Wearable Mapping Suit: Body Mapping for Identification Wearables

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ABSTRACT

This research describes a new design method – the Wearable Mapping Suit – which combines bodystorming and prototyping techniques in a human-centred development process for wearable technologies. The method derives from visually prepared body maps that are used in designerly decision-making processes. The idea is illustrated with an exemplified workshop where four visual Identification (ID) Wearables used for authentication interactions get co-created by six participants and two facilitators.

CCS CONCEPTS

• **Human-centered computing → Usability testing**.

KEYWORDS

Authentication Technologies, Interaction Design Methods, Human-Centred Design, Wearables

ACM Reference Format:
Marie Beuthel, Friederike Fröbel, and Gesche Joost. 2021. Wearable Mapping Suit: Body Mapping for Identification Wearables. In *CHItaly 2021: 14th Biannual Conference of the Italian SIGCHI Chapter (CHItaly '21), July 11–13, 2021, Bolzano, Italy*. ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3464385.3464729

1 INTRODUCTION

In the field of design, the human-centred approach has increasingly drawn the attention of developers in recent decades. By involving potential users of a product, process or service, the final results are more likely to be accepted and successful. So far, wearable technologies have been hard to establish commercially in some areas, often because people remain sceptical of the product and its use of their data [8]. By involving potential users into the design process of wearables and respecting their requirements, therefore, acceptance and trust will grow. As Hartman argues: *"The easiest way to learn how to make something wearable is to wear it."* [9] Wearables, which are devices worn on the body, are recently gaining in significance. Gadgets like smartwatches and smartphones are being integrated more and more into everyday interactions. This work takes a closer look at possible 'Identification (ID) Wearables' – wearables used for authentication – and how they can be developed using a human-centred approach. By using authentication technologies (biometric, possession-based, knowledge-based, and others) people can secure sensitive data or gain access through individual interactions with an identity management system. This study focuses on the use of the Wearable Mapping Suit, an item of clothing developed for use in the design and development process. This unicoloured suit is used to try out design techniques such as prototyping and bodystorming, whereby draft technologies or designs can be applied directly to the body of potential users and to collect feedback in action. Tinkering materials are used to mark relevant body areas and to attach prototypical concepts to body parts. Four design concepts were co-created and tested in a qualitative ideation workshop with six participants and two facilitating researchers where the Wearable Mapping Suit method was applied. These include a belt that can be used at an airport security check, an earring measuring blood pressure and heart rates for hospital patients, a login wristband used by gym members, and smart working shoes which enable access to security zones. In order to conceptualise these prototypes, the researchers employed visually defined mappings on the human body. Based on the body areas where people choose to place conceptual wearable ideas, they could be tested immediately and the whole user experience iterated in possible contexts. Before introducing the suit and demonstrating its applications, some related works are introduced to explain how it was derived.

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CHItaly '21, July 11–13, 2021, Bolzano, Italy

ACM ISBN 978-1-4503-8977-8/21/06…$15.00
https://doi.org/10.1145/3464385.3464729

2 RELATED WORK

As part of an overview of the Wearable Mapping Suit, related work from the fields of wearable technology, authentication technology, and human-centred design are presented in relation to its use in bodystorming and prototyping.

2.1 Wearable Technology

A 'wearable' is defined as any form of miniature electronics and sensor technology worn on the body, which includes accessories such as smartwatches, wristbands, virtual reality glasses, and tokens, as well as smart clothing, which involves integrating items into clothing or objects to be carried around close to the body.

According to this definition, the Sony walkman – invented in the 1970s for playing cassettes and carried or worn on the body – could be considered an early form of wearable. Nowadays, the more direct bodily application of wearables in the form of tattoos or even integrated implants are possible. In the past few years, wearables have become increasingly popular and gained in importance. The worldwide sales forecast for wearables more than doubled from 2018 to 2019 and will increase by another 50% by 2023 [13]. Areas of particular interest for wearables are fitness, health and self tracking [12]. Common literature offers insights into wearable electronics from a technical point of view, looking at how to use and program the relevant technologies [3]. By contrast, Hartman [9] explores aspects of developing a wearable such as where to place heavy items, how to place them comfortably, and how to make them durable by using manual techniques. She also mentions usability and functionality but does not describe exactly what methods might support the design process, besides prototyping in general and testing ideas iteratively. So what might those methods be? One approach that Zeagler introduces in his 'Design Guideline for Textile-Based On-Body Interfaces' [25] is body mapping for wearables. In his dissertation, he considers a set of guidelines for creating textile-based interfaces that support effective on-body interaction. In addition, he develops a collection of different body maps with locations for wearable technology, including recommendations for where and how to measure factors such as movement, heart rate, and temperature. In this work, body maps are used to identify parts of the body where ID Wearables can be worn. This information will be combined with the following related work.

2.2 Authentication Technology

Authentication technologies are made to secure sensitive datasets by interacting with identity management systems. Users can hereby identify themselves to an interface to gain access to certain datasets, artefacts, or spatial areas. In engineering and computer science literature, a distinction is made between four kinds of authentication: biometric, possession-based, and knowledge-based, as well as other technologies [16] [22]. Biometrics involve a person's unique body features such as their iris, fingerprint or gait. A possession used for authentication could be an object such as a smartcard, key, or token, possibly in combination with a reader device. Classic knowledge-based authentication includes passwords and security questions, but might involve other information as well. Other forms of authentications can be based on social contacts or other context-based information. One interesting project that combines biometric authentication with a smartphone looks at the different movements of people when carrying a smartphone while they walk. It analyses individual behaviour and how smartphones are worn in motion to verify a person's identity [14].

2.3 Human-Centred Design

In a human-centred approach to design, people who are supposed to use a product become part of the development process. Their individual experiences are reflected 'in action' [21] and ideas co-created in interdisciplinary teams [19]. Design methods with participatory elements are used to support the collaborative process. The results work as arguments in decision-making processes and illustrate everyone's ideas [18]. In experimental design activities, tinkering materials and idea visualisations can support the preparation, conduction, and analysis of participatory methods. They make concepts visible to participants of the design process [6]. By using exploratory, playful, and creative methods people can become involved and get a stage for co-designing technological visions. There are different levels of participating in a design process and people can get involved in different ways. When people are engaged in the process, tacit knowledge needs to be interpreted by the project team and co-constructed meaning develops in procedures in the use of design materials [2]. Two methods that are commonly used in human-centred design are bodystorming and prototyping.

2.3.1 Bodystorming. Embodied methods can support design processes with rich interactions and user experiences following a human-centred approach. Bodystorming is one such technique. In comparison with brainstorming activities, the entire bodies of participants are involved to ideate while moving, co-create in action, and trying out concepts in specific contexts. In roleplaying activities, interdisciplinary teams re-enact different usage scenarios to help them to draw up design solutions [24][5]. When interacting with the whole body, it becomes apparent which physical aspects of a product, process, or service are most important in its design [20]. Núñez-Pacheco and Loke [15] describe a focus-oriented bodystorming technique, in which mapping on the body takes place on paper. In this way, they can collect emotional impressions from people on the involvement of their bodies, including tacit knowledge and complex ideas that are otherwise not easily described.

2.3.2 Prototyping. Another user-focused method used to design and develop products is iterative prototyping. By simulating concepts with materials such as paper, cardboard, tinkering objects, and electronic components, ideas can be tested by potential users in relevant contexts [11]. People can try out design concepts through interaction and come up with further development ideas. Based on user feedback, these prototypes are refined using an iterative process [4]. The prototypical objects serve as conversation starters, testing objects, interactive demonstrators, and presentation objects.

In the work of Flechtner, Lorenz and Joost [7] bodystorming and prototyping techniques were combined to develop a concept for a wearable soft-robotic support system in a work environment. A toolkit involving prototyping materials that can be attached to the arm and shoulder area are used to inspire potential users with ideas for wearable items. The researchers use gloves that reach along the whole arm of participants to receive direct feedback. This work was a motivation to develop a more general method for wearable technologies using the whole body. Further references combining bodystorming and prototyping include Tomico's and Wilde's [17], and Höök's [10] research.

3 METHOD: WEARABLE MAPPING SUIT

Based on the design methods of bodystorming and prototyping and the related work described, the Wearable Mapping Suit was developed to enable ideation for wearable technology directly on the bodies of potential users.

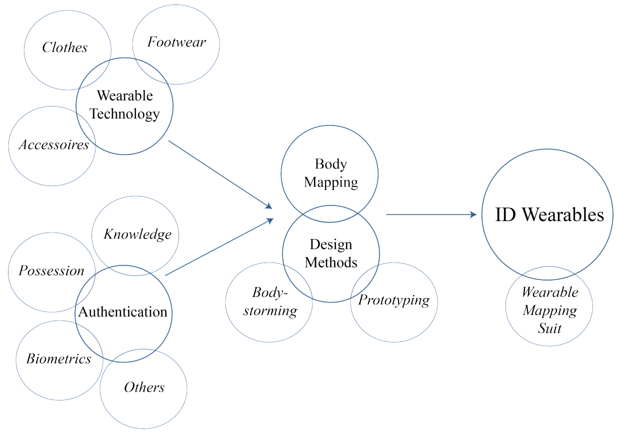

Figure 1: Overview concept derivation of Wearable Mapping Suit

Figure 1 illustrates the concept of the derivation of the method Wearable Mapping Suit and how it is used for the development of ID Wearables. The upper left side presents the wearable technology, which consists in this case of clothes, footwear, and accessories; the bottom left side shows types of authentication, structured in terms of possession, biometrics, knowledge and other authentication procedures. These two aspects are combined in a human-centred approach involving body mapping and the design methods bodystorming and prototyping, shown in the centre of the figure. The result is the Wearable Mapping Suit for ID Wearables shown on the right side. The application process is described as follows.

Preparation

First, an overall – a whole bodysuit that is unicoloured and thus open for interpretation – is prepared depending on a project's goal. It can be combined with unicoloured gloves, overshoes, masks, headgear, and hoodies if necessary. The preparation includes the selection of relevant body areas to be looked at and the visual labelling of those parts depending on the user requirements.

Introduction of Wearable Technologies

The participants got an an overview of sensors and actuators that wearable technology is based on.

Step 1: Body Maps

In the context of this research, the participants are introduced to different body maps, each of which are present possible sensor positions. Zeagler's body maps are used as the basis for this stage.

Step 2: Body Mapping Suit

The mappings are conducted either in cooperation with potential users or based on previous user research. The labelling can be realised with simple markers in different colours (provided they do not bleed through the fabric), tape, paper that can be glued on, fabric patches to be ironed on or pinned onto the suit, or direct prints. These markings show the sections of the body that are relevant for wearable prototyping. The prepared suits and accessories described can then be worn by potential users and stakeholders who are invited for ideation. Participants are given the task of bodystorming and interacting within a given or simulated context to come up with potential ideas for wearable technologies. While doing so, they are asked to mark regions and spots on their Wearable Mapping Suits and explain their choices. Interactions, user requirements, and ideas are collected directly on the body and then compared between all participants. By explaining verbally which body parts were chosen and why, the development team can understand and retrace the ideas.

Step 3: Prototyping ID Wearables

In a third step, the markings are compared and discussed within the group. These findings lead towards wearable concepts that can be visualised and attached directly to the Wearable Mapping Suits with the help of tape, markers, and tinkering materials. The prototypical ideas can be tested, and ideally re-iterated, in simulated or actual concepts.

The Wearable Mapping Suits method was developed within two research projects with the result of a two hour ideation workshop which was conducted in a lab environment with six participants to co-create ID Wearables. The group of participants (n=6; m=2; f=4; age=25-41) had prior experience with wearable technologies. Each participant had at least tried out one wearable before, but had only little familiarity with physical computing. There were two co-creation rounds with each two discussions in between all participants and facilitators. Within the rounds, the participants formed groups of three or rather two and four people for prototyping ideas. The workshop's outcomes are described in the next section. The wearable concepts were co-created based on the participants' ideas in combination with the prior knowledge of the two facilitating researchers.

4 WORKSHOP OUTCOMES: ID WEARABLES

Often technologies are predetermined in research and development projects. In such cases, it is possible to limit the features of the Wearable Mapping Suit method to the given restrictions. Several possible combinations of authentication technologies are introduced in this work, leading towards the design of ID Wearables (Table 1). Since authentication is divided into biometrics-based, possession-based, knowledge-based and other authentication technologies, we introduce possible adaptions for the Wearable Mapping Suit on the basis of these terms. The ideation process occurred in a guided dialogue with the facilitators.

4.1 Possession-Based Authentication

Possession as an aspect of authentication in combination with wearable technologies covers, in general, all electronic accessories and clothes. However, the most interesting items in terms of possible designs are regularly worn accessories such as bags, wallets, smartphones, smartwatches, keychains, glasses, and jewellery. Everyday clothes like skirts, pants, dresses, shirts, underwear, or socks are less suitable as a possession ID Wearable because they are often changed and therefore washed more often. A wearable should not be subjected to this unnecessary mechanical stress or the need to reinstall batteries and electronic components. When using possession for authentication, the chosen items become an object of interest themselves. By carrying and using them in combination with a reader system, one can verify identification. As preparation for the ideation workshop, the body mapping aspect of reachability was specifically explored. When using possessive objects for authentication, they need to be within reach by their owners for

	Possession	Biometrics	Knowledge	Others
ID Wearable	Belt buckle	Earring	Wrist band	Safety Shoes
Body Areas	Waist	Ear	Arm	Feet
Context	Airport control	Hospital Check-In	Gym	Companies Access Control
Functions	Access in Security, Control	Discreet Patient Registration	Gesture Pattern for Access	Body Contact for Collaborative Access
Mapping Aspects	Reachability (Fig. 2)	Blood Pressure, Heart Monitoring (Fig. 5)	Reachability (Fig. 2)	Active Touch (Fig. 10)
Number of Participants	3	3	2	4

Table 1: Overview of ID Wearables Concepts from Ideation Workshop

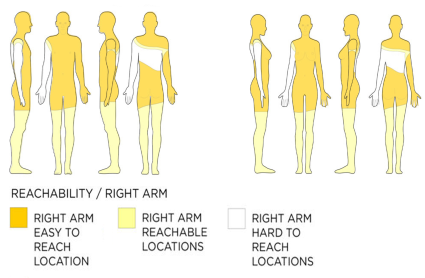

Figure 2: Zeagler's Body Mapping: Reachability of the Right Arm [25]

Figure 3: The Bodystorm Area for Potential Prototypes: Waist

the interaction with a reader. The areas of interest are visualised in the colour yellow in figure 2. In the ideation workshop, the aspect of reachability was respected when bodystorming (Fig. 3) and prototyping (Fig. 4) the idea of using a belt buckle in the context of an airport control, where people remove their belts for the security check anyway. This procedure could become part of an authentication process, in which the placement of the belt on a reader device that is implemented in the security system would not even change the interaction itself. The authentication would happen automatically while the belt is passing by and is inspected in the security lane, where all items besides clothes are being removed and placed in a box. The idea could be realised with a simple reader that is integrated either in the box or conveyor of the airport security. In the belt itself, the other part of the communication needs to be implemented.

Figure 4: A Prototype of a Belt Buckle for Airport Control

4.2 Biometrics-Based Technologies

For biometric authentication, a person's unique physical features such as their iris, fingerprint or gait are used to interact with an access system. All possible biometric aspects have to do with the human body or its behaviour and are therefore ever-present for a person, in contrast to possession-based authentication items, which have to be carried around. Wearables themselves are close to the human body and can track these biometric features in different ways. The measurement of various physical functions is suitable for biometric authentication. For biosensing, Zeagler [25] developed body maps for the measurement of blood pressure, blood glucose, heart monitoring, respiration, temperature, stimulation, and hydration. These measurements are the base for biometric wearables in this case. As an example, in the ideation workshop one participant came up with the idea of using biosensing elements for admission at hospitals, when this information is tracked anyway and is part of medical investigations. Thus, the maps of blood pressure and heart monitoring were combined for a biometric wearable in one body map (Fig. 5). By looking at the overlapping areas on the body maps in the bodystorming part (Fig. 6), possible areas for prototyping (Fig. 7) could be found: the ears, wrists and fingertips. These overlapping areas represent those parts of the body that are suitable for a wearable technology item that can sense these physical values. The prototypical workshop concept concentrates on the ear because it was the most convenient placement for a constantly worn item out of the patients' perspective. Unideal sites would include fingertips and wrists because they could be part of medical

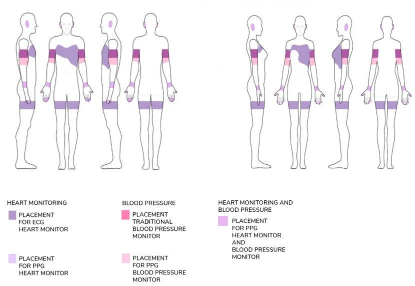

Figure 5: Zeagler's Body Mapping for Blood Pressure and Heart Monitoring [25]

Figure 6: The Bodystorm Area for Potential Prototypes: Ear

treatments. The workshop participants decided to use an accessory, an earring that would involve the measurements discreetly in itself for authentication. The moment of authentication could happen at the hospital entry door or welcome desk as a first check-in. The system would be able to verify a person by their individual blood pressure in combination with the heart rate and gain access to the resource in question. The person could then be sent to a medical appointment or a necessary location. At the same time, the bio-data could be measured and used for medical analysis. For heart monitoring, two different medical methods of investigation, ECG (electrocardiogram) and/or PPG (photophlethysmography) could be used, which were presented to the participants. The monitoring of blood pressure is also possible with two different sensors, one is the traditional blood pressure monitor, the other also a PPG sensor. The participants imagined implementing the monitoring via PPG. For this method, the sensor is using "internal LEDs to bounce light off the arteries and arterioles in your finger's subcutaneous layer and sensing how much light is absorbed with its photodetectors" [23]. Such a sensor is relatively small and thus fulfils the requirement of a discreet and non-disfiguring wearable. The earring can be used as an everyday accessory. However, it should be noted that earrings are not worn by everyone and not everyone has ear piercings. A realisation of the idea in the form of ear clips would also be conceivable.

4.3 Knowledge-Based Authentication Technologies

Knowledge-based authentication requires that the person who is being verified knows and can remember some sort of information. In the case of a wearable product, this might be realised in an interaction whereby a person inserts information such as a PIN or

Figure 7: A Prototype of an Earring for Hospital Check-In

password manually into the item. Another possibility is gesture recognition. This might include patterns that a person remembers and performs – similar to smartphone locking systems with a pattern entry. Their gesture can be measured via movement sensing or textile sensors. For these sensors, reachability is an important consideration. The reachability map was selected as a basis for the Wearable Mapping Suit. As shown in Fig. 2, the map for right-handers was selected first. For left-handers, the case would have to be mirrored vertically. In the workshop, the idea of designing

Figure 8: The Bodystorm Area for Potential Prototypes: Wrist

a wearable to gain access in a gym emerged. Two participants bodystormed possible interactions for this context. Using the body map, the participants marked areas that would be comfortable to make a gesture on the suit. The front of the upper body with the non-interacting arm and the head proved to be suitable areas. It was quickly established that the head as an interaction zone was perceived as unpleasant by the participants. One female participant also felt uncomfortable with the breast area. The most suitable zone in this case was the forearm. The outcome of this bodystorm session was finally narrowed down to an area on the wrist, as shown in Fig. 8. The next step was to prototype an ID Wearable for this body area for gym context. One of the most popular wearables, the smartwatch, is located in this area. The participants came up with a gesture to be used in combination with either a watch or wristband. For example, Google ATAP's development of a Soli radar chip came into the conversation mentioned by one of the facilitators [1]. This small radar sensor is small enough to fit in a wristband, in this case a sporty textile wearable item that fits the context of a gym. This wristband could be equipped with the Soli radar sensor or another textile sensor solution: a capacitive sensor would be a possible alternative, for example.

4.4 Other Authentication Technologies

Other authentication procedures might involve additional information such as the location or physical social contacts of a person. This contact could be represented with touch in wearable technology, which is why the body map of active touch was chosen to support the ideation workshop (Fig. 10). Participants came up with the idea

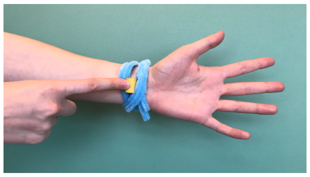

Figure 9: A Prototype of a Wristband for Gym Access

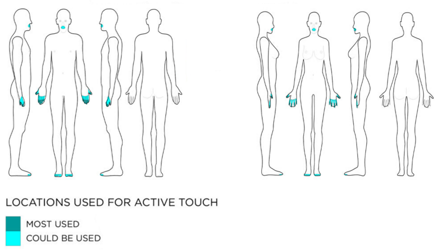

Figure 10: Zeagler's Body Mapping: Active Touch [25]

to gain access to a security area of a company, only in cooperation with another colleague. In this way, a company could make sure that, for security reasons, no-one would enter a restricted area alone. They imagined using the body proximity of two colleagues as a factor for authentication. As in the previous cases, the body map was transferred to the Wearable Mapping Suit. The body areas, which are overlapping in the mapping, include the face, the area around the mouth, the palms of the hands and the soles of the feet. As in the knowledge-based case, the participants felt uncomfortable wearing any item in the facial area. The area of the hands was discussed by the participants, but seemed impractical in a business context. In the final result, the sole of the foot became the focus of attention (Fig. 11). Possible wearable items for the foot are primarily socks

Figure 11: The Bodystorm Area for Potential Prototypes: Feet

and shoes. In the section describing possession-based ID Wearables, it has already been mentioned that clothes such as socks are less suitable as wearables due to their need for frequent washing and changing. Socks are also exposed to high levels of friction and sweat in everyday use. The integration of sensors would, therefore, be suboptimal. For this reason, the participants concentrated on the shoe as a wearable. The idea is to integrate sensors into the sole of the shoes and develop an authentication system based on it. A possible sensor technology that could be used for this application would be an RFID (Radio Frequency Identification) chip, which can accordingly be identified on site. The interaction between two colleagues would happen in front of a closed door in a certain marked area on the floor, where the two shoes are placed next to each other (Fig. 12). The reader system on the floor would read both shoes simultaneously in combination and unlock the access mechanism.

Figure 12: A Prototype of Security Shoes for Company Access

5 CONCLUSION AND FUTURE WORK

The Wearable Mapping Suit describes a design method to be used in the development of wearable technology. In this paper, four cases are described on the basis of an ideation workshop which was held to co-create ID Wearables for authentication interactions. Each ID Wearable concentrates on one area of the human body that accompanies Zeagler's body mappings. The mapping technique is used for bodystorming conceptual ideas. The wearables are then designed for a certain context based on the users' requirements. The functionalities are illustrated in low-fidelity prototypes that are used as testing objects at the same time. In the next step, each of the four concepts can be iterated further and tested in their relevant contexts with potential users. So far, they have not been tested in the actual contexts of interest (airports, hospitals, gyms, and restricted sites) but in simulated environments that were improvised by the participants. Something that is especially important to consider for ID Wearables is the privacy and security concerns that users expressed within the ideation workshop. It is absolutely essential to consider people's fears regarding wearable systems and ensure that wearables protect people's data. The method described could be tested in other fields or other groups of interest for further research, specifically for other types of wearables. Physical computing experts could be involved for technological advancements of the protoyical concepts. It could be developed further into a suit that shows Zeagler's body mappings more obviously on the garment. Also, other body maps based on Zeagler's work could become part of the method and be used in combination. It is possible to go into more detail with the electronic input and output for each wearable system and prepare a set of design materials to be used as a toolkit. Based on these findings, we feel like it is necessary to develop more participatory design methods for the design of wearables in general. Lastly, something to consider for each wearable design is the emotional and social acceptability of wearables. User requirements consequently need to be considered to develop successful products, processes and services.

ACKNOWLEDGMENTS

This work would not have been possible without two research coorperations of the German Research Center for Artificial Intelligence (DFKI GmbH): In the coorperation with the Bundesdruckerei GmbH security and identity management related topics like egovernment lead to human-centred design concepts. The MYOW (Make your own wearables) project supports the DIY scene of e-textiles, provides a network for makers. We would like to thank our project partners, our colleagues at the Design Research Lab and all user test and workshop participants for the great support and cooperation.

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