Focus on Accessibility: Multimodal Healthcare Technology for All

Jobke Wentzel
University of Twente
Drienerlolaan 5 7500AE
Enschede, the Netherlands
+31 53 489 6549
m.j.wentzel@utwente.nl

Thea van der Geest
HAN University of Applied Sciences, Centrum IT + Media
Arnhem, The Netherlands
+31 655371038
Thea.vanderGeest@han.nl

ABSTRACT
New health technologies are not accessible to all users due to the circumstantial or permanent disabilities some users have. Especially in healthcare, attention must be paid to accommodating all potential users or patients. With the smart use of multimodal systems and multimedia solutions, a broader patient group can be reached. In this paper, we lay out the concept guidelines for accessible wearable technology. Wearables are used for many purposes, including health. The research on these guidelines is in progress, first recommendations based on preliminary outcomes are given.

Keywords
Wearable technology; accessibility; design for all; universal design; eHealth; multimodal interfaces; multimodal interaction.

1. INTRODUCTION
A multitude of eHealth applications is available that help persons to monitor or manage their health. Many varieties of applications exist. For example, they can offer (remote) assistance by a healthcare professional and be available via websites, mobile or wearable devices, or even built-in at home technology (domotica). The way the assistance or information is offered is also diverse: (a)synchronous video or telephone contact, written information, video or even haptic feedback. Some interventions combine different modalities to ensure users can access or send information in ways that are convenient to them. For example, text-based instructions may be accompanied by instructive videos or live 'ask-the-expert' Q&A sessions. However, having a choice in the type of media you wish to use when it comes to eHealth is not only a matter of preference. Sometimes, a certain medium or modality in which information is offered or the system can be used does not match the abilities of the user, leaving it inaccessible to the user.

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2. eHEALTH ACCESSIBILITY
Information technology, including eHealth technology, should fit the abilities, needs and preferences of its intended users. When users cannot use the technology in a way they desire, when use is strenuous or not pleasurable, or when it is impossible for a user to use the technology as it was intended, users may ignore, abandon or reject the technology [7, 10].

This is a relevant problem, given the prevalence of (some kind of) disability. In 2014, as much as 10.5% of the USA's population between ages 18-64, reported having a disability. In fact, the WHO reports that worldwide, a total of 39 million people are blind and 246 million persons have low vision [16]. For disabling hearing loss, these numbers are even higher (360 million persons) [17]. Besides these examples, many more types of disabilities exist that can cause persons to experience difficulties using information systems. To them, content is not perceivable or operating the system is impossible [11]. Similar problems exist for persons who face temporal disabilities.

Do persons with a disability use eHealth technologies to manage or monitor their own health? For sure, many assistive technologies exist to support daily life tasks of disabled persons [14]. Despite this, mainstream health technologies may still not always be accessible to persons with a disability because designers and developers neglect to take some basic principles of *Universal Design* [12] or web accessibility into account. They exclude large proportions of potential users because they fail to offer technology that is uniformly accessible, including to persons with a disability. Health information websites that are not compatible with screen readers pose problems for visually impaired users. Information movie clips without captioning are difficult to perceive by deaf users. Persons with low literacy can have severe difficulty comprehending the lifestyle advice provided by an online coach. These examples show how relying on one medium or modality to convey information or interact with an eHealth system excludes users who could benefit from the technology, if only they could access it.

3. DESIGN GUIDELINES

3.1 Web and mobile accessibility

To ensure the accessibility of websites, extensive recommendations are available. The leading set of guidelines for web accessibility, WCAG 2.0, describes basic principles and practical advice for developers [5]. In addition, support is provided for example for accessible user agents, browsers, and non-web content [1, 4, 9]. Mobile phones are another form of technology that is ubiquitous and part of our everyday lives. Platform-based support for mobile app developers are available to stimulate developers to make their apps as accessible as possible and include the platform's accessibility features [2, 3]. For example, iOS offers VoiceOver; a function that allows users to operate their phone through speech. In addition, the design of the device itself can contribute to its accessibility: A home button that can be detected by touch alone (without vision) helps visually impaired phone users to operate the phone and large, easily operated buttons can help making phones accessible to users with problems in fine motor skills. A combination of the hardware, software and application characteristics (and the interaction between them) influences the accessibility of smartphones. So, with some help, technologies can be designed in such way and equipped with certain features that make them accessible to users with the broadest range of abilities.

3.2 Draft Guidelines for Wearables

Increasingly, people make use of wearable technology. Wearable devices, or wearables, include smart watches, glasses, wristbands, belts or other applications that can be worn on or near the body. These devices can be used for communication purposes, activity or health parameter tracking, recording (video) images, navigation, entertainment, and many more purposes. As with smartphones, not all wearable devices and applications are accessible to all users [15], which is why they could benefit from a universal design approach [13]. Few guidelines exist to assist developers and designers in creating accessible wearables. Therefore, we set out to create such design guidelines. A literature search was done and guidelines resulting from this were evaluated based on a heuristics approach [8]. In addition, exploratory interviews with experienced researchers or developers in the field of wearable and/or accessible technology resulted in additions to the identified guidelines, resulting in the following set of draft guidelines [15]:

1. Use multimodal presentation of information to allow users with different preferences and abilities to use information in their preferred way [6].
2. Use multimodal interaction to allow users to interact with a system following their individual preferences and suited to their personal needs [6].
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.
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.
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.
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.
7. The wearable device should be sensitive of social limitations on ways of operating or receiving information.
8. The information and the operation of the wearable's interface must be understandable.
9. The wearable device should be aesthetically attractive enough for users to want to wear it, taking into account current (or foreseeable) shifts in fashion.
10. The information and operation of the wearable's interface must be intuitive. When that is impossible, the system should contain proper affordances or instructions.
11. Wearable systems must be designed for maximal user acceptance.
12. Wearables must be designed and developed via Human Centered Design.

To further refine and validate these guidelines, accessibility and wearable designers and researchers were involved in a Delphi study to evaluate them. This study is described below.

4. METHODS

Literature study and exploratory interviews led to the set of draft guidelines as presented in the previous paragraph [15]. This set of guidelines is further refined in a Delphi study. The preliminary results of this three-round questionnaire study, aimed at reaching consensus about the guidelines with a panel of experts is reported in this paper.

4.1 Delphi study

A total of 59 persons were invited to participate in a study to further refine the draft guidelines. Participants were selected via key publications, snowball sampling, and the authors' network. To be eligible to participate, experience with researching, developing, or designing wearable technology and/or multimodal systems for persons with a disability was a prerequisite. A total of 17 persons fully completed the first Delphi round questionnaire.

The Delphi study consists of three questionnaire rounds in which the respondents evaluate the draft guidelines and propose (argued) amendments to them. For every guideline, respondents evaluate the guidelines based on whether 1) they think it contributes to accessibility, 2) the guideline can be applied feasibly in the design process, and 3) whether designers would be able to apply the guideline. Answer options for these three evaluating questions are yes, no, don't know. Additional explanations are asked after each set of evaluating questions per guideline. Finally, the participants are asked to give three rules of thumb that they think are valid for creating accessible wearable technology. In subsequent questionnaire rounds, the summarized answers of the previous rounds will be communicated, and where disagreement in answers exists, a new voting round (including explanations or proposed amendments) will be done.

The results of the first Delphi round are analyzed by thematically organizing and summarizing qualitative responses. The three closed questions per guideline (on contributing to accessibility, feasibility, and applicability) are analyzed by calculating

frequencies, the modus, and determining whether there is consensus among the participants. Consensus is defined as 80% or more of the participants that give the same answer.

5. PRELIMINARY RESULTS

The first Delphi round is finalized and the results were analyzed. Participants commented on the draft guidelines by answering the three evaluation questions. Agreement percentages for these questions were calculated. The (qualitative) motivations participants provided with their answers were summarized and paraphrased. Likewise, the rules of thumb participants provided were summarized.

5.1 Guideline Evaluations

The results of Delphi round one indicate that participants expect that most of the draft guidelines will contribute to accessibility, except for guideline 6 (platform and device), 7 (social limitations), 9 (aesthetics), and 11 (user acceptance), on which no consensus (>80% agreement) was reached, see Figure 1. Most guidelines were considered to be feasible, as Figure 2 shows. For guideline 4 (adoption of settings), 7 (social limitations), and 11 (user acceptance), no consensus was reached. Lastly, for none of the guidelines consensus was reached regarding whether they are applicable or easy to use in practice, as is shown in Figure 3.

The participants provided some explanations and motivations for their answers. These include comments on clarity and comprehensiveness of the guidelines, uncertainty about what is meant with the guideline, confirmation or rejection of the importance of the guideline topic for accessibility, or concerns regarding designers' ability to put the guideline into practice due to technological constraints or designers' lack of experience/expertise in accessibility issues.

5.2 Rules of thumb

The rules of thumb that the participants offered can be classified as either addressing the process of designing accessible wearables, skills or expertise of the designer, or technical descriptions of what wearable technology should do or offer in order to be accessible. Examples of process rules are: apply a participatory or co-design strategy, know disabilities of your target group and accommodate their needs, and test in any phase with real people. One rule of thumb addressed the skills and expertise of the designer: keep up with technology advancements. Practical rules, addressing features of the technology, include the advice to keep it simple and intuitive, to include multimodal interactions and interfaces, and to empower users and not stress their disability.

5.3 Work in progress

The current results of the Delphi study are fed back to the participants in the second questionnaire round (currently in progress). During this second round, they are informed on how their answers relate to other's answers and are provided with all participants' (summarized and paraphrased) motivations and explanations. Additional explanations are provided. Participants are asked to again evaluate the guidelines for non-consensus items and propose amendments if necessary. Based on the outcomes of this second round, one last third round will be held (if no consensus is reached). Finally, based on the participants' evaluations a final set of guidelines will be formulated. This set is expected to be available in the end of September 2016.

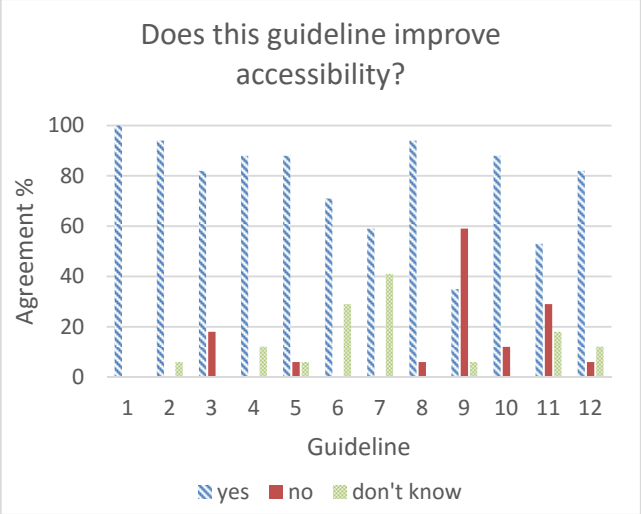

Figure 1. Question 1: improve accessibility

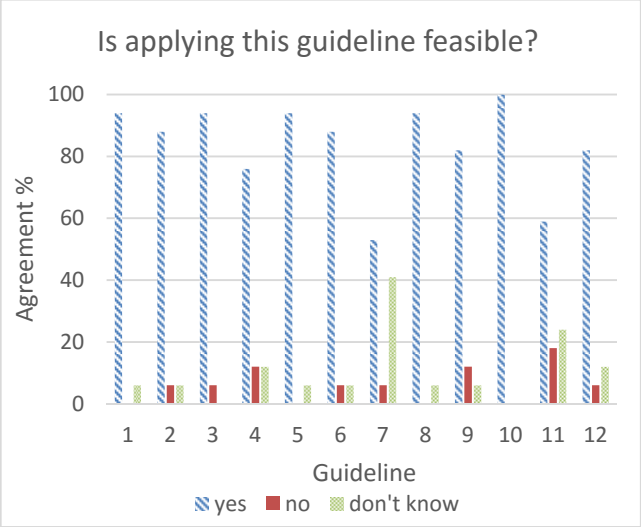

Figure 2. Question 2: feasibility

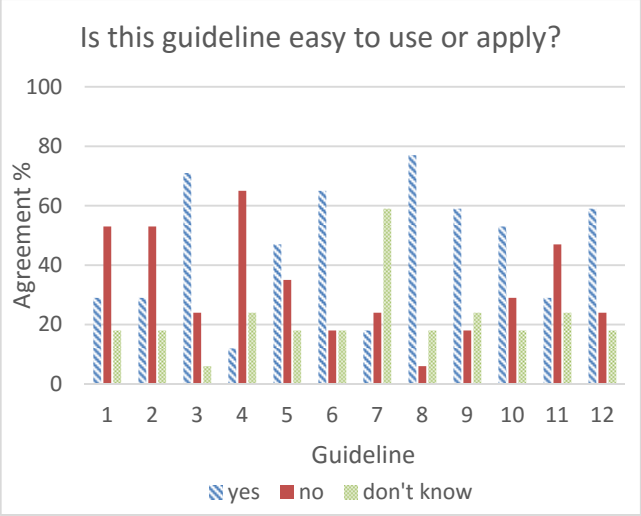

Figure 3. Question 3: applicability

6. DISCUSSION

The results of Delphi round one indicate that there the draft guidelines may need to be complemented with practical advice. No consensus was reached on the applicability of the draft guidelines and based on the comments the participants fear that the guidelines are too abstract for designers to apply. Most topics addressed in the draft guidelines seem valid, although some may not yet be well-understood or seem to be irrelevant to accessibility, based on the comments (resp., social limitations, aesthetics).

The aim of this study was to create design guidelines for accessible wearable technology. Many wearables are applied in health-related interventions or applications. Therefore, by making all wearables more accessible, some of these eHealth interventions become accessible to a broader range of users as well. In some cases, this may include users who were difficult to reach in other ways.

7. ACKNOWLEDGMENTS

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