one can use the advantages of both techniques. A first test could use the controlled lab environment and a working prototype to evaluate the technology itself. Here the prototype can be optimised for the controlled environment and the results can easily be monitored. A second test could use a dummy in a public setting. In this situation there is no risk of damaging a working prototype and the user is probably not overwhelmed by actually navigating through working interfaces, while managing demanding social tasks. The focus can therefore be put on the social aspects involving gesture input and appearance of a device. Contrary to this observations in interviews there seems to be a slight preference for dialogue based interviews - which are more time and effort consuming - over likert or multiple choice alternatives. This might be due to the fact that it is more important to express detailed emotions and opinions when reviewing social acceptability. It is also notable that yet again in most cases both techniques were combined. Again the reason might be to benefit from both advantages, which were mentioned above.

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[7]In fact all of the seven research projects performed some variation of private testing

Table 1. Research Examples sorted in testing variations [3, 4, 7, 9, 11, 12, 13]

Lab testing	Public testing	Dummy test	Device test	Demo video
Belt	Belt	Belt	Belt	Don't mind me touching my wrist
Pinstripe	Pinstripe	Usable gestures	Pinstripe	The social comfort
Usable gestures	Usable gestures	More than touch	Usable gestures	Usable gestures
More than touch		SimpleSkin		
SmartSleeve				

Table 2. Research examples sorted in interview methods [3, 4, 7, 9, 11, 12, 13]

Multiple choice interview	Conversation-style interview
Belt (likert)	Belt
Don't mind me (multiple choice)	Don't mind me
Pinstripe (first study)	Pinstripe (second study)
The Social Comfort	The Social Comfort
Usable Gestures (first study)	Usable Gestures (second study)
Enabling Mobile Interactions (focus on likert)	More than touch
	SmartSleeve
	Enabling Mobile Interactions (focus on gesture creation)

State of social acceptability of wearables

"...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." [4, p. 4162] This quote underlines the current challenge Wearables have to face to succeed in the long term. Since as mentioned by Dunne, Lucy E., et al. [4] the basic needs are figured out for Wearables they now have to please higher needs - such as social acceptability. To illuminate the current state some results of current ~~researches~~ research are presented here.

Result "Belt" [3] : Dobbelstein et al. came to two main conclusions regarding the social acceptability of the tested device - Belt. The first observation was that short interactions were perceived more acceptable by the survey participants. The time was especially relevant when it came to interacting with unusual body regions. The second observation was that natural interactions are more acceptable in general. For example the region above the back pocket was deemed more inconvenient than others. But for the opening of a virtual wallet this area was the preferred region. Because this is the area where usually a tangible wallet is located.

Result "Don't Mind me Touching my Wrist" [11]: The "Jogwheel" ~~[11]~~ mentioned above was used in an online survey to evaluate the social acceptance of an ~~E-textile~~ E-Textile interface by showing a demo video to the participants. The results showed gender and cultural differences in this field. There were large gender-specific differences, especially in body placement. For example, while the placement of the interface on a man's chest looked very accessible and natural to the participants, the same part of a woman's body was perceived as "disgusting". [11] The participants from the USA found the interaction with the interface at the waist by a man more embarrassing than by a woman. The answers of the South Koreans were exactly reversed here, which indicates ~~to~~ cultural differences. [11]

Overall, the results of this study show a gender effect in reference to the placement and interaction of an ~~E-textile~~ E-Textile. Especially the waist (for men) and the chest (for women) revealed to be socially sensitive areas. In contrast, the body positions of forearm and wrist were rated very positively, which could also be due to existing technologies (wristwatches, e-straps).

Result "Pinstripe" [7] : The work by Karrer, Thorsten, et al. did not put a strong emphasis on social aspects, but rather on convenience and accessibility. Nonetheless there were concerns from the survey subjects regarding social acceptability, especially concerning the placement of the Wearable on socially suggestive locations. Interestingly enough the sternum was not mentioned as concerning or problematic, but rather as convenient - which is contrary to other research like the work done by Profita et al. [11].

Result "Usable Gestures for Mobile Interfaces" [12]: The research by Rico and Brewster examined the social aspects of Wearables. During this process various factors were identified which in one way or another influence social acceptability. Besides obvious factors like the type of gesture and the specific, public setting, the authors mentioned a rather interesting factor: repetition. Once the survey participants mastered a gesture and repeated it, it came more naturally to them and did not feel as uncomfortable.

Result "Social Comfort of Wearable Technology" [4] : When it comes to the placement of Wearables there is a strong aversion to inappropriate body locations. While preferred positions are mainly chosen because of easy accessibility, positions are mainly eluded to avoid embarrassment. Also the visual properties of a Wearable are a key factor for acceptance.

Evaluation of placement areas for body-worn controllers

The single most prominent factor mentioned in the respective research projects, besides the type of gesture, was the body region where the Wearable was placed. The figure ~~above~~ 2 shows the preferred regions in the individual studies. When comparing the ~~researches~~ research there are two main observa-
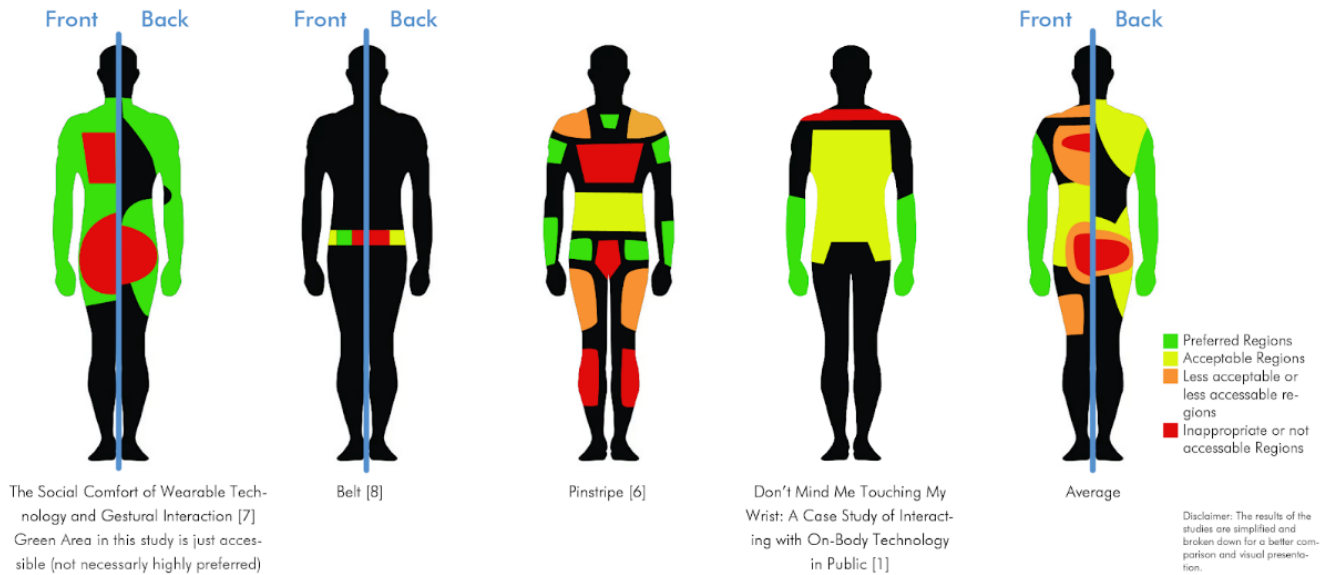
Figure 2. Preferred Regions for Wearables in Different Studies Comparison [3, 4, 7, 11, 13]

tions to be made. First there is a strict aversion against socially suggestive regions for Wearables. These regions include genitalia, the bottom and, especially when asking female subjects, the upper torso area, including the sternum and collarbone. Second the all around preferred area for Wearable seems to be the forearm and wrist region - especially of the non dominant hand. [3, 4, 7, 11] This may be due to the fact that interaction with technologies on these body regions is already established and accepted in society through other devices such as watches and fitness bracelets. However, these body regions are also easy to reach and offer sufficient space for various gestures, which makes these body regions very suitable for body-worn controllers in the future as well.

OUTLOOK ON SOCIAL ACCEPTABILITY OF WEARABLES IN THE FUTURE

When looking into the future of Wearables one of the most interesting parts is the social acceptability. Since physical comfort, accessibility, and usability are for the most part figured out [4]. One, if not the most, important part of social acceptability are the performed gestures. Currently there is always a tradeoff which needs to be balanced when designing gestures, which are meant to be used in public situations. On one hand natural gestures are inherently more unobtrusive and socially acceptable. On the other hand these gestures are far more difficult to track and evaluate precisely, since they are easily confusable with everyday gestures that were not meant to be an input [4]. One approach to solve this problem is improving on better technology and tracking to avoid both confusing inputs and social discomfort at the same time. Another approach could be focussed around the social vocabulary more than around the gestures themselves. "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." [4, p. 4160] Looking at this quote the other solution seems obvious. With the further adaptation of a novel technology there comes a better understanding of the gestures and finally a new social vocabulary regarding it. There were similar developments when the bluetooth headset [4] or the Sony Walkman [11] was were established. In conclusion, the social acceptance of body-worn controllers can be increased through further developments and by bringing them more and more in contact with the public.

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