

Social, Ethical and Ecological Issues in Wearable Technologies

Completed Research

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Abstract

The rapid growth of Internet of Things (IoT) has given rise to a plethora of wearable devices integrated into daily life, however achieving end-user's long-term adoption is still an issue. The purpose of this paper is to investigate social, ethical and ecological issues related to wearable technologies from end-users' perspectives. We undertook a systematic literature review as well as two rounds of interviews with domain experts as well as end-users of IoT wearable devices to find relevant issues related to social, ethical and ecological. After synthesizing the results, eighteen issues found to be relevant to the wearable technologies. These issues have important implications for reducing the negative barriers that challenge the adoption of wearable technologies. The originality of this study lies with its non-technological focus that provides insights into issues that are rooted into individuals' concerns.

Keywords

Wearable Technologies, IoT, Social issues, Ethical issues, Ecological Issues, End-users

Introduction

The term IoT, was first used as an emerging global, Internet-based information service architecture that serves as a backbone for ubiquitous computing. The IoT enables smart environments to detect, identify and retrieve information from the surrounding objects and communicate the information to internet for difference purposes (Weber 2010). While it is expected that around 9 IoT devices will be available for each person by the year 2025 (74 billion devices will be connected by the year 2025 (Statista 2018) and world population is expected to reach 8.1 billion people by that time (Maqbool 2013)), so the effects of IoT over lives of billions of people is unavoidable. IoT brings challenges regarding its adoption and diffusion. One example is the information collected from the IoT devices that encompass the information about a person, in which increases privacy risks and consequently adoption intention of IoT services (Hsu and Lin 2016). Privacy concerns is one of the most researched topics regarding adoption barriers and issues related to the technologies that are enablers of IoT such as wireless sensor networks (e.g. Li et al., 2009), radio-frequency identification (e.g. Juels, 2006) and mobile applications (e.g. Christin et al., 2012). To this end, studies in the IoT are limited on technological challenges such IoT design, architecture and implementation (Atzori et al. 2010; Uckelmann et al. 2011). However, despite the importance of the developments within the field of IoT, researchers know little about the concerns in the IoT from the perspectives of the people who are affected. User acceptance toward a technology is the major determinant of actual usage behavior (Yi et al. 2006). Additionally, user acceptance in the IoT is barely a technical issue and other challenges should be considered attracting and retaining IoT users.

The IoT is an evolving concept that comprises an increasing number of technologies and exhibits a range of changing features such as low cost and energy consumption which are widely used nowadays such those of smart things. Current study is only limited to wearable technologies as one application domain of

the IoT. The simplest definition for wearable technologies is the technological devices that are wearable on a user's body (Nugroho and Beilharz 2010). Accordingly, any kind of sensor that needs to be connected to the users' body or clothes for its primary functionality can be considered as wearable sensors and is included in our study. Examples of these wearables are smart gloves, smart watches, smart glasses and fitness trackers. Wearable technologies consist of five main functions namely, the interface, communication, data management, energy management and integrated circuits (Çiçek 2015). While the market has seen a plethora of wearable devices, some research shows that achieving users' long-term adoption is still an issue (Ledger and McCaffrey 2014; Wu et al. 2016). Exploring and alleviating those issues will lead to maximization of the potentials of the wearable devices, it is thus prominent to accurately understand issues stem from end-users of such devices. There exist studies that have explored the contributing and inhibiting factors that influence the adoption of wearable devices from the technological point of view such as mobility, architecture and functionality (Adapa et al. 2018; Chuah et al. 2016; Kim and Shin 2015), however, non-technological challenges remain as an under-researched area.

A bottom-up approach for IoT policy-making, research and service design allows policymakers and practitioners to account for individual's concerns in relation to their needs (Melis et al. 2016; Padyab and Ståhlbröst 2018). However, individuals' perspectives have been largely absent in the research related to the IoT adoption barriers. Ulrich (2000) argues that the social, ethical and ecological issues and consequences that professional action may impose on others needs to be open to the critique of all those who may be concerned in order to promote a strong civil society. The purpose of this study is to contribute to the understanding individuals' perceptions of challenges regarding IoT use in one domain of wearable technologies. Thus, this research proposes the following research question that guides this study: What are the social, ethical and ecological issues in the wearable technologies from individuals' perspectives? This understanding will serve as a basis to identify the barriers for wearable sensors to be adopted by end-users. To answer this research question, we conducted a literature review and in-depth interview with experts and individuals. An inductive qualitative analysis was adopted to identify the relevant issues particular to the wearable technologies. The results of this research will help future research to theorize about influences of user's decision in adoption of services provided via wearable technologies. From a practical perspective, this study portrays a rich picture of societal debates and questions required as a starting point to analyze a sustainable IoT with respect to non-technological issues.

The structure of this article is as follows: first, the research methodology is presented. This is followed by presenting the findings of this study under social, ethical and ecological categories. Next, the contributions and implications of the results are discussed. Finally, limitations and ideas for further research are indicated.

Methodology

Qualitative data collection was conducted in different phases with different sources of data in each phase. The corroboration of data sources allowed us to achieve this rich picture we set out to achieve, meaning that primary and secondary data were used in this study, where each phase's data collection gave insights to the later phase.

First Phase - Literature Review

The first phase comprised of understanding the ethical, social and ecological issues related to wearable devices discussed in the literature. The method employed for this review was guided by Webster and Watson (2002). A literature review is a natural starting point in order to have an initial set of issues that are known to researchers. Literature search was performed from February to April 2018, limited to articles in English only. We grounded our review in the population of IS literature published between 2005 and 2019. The reason for selecting this period was that wearable technologies have just become a popular topic over the past decade (Çiçek 2015). The starting point of any review is to retrieve small sets of highly relevant publications in high ranked journals indexed in Web of Science. Next, the search was expanded into conference proceeding databases to identify papers that focused on wearable technologies. ACM Digital library, IEE and AIS proceeding databases were elected for this purpose since they cover a fair amount of proceeding publishes. Using search engines of digital databases and combination of terms "wearable" + "technology", "wearable technology" and "Wearable technologies", the largest amount of returned hits was considered for inclusion.

The titles and abstracts of each article were examined to verify for inclusion and after initial screening, 78 articles were then acceded into more detailed investigation. The articles focusing only on the technological issues were excluded from the review. A total of 26 papers were identified to be relevant, i.e. mentioned about the social ethical and ecological issues related to wearable devices.

At the end of this phase, 39 issues were extracted from the literature. After removing duplicates and grouping them, we identified 14 issues that could be grouped into 8 high-level categories of: Privacy protection, Security of physical and digital assets, Intellectual Property Right (IPR) issues, High power/energy consumption, Using recyclable material, Limited communication range, Design constraint/bulky size and Overreliance on the technology.

Second Phase - Interviewing Experts

In order to promote stronger interaction between research and practice and to obtain more reliable knowledge, social scientists recommend that studies should include different perspectives. Van de Ven (2007, p. 9) emphasized for "...a participative form of research for obtaining the different perspectives of key stakeholders (researchers, users, clients, sponsors, and practitioners) in studying complex problems. By involving others and leveraging their different kinds of knowledge, engaged scholarship can produce knowledge that is more penetrating and insightful than when scholars or practitioners work on the problem alone." Accordingly, in the second phase, we sought to interview experts who use the wearable sensors and have been active in the development process of wearable technologies. The aim of the interviews in this phase was to gain insights regarding experts' perspectives on what they deem as issues, and to reflect on the identified non-technological issues identified in the first phase. Semi-structured interviews were conducted with the help of an interview protocol as a guide through the interviewing process. The 8 identified categories extracted from the literature formed the basis of the interview protocol with some open-ended questions to foster further discussions on new any issues. Two researchers conducted each interview with typically one asking the questions and the other one taking notes and building upon initial questions. In total, 8 interviews were conducted with Swedish and Norwegian experts working in the industry and academia. The interviews were conducted in English and each lasted between 45 to 90 minutes.

All interviews were transcribed from the audio recordings captured during the sessions and were coded and combined using Microsoft Excel 365. The main analysis method employed in this phase was qualitative data analysis, and performed deductive categorization of the data (Mayring 2000). The text was classified and coded based participants' answers under ethical, social and ecological themes. The last step in the analysis was for the research team to develop a common view of the main themes, therefore all texts were discussed iteratively and in the case of uncertainties, the research team met and built a shared meaning.

Third phase - Interviewing End-users

To explore how individuals think and feel about the issues related to wearable devices, interviews with end-users were conducted allowing for the development of "thick" data. A total of 9 interviews with end-users (among our colleagues, close friends and families) who are already using or have experienced using wearable technologies were conducted. The demographics of participants varied in terms of occupations (4 student, 5 employed), gender (3 female, 6 male) and age (17 to 55). All interviews were conducted in English and each lasted between 35 to 60 minutes. The procedure for interview was similar to the second phase, except that new issues found at the second phase was included in the interview protocol. Data analysis procedure in this phase was similar to that of second phase.

Results

The results from the literature review, expert and end-user interviews are presented under social, ethical and ecological themes. Under each theme, first we will present the issues that were found from the literature followed by experts' and end-users' opinions about these issues and any additional issues which they believed to be relevant are presented. After synthesizing all the issues and eliminating redundant or similar items, we ended up with the final categories which are shown in table 1.

Ethical issues	Social issues	Ecological issues
Privacy protection	Security of physical and digital assets	High power/energy consumption
Secretly videotaping or recording	Physical threats	Battery life and heating
Secondary use of data	Data threats (information content/leakage)	Waste
Collecting unnecessary data	Integrity (e.g. validity and reliability of data)	limited communication range and lifespan
Personal data threats (information content/leakage)	Overreliance on the technology	Software reusability
Security of physical and digital assets		Reusable material
Intellectual Property Right issues		

Table 1. Issues Related to the Wearable Technologies

Social Issues in Wearable Technologies

Issues from the Literature Study

Two important social issues discussed in the literature, were: 1) an overreliance on the technology, and 2) security of digital and physical assets. These two issues are discussed in here:

Over-reliance of Technology

A first important social issue when it comes to the implementation of wearable IoT devices is that it may lead a society to over-rely on these kinds of technologies that can in turn affect different areas in the society such as education. Educators might prefer to use wearable sensors to educate students instead of designing learning activities for the society (Bower and Sturman 2015; Rauschnabel et al. 2015). Reliability and validity of the generated data by the wearable sensors can also be considered as a social issue, especially if they contain health-related data. In this regard, unreliable results can have significant consequences on the wellbeing of the users (Piwek et al. 2016).

Security of Digital and Physical Assets

Information leakage and physical security of the devices have potentially of high impact on society. For example, a stolen wearable device can pose a threat to the personal information and physical security of a person. Needless to mention that various surveillance programs by some governments put people's private information and the society's safety in danger (Ching and Singh 2016; Sivathanu 2018).

Issues from the Expert Interviews

All interviewed experts confirmed the overreliance on the technology as well as security of digital and physical assets, however, they discussed about additional issues such as: social pressure, and information and education on wearables.

Overreliance on Technology and Human Interference

Over reliance on the wearable sensors regarded as a social issue that was highlighted by the experts. This issue can also result to reduction of the interference of human being. As an interviewee mentioned, *“it might reduce interference of human being, which I see as positive, but I don’t see a point on the short term (25 years) where human beings will not play a role in society anymore.”* (Quotation (Q)).

Social Pressure

Social pressure was mentioned many times during the interviews. It refers to the influence of peers to use a device despite individual's inner will. One interviewee mentioned: *"you're the weird guy if today you say I don't want to use e-mail. But IoT devices may be the future in work and daily life and then you're the weird one if you don't use them"* (Q).

Popular Information and Education on Wearables

Understanding wearables (i.e., what should it be used for and how) is also a social issue as the companies produce devices but sometimes people do not understand it due to complexity of using it. Moreover, sometimes the users do not understand the benefits of using wearables. As one interviewee recommended, *"The only solution is to have workshops and educate the users [...] and let them understand what the data means and how the device should be used"* (Q).

Security of Physical and Data Assets

Other social issues that were highlighted by the experts were related to the security of physical assets, data threats and affordability of the users to buy and use wearables owing to the costs of sensors being expensive, in which could affect the society negatively in terms of thefts and robberies.

Issues from the End-user Interviews

To the end-users, overreliance, security of physical and digital assets, information and awareness on wearables and loss of social interaction were important social issues.

Information and Awareness on Wearables

Regarding individual adoption, users think people are not enough aware of wearables devices in order to adopt them. There is less social awareness among people for using wearable devices. They explained that earlier they were not very interested in using the wearable devices owing to the lack of awareness: *"I used to be hesitating to use wearables devices. I think training programs and generating awareness about the safety and reliability of the devices will overcome this social issue"* (Q).

Security of Digital and Physical Assets

The interviewees thought that the cost of the devices creates a social issue. The desire of getting a device might lead to safety and security issues such as danger of thefts and the physical safety of the people. The information can be hacked once stolen and can raise security concerns, as one explained: *"once I encountered a theft incident for my smart watch ... [thieves] were able to see my personal data."* (Q).

Overreliance: Loss of Interaction

Finally, users mentioned that today many are too reliable on the technologies including the wearables. Users thought that wearable technology has invaded in the social lives, affecting personal communication. The challenge will be on how wearables can serve a broader goal of enhancing social interactions and relations between people.

Ethical Issues in Wearable Technologies

Issues from the Literature Study

Reviewing literature on wearable technologies revealed that ethical issues have been more often discussed compared to the social and ecological issues. Below, the three main ethical issues that could be derived from the literature are discussed: privacy protection, security of physical and digital assets and IPR issues.

Privacy Protection: Data Privacy, Secret Gathering, Data Treats and Inappropriate Secondary Use

Privacy in wearable technologies is among the major issues to tackle in order to be adopted in the market. Wearable sensors are capable of collecting a vast amount of data, including sensitive data such as health-related data and credit card information (Ching and Singh 2016), with a corresponding increase in the danger of information leakage (Friess 2016; Lee et al. 2016). The second concern related to privacy is that data is collected in an obtrusive manner beyond end-user awareness (Bower and Sturman 2015).

Collecting unnecessary data and storing them for long time is a crucial privacy concern, especially when one considers that sometimes it is not clear for the users what is collected and which party has access to the stored data (Thierer 2014). Moreover, the definition of what is 'personal information' is not always uniformly understood by the different parties involved in the development in one hand and the end-users on the other hand i.e. what a producer might see as appropriate to collect might not mean the same as end-user's perception (Segura Anaya et al. 2018).

Personal Data Threats

Security of data produced by wearable devices were brought up by some studies. One reason that end-users are concerned with third party access (e.g. government and hackers) is because traditional non-IT producers are mostly producing wearable IoT sensors, which do not have enough competence to address data security issues as hardware and software companies usually do (Shahmiri 2016). These security issues also increase the risk of secondary use of data that is produced by the sensors (Lee et al. 2016; Pustiek et al. 2015).

Intellectual Property Right

IPR is also one concern as users of wearables usually do not own their data and sometimes, they do not have full access to remove their personal data (Piwek et al. 2016). In this regard, they own the device, but not the resulting data.

Issues from the Expert Interviews

The interviews with the experts confirmed the three issues above but also added three more concerns: 1) The need for informed consent under privacy protection, 2) A concern with stigma and physical harm under the issue of security of physical and digital assets and 3) IPR and ownership and use.

Privacy Issues: Data Privacy, Security and Informed Consent

Similar to the literature, privacy and security issues in relation to using wearables were more highlighted by the experts. According to the experts' opinion, it's of crucial importance to inform the users of wearables about the purpose of the collection and what it is used for. As one noted: *"We had people withdrawn from using wearables after knowing these factors"* (Q). Accordingly, the users must be given full and informed consent and be able to revoke their data at any time. This consent is especially important with those users who have special diseases such as dementia. Also, the data must be anonymized as much as possible. As another interviewee mentioned: *"Of course at some place in the system the ID is linked to the data, but that we try to keep them separated"* (Q). The other ethical factor that all interviewees confirmed as an important ethical issue was secretly videotaping or capturing information by the wearable sensors.

Intellectual Property Rights: Ownership and Usage

IPR issues mentioned by the experts were related the ways of managing, storing and accessing the sensors' data. In this regard, it's important to educate the users to be aware of the technology and tools and data around them. One expert mentioned that: *"We also try to make sure that the owner of the sensor owns the rights to the data. Actively avoiding the storage of any historical data"* (Q). One challenge here is that when an end-user accepts to wear a sensor, he/she usually gives the ownership of the data to the company. However, interviewees believed that the end-users should own the data and have control over it. According to one expert, *"the question of who uses the data is more important than who owns the data"* (Q).

Stigma and Physical Danger

Experts warned the danger of 'stigma' as an important ethical issue. Wearables can easily make cognitive or health problems more visible to outsiders. For example, if someone places a camera around a person's neck, everyone knows that that person has specific problem. But outsiders might also make wrong conclusions as they don't know the aspects of the disease. Moreover, experts highlighted the risk of physical threats for a person's personal safety and physical security. If a user, for example, wears sensors that cover his/her eyes in a certain way, that person might stumble or fall, leading to physical harm. Lastly, resolving ethical issues requires a lot of experimenting and trialling, as different players –

developers, end-users and stakeholders – might have different notions and norms with respect to ethical issues and it is important to take such concerns into account when designing wearables. A relevant ethical question one can pose is the question if the supposed benefits outweighs the ethical costs.

Issues from the End-user Interviews

The ethical issues that were particularly vibrant among the interviewees was privacy protection, especially the fact that they have limited control over personal information and a fear for secretly taking photos and recording videos. One participant gave an example of the data stored in the cloud: *“I store data in the cloud so that it can be retrieve if needed. However, I found out that the data can retrieve not only to the smartwatch but also to other devices on the same network...without my permission and other people accessing the device were able to see my personal data”* (Q). One other participant brought up the issue with the informed consent: *“Wearables devices have feature that allows to photos and recording videos... the users think that people do not care of other people’s privacy and take photos and record videos without permission of the concerned person”* (Q).

Ecological Issues in Wearable Technologies

Issues from the literature

In the literature, ecological issues are mainly associated with the power or energy consumption of wearable sensors.

Energy Consumption

Wearable devices usually have very low battery life as they are connected to different networks such as GPS and other wireless networks (Pantelopoulos and Bourbakis 2010). This high level of energy consumption in turn produces heat which is generally known as a risk for sustainability (Adapa et al. 2018). Duval and Hashizume (2006) recommends that the wearable sensors should be environmentally friendly and use as little energy as possible. Hence, Çiçek (2015) argues that the companies still have not found an acceptable solution for the issue of battery life and heating.

Issues from the Expert Interviews

The experts confirmed the issues extracted from the literature and referred to high energy consumption and the need for using recyclable material as most pressing ecological impacts of wearables.

Usage of Recyclable Materials and High Energy Usage

Some sensors produce a lot of waste and the problem is compounded owing to the low price of sensors and some producers might give these sensors more priority to reduce their costs. For example, the RFID sensors in many cases not reusable or recyclable. Despite the fact that there has not been a significant effort to reuse some waste materials of wearable sensors, an expert stated that he tries to reuse those material in other context where possible: *“Personally I am also afraid of electronic waste, so I try to reuse the gloves or wearables in other contexts”*.

The most common point mentioned by the interviewees was concerns with high energy usage and its potential harmful impacts on the climate and the economy. One expert stated that this potential impact can only be remediated if the problem is also perceived as a technological challenge to which resources can be directed for research on reducing battery consumption. Reducing energy consumption, despite the relative cheap price of current sensors, is therefore an important technological challenge with consequences on the environment.

Issues from the End-user Interviews

In line with the literature and experts, end-users also identified the heating of batteries, the usage of toxic material and the high energetic consumption as the main ecological concerns they have with respect to wearables. Five interviewees referred to lithium and other materials that are commonly in wearable devices as not environmentally friendly and urged for using eco-friendly materials instead. Others pointed to the high energetic usage and the need to use alternative power sources, such as solar energy, to provide

clean energy. For the end-users, the ecological concerns they had impacted their willingness to use certain wearables.

Discussion and Conclusion

Social, ethical and ecological aspects in wearable technologies are integral parts of technology acceptance and the mitigation of social challenges will enhance and affirm the existence and deployment of wearable devices (Adapa et al. 2018; Kirkham and Greenhalgh 2015). As a result, it is of vital importance not only to understand technological issues related to the implementation of wearable sensors (Chuah et al. 2016; Saleem et al. 2017), but also to identify the issues underlying individual's social, ethical and ecological concerns of wearable devices. Many of these issues can be considered as obstacles or barriers for IoT solutions to be adopted by end-users. These findings are major contributions of this research beyond the dominant technological discussion in the literature. That in turn leads us to a better understanding of adoption barriers in this domain and serves as a basis to understand how these adoption barriers should be tackled. Moreover, understanding the issues that should be addressed during development of IoT wearables will maximize the end-user's acceptance and satisfaction of wearable sensors. In addition, we identified new issues not found in the current IoT wearable literature. Stigma and physical danger of wearables were notable findings stem from the interviews. It showed that the concerns related to individual's health being affected by using a wearable is a concern from end-user's perspective that should be discussed beyond policies and regulations (Troiano 2017). Another important finding was related to various ecological beliefs of end-users that are rarely discussed in the previous studies. The fact that our participants' choices of use depended on whether environmental-friendly materials were used, is a step forward from previous studies which have been only focused on technically-efficient devices (Lee et al. 2016).

This study offers several implications for wearables and IoT. Summarizing extant research, current study enables us to obtain insights into the potential (intended and unintended) consequences including benefits and drawbacks of using wearable sensors by end-users in their real-life everyday use context. The theoretical contribution highlights what issues are to be considered when studying adoption behavior in an IoT context. In this vein, future research can include these issues to effectively evaluate and analyses the adoption barriers related to human needs, expectations, and values that end-users have. For practice, our findings point into two trajectories. First, to allow service providers in addressing the issues by developing recommendations on how to facilitate adoption of IoT wearable technologies. In this vein, our study can help future research in addressing information that needs to be communicated such as opt-in opt-out options, data collection and use practices, safety issues, sources of materials used and company's green choice policies. Second, there are some implications for the policymakers. The results herein suggest that a transparent policy that addresses such concerns paves the path towards fair and transparent product and service development. For enabling the IoT, end-users must be empowered, and their views included into policy discussions (Melis et al. 2016). The issues found in this study can be used as a framework to initiate policy discussions related to developing governance for the IoT.

In terms of limitations, the IoT is an evolving concept that comprises an increasing number of technologies and exhibits a range of changing features. This study was only focused on one domain and the aim with the future research is to expand the issues into other domains such as autonomous driving, smart city, smart healthcare and smart food and farming. Moreover, the results should be tested with a larger sample. For this reason, our future research is aimed to complement this study with other methodological means such as a hypothesis-driven research for building a model for the end-user adoption of IoT wearable technology. Moreover, different application domains in wearables might have their own challenges and thus the issues and adoption barriers vary. Furthermore, end-users of wearable technologies are different, depending to the age, health situation and other relevant factors.

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