Developing Accessibility Design Guidelines for Wearables: Accessibility Standards for Multimodal Wearable Devices

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Abstract. Smart wearable devices are integrated our everyday lives. Such wearable technology is worn on or near the body, while leaving both hands free. This enables users to receive and send information in a non-obtrusive way. Because of the ability to continuously assist and support activities, wearables could be of great value to persons with a disability. Persons with a disability can only benefit from the potential of wearables if they are accessible. Like other devices, platforms, and applications, developers of wearables need to take accessibility into account during early development, for example by including multimodal interfaces in the design. Even though some accessibility guidelines and standards exist for websites and mobile phones, more support for the development of accessible wearables is needed. The aim of our project is to develop a set of guidelines for accessible wearables. Three approaches are combined to develop the guidelines. A scan of the literature was done to identify publications addressing the accessibility of wearables and/or development guidelines. Semi-structured interviews were held with developers of accessible wearable technology. Based on these first activities, a draft set of guidelines is created. This draft is evaluated with developers and researchers in the field of universal design, accessibility, and wearables. Further, the draft is evaluated with visually impaired people (VIP) in interviews. Based on these results, a final set of guidelines will be created. This set is evaluated against an actual project in which apps are developed for VIP. This study is in progress; first results are presented (literature study, semi-structured interviews, first draft of guidelines) and a call for participation in the Delphi study is issued.

Keywords: Accessibility · Wearables · Guidelines · Universal design · Multimodal interfaces · Visually impaired people

1 Accessibility of Wearable Devices

Information, services, and communication are increasingly offered via high-tech ICT application and devices. This development potentially gives visual impaired people (VIP) and persons with other disabilities better and easier access to the information and services. Wearable devices enable users to collect, process, and transfer data without intensive

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interactions with the device. Wearable devices are worn on, near, or in the body, leaving the hands free. These devices can in some cases be operated by touch, but often performing a certain gesture or giving voice commands are also available as interaction mechanisms. Because many wearables have a multimodal interface, hands-free operating system, and mobile character, wearable devices can be especially useful for persons with a disability. In fact, various assistive devices and applications exist, aimed at VIP [1]. The existing applications support tasks such as navigation, wayfinding, text to speech conversion, and object recognition. To use such devices or applications, users need to hold their assistive device or smartphone, which usually makes them quite obtrusive in daily life activities. In addition, the number of separate devices needed to tackle the different tasks one faces throughout the day can be too much to carry around (e.g. a screen reader, a smart cane, a GPS navigation device, and a magnifier). Wearables are in principle able to take on many of the assisting roles these devices and apps have. The advantage of wearables are that they can offer such support unobtrusively and hands-free.

The potential benefits of wearables can only be realized when the devices, applications, and content are designed to be accessible. A visual display that offers no audio or tactile alternatives, cannot be used by blind persons. Input and output modalities should be multimodal to ensure that users do not have to rely on an interaction modality that is inaccessible to them. To be able to fully participate in society, professionally or personally, persons with a disability should have access to information and communication technology. Not having access to ICT may lead to exclusion and a higher dependence on others or public support [2, 3]. As wearables are increasingly integrated into people's daily life, the digital divide can increase when these wearable technologies are not accessible to everyone. Conversely, accessible wearables open up information support and assistance to persons with a disability and can stimulate empowerment and participation [4]. Given the rise of wearable availability and use by the general public, this is the time to think about design for all and accessibility of wearables.

2 Design Standards for Accessible Wearables

Accessibility should be warranted on different levels: the device or delivery platform (e.g., smartphone, wearable device, desktop computer), the operating system (e.g., windows, Android, iOS), and the content and function (e.g., a navigation support app). Many wearables rely on and synchronize with smartphones. Therefore, the actual accessibility of wearables stretches beyond the wearable device and its application; any necessary supporting devices and applications need to be accessible as well. The accessibility of wearable devices depends on issues resolved in all of these areas. There are guidelines, documents, and support tools for web accessibility, or multimodal interfaces [5]. Legislation that aims to protect persons with a disability from exclusion or discrimination, both online and in the physical world [2, 6] powers the discussion on digital accessibility and the creation of guidelines. Best known are initiatives of the World Wide Web consortium (W3C), which focus on establishing and communicating standards for web accessibility [7]. According to W3C, accessible design has content that is: "(1) Perceivable: Information and user interface components must be presentable to users in ways they can perceive, (2) Operable: User interface components and navigation must be operable, (3) Understandable: Information and the operation of user interface must be understandable, (4) Robust: Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies” [8]. These generic principles are applicable to new technologies and devices as well. With mobile devices, such as smartphones and wearables, information is at the tip of our fingers wherever we go. To ensure persons with a disability can benefit from these mobile and wearable technologies, they should be accessible. Most smartphones offer disability modes or features and developers can access tools and guidelines to support them to include accessibility features in their products. Certain accessibility features are supported in some wearables, like Google Talkback and VoiceOver in MyGlass app for Google Glass, or Voice Over and Font adjustment in Apple Watch [9–11]. A bridge between web accessibility and accessibility of other devices and applications is acknowledged and supported in WCAG2ICT [12]. This initiative provides guidance to develop non-web documents and software, based on web accessibility guidelines. Specific guidance for the area of wearables is not covered in this initiative however.

Accessibility is best paid attention to throughout the development process, starting in early development phases. Hard numbers on cost effectiveness lack, but various publications indicate that adjusting an already existing design to make it accessible (retrofitting) is more costly than creating accessible sites from the start [13–15]. Furthermore, accessible websites are usable bu larger audience, and can be easier to maintain. Therefore, it is advisable to pay attention to accessibility throughout the development process, starting in early development phases, to create a robust, good technology, without costly redesigns later on [15]. Applying universal design to web design, as well as wearable design can provide an approach to take into account accessibility during early development phases. It can be difficult, stigmatizing, or costly to adapt existing designs to make them accessible. Universal design aims to support individuals by requiring a minimal amount of adaptation, while supporting inclusion of the broadest range of people in daily activities [16]. Seven universal design principles are formulated which provide a starting point or guidance to develop accessible designs. The seven principles are summed up below:

1. Equitable Use: The design is useful and marketable to people with diverse abilities
2. Flexibility in Use: The design accommodates a wide range of individual preferences and abilities
3. Simple and Intuitive Use: Use of the design is easy to understand, regardless of the user’s experience, knowledge, language skills, or current concentration level
4. Perceptible Information: The design communicates necessary information effectively to the user, regardless of ambient conditions or the user’s sensory abilities.
5. Tolerance for Error: The design minimizes hazards and the adverse consequences of accidental or unintended actions.
6. Low Physical Effort: The design can be used efficiently and comfortably and with a minimum of fatigue.
7. Size and Space for Approach and Use: Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user’s body size, posture, or mobility [17].

To provide guidance in creating accessible wearable technology, Tomberg and colleagues discuss universal design principles in the context of wearables [4]. They offer concrete examples of universal design principles applied to wearables, such as multi-modal interfaces (vibration or even smell) to communicate perceptible information. In addition, they stress that universal design is a process as well as an outcome that should be applied already in early design phases [4].

Our current project aims to develop and validate accessibility standards for a new generation of smart, wearable ICT devices. We involve developers, designers and technology users with a disability (VIP), to ensure the views and needs of these stakeholders are reflected in the guidelines.

3 User-Validated Accessibility Standards for Wearables

Our project aims to develop and validate a set of guidelines containing accessibility standards for wearables. With the standards we aim out to guide developers beyond web or mobile accessibility. The accessibility standards will focus on wearable technology, with special attention to the multimodal interfaces needed to accomplish accessibility. Multiple stakeholders will be consulted throughout the project, to foster applicability and relevance on various levels. We take a three-track approach to create a set of draft guidelines; a *literature* scan, semi-structured interviews with *developers* regarding their experiences in developing/researching wearables or accessible technology in practice, and *VIP* involvement via interviews. This draft is evaluated and refined in a Delphi study with developers, and in interviews with VIP. In addition, to ensure real-world validity and applicability of the guidelines, a concurrent development cycle is followed and evaluated. In this parallel project, apps for smart glasses are developed for VIP. The results of this development process is evaluated against the newly created guidelines, to assess real-world validity. The research methods are described more precisely below. This study is currently in progress. The first two phases of this study are being finalized; the literature review and expert consultations. Preliminary findings, as well as a preview on future research activities, are described below.

4 Development Process

4.1 Literature Review

Guidelines and publications addressing wearable technology, accessibility and/or multimodal interfaces are collected and analyzed. Documents containing standards, guidelines, or some form of 'lessons learned' concerning accessibility of wearable technology and/or multimodal interfaces are identified by searching Google Scholar, and databases of ISO, BSI, and NEN. Furthermore, key publications' reference lists are scanned for relevant publications. Publications that do not specifically mention wearable technology, but are relevant because of overlap are included. For example, some web accessibility guidelines apply (partially) to wearables too, as do lessons learned from a participatory development process with VIP. Such publications are considered for review.

For every publication, the type of publication is identified (empirical study or standard/guideline). Further, the domain (wearables; website; specific device; multi-modal interfaces in general; and focus on participatory or human centered design, no specific domain) and level of instructions/advice (process or technical instructions). The key message and/or lessons are noted down.

4.2 Semi-structured Interviews with Developers

Exploratory semi-structured interviews with developers of wearable/mobile technology are held to further refine the body of readily available guidelines and standards. In addition, reasons for (non) use of such guidelines are explored. Interview questions include:

1. Describe your experience in inclusive design/designing for persons with a disability/accessibility and/or multimodal interfaces?
   (a) More specifically, describe the project goal and output, timeframe, followed approach.
2. Were end-users involved in the project(s) you described? How?
3. Do you have experience designing for wearable technology?
   (a) How do you think this differs from mobile or non-wearable technology?
4. Which supporting documents/standards/guidelines did you use?
5. What guidelines/standards for accessibility are you aware of?
   (a) Have you used them?
   (b) What are the reasons you use these documents?
6. Do you use any of these [show list] standards or guidelines? If so, which and why?
7. What do you think is missing in the guidelines/standards that are currently available?
   (a) What do you need?
8. How do you keep up to date regarding accessibility developments?
   (a) And regarding wearables?
9. Do you have other comments or suggestions?

Experts who have previously worked on projects developing or designing wearable or mobile technology for persons with a disability or practice universal design were invited to take part in the interviews. In addition, developers or researchers who have experience with multimodal interfaces are invited to participate as well, even if they have no direct experience with wearables or universal design. Respondents are recruited via the authors' networks and via snowball sampling.

4.3 Delphi Study

Based on the literature review and semi-structured interviews, a medium-fidelity draft for the accessibility guidelines will be created. This draft will then be refined via a Delphi study [18]. In this study, developers will be invited to comment on and refine the draft, based on their own views or experiences. Participants who participated in the semi-structured interviews are invited for the Delphi, as well as newly recruited developers and researchers. In three rounds, participants are asked via email to communicate their suggestions about the draft and propose amendments. The Delphi study is will take place between April and September 2016.

4.4 VIP (User) Interviews

Interviews with VIP will be held to establish what they feel should be reflected in the guidelines. Based on the review of available standards and the expert consultations, rough drafts will be created and discussed with VIP. VIP participants are selected for their self-reported type of impairment (congenially or later acquired) blindness, peripheral view, reduced visual field, reduced acuity. The respondents will be recruited mainly via the researchers' network. The interviews will be conducted face to face or via telephone or skype.

4.5 Check Against VIP Smart Glass App Development Project

The final set of guidelines will be checked against a concurrent app development project. In this project, two applications that assist VIP with certain daily life activities will be developed for smart glasses. One of the applications targets emotion recognition, the other application supports navigation/wayfinding. These applications will be evaluated regarding accessibility. Also, the apps and their development process will be checked against the then finished set of guidelines for accessible wearable technology. This way, we will evaluate the guidelines against a real-world project.

5 Results

5.1 Existing Guidelines

Various guidelines and publications holding advice on development of wearables or multimodal interfaces for VIP were identified. A selection of the findings is discussed below.

Several publications that address the development of multimodal interfaces are identified [19–25].

Guidance for developing mobile apps is provided in one publication [26]. It specifically focuses on inclusion in public life by developing applications that assist persons with a disability. Advice on wearable development is provided in several publications [4, 27–32]. Some of these describe the development of applications for persons with an impairment. In one publication, the potential of wearable technology to offer monitoring and an easy means of communication is explored. In this case, research shows that wearables could be used to support persons with a mild cognitive impairment's to participate and become professionally active [30]. A study focusing on VIP shows how co-creation can be applied to develop and test prototypes, for example for to support landmark identification in navigation tasks [31]. It is important to involve end-users (in this case VIP), to ensure that the technology fits their specific needs and situation. In addition, special attention should be paid to the avoidance of 'masking'; blocking the senses (for example with earplugs) [30].

Guidelines that provide very detailed technical advice and instructions regarding (web) accessibility include WCAG 2.0, as well as guidelines focusing on interface design [8, 33, 34]. The gap between web accessibility and the Internet of Things is bridged by initiatives such as WCAG2ICT [12]. It provides guidance for developers non-web documents and software, based on WCAG. Furthermore, the ATAG tool offers developers a means to check and test their designs for accessibility [35]. Ergonomics of human-system interaction are addressed in publications as well, for example [36, 37].

As the identified publications are very heterogeneous, we will evaluate them against quality criteria for guidelines or heuristics [38]. Based on this evaluation (work in progress), relevant heuristics will be included in the draft set of guidelines that will be evaluated in the Delphi study.

5.2 Guideline Use in Practice

So far, various experts (researchers and developers) were consulted regarding their experience with (guidelines for) accessible multimodal interfaces and wearable technology. We interviewed four males and three females, who have the following professions: researcher in the field of haptic wearables, researcher in the field of haptic and tactile feedback, developer, accessibility consultant, researcher and lecturer in the field of human-computer interaction and technological innovation. The respondents had experience with accessibility, designing for persons with a disability, multimodal interfaces, and/or wearable technology. Some main findings are summed up below.

The projects that the respondents mention include consultancy/giving training about web accessibility. Further, the respondents mentioned projects in which wearables for autistic persons, elderly persons with mild dementia, and deaf-blind persons were created. One of te mentioned projects focused on tactile displays for specific tasks/settings. End-users were not involved in all the projects mentioned by the respondents. Especially in web accessibility consultancy, testing accessibility with end users seemed not to be standard. Most respondents do stress the importance of involving the end-user group and continuously learning from them, however difficult communication sometimes may be (e.g., deaf-blind persons, autistic persons).

Respondents point out that, for as far as they have any experience with wearables, the ergonomics or human factors associated with developing wearables are what make them different from other (e.g., website or mobile) development projects. Issues with comfort need to be resolved. In addition, when there is no display or only limited visual output, the search for alternative ways to convey complex information can be challenging.

The respondents mention having used some guidelines, mostly originating from internal or self-created handbooks. Most respondents are familiar with web accessibility guidelines. Reasons for not using guidelines are the level of specificity; they are either too specific and not relevant for a particular project, or too generic to be of real use. Also, having sufficient expertise is mentioned as a reason not to use guidelines. However, sometimes, guidelines or publications are helpful. For example, when working with very specific target groups (e.g., persons with autism), guidance and examples of how to setup and perform user studies is insightful. Often mentioned strategies of staying informed are colleagues, social and professional media, and conferences.

5.3 Work in Progress

Currently, the literature review is being finalized. In addition, additional semi-structured developer interviews are held. The preliminary results have been analyzed and translated into a draft set of guidelines. Below we describe this draft, and future research activities.

Draft Set of Guidelines. Based on the literature review and interviews, preliminary principles for the development of accessible wearable technology were synthesized and a draft set of guidelines is formulated.

A key necessity for accessibility to a broad audience is the multimodality of the system. Different modalities of interaction with the system should be available and equivalent to each other. Therefore, two principles from the ETSI guideline [20] are mentioned first:

1. Use multimodal presentation of information to allow users with different preferences and abilities to use information in their preferred way.
2. Use multimodal interaction to allow users to interact with a system following their individual preferences and suited to their personal needs.

In addition, the system should provide adequate feedback to its users. What is adequate depends on the need for reassurance, confirmation, or feedback on the one hand, and sensory or cognitive overload on the other hand. A third principle has been formulated:

3. The system or application should provide relevant feedback on the user behavior and the system actions. This can consist of positive confirmation and reinforcement of actions, and/or status or process updates, or notification and instructions on unexpected or incorrect behavior or actions.

Users can have different preferences across different settings. Therefore, the system's settings should be adaptive and/or adaptable. The following principle is formulated:

4. Adaptation of preferred settings (e.g., for input/output modalities, feedback intensity) should be contextual; based on localization, task, and/or user preferences. The system should be self-learning to enable optimal automated adaptive settings.

Wearable technology which is worn on the body, asks for some special attention with regards to ergonomics or human factors engineering. In fact, developers need to ensure that the device can be worn without discomfort and optimally blends into and supports the work or life-processes of the person using it. To voice this concern, the following principles were formulated:

5. The design of the wearable device should take human factors into account, to ensure the device can be used with ease and without discomfort, and without blocking the

users' senses. Special attention should be paid to the range of mobility/movements the person has, and the senses available to the person with a disability.

6. The decision on platform and device should be based on a careful analysis of the user needs and platform/device options regarding accessibility and multimodality.

In the Delphi study, these principles will be further refined and complemented. Developers and researchers in the field of wearables and universal design are invited to share their experiences and thoughts on the draft. In addition, interviews with VIP will be done to learn their take on accessible wearables and values that should be included in the guidelines. The final set of principles (guidelines), is evaluated against actual accessibility development projects.

6 Discussion

The preliminary results of the interviews with developers and reviewers show that there is a need for some form of guidance for developing accessible wearables. The aim of the discussed projects' scopes and aims differ, but even generic guidelines are not used often. This finding is in line with other studies, indicating that even when guidelines for accessibility are known, they may not always be used [39]. As argued, universal design forms a good starting point for formulating guidelines for accessible wearables [4]. The literature and interviews further stress the importance of a human centered - and participatory development approach [31, 40].

The draft guidelines will be refined based on the ongoing analyses of literature and expert interviews. We invite researchers and developers who wish to participate in this project's next research stage, a Delphi study to further finalize the guidelines, to contact us.

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