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DESIGN PRINCIPLES OF WEARABLES SYSTEMS: AN IOT APPROACH

Stelvaga, Anastasia; Fortin, Clement
Skolkovo Institute of Science and Technology (Skoltech), Russian Federation

Abstract

Wearable technologies comprise a large variety of electronic devices that are suitable to wear on the human body. These technologies were considered initially as an isolated consumer product but are now more and more designed as a component of a set of systems based on the Internet of Things (IoT) concept, where the design of the user experience based on high connectivity, is so critical. The aim of this paper is to formulate a set of new design principles specifically for highly connected wearables. This research work focuses on the conceptual design phase, specifying a set of activities devoted to new product concepts generation, testing, and selection. An overview of technological challenges in wearables design is first presented. Based on these features and challenges, 9 Design Principles were developed. Practical guidance aimed at providing a fluent human-device interaction are proposed. A methodology, describing the order of application of the Principles is also proposed. An analogy of the given Design Principles with an existing design model for the IoT domain is also presented.

Keywords: Design practice, Design methodology, Design methods, Design for IoT

Contact:
Prof. Clement Fortin
Skolkovo Institute of Science and Technology (Skoltech)
Dean of Education
Russian Federation
c.fortin@skoltech.ru

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1 INTRODUCTION

Wearable technologies comprise a large variety of electronic devices that are suitable to wear on the human body within the medium-to-long periods of time. These technologies were considered initially as an isolated consumer product (Ferraroa et al., 2011; Papetti et al., 2013; Seki et al., 2011) but are now more and more designed as a component of a set of systems, based on the Internet of Things (IoT) concept (Wendrich et al., 2016; Rowland, 2015), where the user experience design for a highly connected product is so critical.
The wearables industry is still fairly young and there is a need to develop a well-adapted design methodology or at least some design principles for this type of complex product and system, that would improve their ability to fulfil user needs and therefore their market success. In practice, most of the developed technologies have an established "dominant design" - a concept introduced by James Utterback in his work "Mastering Dynamics of Innovation"(1996). This concept implies that there exist a de-facto standard for the product design in a particular industry. This standard emerges at a certain point of time when the underlying technology becomes mature. Wearable technology has not reached this point yet. Thus, there is an urgent need to study the design of such products and systems and to propose an adapted design methodology.
The aim of this paper is thus to formulate a set of new design Principles specifically for highly connected wearables. These Principles are developed with a view to help product designers during the conceptual product design phase, specifying a set of activities devoted to new product concepts generation, testing, and selection. Those Principles are essentially designed to increase the chances to generate a dominant design of a wearable product idea and decrease the risks when creating a new product.

2 WEARABLES CHALLENGES

Designing wearables is a complex task since they are essentially an interconnected system. To better understand the design challenges associated with an interconnected wearable and based on a broad research of tendencies of wearable systems, the following characteristics were formulated for the wearable features that can influence the design significantly.

2.1 Distributed system architecture

Wearables should be considered not as separated devices but rather as a part of a complex system. The typical system architecture includes a wearable device itself, an associated application running on the user smartphone and cloud server service as shown in Figure 1.

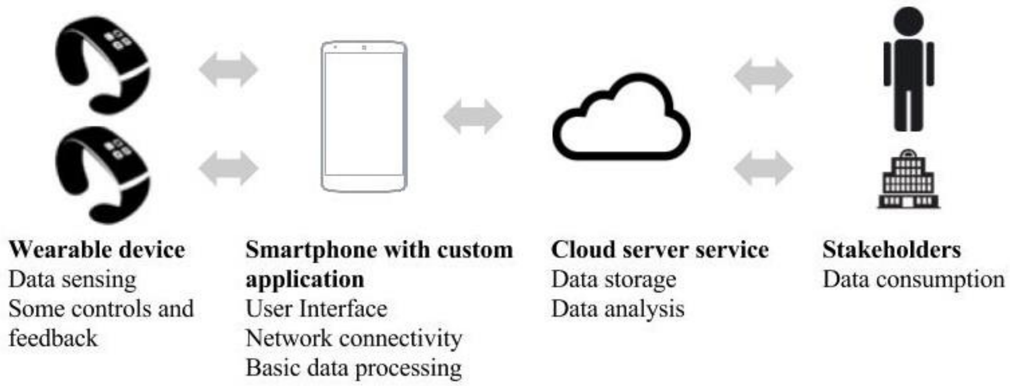

Figure 1. Example of wearable system architecture

Systems, involving wearables can be both simpler and more complex than the one shown in Figure 1. For instance, some advanced navigators used by mountain hikers connect directly to a GPS system, thus excluding the usage of a smartphone. On the other hand, there can be a physical activity tracker exporting information to an insurance company for better prediction of health problems and personalization of insurance rates for a particular customer. In this example, a larger number of stakeholders and technical solutions are involved.

The first impact on the design is that the functionality is distributed across multiple devices with different capabilities. It is important to not only consider the usability of individual devices but their "interusability", defined as the distributed user experience across several devices (Wendrich et al., 2016). Moreover, all those architectures have in common a distribution of system nodes in the physical space. Hence, there are both human and technical limits. There is a need to consider carefully the context during the design to optimize the interaction with a user. An example of the first type of limit necessitates considering the wireless network visibility range. An example of the second type of limit needs to carefully take into account the context of the design to optimize the interaction with a user.

2.2 Network connectivity

The system structure described in the previous section clearly demonstrates the importance of connectivity. All the system elements are connected to each other via different networks. Thus there are many parts that can be offline at some point. The Internet latency is out of the designer control and time delays between the users action and the wearable response is unpredictable, in cases when a wearable needs to reconcile its actions with a remote node, like a cloud server. Those issues are accepted when working with digital services as they are considered part of the nature of the Internet itself. However, we do not expect internet-like glitches from the real physical world that is the realm of wearable devices. System designers need to decrease these unpleasant consequences. Connectivity issues are discussed in detail in a number of papers (Ngu et al., 2008; Agiwal et al., 2016).

2.3 Asynchrony

For desktops or smartphones, it is possible to handle network outages gracefully and assume that the flow of interactions will be reasonably smooth. But with wearables, the whole system becomes largely asynchronous. Due to the limited power resources, a constant connectivity cannot be maintained and only intermittent connectivity can be afforded. For instance, the wearable device can be connected with a phone with a low power consuming protocol, such as the Bluetooth Low Energy protocol (Rowland, 2015). This can cause de-synchronization of the system components and create discontinuities in the user experience. For instance, when a user has just finished his physical training, his fitness tracker already has information about the activity, but the corresponding transfer to the phone application cannot be completed, until the next period when scheduled data exchange with a wristband will happen. Those mismatches would lead to unpleasant problems if a system designer does not take them into account.

2.4 Sustainability

The very concept of the wearable product implies that a person should carry it for long periods of time. A device should also be resistant to the jolting, possible physical damages, and environmental changes (Lee et al., 2016). For instance, those aspects influence sensor readings significantly. The continuous shaking of the device produces a lot of noise for the accelerometers and requires clever data post processing. Another such factor is humidity, which can cause an increased skin conductivity signal on the output of a galvanic skin response sensor. These disturbances need to be filtered at the software level as much as possible before carrying out any data analysis.

2.5 Limited resources

To be carried comfortably, many restrictions are imposed. Firstly, a wearable device should be lightweight in order not to overburden the user. Secondly, the overall size should be relatively small. For instance, this is one of the most difficult technical tasks when designing a wearable electronic ring (Nirjon et al., 2015). Thirdly, the energy resources are very small. All functions including computing capability, powering sensors and network connectivity suffer from the lack of energy resources and the design is highly constrained by this requirement.

2.6 Convenience and ergonomics

As a wearable is often attached directly to the body, it should be comfortable to wear. A frequent problem is skin irritation when a synthetic material rubs the skin surface. This requirement limits the types of materials that can be used in the product design.

Another side of this issue is a proper form factor. The key to convenient usage is the proper shape of the device, conforming to natural body curves as described by Ferraroa and Canina (2011). The development of flexible electronics can help to solve this problem. Wearable clothes get dirty with time and the user must be able to refresh them. In the best cases, wearable devices integrated into clothes should be machine washable. The importance of convenience and ergonomics factors correlates with results of interviews described by Kuru and Erbug (2015), where the corresponding parameters “Comfort' and 'Product Size” constituted 47 % of the user product discussion.

2.7 Service focus

Users often tend to perceive the wearable as a separate object. However, the device behavior can be influenced by a software algorithm, deployed somewhere else on the network. This means that the service built around the wearable is just often more critical in delivering the proper user experience than the device itself (Chan et al., 2012).

3 FORMULATED PRINCIPLES

Analysing the state of the art and the wearables features listed above, a list of Design Principles for wearables was developed. Those Principles should be taken into consideration during all development processes and they generally increase in complexity from the top to the bottom. The Principles summary is provided in Figure 2. In the next sections, a detailed description of these Principles is presented along with the reasons that lead to their definition.

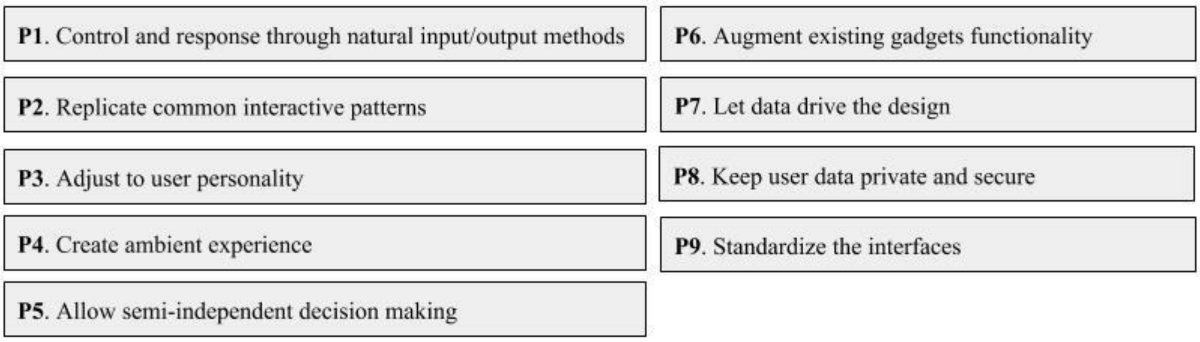

Figure 2. Proposed Design Principles

3.1 P1. Control and response through natural input/output methods

As mentioned above, resources of wearable devices are highly limited. Thus interaction with wearables with regular input and output approaches is complicated (Nirjon et al., 2015; Steimle, 2016). For instance, there is often no opportunity to endow a wearable with a touch screen display of any reasonable resolution, enabling entering text with a visual keyboard. A correct approach would be to use more intuitive methods.

The input methods can be divided into two categories: intentionally controlled and unguided.

Some of the controlled methods include speech, whole body movements, gestures, the person position in space, touch and pressure. Unguided methods include the measure of physical parameters such as galvanic skin response, heart rate, skin or body temperature, brain waves read from an electroencephalogram and others. Most of the mentioned methods are still at the development stage. A number of scientific questions should be answered in order to be able to employ them fully. It is important for the designer to keep track of all options and utilize technologies as they become mature.

Suitable output methods comprise visual methods through LEDs, screens, projections of an illustration on the skin, auditory, smell, temperature and tactile such as vibration and force feedback.

It is also important to use input and output tools effectively. Since expressive tools are very limited, each interface element can be given additional meanings. For instance, available device dimensions can be expanded by assuming that the text color changes in accordance with some other parameter change. For instance, this could be related to the ambient temperature or a traffic jam on the preferred way to home.

3.2 P2. Replicate common interactive patterns

So far society has not yet fully accepted wearables. The general population is not familiar with them and the whole user experience can be significantly spoiled by the inability to access a function.

Therefore, a good practice would be to replicate the interface or interaction pattern from a gadget or service, which the target user is already familiar with. That can be implemented through the variety of different tactics. For instance, Windows customers are used to looking in the upper right display corner when looking for the sign of a cross to close a window. This feature can be replicated by putting the button to turn off the wearable screen in the upper right part of the panel. A good user experience designer is always looking for appropriate interactive patterns and find ways to embed them in the new wearable device (Garret, 2011).

3.3 P3. Adjust to user personality

Some popular types of gadgets, for example tablets or smartphones, are perceived by people as faceless universal tools. Unlike these, wearables are treated as accessories and in some sense are similar to clothes when we speak about their acceptance by the end user. Clothes represent our way to express our uniqueness and our own personality for the people around us. The consequence of this is that not only should the wearable be comfortable but also have a "personalized" style and fit the fashion trend preferred by a particular user category also. The example of one strategy to match this principle is to proceed with a single target sub-segment and adjust the industrial design to it. For example, one can produce a wellness band in a glamorous style specifically for young women. Another strategy could be a generalization of the appearance with the opportunity to personalize it. For instance, the wearable can be made in the format of a module attached to different straps and chains in order to suit a wide spectrum of occasions and preferred clothing styles.

3.4 P4. Create ambient experience

It is essential to consider the context, surrounding the wearable at a particular moment. Its goal is to not distract the user from their normal daily routine but rather compliment it with useful features.

It is proposed to separate this objective into two types of information which need to be included in the design process – the external context such as data about surroundings and including people being physically nearby, and the internal context such as data relating directly to the user and his actions.

Several subclasses, representing the external context can be introduced. Firstly, environmental parameters such as climate and weather should be considered. This feature could help to calibrate the device sensors to get more precise information about the user. For example measuring the outside temperature would enable the normalization of the skin surface temperature received from the sensor. Secondly, information about the geo-position can give us useful hints. A third subclass describes the social context, different in such situations as being at a meeting, detecting a friend nearby or visiting a party. To make the experience appropriate to a particular situation, for example, on networking events, emphasis should be given to the intensification of communication. Yet, devices are often designed to isolate the user. On the hand, it is better to mute the sound when the user is at a business meeting.

The second type of context is the inner one. In this research project, several subtypes were identified: physical activity such as sleeping, being on the walk, running or training, health parameters such as resting heart rate, respiration rate, and others, physiological states such as physical tiredness or possible illness, or even the psychological state such as mood. Similar findings to those were found by Chan (2012).

3.5 P5. Allow semi-independent decision-making

As described earlier, wearables depend upon network connections and are largely asynchronous. Because of the connectivity issues, it is essential to let the wearable make most of the calculations and decisions within itself without supervision from the outside digital service. However, the computing power of a wearable is usually quite limited. This leads to a trade-off between decision-making on the wearable itself and on off-device resources. The optimal solution is to leave most crucial features embedded in the device while delegating less important tasks to other devices within the cloud service. This principle somehow correlates with the Interoperability concept as described by Chan et al., (2012).

3.6 P6. Augment existing gadgets functionality

The wearable device should provide a unique value proposition. Instead of duplicating features of other gadgets, the designer is better to concentrate on those, which can only be embedded in the wearable format. For instance, only the device having a continuous contact with the human skin has the ability to read a heart wave curve profile.

3.7 P7. Let data drive the design

Wearables are bridging the physical and the digital worlds. The fundamental basis of wearables design relies on the ability to obtain and analyse real life data. There are two stages of mastering the data: basic recognition and deeper analysis.

Most of the currently produced wearables are focused on the first task, for example, detecting a type of current physical activity, body health parameters or physiological conditions of the user. The most popular case is physical activity recognition. A pre-processed and labeled data about steps, amount of minutes spent in physical activity and sleep quality is directly demonstrated to the user who has to analyse it by himself. Such data seems to be pretty entertaining at first but after some time lose the interest of the user, as no meaningful results are provided. As mentioned in the report by Endeavor Partners (Ledger et al., 2014), more than a half of consumers who own wearables no longer use them.

The second on-going task is the intelligent analysis of the data. This research defines two options for future improvement of data analysis in the context of wearable technology.

The first option is about searching possible correlations between different events and changes in the user everyday life. For example, with a possibility to track emotions, one could find interdependencies between the time spent watching a particular TV-series and a subsequent depressive state. Of course, a powerful analytical apparatus should yet be developed for a full-scale implementation, but recent successes in Artificial Intelligence are promising.

Another option is the identification of behavioral and health patterns in order to predict future personal behaviour. For instance, asthma attack symptoms could be tracked for days before the attack itself. There is a lot of space for data science improvements and further applications in this domain.

3.8 P8. Keep user data private and secure

Essentially, wearable technologies deal with a lot of private data; the requirement to keep this data secured is one of the most important requirements (Paul et al., 2015; Ching et al., 2016).

The concept of security describes the degree to which a system can protect data. The commonly used model of Internet of Things security "CIA triad" includes three main subtopics: confidentiality, integrity, and availability (Ledger et al., 2014; Committee, on National Security Systems, 2010).

The privacy concept is more connected with collecting data about people and making it available to other stakeholders. An example of a hardly solved ethical question is "Is it ethical to track the daily routine of the elderly parent and alert the local doctor if unusual patterns are recognized"?

3.9 P9. Standardize the interfaces

Since wearables should be considered not as a separated device but rather as a part of a complex distributed system, usage of standard physical and digital interfaces and protocols is a required practice (European Commission, 2016). However, designers frequently ignore it.

The creation of a custom charging dock station and interface represents such a case. This custom charging dock complicates the product usage, since the user must always remember to take a specific docking station away from home, but also in the case of a loss, the user needs to wait for the order shipment of a similar one. A better option would be to use a standard charging interface. Unfortunately, a Micro USB connector, which is a de facto standard in the industry, requires a significant volume inside the tiny wearable housing and is not waterproof. Nevertheless, new developing standards such as wireless-charging methods could be great solutions.

Another important point is the design of the Application Programming Interface (API). If the product is designed to be a platform and serve as a basis for other developers to create custom applications, the API design is even more crucial. Another valuable practice is the involvement of application developers in the product platform design process in order to make sure that the platform capabilities would meet their needs. For instance, it makes sense to use standard network protocols for compatibility reasons.

4 ANALOGY WITH THE MODEL FOR INTERNET OF THINGS

Based on the presented challenges and proposed design Principles, it can be foreseen that the wearables design process is similar to IoT systems design, which is different than the design of smartphones, for example. And indeed, it is possible to draw an analogy between our proposed Principles and the elements of the IoT Design Model, presented by Claire Rowland (2015). The correlation of our independently developed results with this model can be used to prove the correctness of our approach for wearables design as highly connected products.

The Model is related to the wider domain of the Internet of Things, which includes smart home devices, urban systems, connected cars, and other products. Rowland also references the User Experience model created by Garrett (2011) as the more general and activity-centred model. Elements of the described model are not discrete design activities. Instead, it is stated that "a good overall product requires integrated thinking across all these layers"(Rowland, 2015).

A careful analysis of our proposed design Principles revealed a close correlation with this model for IoT devices. In particular, our Principles show how the corresponding components should be implemented in the case of wearables. The correlation is shown in Figure 4. The blue rectangles represent Rowland's model elements and the gray rectangles the Principles proposed in this research. P1 and P2 Principles explain how the user interface (UI) of the wearable should be implemented. From an industrial design perspective, the focus should be put on personalization (P3). Creating the ambient experience (P4) should be made through improving interaction design. The proposed semi-independent architecture of the wearable system (P5) adresses the interusability aspect. While most of the decisions should be made on the wearable, the computations should be transfered to the cloud. The conceptual model of the wearable should focus on the augmented and non-overlaping functionality with the other devices (P6). The main value of the product is supposed to come from the data obtained by the wearable (P7) providing means for productization. While moving to the digital era, data privacy becomes one of the main customer concerns (P8); thus this should be the main focus during the service component design. As the wearable platform spans far beyond the device itself, its interface standardization is one of its key component towards an efficient and lasting wearable design (P9). The given mapping provides a deeper understanding of the interrelations between the proposed Principles. Decisions made under these Principles, which are directly connected with the orange line, strongly influence each other and therefore have a more general influence on the design.

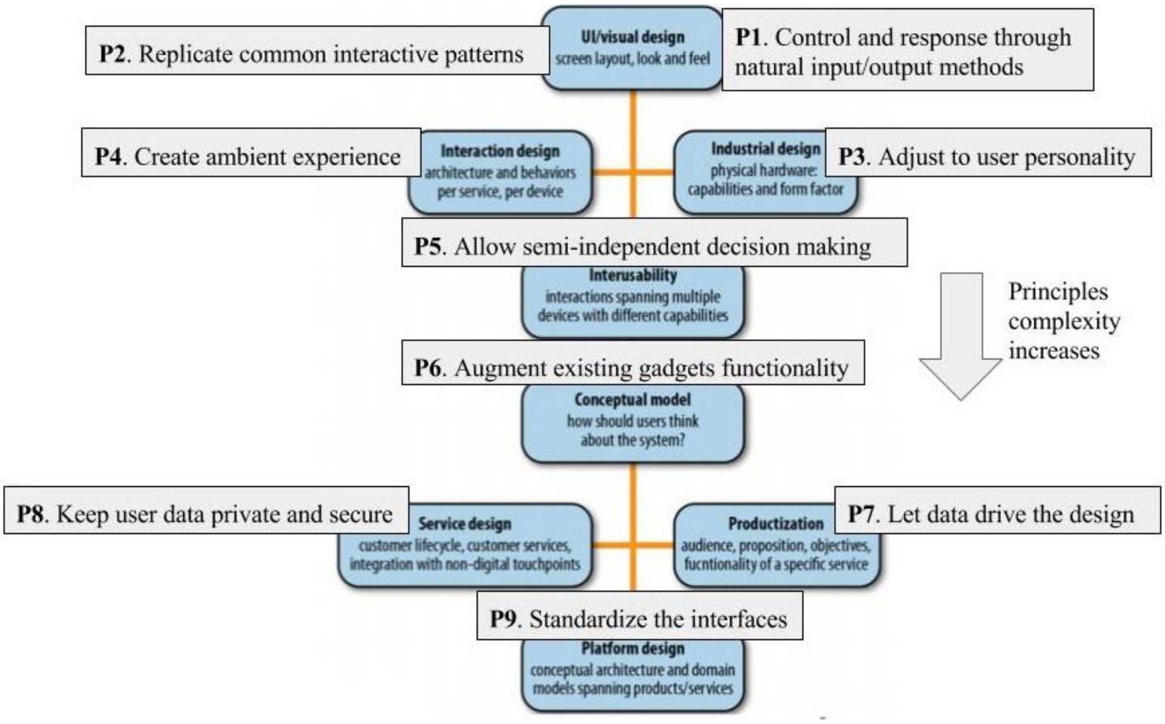

Figure 3. Proposed design Principles mapped on the Internet of Things Model

5 METHOD OF APPLICATION

The number of each Principle relates to what extent the given Principle implementation is visible to the user in the final product. The more visible elements have smaller numbers and are closer to the top in Figure 3. Elements that are hidden from the end user have higher numbers and are located closer to the bottom. The Principles with a higher number are connected with the technical issues rather than the appeal and the user experience (UX). It is also important to note that, Principles related to the engineering and technical questions are harder to verify, since their build and evaluate cycle requires more resources and time.
To decrease the design cycle time, it is proposed to consider the Principles in their numbering order from top to bottom in Figure 3. Firstly, after an initial problem investigation, a set of product concepts should be generated. Then the design team should test each of those concepts for their conformity to P1. If a particular concept does not satisfy P1, the concept should be eliminated from the design space. Then concepts should be tested with respect to P2 and so on. Concepts that are remaining after the initial pass need to be investigated further. If some concepts are modified or introduced at the next design iteration, the whole procedure should be repeated.

6 CASE STUDY

The proposed Principles were applied during the case study described below. The Principles assisted in the decision-making process by helping to eliminate unfeasible concepts and determine the proper design solutions. The idea behind the case study was to investigate how wearable technology can facilitate communication of people being in long distance relationships (LDR). The communication related nature of the problem is highly suitable for the proposed approach to wearables design as parts of interconnected systems.

6.1 Motivation

The modern trends in globalization often push people to live far away from their family for study or work purposes and try to maintain distant relationships. This leads to loneliness, sadness and depressions, which negatively influence people's health and productivity. We have identified couples that struggle to maintain long distance relationships as the primary users for the device designed in this case study. Couples in LDR try to replace face-to-face communication with text messaging and phone or video calls. The idea was to use wearable technology to extend these channels with a new one, which would help couples to share more intimate and physical-world related information.

6.2 Final concept

The 3D model of the final concept satisfying the nine design Principles is represented in Figure 4.

Figure 4. 3D model of the solution concept

The natural interaction with the device (P1) is implemented through transmission of haptic signals between the devices. The wristband format with a dual clock face, similar to a watch, is replicating a well-known design pattern (P2). In order to make a wristband suitable for both men and women, it was decided to follow the generalization strategy option within the P3 principle and make a unified device design. To create an ambient experience (P4), there are illuminating signs giving information about the other person availability. In accordance with P5, in case of connectivity problems, the device would notify both users to avoid misunderstandings. In conformity with P6, the wristband augments modern smartphone capabilities with physiology related functions. The P7 principle is visible through the whole wristband design, as it is built around the idea of transmitting data about emotions, which could be articulated by changing the luminous strip color. The last two Principles which are P8 and P9 should be implemented by technologies related to cyber security and design refinements.

6.3 Design process

This section describes how the Principles were use to judge the solution concepts and how the concepts evolved during this process, gradually satisfying Principles with higher numbers. The P1, P2 and P3 Principles were met in one of the early concepts. It was a couple of wearable electronic pendants, which vibrated in response of the another user touching his pendant, thus, transmitting a thought "I am thinking of you" with a tactile signal. P3 was satisfied as the pendant was aimed to look pretty simple and be kept under the clothes. P4 and other Principles were not met and it was confirmed by interviews, conducted with couples being in LDR. Respondents highlighted a high probability of being annoyed with vibrations while being busy and unable to answer their partner. In other words the concept did not create a proper ambient experience (P4).

In order to provide a proper ambient experience and respond to higher number Principles, the concept was modified to be a wristband displaying status information about the partner availability ("sleeping", "driving", etc.). P5 was realized with embedded software logic, keeping the minimum functionality when being disconnected from the network. This concept did not really augment smartphone functionality and satisfy P6, since sharing status information could have been done through the mobile application without using an additional device.

To provide a unique wearable functionality, the wristband capability was extended to include sensing heartbeat with a sensor and transmitting it to the partner device with short vibration impulses. For instance, this would let couples listen to one another's heartbeat. This solution did not fully satisfy the seventh principle "Let data drive the design".

To cover all nine Principles the information extracted from the heart beat signal has to be maximized. An additional investigation confirmed the possibility to recognize human emotions based on the heart wave parameters. The ability to share such intimate feelings as emotions can make a couple feel closer. This aspect became the main product feature justifying P7. Choosing appropriate software technologies should mostly do fulfilling P8 and P9 Principles, for example, the structure of the cloud database and the data exchange protocols correspondingly. This process requires additional resources and was out of this project scope.

6.4 Case study analysis

The design process, conducted with a reliance on the proposed Principles, has resulted in a possible original solution, which is considered to be promising according to results of preliminary customer interviews. The given Principles have been shown to be particularly useful during the concept design phase.

The concepts development process followed the top down direction as shown in Figure 3. The given concept is the subject of further refinements through conducting next design iterations with associated prototyping and interviewing.

The case study has proven that the proposed Principles can serve as a powerful tool to assist wearables designers.

7 CONCLUSION

The analysis of the main features and challenges of modern wearable technology show that they have become interconnected products relying on sophisticated information networks.

Based on the presented wearables challenges and features, a set of design Principles for wearable product creation have been proposed. The proposed nine Principles relate to the various design aspects, starting with the visual appeal and ending with the technical architecture design. One of the most important proposed Principles postulates that wearable product concepts should be based on the data received from sensors and naturally extend the smartphones and other existing gadgets functionality without duplicating their capabilities. Another important group of Principles refers to the practices of providing the best possible user experience. They include comfortable input and output information methods allowing fluent human-device interaction without unneccessary user distraction.

The appropriateness of approaching wearables as highly connected products was proven by the analysis of the analogy between the Principles and the existing design model for IoT. The design method while proposing a process for the conceptual design phase, can also possibly support later critical design phases of wearables.

Following further investigation, it is possible that the proposed Principles could be used as a basis for the development of a methodical and efficient workflow for the design process. Since the abstraction level of the Principles was intentionally kept at a high level, it is foreseen that they could be applicable for major evolutions in wearable technologies and for different usage scenarios such as B2C scenarios.

REFERENCES

Agiwal, M., Roy, A., Saxena, N. (2016), "Next Generation 5G Wireless Networks:A Comprehensive Survey", IEEE Communications Surveys & tutorials, Vol. 18, No. 3, THIRD QUARTER 2016.

Chan M., Estève, D., Fourniols, J.Y., Escriba,C., Campo, E. (2012),"Smart wearable systems: current status and future challlenges", Artificial Intelligence in Medicine 56.

Ching, K.W., Mahinderjit, M. (2016), "Wearable Technology Devices Security and Privacy Vulnerability Analysis", International Journal of Network Security & Its Applications (IJNSA), Vol.8, No.3, May 2016.

Committee, on National Security Systems (2010), "National Information Assurance (IA) Glossary", CNSSI No. 4009.

European Commission (2016), "Smart Wearables: Reflection and Orientation Paper".

Ferraroa, Canina (2011), “A New Approach to Wearable Systems: Biodesign Beyond the Boundaries”, ICoRD2011 Conference Proceedings, p. 283-291.

Garret J. (2011), "The Elements of User Experience", Second edition, New Riders Publishing Thousand Oaks, CA, ISBN: 9780321683686

Ledger D., McCaffrey D. (2014), "How the Science of Human Behavior Change Offers the Secret to Long-Term Engagement", Endeavor partners report, http://endeavourpartners.net/

Lee, J., Kim, D., Ryoo, H.Y., Shin, B.S (2016),"Sustainable Wearables: Wearable Technology for Enhancing the Quality of human life".

Kuru A., Erbug C. (2015), "Design for physical activity: design aspects of wearable activity trackers", Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol 1:Design for Life, Milan, Italy, 27-30.07.15

Nirjon, S., Gummeson, J., Gelb, D., Kyu-Han, K. (2015), "Typinring: A wearable ring Platform for text input", MobiSys'15 Proceedings of the 13th Annual International Conference on Mobile Systems, Applications, and Services, Florence, Italy — May 18 – 22.

Ngu A., Gutierrez M., Metsis V., Nepal S., Sheng Q. (2008), "IoT Middleware: A Survey on Issues and Enabling Technologies", IEEE Internet of Things Journal, Vol.X, No.X, March 2016.

Papetti, Peruzzini, Capitanelli, Germani (2013), “A methodology for interoperability and information management in smart home environments”, ICED 2013 Conference Proceedings, p. 149-158.

Paul M.A. Baker, Maribeth Gandy, and Clint Zeagler (2015), "Innovation and Wearable Computing. A Proposed Collaborative Policy Design Framework", IEEE Internet Computing.

Rowland, Goodman, Charlier, Light and Lui (2015), “Designing Connected Products: UX for the Consumer Internet of Things”, O’Reilley Media, , ISBN: 978-1-449-37256-9, 726 pages.

Seki, Nishimura, Zhu, Balmelli (2011), “A Parametric Design Framework to Support Structural and Functional Modeling of Complex Consumer Electronics Products”, ICED 2011, p. 282-291.

Steimle, J. (2016), "Skin- The Next User Interface", Issue No. 04 - Apr.(2016 vol. 49),ISSN:0018-9162, pp:83-8.

Utterback, J. (1996), "Mastering Dynamics of Innovation", Second edition, Harvard Business Review Press, ISBN-13: 978-0875847405

Wendrich, Kruiper (2016), “Keep it Real: on Tools, Emotion, Cognition and Intentionality in Design”, Design 2016 Proceedings, p. 759-768.

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