Requirements Elicitation and Utilization Scenarios for In-Car Use of Wearable Devices

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Abstract

With the increasing popularity of wearable technology, companies have been evaluating if wearable devices are relevant to them. In the context of a project in the automotive industry, we set out to assess user requirements for successful application of wearable devices in connection with the vehicle. In order to identify user requirements relevant for our research, we (1) reviewed existing literature to extract requirements already discovered in previous research; (2) we conducted a market analysis in order to gain an overview on functionalities and use cases of current wearable devices; (3) we developed customer journeys as a tool for the focus group and the development of utilization scenarios; (4) we tested our findings in a focus group, and (5) developed five utilization scenarios for in-car use of wearable devices. Results show that key requirements for users are contextual intelligence, making use of sensory input and connectivity, anticipation of user needs, unobtrusiveness, and compatibility with other devices and operating systems.

1. Introduction

Wearable devices are not a recent development, but belong to the concept of ubiquitous computing, a term coined by Mark Weiser in 1988, meaning that technology will increasingly fade into the background and disappear [40]. Wearable technology facilitates a new form of human-computer interaction for being always on and readily accessible [22].

Even though wearable technology is a popular topic in the current discussion, we notice that there are different ideas on the definition of wearable devices. For our research we propose the following definition of wearable technology:

Firstly, as it is evident from the name, one defining feature of wearable devices is that they seamlessly integrate with the user's outfit [5]. This characteristic distinguishes them from smartphones: Wearable devices are *worn on the body*, as opposed to being carried.

Secondly, since devices are worn on the body, they can collect information that usually cannot be accessed in another way, for example measure the user's heart rate, or access data through gyroscope or accelerometer. Wearable devices allow for *sensory input* [23].

Thirdly, wearable technology does not function solely on its own, but it must be connected and communicate its information to the user, either on a display or via connection to an internet platform. This does not necessarily happen at the time of usage, a connection can also be established after use. Wearable devices are *connected*.

Lastly we added another characteristic which is important in the specific context of our research. Looking at devices available in the market, we find intelligent devices that fit the characteristics defined, but have been developed for a specific use case only and are only available for a specific, pre-defined target group. Therefore we exclude devices that serve a highly specialized (e.g. medical or military) purpose only. Which brings us to our last defining characteristic: Wearable devices serve *multiple purposes*.

Only recently has wearable technology become increasingly popular and moved from niche product to mainstream. More and more devices are entering the market and contain advanced sensors and features. The success of consumer devices in the fitness and wellness sector is having a strong impact on vendors[43], with one in 10 US-Americans over 18 years old owning an activity tracker [20]. The worldwide revenue is said to increase from $1.6bn this year to $5bn by 2016 [34]. According to the Gartner Hype Cycle for Emerging Technologies 2013 [13], wearable technology is currently classified at the "Peak of Inflated Expectations". Considering the strong growth in the consumer sector, we expect wearable technology to have an impact on business use cases as well. Recently we have seen business

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applications of wearable devices in industrial [25] and healthcare settings [23,26].

In the past years automotive manufacturers have developed various possibilities to connect the mobile phone with the vehicle in order to enhance the driving experience, give information on the vehicle as well as on the surroundings or allow for communication and entertainment. The "connected car" that is linked with the user or external objects and allows for data exchange, communication and new ways of interaction has been a trending topic in the industry for some time [17]. Therefore, wearable devices are particularly interesting for the industry, since they interact with users in a more subtle way and can be operated with minimal cognitive effort [5]. Other trending topics for wearable devices in the automotive industry include gesture control, gaze control or biometric driver identification [17].

This research is based on a project within the automotive industry, conducted between February and May 2014. Our client posed the question, "what role will wearable devices play in the future and in what way they will be important for service design and business models?" Therefore, we set out to explore basic user requirements that wearable devices need to fulfill before specific products and services can be developed. Based on user feedback, we defined possible utilization scenarios for the application of wearable devices in the vehicle. As wearable technology is a rising topic at the moment with no obvious business case and clearly defined use case from our client's side, the initial high-level requirements may serve as an indicator for potential market acceptance of various applications. It is acknowledged that initial requirements of users need to be concretized first – which constitutes the goal level – before defining requirements on a system level and functional level [3,15,19]. This research may also serve as groundwork for other researchers that investigate concrete requirements for more specific products or services. Since the initial requirements are high-level, we consider the results to be transferable to other industries as well.

We structure this research paper as follows: After stating our research question and describing our research approach in section 2, we summarize the findings in section 3, following the clusters we identified in the literature review. In section 4 we present the utilization scenarios that we defined from our research. We discuss our results in section 5 and some limitations of our research in section 6. Finally, section 7 covers the conclusion of our research as well as an outlook on possible future work.

2. Research Design

For our automotive study we propose the following guiding question: What are user requirements for wearable technology applications and what are possible scenarios where wearable technology can be used as an added value in connection with the vehicle?

The success of an information system depends to a great part on its fit to the user requirements [8]. In order to facilitate user adoption of wearable devices and services that are enabled by wearable technology there needs to be a clear understanding of user needs and constraints. The subject of requirements engineering is concerned with translating real-world observations into a set of specific requirements [42].

Since the aim of this research is not to design a specific service, but to gain a broader view on the potential of wearable devices, we do not apply the full requirements engineering process [27]. Instead, we focus on requirements elicitation [44] that reveals the needs of stakeholders [16]. To achieve a valid list as a result, we are combining different methods and not only rely on asking potential users of these systems [38].

Also, by combining several research methods we are covering two different perspectives on innovation: technology push, where the innovation comes from the desire to make use of existing technological knowledge, and market pull, where innovation comes from the demand of customer needs [35].

2.1 Existing Research

As a first step we conducted a literature review in order to present a representative overview of existing research on user requirements for wearable technology. Defining the scope of the literature review we applied the taxonomy of Cooper [9].

Table 1: Taxonomy of literature review according to Cooper [9]

Characteristic		Categorization
1	Focus	Research outcomes
2	Goal	Integration, Identification of central issues
3	Perspective	Neutral
4	Coverage	Representative
5	Organization	Conceptual
6	Audience	Specialized researchers, general researchers, practitioners

We searched for publications that contain the search terms “wearable” and “user requirements”. The search was limited to scholarly and peer-reviewed publications in order to ensure quality of the selected publications. We applied this search string to the following databases in order to achieve exhaustiveness in our research and to cover all top journals: *EBSCOhost, AIS Electronic Library, JSTOR, Emerald Insight, IEEE Xplore,* and *Springer Link*. This search yielded 85 results, in total of which twelve publications proved to be relevant to our research objective. We took a concept-centric approach [39] and extracted all requirements mentioned in these articles and clustered them into groups of similar factors.

As a result from this analysis, we will be using the requirement clusters “physical form”, “interaction design”, “functional features” and “intelligence” as guiding categories for our requirements elicitation.

2.2 Market Analysis

We conducted a market analysis in order to gain an overview of devices available in the market, their fields of application and capabilities. This step should allow us to gain insight on the technology-push perspective and assess capabilities of wearable devices available on the market**.**

As a base for our research we used the database of Vancouver-based consultancy Vandrico [45], which – to our knowledge – provides the most exhaustive overview on current wearable devices, with at that time around 220 devices [21]. Applying our definition of wearable technology, 136 devices remained for analysis. For all devices we gathered information on the following criteria: physical form, connectivity, compatibility, market focus, price, and sensor technology.

2.3 Customer Journeys

As a second step we developed customer journeys based on available material of customers and our own experiences. The customer journey clusters multiple use cases, customer actions, and needs into a scenario [7]. We used these customer journeys in order to identify relevant situations where wearable technology can enhance the driving experience and hence as a structured method to create the utilization scenarios. Furthermore the customer journeys were used in the focus group as a tool to collect insights on current driving behavior as well as to communicate the requirements. In this early and interactive phase of the requirements process, it showed that a higher degree of formality in requirements specification was not required [41]. This step shifts our perspective to the market-pull, focusing on demands of the user**.**

We created three customer journeys for the most critical use cases when interacting with a car. The first was the journey of a family, using a car for their daily activities in a known environment. The second was a business user, who needs a car for business and long-distance travel. The third journey was focusing on vacation by car, so having to drive in an unknown neighborhood. These journeys were signed-off by our client stakeholders. Based on the results of the market analysis and of the customer journey, five scenarios were developed.

2.4 Focus Group

In a third step, we presented and discussed the customer journeys and the scenarios in a focus group. The focus groups have proven to be a valuable method, which allows for gaining rich, in-depth insights into user needs [4,18] through group-based discussion and reflection [12].

We required participants (n=6) to own a car, use a company car or use car-sharing services on a regular basis. Age groups and genders were mixed. For this initial gathering of ideas, participants were required to own a smartphone and use it on a regular basis, since we assumed that rather tech-savvy users would be more interested in giving feedback and it would be easier for them to imagine scenarios where they would use a wearable device.

In a first step the customer journeys were presented and discussed with the participants. The participants were asked to add situations that were difficult for them when driving. At this point we were requiring the participants to reflect on past and current behavior and not think about future use cases. In a second step the initial ideas for utilization scenarios were presented. The participants were asked to criticize these ideas, explain their doubts and consent and add new ideas.

The three-hour discussion was facilitated by an experienced moderator. We used a rough question guideline which outlined the key questions but the exact question technique was subject to the interviewer’s facilitation. During the session, all results were collected and clustered on notes on a wall. Thus all items being discussed were visible for all participants. The focus group was also documented by a note taker who collected quotations and emotions from the participants. After the session we took the result clusters that the group agreed on from the notes and complemented them with the codes derived from the detailed session minutes.

3. Findings

This section presents our findings from the different phases of our research summarized in the clusters “physical form”, “interaction design”, “functional features” and “intelligence” that were deducted from the literature review.

3.1. Physical Form

Regarding the *physical form,* existing literature states that wearable devices need to allow for hands-free usage, since they are required to be used in a mobile context or while the user is in motion [2,7,37]. Also, the design of the hardware should provide for portability, comfort and unobtrusiveness [26,30].

The market analysis showed that the prevailing physical form of wearable devices is a wristband or smart watch. More than 60 percent of the devices analyzed belong to this category. This indicates that the wrist is a common position for wearable devices. Therefore it can be assumed that these devices have a higher maturity than others. Our analysis also showed that other physical forms are often used for very specialized devices.

Focus group participants showed a strong preference towards inconspicuously looking devices. However, participants saw great potential in smart glasses, for the ability to display information within the range of vision and therefore provide an added value over the smartphone:

„Google Glass would be a potential game changer for me, because information is better displayed.” (Male user, age 21-30)

Participants also mentioned the importance of the device looking fashionable and being something that can be worn with proud:

“A gadget can also be a status symbol. Like the car key of a Porsche.” (Male user, age 31-40).

Summarizing the requirements regarding the physical form of the hardware we state that wearable devices should be unobtrusive and not interfere with the actual task that the user is carrying out. The hardware should have a beautiful and fashionable design, to be socially accepted or enhance the user’s status.

3.2. Interaction design

In terms of *interaction design*, the existing research states that wearable devices need to offer good usability in its interface design and require minimal cognitive load to use [2,6,24,30,32]. Interaction with the device should not interfere with the original task that the user needs to carry out [2].

Users confirmed that it is extremely important that interaction with the devices should not require too much cognitive load. Since wearable devices will be used either in movement or in constantly changing contexts, they need to be controllable even in multi-tasking situations. One of the users in the focus group observed this in a driving situation:

“I thought when driving I could at the same time dictate my reports to an audio recorder and have my assistant type it afterwards. However, then I noticed that I was always using the same words when I was busy driving and I stopped doing this.” (Male user, age 51-60).

Wearable devices have an advantage over the smartphone, since the position on the body allows them to give direct, tactile feedback and they do not rely on the user directly looking on the device.

“Discreet feedback is better than having to pull out your phone every time.” (Male user, age 21-30)

Besides these aspects, it also played an important role for users that the device was enjoyable and fun to interact with. This becomes even more relevant in facilitating continuous use of the system.

“I love gadgets, but I usually lose interest quickly.” (Female user, 21-30)

Many wearable devices available on the market do not have a display but function in connection with the smartphone. Therefore, we analyzed the connectivity of wearable devices in order to understand how well this works for users. The analysis of connectivity showed that twelve percent of devices are standalone devices, while 45 percent work in connection with the smartphone and 43 percent allow for both standalone and connected functionality. We draw the conclusion that wearable devices that are connected can profit from existing smartphone apps, for example display notifications on the wristband that usually are only visible on the smartphone. Also, users are already familiar with the interaction with a smartphone and therefore do not require getting used to a new system.

However, in the focus group, participants resented changing between different devices within the same usage situation. This requires too much effort and interrupts the user experience.

“For me a wearable solution should be integrated, so I don’t need any further interaction.”(Male user, age 51-60)

Summarizing the requirements on interaction design, we state that wearable devices should require minimal cognitive load, allow communication through tactile or audio feedback instead or in addition to visual cues, they should be enjoyable and fun to use and allow for both standalone use and connection with a smartphone.

3.3. Functional features

Regarding *functional features,* the existing literature states that users demand devices to offer some kind of communication functionality or the ability to retrieve information [7,14,23,31]. Other important factors are good performance and sufficient battery life [1,30,31].

In terms of functional features, our research focused on the advantage that wearable devices have over smartphones. For the users of the focus group, this was the availability of one or multiple sensors. Sensory input allows the user to collect information that was not available previously. With the wearable device this data can now be used in a variety of use cases, such as preventing accidents, emergency situations or entertainment.

"The wearable device can collect my vital data. For example, it can alert me, when I'm not concentrated while driving." (Female user, age 21-30).

Our market analysis showed that more than 50 percent of wearable devices contain a maximum of two sensors. Sensory input is important, since it allows for innovative use cases. The sensor technologies that are most commonly used in today's wearable devices are accelerometer and gyroscope. Devices can also offer more advanced health sensors, like measuring heart rate, sweat or oxygen saturation.

It also became clear that wearable devices should be compatible to existing operating systems, so users are not required to adapt to different systems and can incorporate wearable devices easily in their existing ecosystems.

Regarding the range of available features, the users showed a strong preference towards multi-purpose devices. Wearable devices with a very limited functionality were assumed to be easier to use, however, users reject the idea of having to carry multiple devices. From today's smartphones, participants are used to the convenience of having one device, which services multiple use cases.

"It could be very important to create an "all-in-one solution". It also should be open for interfaces and several operating systems." (Female user, age 31-40)

We state that in order to be accepted by users, wearable devices should offer sensory input, since users perceive this currently as the key distinctive feature over smartphones. Also, devices should be compatible to other existing operating systems, and aim for multiple purposes.

3.4. Intelligence

Lastly, users require wearable devices to offer some kind of *intelligence*. In the existing research we found various factors regarding intelligent features, since wearable devices apply to a variety of use situations, and therefore these devices need to provide context-awareness and react to changing situations and usage scenarios [1,7,14,24,31,37].

The fact that wearable devices allow for both sensory input and connectivity enables them to interact with the environment. This characteristic is not exclusive for wearable devices, but applies to modern mobile devices as well [29,33]. Since wearable devices are used in mobility and in various changing contexts, participants expect that the device reacts to the context and provides respective information.

"I have a very long to-do list. So it would help me to know when I am driving, if there is anything on the way, I can do next. For example drop off my glass garbage around the corner." (Female user, age 51-60)

Also in terms of communication the device should provide the possibility for smart or personalized information. The wearable device is a personal device, which possesses access to a variety of information, such as the user's calendar, location or messages and can therefore offer information based on the personal preferences of the user. Focus group participants mentioned that, for example, when driving, not everybody present in the car should be aware of alerts or notifications.

„SMS should not be read out loud. Do I really want everybody in the car to hear what somebody is texting me?" (Female user, age 31-40)

Therefore the wearable device should be able to communicate in a secretive way or even use codes, which only the owner of the device can interpret.

"Maybe a bracelet that changes color, but only I know what that means." (Female user, age 31-40).

Another requirement for users is that the device needs to push information intelligently and depending on the context, in order to reduce information overload for the user.

„When every bit of information is available for the device, I would need it to be proactive and push information to me." (Female user, age 31-40)

From our experience in the focus group, this capability produced some of the strongest positive reactions among the group. Therefore, we add the requirements of contextual intelligence, personalization and anticipation of user needs for wearable devices.

3.5. Summary of Findings

Our results take into account the various findings from the literature review, the market analysis, the customer journey and the user discussion in our focus group session. We found that the discussion of users was in accordance with the findings from the literature review and market analysis. In summary, we provide the following consolidated list of findings:

Table 2: Consolidated Findings

	Requirement	Description
Physical form	Unobtrusiveness	Must not interfere with other tasks carried out simultaneously. In an in-car scenario it must not interfere with driving activities. If it is to be used in movement, it should be easily portable allow for hands-free usage.
	Beauty	The device should look fashionable so users enjoy wearing it. It should be enjoyable and fun to use.
Interaction design	Intuition	Interaction with the device should require minimal cognitive load. The device should allow for intuitive input mechanisms, e.g. audio and / or tactile feedback instead / in addition to visual cues.
	Connectivity	The device should be able to be used both in connection with smartphone as well as standalone use. In an in-car scenario the device should be able to connect to the vehicle and access as well as display data.
Functional features	Sensory input	The device should contain one or multiple sensors, which allow for information that the user normally does not have access to.
	Compatibility	The device should use known operating systems and common standards. It should be easy to integrate into an existing device ecosystem.
	Multi-purpose capability	The device must be used in multiple different contexts. It should not only be dedicated to a single purpose.
Intellig ence	Contextual intelligence	It should provide intelligent information based on the current context of the user. The information should be displayed according to changing situations. Functionalities should be offered according to the current context.
	Personalization	Available information on the user should be used for smart and personalized recommendations. Information should be filtered according to personal preferences.
	Anticipation of user needs	Information should rather be pushed to the user than have the user ask for a specific information himself.

4. Utilization Scenarios

Based on the market analysis and on the customer journeys, the researcher team defined the following scenarios, where wearable devices could be used in connection with the vehicle. These scenarios were presented in the focus group and the participants were asked to critically assess them, add further needs and state whether these were plausible use cases for them. All scenarios were confirmed by the participants of the focus group.

The first scenario is focusing on *authenticating the driver* through a wearable device in order to open the vehicle. This addresses the pain point of users that car keys are easily lost or hidden. Keyless entry is being used by some manufacturers; however, if the authentication token is worn on the body, it is less likely to be lost. Preferred devices would be a wristband or a smart ring. Besides opening the vehicle, users imagined that it would be convenient to automatically adjust the preferred seat position, and temperature settings.

The second scenario deals with assessing vital information in emergency situations or in order to *monitor the physical conditions* of the user while driving. Smart devices like wristbands could access the driver's heart rate or body temperature and based on this data release a warning when the driver becomes tired, agitated or too sick to drive a vehicle.

The third scenario describes how wearable devices can be used for *interacting with the vehicle interface*. As more and more technology is embedded in the vehicle, interaction will be increasingly complex. While in motion the driver should focus on the traffic and not be distracted by in-car systems. Therefore users imagine that using gestures will be easier than different controls.

The fourth scenario revolves around *projecting information as augmented reality* within the vehicle. Smart glasses could be used to display navigation information or points of interest within the driver's field of vision while in motion. Also, this could be used to display interaction controls the user can interact with through touch instead of using the in-car controls. Another example would be a tutorial on how to use in-car controls, which users thought to be useful when driving a new vehicle for the first time, for example a rental car.

As the focus group discussion evolved, we noticed that the users added use cases, where the wearable device would serve as medium to interact with external devices. Therefore, we expanded the predefined set with another scenario. Besides interacting with the car interface, for users it can be also important to *interact with connected objects*, possibly also through the use of wearable devices. This became evident from the example that "parking" was named by the users as one of the most difficult situations when driving. In this case the users imagined that the wearable device could exchange data with other devices in the city and thus detect, if another driver close by is leaving a parking spot available. This example shows that not only in-car information is important to the user, but also – if not to an even greater extent – external information on the environment, which could be made available through the exchange of data between connected objects, such as wearable devices.

5. Discussion

While the findings show that wearable devices provide some advantages over smartphones and we have seen in our analysis that wearable devices gained a lot of momentum recently, the diffusion has not reached critical mass yet and only early adopters are reached [28].

According to the Technology Acceptance Model (TAM), variables that facilitate adoption for new technologies are *perceived usefulness* and *perceived ease of use* [10]. Regarding *perceived usefulness* we see that multi-purpose usage, openness and expandability and distinctive features compared to other devices can be important drivers for wearable devices. Drivers for the variable *perceived ease of use* are a platform or operating system, which is familiar to the user, an intuitive interaction design and improved solution on known pain points, such as weak battery life. We assume that devices offering these features will have an advantage in adoption. However, in particular with in-car usage it needs to be considered that ease of use can be a competing factor to security and can facilitate distraction. Therefore, when designing services that are supposed to be used in a safety-relevant context, there needs to be a careful balance between potentially distracting features while still ensuring superior usability.

Currently there are many different players in the market offering a wide range of devices. Looking at global smartphone sales, we see that in the past some market entries have had a disruptive impact on the market, with new players surpassing previously established vendors. The introduction of Android and the following decrease of Symbian and RIM can be stated as an example [36]. Therefore at this point it cannot be predicted which vendors or devices will provide the leading platform for the future. It has also shown that the key success factor is providing more than just a device, but an ecosystem that combines hardware, software and services.

We assume that in the midterm wearable devices will not be able to substitute the smartphone. However, regarding business use cases, there seem to be very specialized use cases where wearable devices can provide a measurable improvement to organizational workflows, for instance in industrial applications or in healthcare [23,25,26].

However, even if wearable devices will not take over the mass market, it is obvious that everyday devices will be increasingly connected anytime, anyplace and with anything [11]. Therefore, requirements discovered in this research are also valid for these future "internet of things" applications.

6. Limitations

This research provides a number of interesting insights into user requirements and possible utilization scenarios. Also, we have seen from our literature review that our findings conform to the findings of existing research, which proves their validity. However, our research does not present an exhaustive list of requirements, since the scope of research only covered a limited range of scenarios and the sample of users included in the focus group was reasonably small.

Focus groups with regular users always bear the risk that users cannot imagine use cases and functionalities that they do not know and therefore are not appropriate for idea generation. We mitigated this risk by asking users to explain their current driving behavior, needs and problems. After exploring these customer journeys we then introduced the utilization scenarios built by the researchers based on a review of existing literature and the market analysis. We think that using customer journeys as a frame and getting users to reflect past behavior first, helps them to think about actual needs rather than projecting their potential future behavior.

Therefore we recommend that further research use a combined approach with various qualitative methods in order to validate this list. Since the scenarios we created are solely based on user needs and have not undergone a proof of concept, we expect these findings to have an impact on the development of products or services and thus have our findings validated with testing data of a real prototype. Nevertheless we think that our findings not only apply to wearable devices, but may be transferrable to other connected objects as well and therefore our research forms a valuable contribution for practitioners as well as researchers in this field.

7. Conclusion and Outlook

In this paper we have researched user requirements for wearable devices and how they can be used in connection with the vehicle. In a literature review we identified physical form, interaction design, functionality and intelligence as important categories for requirements. We combined domain knowledge with user insights and conducted a market analysis on available wearable devices, created customer journeys as tool for the ideation phase and validated and expanded our results in a focus group discussion. As a result, we derived a set of user requirements describing desired qualities of wearable devices. Based on the user needs identified, we created utilization scenarios for wearable devices in connection with the vehicle. The scenarios cluster possible use cases for authentication, monitoring physical conditions, interaction with the vehicle, augmented reality and interacting with the environment.

Our future research activities will build on these requirements and validate them with further users in various scenarios. It will also be interesting to see how wearable devices can be used in an enterprise context and whether the same requirements also apply there. We are confident that further research will both confirm and expand our findings.

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