How Two become One – Creating Synergy Effects by Applying the Joint Interview Method to Design Wearable Technology

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Abstract. This paper addresses the design of wearable technology and its user acceptance by applying the *Joint Interview Method*. In order to further develop a wearable warning system in form of a glove, five semi-structured joint interviews were held by a trained human factors specialist. Each joint interview consisted of one respondent with an engineering background and one respondent with a psychological or cognitive-science background. In this process, the *Joint Interview Method* revealed two advantages: First, the interviews benefited from the discussion between both participants and, second, it enabled an observation from two different perspectives (i.e. one implementation-oriented view, which focused on the technological capabilities and the other user-oriented view, which focused on human perception and information processing). Both aspects mentioned led to synergy effects. To sum up, the *Joint Interview Method* turned out to be a promising usability approach to explore new technologies' potential and user acceptance and therefore, can be recommended for its use in the process of designing and evaluating wearables.

Keywords: dyadic interview, two-person-interview, user-centered design, user acceptance, smart clothing, wearable warning system, industrial maintenance.

1 Introduction

Technological developments are advancing rapidly while components are getting smaller and more powerful at the same time. As one result, technology is getting closer to the human body and becomes "wearable". This year's International Consumer Electronics Show (CES) held in January 2014 in Las Vegas was focusing on this so-called *wearable technology*. This kind of technology which is usually worn directly on the human body seems to be the next big thing in consumer electronics. At the CES 2014, visitors had the possibility to marvel miscellaneous smart devices such as watches, wrist- and sweatbands, glasses and contact lenses and even jewelry. Most of these devices are designed to give the wearer condensed information gathered from measures of his or her physical and mental state combined with environmental parameters. The majority of these devices are definitely bursting with technical ingenuity, but what manufacturers really need to know is what potential users seek in

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smart devices and how these wearables have to be designed in order to convince users to wear those (Gibbs & Arthur, 2014).

Addressing the important issue of user acceptance when designing wearable technology, this paper presents and discusses the *Joint Interview Method* as a promising usability approach which allows evaluating user's opinion in a profound yet efficient way. For this purpose, the paper focuses on the design of a second version of a wearable warning system by applying the *Joint Interview Method*. At the outset, the theoretical background of wearable technology and of usability testing methods, especially the *Joint Interview Method*, is introduced. This is followed by a description of the research design and its implementation in this application context. Later on, findings and the following design process are presented and discussed. This paper concludes with some general advice on how to use the *Joint Interview Method* to design wearable technology.

2 Theoretical Background

2.1 Wearable Technology and Smart Clothing

Currently, wearable technology is having a great deal of attention and there are many attempts to design them in different fields of industry. Some examples are a haptic shoe for visually impaired people guiding their way and warning against obstacles (Saha, 2012), an intelligent curve warning glove for motorcyclists providing warnings by haptic signals (Huth, Biral, Martín & Lot, 2012) or for introducing wearables in industrial contexts a data glove made for hands-free interaction during aircraft maintenance was developed (Nicolai, Sindt, Witt, Reimerdes & Kenn, 2006).

There are many other examples referring to technology that is more or less wearable. Related terms are *smart clothes* or *clothing*, *wearable (computing) technology*, *E-textiles*, *I-wear* and *intelligent garments*. In this paper, the terms *wearable technology* and *wearables* will be used synonymously. Wearable technology aims to develop electronic devices which are wearable. In contrast, smart clothing emphasizes the importance of clothing (Barfield et al., 2001). The components used in wearable technology are conventional and non-textile which oftentimes make them feel bulky and impeding (Cho, Lee & Cho, 2009). In contrast, smart clothing uses textiles in which electronic functions are embedded (Barfield et al., 2001). General examples for electronics becoming wearable are conductive thread, flexible conductor boards or light and flexible sensors. Combining textile characteristics and electronic functionality, users favor smart clothing over wearable technology because of the lightweight design, flexibility, comfort and practicability in terms of washability and robustness (Kirstein, Cottet, Grzyb & Tröster, 2005).

Wearables are numerous and diverse but the main idea is to develop technology for use in practical tasks while releasing the user from having to carry around an extra device such as a tablet or laptop. Another aspect is to enable the user to perform all the necessary tasks without losing focus due to distracting eye movements or interrupting actions. Furthermore, since our world is becoming more and more complex, there is a need for technology that supports its user anytime and anywhere in a personal, unobtrusive and embedded manner (Cho et al., 2009). Focusing on wearable technology, another important aspect to consider is the "wearing comfort". Thereby, three aspects strongly determine the user's well-being and the user's willingness to use a device regularly. These factors are the thermophysiological comfort, the sensorial comfort and the body-movement comfort (Hatch, 1993).

In order to meet these diverse requirements it is essential to involve potential users from an early stage and to develop and test wearables in iterations.

2.2 Usability Engineering Process

A well-known process model to design in iterations and test various kinds of human-machine systems is the *Usability Engineering Lifecycle* according to Deborah Mayhew (1999). This approach consists of three main phases which are named as *requirement analysis*, *design, testing and development* and *implementation* of the system in an applied setting. Everything revolves around the user's needs in order to facilitate an effective and efficient but also satisfying interaction with the designed product.

After defining user profiles and tasks at the first stage of the *Usability Engineering Lifecycle*, the second stage deals with the iterative design and testing of increasingly advanced prototypes of the future system. Thereby, less than ten potential users per test cycle are sufficient to detect most of the major usability problems and to collect suggestions for further improvements (Nielsen, 2000).

In order to reasonably integrate users in the design process several usability testing methods are at hand (e.g. Sarodnick & Brau, 2006). For instance, observing a user's interaction with a prototype and afterwards asking the user about the experience is an often used combination of methods. Advantages lie in the opportunity of an early detection of usability problems as well as in a selection of ideas for further improvements implemented in a following version of the system. In some cases this combination of methods should be used with caution: High fidelity prototypes, for example, might inhibit the user to express general criticism towards the prototype or its usage. On the other hand, low fidelity paper pencil prototypes, where users might feel less inhibited to express negative thoughts, might lack important physical impressions such as touch. Having this dilemma one should carefully consider how elaborated a prototype has to be and what other options might exist for testing its physical appearance as well.

2.3 The Joint Interview Method

Designing a wearable warning system involves several topics to be considered: On account of its novelty and its closeness to the human body, a participatory design is helpful to identify the needs and doubts of potential users. In this context, semi-structured interviews can be useful (Frieling & Sonntag, 1999). In comparison to a structured interview, a semi-structured interview still captures a predetermined range of issues but ensures flexibility in the topics' arrangement and depth in which they are addressed (Dunn, 2005). Moreover, a semi-structured interview allows a rather natural course of conversation. In this, the interviewees can refer or return to earlier discussed topics thus a topic can be amplified or neglected.

Usually, interviews and user studies are conducted one-on-one: One interviewer asks one respondent. In this case, a different format was chosen: joint interviews. This term is used heterogeneously. Either it means that two interviewers ask one respondent or it refers to the opposite, two interviewees asked by only one interviewer (Arskey, 1996).

In this paper, the term is used if one researcher interviews two respondents at the same time. This constellation has been named differently in the past: *dyadic interview* (Morgan, Ataie, Carder & Hoffman, 2013) and *two-person-interview* (Eliot, 2010). To the authors' knowledge, the *Joint Interview Method* has been scarcely investigated from an explorative design method point of view. Several reasons led to the selection of this method. Because the field of wearables is rather new and has a great potential for innovation, the interviews have an explorative purpose. The respondent's interaction and their sometimes contrary opinions can reveal new theoretical and practical implications to think about. Moreover, the interviewees spur each other to develop and discuss new ideas. Analogically, in usability test sessions a method is used in which two participants are invited to participate simultaneously, interacting with each other. This is also known under the terms *co-discovery method* and *constructive interaction* (Beier & von Gizycki, 2002). In contrast to a focus group, the *Joint Interview Method* avoids biasing group dynamics. One or two dominant group members can control the topic selection which leads to less varied suggestions (Frieling & Sonntag, 1999). Besides, group cohesion makes it hard for one person to have a different opinion on a topic and to express elaborated thoughts about it (Fern, 2001). Therefore, joint interviews offer a rather balanced discussion between two interviewees in which less dominant participants can express their ideas freely.

3 Applying the Joint Interview Method

In order to develop a wearable warning system to support a human operator performing industrial maintenance, this research project used the *Usability Engineering Lifecycle* from Mayhew (1999) which suggests an iterative design process and intensive user involvement. As explained in chapter 2.1, the user-centered approach becomes even more important when designing wearable technology. To choose and implement the appropriate usability method, several aspects have to be considered. As mentioned in chapter 2.2, one should carefully determine how advanced the prototype has to be and how to test its physical appearance. Another crucial aspect is, as mentioned in chapter 2.3, to choose the appropriate form of user involvement to get as much feedback and suggestions as possible, but also to work efficiently and avoid undesirable side effects, e.g. opinion leadership (Frieling & Sonntag, 1999).

Before describing how the *Joint Interview Method* was applied for designing a second version of a wearable warning system, chapter 3.1 briefly introduces the previous prototype which was developed in form of a warning glove.

3.1 Status Quo – The First Version of the Warning Glove

The research project's purpose is to develop a warning system that supports a human operator and reduces human error during maintenance tasks in industrial settings.

Conventional warning systems which are directly attached to a machine often suffer from a lack of what we refer to as *action-specificity*, as signals are not clearly related to the operator's actions and with that do not provide specific instructions to prevent further errors. Furthermore, these warnings are usually given visually and auditory (Wogalter, 2006) excluding the haptic perception.

This research project attempts to avoid both problems by designing a wearable warning system that fits stimulus-response compatibility more appropriately and effectively. Thus, by combining both action-specificity and multimodality including the haptic sense a warning glove was designed and tested against a conventional warning system (Schmuntzsch, Sturm & Rötting, 2012; Schmuntzsch & Feldhaus, 2013). Aiming to minimize body-movement restrictions and maintain natural performance, the first prototype was a glove for the right hand with free fingertips. To directly present multimodal warnings on the glove before or while an operating error took place several electronic devices were attached. Following the given definition of wearable technology and smart clothing from Barfield et al. (2001), as stated in chapter 2.1, the designed warning glove would rather be classified as wearable technology than smart clothing. For transmitting visual warnings, two LED stripes with three red LEDs each were attached. Auditory warnings were given through a small speaker. For tactile warnings two vibrating elements were used. The electronic devices were controlled by an Arduino microcontroller using a wireless XBee connection (Fig 1).

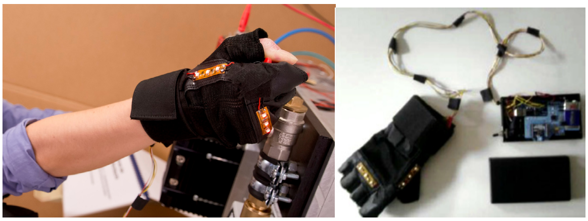

Fig. 1. Warning glove with multimodal devices (left) and glove with Arduino microcontroller and XBee receiver (right)

Using the warning glove, both quantitative and qualitative data was collected in the first study in which the prototype was tested against a conventional warning system. Generally, the warning glove has proven to be an appropriate support to a human operator performing an industrial maintenance task. A trend was observed for reaction times: individuals wearing the warning glove tended to respond quicker to warnings than when using the conventional warning system. This effect was especially commented on tactile and auditory signals. Qualitative interviews revealed that the majority of respondents preferred receiving warnings from the warning glove. However, due to its rigid components which were more attached than incorporated participants mentioned comfort as the main aspect to improve and their feedback clearly gave direction to smart clothing.

Before developing the second version of a wearable warning system another round of iterative user involvement was scheduled to ensure that the new prototype will meet user's requirements. Therefore, due to the benefits mentioned in chapter 2.3, the *Joint Interview Method* was chosen and implemented.

3.2 Research Design and Implementation

To explore the potential of wearables used as warning systems and to seek for user's needs while working with them, a human factors specialist with a psychology background conducted five semi-structured joint interviews. For an effective pairing, the ten participants were selected in consideration of their academic background: One having a social science background, e.g. psychology or cognitive science, the other having a technical background, e.g. mechanical engineering or computer sciences. Merging these differing perspectives, the joint interviews were expected to profit from synergy effects in two respects: First, it should allow for an observation of two different perspectives at once (i.e. one implementation-oriented perspective focused on the technological capabilities and the other user-oriented perspective focused on human perception and information processing). Second, while interacting with each other, the interviewees should inspire each other, building on topics and ideas raised by each other and so stimulating each other's imagination.

During the joint interviews, participants were able to see and touch components and materials which were considered to be used. This permitted the interviewees to develop an accurate impression about the technical components and materials used, to encourage their imagination and to express themselves by pointing at materials.

The interview started with a short introduction of the topic, presenting a maintenance scenario as a possible use case, the first warning glove prototype, and possible components for the new prototype (e.g. OLED-display, warning lights, speaker). Guiding through the conversation, the interviewer asked questions from a set of 15 open-ended questions. The initial topics covered a wide range of aspects such as:

- Possible areas of application and user acceptance (e.g. "In which field of work do you consider the warning glove as a reasonable work support?")
- Specific aspects referring to the wearable's design (e.g. "Can you think of a different wearable fulfilling the same or similar functions?")
- Specific aspects regarding the warnings' characteristics such as the length of warning signals (e.g. "How long should the signal continue?") and the use of word-based warnings versus warning symbols (e.g. "Would you prefer keywords or warning symbols on a display?" and "What sort of keyword would you wish for?").

Starting from a general perspective, participants had the chance to become acquainted with the topic and to develop a mindset including possibilities of wearables in an industrial context before specific characteristics were addressed. Furthermore, the interaction between the interviewees was encouraged by further questions based on previous answers. The semi-structured manner of the interview allowed for a certain level of standardization and subsequent comparability among the answers. Alternatively, there was enough flexibility for the interviewer to explore interesting aspects of the discussion in more detail.

All interviews were video-taped and analyzed. Reoccurring suggestions and differing opinions were summarized. The interviewing time was one hour at most.

4 Results

4.1 Participants

The sample consisted of ten participants (N=10, mean age = 24.8 years, range in age = 23 - 29 years; 6 male and 4 female). All participants were human factors students from the Technische Universität Berlin, either with a bachelor's degree in psychology or in engineering. Participants were recruited by advertisements to the general campus as well as on an internet platform accessible for human factor students. As part of required student assignments, students got credits for participation.

4.2 Findings of the Joint Interview

The findings were rich in content and contrast. Opinions ranged from total rejection to enthusiastic opinions. Of the vast amount of insights which could be gathered, only a certain amount can be mentioned in here. Several theories which should be considered while designing a wearable warning system were mentioned by the participants, e.g. the *stimulus-response compatibility* (e.g. Kornblum & Lee, 1995), the *proximity compatibility principle* (e.g. Wickens & Carswell, 1995), the *cry wolf effect* (e.g. Breznitz, 2013) and the *theory of prospective memory* (e.g. McDaniel & Einstein, 2007). To illustrate the dyadic discussion, the prospective memory was referred to when a rather technical-driven participant mentioned a reminder function build in the glove. His fellow interviewee pointed out that this would support the prospective memory leading to a conclusion that a good application for the warning glove would be given in tasks in which many subtasks are included.

In general, a majority of participants stressed the importance of the task nature. In their opinion a wearable could support a user either when the task has to be done in irregular intervals or when the task is new and the user needs support in his or her learning process (e.g. if the user is an apprentice). Especially, if the task consists of several subtasks a long learning process could be reduced. A recurrent topic was sensors capable of broadening the sensory input of humans and hence the user's perception. Participants suggested perception of magnetic and electric fields, a camera (e.g. an endoscope) attached to the tip of a finger as well as a sensor for heat and weight.

According to the participants, the glove would need to be reliable in order to avoid negative effects such as the *cry wolf phenomenon* (Breznitz, 2013). Furthermore, participants wished for positive feedback. An analogy was drawn between the glove and a build-in car parking assistance: Here, it can be seen how easily people adapt to support signals and use these signals but at the same time why the signals have to be reliable. This marks that a certain routine is important to work efficiently with the warning system. Due to this routine and the immediate feedback, a participant with a rather theoretical background inferred that a consistency between error signals and error-prone situations would assist users to develop a certain sensibility for adverse situations. To conclude the interviewees saw two main opportunities to use the warning glove: First, to use it as an instructional tool and second, to use it as a warning system.

Asked about possible combinations of wearables, one third of the participants asked for data glasses (e.g. *Google glasses*) as well as for earphones to complete the warning glove support. Combined with glasses, the human perception could be enriched with additional data displayed as augmented reality. Participants who asked for earphones thought about sound signals which would only be heard by the user and not by his or her surroundings.

If a glove is already part of protective clothing, a warning glove was considered perfectly feasible. If not so, the majority would prefer for a warning collar in order to have a high degree of freedom in hand action. Maximal closeness to the operator's hand was demanded to fulfil the proximity compatibility principle. This principle states that warning signs and displays showing warning information should be placed together close to the origin of the warning (Wickens & Carswell, 1995).

The major advantage reported by nine out of ten participants is the haptic feedback. Perceived as beneficial is the anonymity especially if several operators are in the surroundings. Additionally, the direct and body-related feedback was emphasized. Moreover, four out of ten interviewees favored a display for a new wearable warning system by. The display should be bigger than the one (0.96") shown as a possible component and if possible it should be a flexible and moveable OLED-display. If the display has to have a fixed positioning than the majority rather preferred a positioning analogically to a watch than on the back of one's hand.

4.3 Insights of the Following Design Process

Generally, the inclusion of the *Joint Interview Method* in the design process of a wearable warning system can be considered beneficial. Due to the participants' discussions new insights were gathered and especially their interaction revealed synergy effects. Furthermore, presenting the maintenance task, the first warning prototype and possible materials for the second version has proven to be stimulating participant's imagination. Many of the ideas gathered in the joint interview were easily applicable.

As mentioned in 4.2, participants asked for a bigger flexible, moveable OLED-display. Due to the still ongoing development of flexible displays and the risks as well as the costs involved in this, a conventional – meaning an inflexible – OLED-display was selected. Nevertheless, the display was exchanged to a 1.5"-display and a watch-like positioning was chosen. The amount of used fabric was decreased. To assure a high degree of hand flexibility, the idea of glove was withdrawn and, as the majority wished for, the idea of a collar was realized. Here, participants asked for a watch-like dimension. Although a high fidelity prototype with microcontrollers was our aim, technical and temporal limitations led to the development of an arm collar with 13cm in width. These microcontrollers are part of the Arduino LilyPad series which are designed for wearables. The idea of additional sensors was not realized since the project focuses on investigating how to design more action-specific warnings and not on the detection of human errors. For positive feedback, green LEDs were integrated next to the yellow and red LEDs for warnings. The warning collar is shown in Fig. 2.

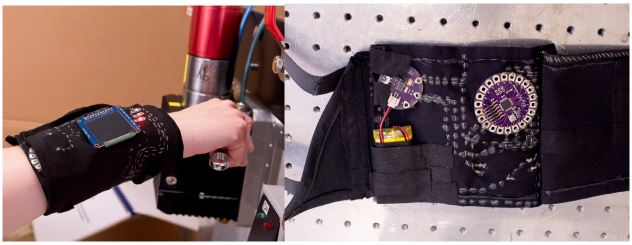

Fig. 2. Warning collar with multimodal devices (left) and the inside of the collar with Arduino LilyPad microcontroller and lithium polymer batteries (right)

5 Discussion

Driven by the project's goal to support human operators while performing maintenance tasks in industrial facilities, a wearable warning system in form of a warning glove was developed and tested. Based on the *Usability Engineering Lifecycle* from Mayhew (1999) this wearable warning system was improved after the consideration of user's feedback. To ensure that the second prototype would meet user's requirements the *Joint Interview Method* was chosen and implemented. Using that method, this paper presents a promising usability method which allows addressing the crucial issue of designing wearable technology and evaluating its user acceptance, a topic also raised at the CES 2014.

In view of the process and its results, applying the *Joint Interview Method*, the project's aim – to create synergy effects – was achieved. First, synergy effects were created by simply interviewing two participants at once. Second, synergy effects also emerged due to the effective pairing of participants one having a rather technical-oriented background and the other one having a psychological background.

According to the first aspect mentioned, having two participants turned the interview more into a dialog between two interviewees rather than a direct face-to-face questioning between one interviewer and one respondent. The interview's atmosphere became more relaxed and both participants stimulated each other so that one idea led to another. Comparing the *Joint Interview Method* with a normal interview, another advantage of the *Joint Interview Method* was found to be timing. While one participant was talking the other one could reflect about the topic profoundly. This led to both a deeper comprehension as well as to more sophisticated ideas regarding the further development of the prototype. Comparing the *Joint Interview Method* with a focus group in which five participants are asked for their opinions at once, a joint interview is less demanding for the interviewer and allows responding individually to each interviewee without strain. Moreover, negative side effects of focus groups such as opinion leadership can be avoided. However, in one of the five joint interview sessions this problem also evolved since one of the interviewees was extremely dominant. In order to equalize the contributions the interviewer then explicitly asked the more silent participant first. With an eye to the participants of a focus group, the situation can be exhausting and frustrating since individuals have to wait for their turn to express their thoughts, while in the meantime the discussion might have already taken another direction. This may result in unexpressed ideas and less active involvement of some individuals. Thus, applying the *Joint Interview Method* facilitates tapping into the individual potential of each interviewee.

According to the second aspect mentioned, interviewing one implementation-oriented participant, focused on the technological capabilities and one user-oriented participant, focused on human perception and information processing allowed for an observation of two different perspectives at once. This led to a combination of theoretical and practical ideas which again complemented each other. Thereby, different roles could be observed: the implementation-oriented participant mostly took the practical part and created lots of ideas whereas the user-oriented one brought in a kind of theoretical skepticism and tried to get to the bottom of the ideas. This in turn sparked new thinking processes and led to more sophisticated concepts expressed by the implementation-oriented participant. In contrast, sometimes the user-oriented participant also underpinned the technical ideas with psychological concepts and developed them further. However, during one session one participant's extreme dominance led to the situation that despite the subtle counteraction of the interviewer the other more psychological-oriented participant secluded herself. Thus, the dialog turned into a monolog and with that the more pragmatic technical-oriented opinion leadership prevailed. Later on, the interviewer tried to balance the dialog, as mentioned above, by asking the rather quiet participant first. However, such a dominant form of opinion leadership happened only once whereas the other interviews were characterized by a balanced and varied dialog.

All in all, it can be stated that the *Joint Interview Method* is helpful for creating synergy effects and supports a user-centered design approach to develop wearables. Although the sample was not representative since all participants were human factors students and thus trained to cooperate interdisciplinary in contexts of human-machine-interaction, the *Joint Interview Method* is considered to be also beneficial in other constellations. Here, participants must be paired effectively and have to be sensitized for interdisciplinary collaboration. Moreover, from our experiences, in order to successfully apply the *Joint Interview Method* it is important to bear certain things in mind: The interviewer must be well-trained and prepared for this task which includes being practiced in interview techniques as well as being aware of group dynamic processes and different personality traits. Furthermore, the interviewer should be open for any directions the interviewees might take even though they wander off the point. During the interviews it became apparent that participants found their way back to the topic without the interviewer's intervention. In fact, it seemed that this deviation led to a deeper understanding and to a development of more sophisticated ideas. Apart from digression the interviewer should also be tolerant if somebody has a calmer mood or says nothing to one or the other aspect.

With regard to promoting the user-centered design of wearables, the *Joint Interview Method* offers a particularly great opportunity for early user involvement. Since physical appearance and touch is of immense importance for wearables, it is highly recommended to not only show paper pencil prototypes but also basic materials such as fabrics and technical components, e.g. OLEDs, speakers and vibrating elements. Because the maintenance scenario, the first warning glove and the materials possible for the second prototype were presented to the participants, the participants were able to develop a certain understanding of the innovative topic “wearable warning systems”. As a result, more sophisticated ideas for the second prototype in form of a collar evolved.

6 Conclusion

To sum up, this paper presented and discussed the *Joint Interview Method* as a promising usability approach for designing wearables and evaluating user acceptance. Therefore, the method was used to exemplarily enhance a wearable warning system whose first prototype was a glove whereas the second version turned into a more sophisticated collar. Since one interviewer questions not only one but two interviewees this method facilitates a relaxed and stimulating dialog. Thereby, synergy effects automatically evolve as an inherent part of the *Joint Interview Method* due to the explorative and dyadic character. Finally, from our experiences, applying the *Joint Interview Method* in the design process of wearables can be highly recommended.

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