User Requirements for Digital Jewellery

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ABSTRACT

In recent years, wearable devices have been an emerging trend on the market. Though, recent studies show that people abandon their wearable devices after a couple of months. One of the main reasons supposed is the technical look and feel of the gadgety devices and thus, an insufficient suitability for daily use. Digital jewellery, the concept of concealing technology behind fashionable jewellery, is a promising approach to address this problem. However, little research has been done to clearly define the requirements for digital jewellery. In this work we present the design and results of an online survey, in which we investigated, which requirements are important for digital jewellery, and how important specific requirements are perceived by potential users. Overall, participants considered functionality, form factor, and interaction and display design as very important, whereas they found body location, context awareness and customisability less important. We also found differences in the importance ratings, that are related to gender and age. Our results will help designers of digital jewellery to focus not only on the right, but also on the more important requirements first.

CCS Concepts

•Human-centered computing → Ubiquitous computing; Personal digital assistants;

Keywords

Digital Jewellery, Wearable Computing, Requirements, Design

1. INTRODUCTION

Wearable devices have been an intensively researched field and, in recent years, also a growing trend on the market. Current application areas on the consumer market are fitness and wellness (e.g. activity trackers), and infotainment (e.g. smartwatches).

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Market researchers predict that the global wearable device market will grow about 4000% between 2012 and 2017 [11]. However, recent studies in the U.S. show that a third of owners of a wearable device abandon their device after six months. Supposed reasons are, e.g. a lack in useful functions for a broad range of people, aesthetics and comfort, and a too short battery life [11].

Digital jewellery has been proposed as an approach that could overcome the problem of abandonment and increase the long-term acceptance of wearable devices. The term describes the seamless integration of technology into jewellery [16]. Digital jewellery has been gaining a strong interest among potential users [18] and market researchers: "Wearable technology will be increasingly hidden behind stylish designs, that will have a wider appeal than the technology-forward gadgety devices in the market today." [11]. Few research tried to derive general guidelines for the design of wearable devices [6, 17, 9]. However, the requirements proposed so far are spread out between various specific evaluation and guideline reports and thus hardly to follow. It remains unclear, which requirements to address for which form factor, user, or use case, and which requirements are the most important and should be addressed first.

In this paper, we present the results of an online survey on user requirements for digital jewellery. We investigated, how important potential users considered specific requirements of digital jewellery. We found that there are differences in the perceived importance of different requirements of a digital jewel. We also found differences in the importance ratings, that are related to gender and age. Overall, participants considered functionality, form factor, and interaction and display design as very important, whereas they found body location, context awareness and customisability less important.

The contributions of this paper are as follows:

- We provide a ranking of requirements that helps designers of digital jewellery to focus on the - from a user perspective - more important aspects
- We highlight differences in the requirements for males and females, and differences in different age groups

The paper is structured as follows. After we give insights into the background of digital jewellery, we present the design and results of the survey. After discussing our findings, we conclude with a summary of insights, and the key contributions.

2. BACKGROUND

We see a *digital jewel* as a piece of jewellery that - besides being a fashionable accessory - offers one or more useful digital features. These could, e.g. be a reminder for regular fluid intake, a feedback tool on daily physical activity, or a notifier. The features are integrated decently, i.e. in a way that observers would not recognise the jewel as being more than just a fashionable accessory [4]. Unlike the definition of digital jewellery by Miner et al. [16], we see the jewel and not the technology as the base. This view is also proposed by Wallace et al., who stated that people identify with things they wear on their body and that therefore, aesthetic, comfort, but also behaviour and functionality are important aspects to consider when designing a digital jewel [20]. McCarthy et al. [14] take this up and argue that an enchanting technology like a digital jewel can make a user more willing to wear and to use it. The contemporary jeweller and researcher Kettley argues that craft as a creative process for the design of everyday wearable computers leads to products with more authenticity and less 'borg'-like aesthetics [10].

To investigate the design space and application areas for digital jewellery, Perrault et al. [18] conducted an online survey. They asked people about what kind of jewellery they wore, how much they were interested in various kinds of digital jewellery, and what kind of tasks they could imagine to use digital jewellery for. 79% of participants wore at least one piece of jewellery daily, whereas overall, wrist was the preferred location, followed by finger and neck. About 60% of participants were in general interested in digital jewellery. For participants wearing jewellery daily, this proportion rose to 74%. The most stated reasons for a lack of interest were the redundancy with smartphones, and the concern that integrating technology into a piece of jewel would compromise its decorative characteristic. Preferred tasks to use digital jewellery for, were playing music, reading and sending text messages, GPS navigation, and phoning.

Activity trackers are probably the widestly used wearable consumer devices today. Meyer et al. [15] investigated how users experience activity trackers in daily life. They found that visibly worn trackers are perceived as fashionable accessories, such as a watch or jewellery. As such, they must meet the user's needs for aesthetics and suitability for daily use. Companies have picked up on these needs and offer cases for common activity trackers that look like fashionable jewellery[1].

Previous work has investigated different kinds of information displays embedded into bracelets and smartwatches. The shimmering smartwatch concept uses a visual, but non-graphical display, embedded into a regular wristwatch, to present information in a more jewellery-like way [22]. Other research has put a focus on designing jewellery-like bracelets and rings to present everyday information. Ahde and Mikkonen [1] describe their vision of communicating spatial proximity of friends by using interactive light bracelets. Hansson and Ljungstrand [7] provide some ideas on how to use a bracelet for displaying calendar reminders in an unobtrusive way. Like Ahde and Mikkonen [1] they use single light spots to present information. Williams et al. [21] present a concept for displaying social network activity cues via LEDs on a fashionable bracelet. Another fashion-oriented light bracelet to promote a better drinking behaviour was developed by Fortmann et al. [3, 5]. A field evaluation confirmed that users appreciated its practical and discreet design. Lüers et al. [13] presented the Illuminated Ring. They evaluated the information presentation with different arrangements of single LEDs on a metallic finger ring. These LEDs should present feedback on daily fluid intake. Besides, fashion-oriented market products in form of watches (e.g. Motorola Moto 360[2]), bracelets (e.g. AH!QUA[3]), rings (e.g. Ringly[4]), and combined solutions (e.g. Misfit Shine[5], Cuff[6]) are available or announced.

Various research has been conducted that evaluated wearable devices to gain a further understanding of the requirements and design space for wearable devices. Mostly, investigations have been done for specific applications and specific display concepts of wearables [3, 12, 2]. Few research tried to derive general guidelines for the design of wearable devices. These strongly focus on specific aspects, such as wearability [6], and touch input [9], or are formulated on a more general level addressing aspects, such as context awareness, appearance and affordance [19, 17]. When we aggregate all the different suggestions for improvement and defined requirements, this forms a long and unfocused list of requirements. For a designer, addressing all the requirements appears as an impossible task.

Thus, we see two important things missing. On the one hand, we need the definition of requirements related to specific characteristics of the wearable device, such as form factor, modality, users, and use cases. On the other hand, we need some kind of importance ranking for the requirements that help to focus on the most important requirements first. Altogether, these two aspects would enable designers of wearable devices to focus firstly, on the right and secondly, on the most important requirements.

3. ONLINE SURVEY

To verify, rank, and complement the previously gathered user requirements for a digital jewel, we conducted an online survey. We defined the target group as young to middle aged adults, because this age group is especially interested in fashionable jewellery and new technologies. People could take part if they were at least 18 years old. The survey was provided in German through an online survey tool. Participants completed the survey during a period of eight weeks between June and August 2014.

3.1 Survey Design

The survey started with an introduction in which we explained the term of a digital jewel. Participants should imagine a new technology that looks like a real piece of jewellery or a common wristwatch. This digital jewel could offer one or more useful functions. It could, e.g. support them in keeping a healthy lifestyle, in that, e.g. it helps to drink enough water, or to move regularly over the day. As an illustrative example for the display of such a digital jewel, we gave single light spots hidden in the jewels, e.g. under gems in a ring, a bracelet, or a watch. These light spots could

[1] http://www.bezelsandbytes.com/shop-1/

[2] http://www.motorola.co.uk/consumers/moto-360-header-gb/Moto-360/moto360-pdp-gb.html

[3] http://www.ahqua.at/ahqua_think_to_drink_produkt_e.html

[4] https://ringly.com/

[5] http://misfit.com/products/shine/

[6] https://cuff.io/

light up to indicate that, e.g. the wearer has been sitting for a (too) long time. We pointed out that this was just an example and participants could imagine any other kind of display and use case.

The survey had a total of seven questions. The first question served as the basis for the ranking of the requirements. In the first question, participants had to distribute a total of 100 points among 16 given requirements of a digital jewel with regard to their importance. The higher the points the more important a participant rated a requirement. In a previous focus group with five HCI professionals from our research team we defined the requirements to be rated. The requirements were derived from previous studies with digital jewel prototypes [3, 5], an interview with a goldsmith, and experiences that users of wearable devices, such as activity trackers, reported [15].

The requirements were phrased as 16 statements. For a more generalised analysis, we assigned the requirements to six categories. Categories are *Form Factor*, *Functionality*, *Body Location*, *Customisability*, *Interaction and Display Design*, and *Context Awareness*:

Form Factor

FF1 It looks good.

FF2 It is small.

FF3 It is lightweight.

FF4 It is solid.

FF5 It is comfortable to wear.

Functionality

FU6 Its battery lasts for at least 24 hours.

FU7 It offers several functions (e.g. feedback on physical activity and reminder of regular water drinking).

Body Location

BL8 It can be worn on a finger (as ring).

BL9 It can be worn on the wrist (as bracelet or watch).

Customisability

CU10 I can change its appearance (e.g. changing modules, changing colours of the jewel)

CU11 I can configure how the information is presented (e.g. certain light colours).

Interaction and Display Design

ID12 The functionality is integrated unobtrusively and it can be operated unobtrusively.

ID13 I can operate it quickly and with few effort.

ID14 Without further knowledge, people near by cannot understand the meaning of the displayed information.

Context Awareness

CA15 The display adapts to my environment (e.g. brightness of the light display adapts to lighting conditions).

CA16 The display adapts to my situation (e.g. display is deactivated while driving; light display is dimmed during a meeting).

We restricted the requirements to a number which we considered as manageable, considering that participants had to distribute the points among the single requirements. This resulted e.g. in the decision to integrate only two different body locations for which previous work reported [18, 8] that they are the most preferred and suitable locations for a piece of jewel or a wearable display. We chose an aggregated assessment method because, in the first question, we did not want to investigate which requirements are important at all – we already know this from previous work – but how important a requirement is perceived when directly compared to another. We expected all of the 16 requirements to be, to some extent, important, and wanted to come up with a ranking. Therefore, we asked participants to assess the single requirements in direct comparison to each other. To cancel out sequence effects, requirements were displayed in random order.

In the second question we asked for further requirements of a digital jewel that were not included in the first question (free text). Question #3 asked for any comments on the requirements named in question #2 (free text). The other questions asked for demographic details, such as the participant's age (question #4, integer), sex (question #5, choice) and nationality (question #6, choice). Question #7 was for general comments and feedback.

3.2 Participants

47 volunteers completed the online survey, of which 20 were males and 27 females. Their age varied between 20 and 48 ($M = 30.6$, $SD = 7.2$). All participants were German. Participants were acquired through public announcements in social networks and an online forum of the local university. Participants were not paid for taking part.

4. RESULTS

In the following we describe the results of the survey. The first three subsections present the results of survey question #1, the rating of requirements. Besides the overall rating, we analysed the ratings with regard to gender, and different age groups. For the analysis, we aggregated the points for each requirement. In the last subsection we report on further requirements for a digital jewel by summarising the results of survey questions #2, #3, and #7.

4.1 Overall Rating of the Requirements

Figure 1 shows a bar chart that illustrates the ranking of the 16 requirements (aggregated points per requirement). Colours of the bars indicate the category a requirement is assigned to. The ranking shows that a quick operation (ID13) is the most important requirement for participants, closely followed by a long battery life (FU6). Ranks 3 to 6 are hold by requirements describing the form factor, which are a good appearance (FF1), wearing comfort (FF5), robustness (FF4), and a light weight (FF3). On position 7 we

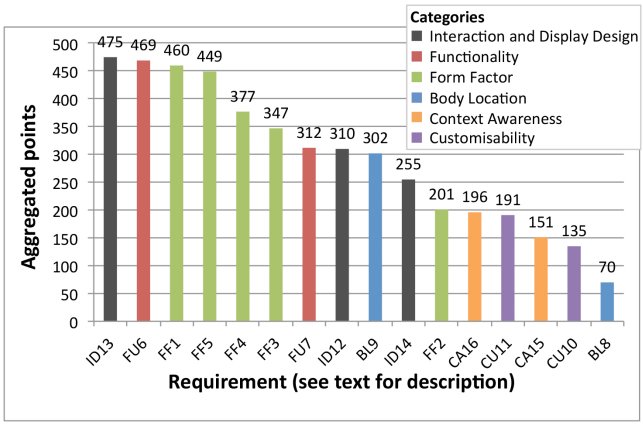

Figure 1: Aggregated points of the 16 requirements in backward sorting from most to least important. Abbreviations of requirements are described in the Survey Design section. Bar colours indicate categories.

find a comprehensive functionality (FU7), closely followed by an unobtrusive integration and operation of functionalites (ID12). Ranks 9 and 16 are hold by the body location requirements, which are wrist (BL9, rank 9) and finger (BL8, rank 16). Privacy concerns with regard to the displayed information (ID14) were rated less important and ranked on position 10. The requirement *small* (FF2) follows on rank 11. Context Awareness expressed by the adaption of the display to the situation (CA16, rank 12) and the environment (CA15, rank 14) were rated less important. Customisability regarding the information presentation on the jewellery (CU11, rank 13) and the jewel's visual design (CU10, rank 15) were ranked among the least important.

Figure 2 shows the ranking for the six categories. Displayed are the aggregated points over all requirements in a category, divided by the number of requirements in the category. The chart shows that participants rated the three categories *Functionality*, *Form Factor* and *Interaction and Display Design* distinctly more important than the other three categories *Body Location*, *Context Awareness*, and *Customisability*.

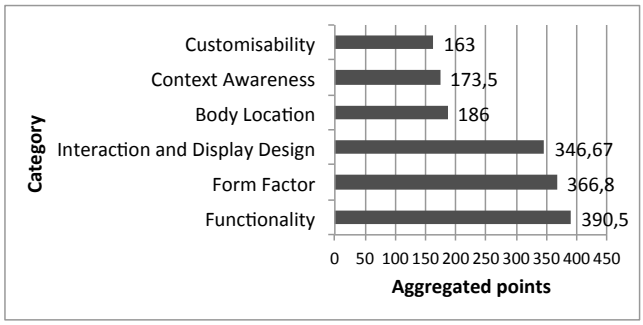

Figure 2: Aggregated points for the 6 categories, divided by the number of requirements in a category

4.2 Differences in the Rating between Males and Females

For each sex, we calculated the variation of points over all requirements. Therefore, we divided the Standard Deviation over all requirements by the Mean over all requirements (SD/M). The lower this value is, the less the points vary among the requirements.

We found slight differences in the rating of males and females. Overall, the curve of male participants runs similar to the general curve. In general, the variation of points was higher for males (SD/M = 0.57) than for females (SD/M = 0.41). That means, in general males differentiated more between the ratings of the single requirements than females. Males rated a good appearance (FF1) as the most important requirement, and – in contrast to females – a quick operation (ID13) only on rank 5. Figure 3 also shows more distinct

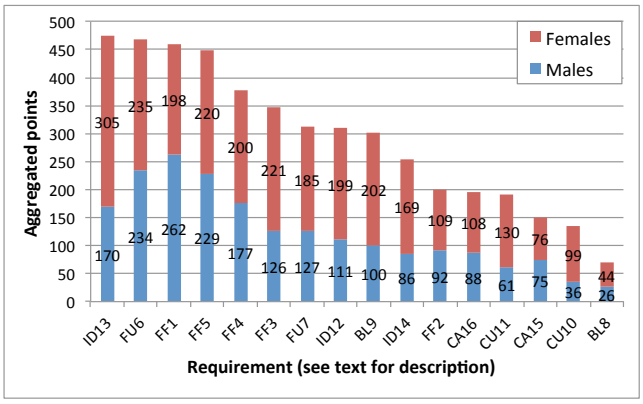

Figure 3: Aggregated points for the 16 requirements pigeonholed into females and males. Abbreviations of requirements are described in the Survey Design section.

differences on the lower ranks: Males rated the customisability with regard to the information presentation (CU11) on rank 14, whereas females ranked this on 11. The curve for females falls evenly down to rank 10, when it drops distinctly from 169 points (ID14) to 130 points (CU11). Female participants rated a quick operation (ID13) distinctly more important than all other requirements. A good appearance (FF1) was – in contrast to male participants – only rated on rank 6.

4.3 Differences in the Rating between different Age Groups

For each age group, we calculated the variation of points over all requirements in the same way as for the gender, i.e. SD/M (cp. Section on Differences in the Rating between Males and Females).

Having a look at the different age groups of participants, we found some differences. Figure 4 illustrates the distribution of points for three different age groups: *20-29* years (N = 22, 12 females), *30-39* years (N = 17, 10 females) and *40-49* years (N = 8, 5 females). In general, the points varied more for the *20-29* and the *40-49* years old (SD/M = 0.52) than for the 30-39 years old (SD/M = 0.38). That means, in general the middle-aged 30-39 years old differentiated less between the ratings of the single requirements than the younger 20-29 years old and the older 40-49 years

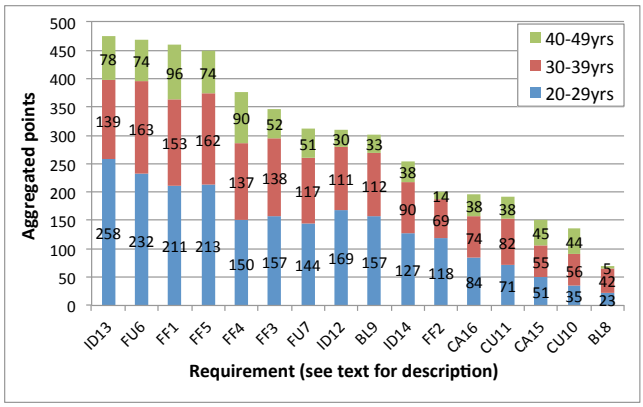

Figure 4: Aggregated points for the 16 requirements pigeonholed into three different age groups: *20-29*, *30-39* and *40-49*. Abbreviations of requirements are described in the Survey Design section.

old participants. For the *20-29* years old, the general curve fits on the whole. We find slight differences in the rating of an unobtrusive integration and operation of functionalites (ID12), which this youngest age group rated three ranks more important (rank 5) than all participants together (rank 8). Also, for the *30-39* years old, the general curve fits on the whole. However, the curve is more evenly distributed than the general one. The ratings of the *40-49* years old differ from the general ratings. E.g. a small size (FF2, rank 15) and an unobtrusive integration and operation of functionalites (ID12, rank 14) were ranked very low. In contrast, a good appearance (FF1, rank 1) and robustness (FF4, rank 2) were ranked as the two most important requirements.

4.4 Additional Requirements for a Digital Jewel

In the survey, we further asked for additional requirements participants considered to be important for a digital jewel, besides those listed in question #1.

Participants gave a lot of answers regarding the functionality of a digital jewel. Many, i.e. about 20% of the statements were related to the synchronisation and networking between different digital jewels, and between a digital jewel and other technologies, such as a smartphone, computer, TV, or scale. Also, participants named technological features such as WLAN, GPS, heart rate monitor, temperature sensor, and a watch display. Participants wanted the battery of a digital jewel to be charged easily and quickly, e.g. via induction. Overall, the answers show that participants wished for a multi-purpose device that serves as an everyday companion, i.e. besides supporting a healthy lifestyle, it should, e.g. remind for dates, send out a distress signal in case of emergency, and allow to control other devices in a smart home environment.

Regarding the interaction design, participants stated that they would like to have the choice for different output modalities, such as light, vibration, sound, and heat. As input concepts they named push buttons, finger gestures on the display, and pressure on the digital jewel itself. Two participants stated that a stand-by or silent mode is important.

Participants named requirements with regard to the form factor of a digital jewel. The most named requirement was that it should be waterproof. Also, participants wished for a high-quality fabrication, including a material that is suitable for allergy sufferers. For the attachment participants named the integration into glasses, and the possibility to wear it as a clip or magnet attached to the clothing. Robustness and the possibility to wear the digital jewel during sports were also mentioned.

Other requirements mentioned were a reasonable cost price, and the possibility to use a digital jewel even when it is not worn, e.g. by connecting it to a docking station.

5. DISCUSSION

The study results show that there are differences in the perceived importance of different requirements of a digital jewel. We also found differences in the importance ratings, that are related to gender and age. In general, males tend to be more focused in their conception regarding which requirements are important, than females. Further, the results indicate that the age groups of 20-29 years old and 40-49 years old are more focused in their conception regarding which requirements are important than the 30-39 years old.

The results of the survey show that requirements regarding a digital jewel's functionality, form factor, and interaction and display design are very important. This includes aspects such as a long battery life, an aesthetic and unobtrusive appearance, and a quick operation. Requirements with regard to a digital jewel's body location, context awareness and customisability are less important. These are, e.g. the location where a digital jewel is worn, if it adapts to the environment, or if a user can customise its appearance. With regard to the body location, participants clearly preferred the wrist to a finger.

Interestingly, today's wearable market products more and more put a focus on customisability, e.g. they offer devices in various colours, but miss general aesthetic requirements, such as a business-suitable look. Also, there are many devices that serve just one purpose. Our study results indicate that aspects such as a long battery life, a comprehensive functionality, and a digital jewel's aesthetic appearance, wearing comfort and weight, play a much more important role for users. We assume that the extent to which the aspects that users consider to be of most importance are realised in a digital jewel, will influence whether a user is accepting the wearable in the long term or not.

Overall, the points varied more for males than for females. Thus, males make a sharper distinction between the different requirements than females do. This indicates, that, when designing a wearable device for males, the consideration of the requirement rating is even more important. The study results show that the females' preferences differ from the males' in a few factors. For females, a quick operation was the most important requirement, and a good appearance was the sixth most important. In contrast, males rated these requirements reversely, i.e. they ranked a quick operation on position 5, but a good appearance as the most important requirement. Customisability was in general considered less important, but it was rated as more important by females than by males.

Overall, the points varied more for the younger, 20-29 years old, and the older, 40-49 years old, than for the middle-aged 30-39 years old. Thus, the middle-aged 30-39 years old distinguish not as sharp between the different requirements as the other age groups. This indicates, that, when

designing a wearable device for 20-29 or 40-49 years old, the consideration of the requirement rating is especially important. The results show that older people tend to have different preferences than younger people. Younger participants (20 to 29 years) consider an unobtrusive integration and operation of functionalities more important than all participants together. Older participants, i.e. the 40-49 years old, differed more from the general rating of all participants. They considered a good appearance and robustness as very important, whereas requirements such as an unobtrusive integration and operation of functionalities were ranked very low.

Our study is limited in that only Germans participated in the survey. We assume that the results would be similar for people from other modern, western countries, but we cannot be sure. Especially for other cultures, that have very different attitudes towards technology, fashion, clothing and items worn close to the body, we would expect different results and would encourage researchers to run similar studies.

In the survey we asked participants for further requirements they consider important. Due to the study design, these additional requirements were not ranked by participants. So, we could not include the requirements that were additionally mentioned in the ranking.

6. CONCLUSION

In the last years, wearable devices have been an emerging trend on the market. However, recent studies show that a third of owners of wearable devices in the US abandon their devices after six months [11]. Thus, current wearable devices do not seem to fulfil the users' requirements.

In this paper we presented an online survey, in which we investigated, which requirements are important for digital jewellery, and how important specific requirements are perceived.

Our results show, that there are differences in the perceived importance of different requirements of a digital jewel. We also found differences in the importance ratings, that are related to gender and age. Overall, participants considered functionality, form factor, and interaction and display design as very important, whereas they found body location, context awareness and customisability less important.

We conclude that for a designer of digital jewellery, it is worthful to consider the specific requirements of the target group. In this paper, we provide a ranking of requirements that helps designers of digital jewellery to focus on the more important aspects first, before considering the less important ones. Further, we highlight differences between males and females, and differences between different age groups.

In general, designers of digital jewellery should focus on the functionality, form factor and interaction and display design first, before considering aspects with regard to body location, context awareness, and customisability. In particular, when designing wearable devices for males, or 20-29 years, or 40-49 years old, designers should consider the respective importance ranking with regard to the different requirements.

The requirements a designer should focus on also highly depend on the use case of the digital jewel. In this study, we focused on everyday consumer products, i.e. products that are typically just worn for fun. For those, addressing highly ranked user requirements is very important with regard to the acceptance of the device. The results we presented here refer to such everyday systems and are presumably not applicable to, e.g. safety-critical or lifesaving systems.

In future work, we want to conduct user studies to investigate, how users perceive the requirements when implemented in real prototypes. We want to explore how users assess different prototypes, in dependence on the importance level of implemented requirements. Furthermore, we want to investigate how observers define the requirements of a digital jewel from their perspective, and how they actually perceive a digital jewel when worn by a person in proximity.

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