An Expert Interview Study of IoT Wearable Technologies for an Aging Population from Product, Data, and Society Dimensions

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Abstract. This research focuses on investigating the product, data, and society dimensions around IoT (Internet of Things) wearable technologies with insights and empirical knowledge from exploratory expert interviews. The purpose is to find implications around future designs of IoT wearable technologies for the aging population. Quantitative and qualitative data were collected through in-depth expert interviews and pre-surveys to explore topics and insights related to the design and development of IoT wearable technologies. Through synthesizing findings from expert interviews and pre-surveys, insights and concerning issues were summarized into three dimensions: product, data, and society. The implications from this research can help overcome the obstacles that impede the inclusiveness and adaptability of IoT wearable technologies. This study concludes that it is essential for designers, engineers, and researchers to consider these non-technological issues when designing and developing future IoT wearable technologies for the aging population.

Keywords: IoT wearable technology · Data ethics · Design with data · Aging population · Expert interview

1 Introduction

IoT (Internet of Things) wearable technologies have become increasingly prevalent and been used in a wide range of scenarios [1, 2]. In this study, IoT wearable technology is defined as a type of electronic product that can be used as a hands-free device with the feature of internet connectivity to transmit data and information. There are increasing needs for IoT wearable technologies in the field of healthcare, fitness, entertainment, education, and communication. IoT wearable technologies can reduce the nursing demand and cost in expensive healthcare institutions, but more importantly, they monitor real-time health conditions of the aging population to help maintain their independence and

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well-being [3]. The application of healthcare IoT wearable devices make it possible for aging population to stay in their home longer, and to help mitigate the workload and stress experienced by healthcare providers [4]. However, with design opportunities brought by the flourishing of IoT wearable technologies in the aging market, there are also innumerable challenges, among which are user acceptance, such as data-related issues include data relevance, security and privacy, and possible bias associated with programs and algorithms used [5–7].

This research utilizes qualitative and quantitative methods to explore, analyze and synthesize insights gathered from exploratory expert interviews and surveys on IoT wearable technologies. The purpose is to find design implications, and identify opportunities and challenges that the design team, including designers, researchers, and engineers, may come across in the process of designing and improving IoT wearable technologies [8, 9]. Our approach includes the discussion of data ethics issues related to IoT wearable technologies for aging population [10]. The in-depth exploratory expert interview outcome as the fundamental of research materials. We harnessed the expert pre-survey result and its qualitative analysis as auxiliary materials to support the qualitative result and conclusion from the expert interview [11]. The interview process sought to collect the experts' perceptions about smart home, related professional experiences, examples of interacting with IoT wearable technologies at home, interpretation of the relationship between design and data, discussion about data ethical issues, and perspectives around how they view IoT wearable technologies can help people in the future. The utilization of expert interviews in this research aimed at resolving three key questions:

1. From the three dimensions, product, data, and society, what should be emphasized in detail in the IoT wearable technologies design process?
2. What other dimensions should be considered during the product design and development of IoT wearable technologies?
3. As for designing IoT wearable technologies for aging population, what are the other considerations?

This research also aims to address issues around the use of data associated with IoT wearable technologies. While past research has included experts' perspectives in utilizing human-centered design approach to understand people's needs, designing for elderly adults [12], addressing psychological demands faced by elderly adults, and mitigating the stress of healthcare workers [13], issues around data collection and use have been neglected. As additional discussions designers, researchers, and engineers over responsible and ethical use of data becomes increasingly essential [14], this study sought to include discussions around data-related design considerations. The social issues including technological bias, inclusiveness, sustainability, and acceptance of technologies are taken into consideration in this paper. Synthesized from the interview insights, what positive and negative impacts IoT wearable technologies will bring to society is a consideration that designers, researchers, and engineers need to take in the process of design and improvement.

2 Data Collection: Expert Interview and Pre-survey

In order to better understand the importance of IoT wearable technologies for the aging population, as well as apply the evaluation framework of collecting, generating, analyzing, and utilizing users' data properly and ethically in the process of design and improvement of IoT wearable device, we recruited experts of different backgrounds to leverage their professional perspectives and well-thought-out considerations. Recruited experts participated in 1-on-1 interviews, as well as a pre-survey with questions complementing the interview contents.

2.1 Preparation and Expert Recruitment

A literature review and secondary research were conducted to develop relevant and specific interview questions. A survey of existing papers and publications spanned related topics such as "ethical issues in wearable technologies [15]", "data and wearable device [16]", "wearable device design [17]", among other themes. Based on findings from the literature review, we developed questions to be used in a qualitative interview method combined with a quantitative pre-survey, with the purpose of securing a more objective, clear, and balanced findings [18].

Expert interviews have been adopted as a tool of qualitative research as widely discussed in social research [15–17]. In order to get diverse perspectives in the study, we selected and recruited thirty-one experts from the field of industrial design, user-experience design, education, healthcare and medicine, cognitive science, IoT, software engineering, electronics engineering, and aging research. Experts were invited to participated in in-depth interviews around what needs to be considered in the process of IoT wearable technologies design and development. Recruited experts represented diverse backgrounds across different disciplines and included technological entrepreneurs (18%), people in leadership roles (24%), consultants (18%), designers (16%), technologists (4%), educators (16%), and extreme users[1] (4%) (Fig. 1).

To better highlight the individual perspective and insights from experts [19], as well as quantify the expert interview result based on the expertise and credibility of experts, we started the evaluation of experts based on their professional knowledge and experience in IoT wearable product design, understanding of IoT wearable technologies and the comfort level of talking IoT wearable device related topics). This evaluation is a subjective framework for us to make a high-level evaluation based on the interviewees' empirical and fact-based knowledge, and meanwhile, it serves as a tool eliminating the bias of experts due to their personal experience with IoT wearable technologies [20]. The three criteria cover: adaptability—understanding the comfort level of the interviewee when facing IoT products and their challenges; expertise—understanding how knowledgeable the interviewee is about the IoT industry; responsibility—understanding the perception of the interviewee about the ethics of IoT and data-privacy-related issues, which reflect the three dimensions of knowledge which experts can contribute to resolving the problem [21].

[1] In the study, we define an extreme user as one type of expert.

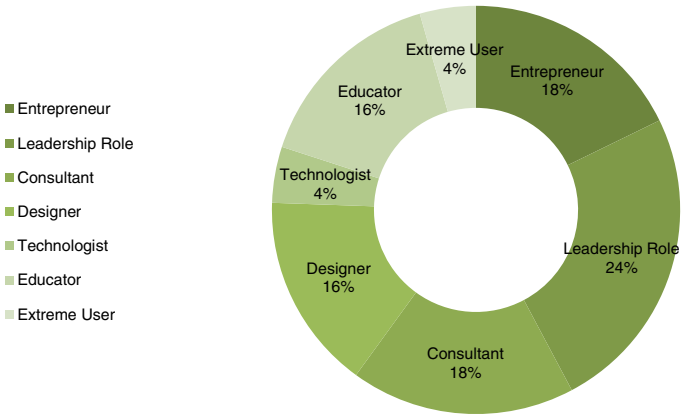

Fig. 1. Participants' backgrounds of the expert interview (n = 31)

2.2 Expert Interview Procedure

An interview guide and a pre-survey was developed to curate the interview in a systematic and structural way. Each expert interview lasted about 45 min and was conducted online. Additionally, a 3-min online pre-survey was completed prior to the interview. Figure 2 illustrates the overall procedure of the mixed-methods approach, as well as contents and topics covered in each stage of research. As shown in Fig. 2, five main steps were taken throughout the research process, including (1) recruiting; (2) interview pre-survey: a quantitative survey asked experts to share their perspectives on wearable technologies in a pre-defined format; (3) semi-structured interview: open-ended questions were posed to allow experts to share and express their views and knowledge in their own terms across the product, data and society dimensions, such as cases of IoT wearable device design to obtain detailed insights around specific dimensions of IoT wearable technology design and development [22]; (4) interview material review: after each interview, the interview team quickly reviewed the contents and completed notes to find lessons and insights.

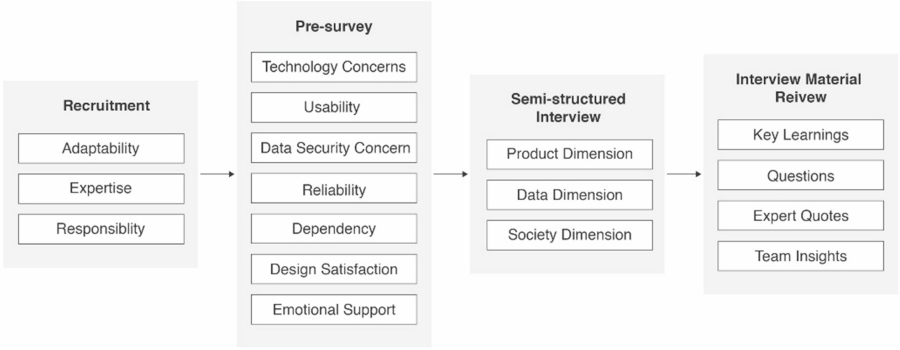

Fig. 2. Expert interview flow and key considerations

3 Result

From the thirty-one expert interviews, we categorized and synthesized findings into three dimensions: product, data, and society, to discuss the topic of IoT wearable technologies for the aging population in a comprehensive perspective (Table 1). For the product dimension, we emphasize how critical it is to apply a human-centered design process to address the needs of the users' (e.g. aging population), their lifestyles, and life routines for creating better human-centered IoT wearable technologies. For the data dimension, data ethics issues of IoT wearable technologies in terms of data privacy, data security, data clarification, and communication were considered not only for the general public but more importantly, for the aging population. Whereas for the society dimension, we considered design implications related to inclusiveness and social responsibility beyond IoT wearable technologies with a focus on implications for the aging population.

Table 1. Dimensions of IoT wearable technologies in product, data, and society

Product	Data	Society
– Human-centered approach and framework – Design considerations based on users' needs, behavior, and ritual – User-friendly interface across touchpoints of the user journey – Intuitive design in product, service, and experience	– Personal data privacy concerns – Data security in digital and physical assets – Data awareness of users – Data communication among devices – Proper distribution of secondary data	– Inclusiveness of product feature – Social and environmental responsibility of design teams – Social acceptance of the technology – Potential bias caused by technology

3.1 Product

Apply a Human-Centered Approach. According to the expert interview study, some experts mention that a great IoT wearable technologies design results from a human-centered approach. One expert said "A successful IoT product won't mention it as an IoT product, since people won't purchase an extra coffee machine with sensors. Instead, designers need to reinvent the overall user experience for using a coffee machine.", which reinforces the importance of understanding users by applying a human-centered approach [23]. A further step of the study is to (1) understand how we refine a typical product design process of an IoT wearable technology for the aging population. (2) learn how we conduct a user (e.g. aging population) and expert interview integrated into an IoT wearable technology design and development process. (3) apply a human-centered approach to clarify users' the core needs of users (e.g. aging population) by understanding users' behavior, knowing users' rituals, and identifying users' purpose of why or why not use IoT wearable technology at home.

Understand Users' Needs, Behavior, and Ritual. "I only want my IoT product to show the things, the functions that you (product) promise and I don't want to have any surprises," said an expert who talked about his viewpoints as an end-user. Understanding users' needs are critical and essential from the expert interviews, as one expert said "Any other kind of design: you have to understand your customer and you must have a vision. Data alone will not yield great products and services." Some experts mentioned that IoT wearable technologies should respond to the users' needs precisely and they can offer many options. It can also predict users' behaviors and know their rituals in order to help users explore themselves from different angles. While others said that understanding users' needs through IoT wearable technologies is a tricky issue, because it is often used to serve the purpose of companies that own the IoT wearable technologies rather than meeting the core needs of end-users.

According to the pre-survey result (Fig. 3), expert interviewees hoped that IoT wearable technologies could make life convenient (75.9%), which echoed by some of the experts' responses: "When I choose IoT products, I consider three aspects: (1) efficiency—it can make my life convenient; (2) the pace of my life—It can help me control my life pace; (3) cost—this is the least critical one since every product has its price.", "I want every smart IoT device in my home to be seamlessly connected and they can have the conversation so that I don't even need to bring and use my phone at home.", and "IoT products can easily predict people's daily behavior, move, and trajectory, but it's hard to read what's on people's minds. The time of "I know what you think" is yet to come." In the interviews, it was revealed that the experts' interpretation of convenience included offering customized services based on an understanding of user habits, daily rituals, and individual needs.

Since we didn't specifically mention the aging population as our target user in the pre-survey, the result of Fig. 3 reflects more about the needs of the general public through the lens of the experts. For further study, we can define the aging population as the target users and make a comparison with diagram 2 result to probe into what are the goals and requirements that the aging population want to achieve according to their core needs.

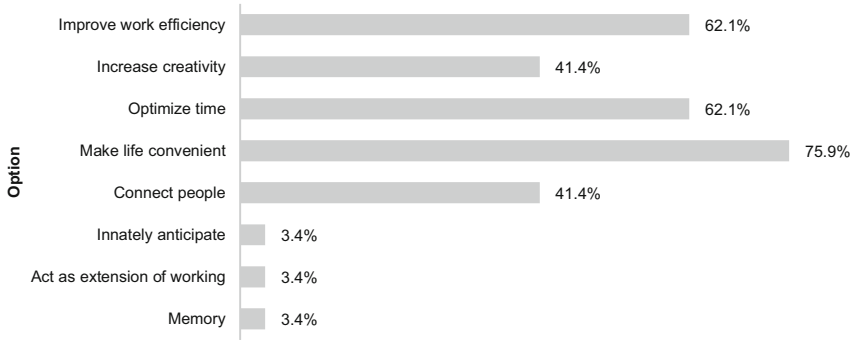

Fig. 3. Experts' choices on what IoT wearable technology may help users with (n = 31, multiple selections)

3.2 Data

Data issues were frequently highlighted during the expert interviews, as much of the related literature indicated that disclosure of data collection, data interpretation, and cybersecurity is significant for keeping personal information private and consent. Among all the topics we looked up from the interviews, the most commented are using data as design research tools, concerns on data privacy, proper usage of data, ethical considerations, and the waste of data were among the most heavily discussed. The following part shows the three key dimensions of using and deploying data in the process of designing and developing IoT wearable technologies: (1) leverage data in the iterative design process properly; (2) consider personal data privacy and security; (3) enhance users' data awareness.

Leverage Data in the Iterative Design Process Properly. "The more we can understand all aspects of data and all the various touchpoints, the more that we can develop systems and opportunities for greater and more ethical products," emphasized an expert from the design industry. On the one hand, data collected through IoT wearable technologies serve as sources for ubiquitous and context-aware computing [17], on the other hand, it also contributes to the iterative design process for enhancing the experiences of users (e.g. aging population) and understanding their needs. However, in the process of leveraging data for research purposes, it is critical to consider secondary data distribution and privacy issues for individual users.

As discussed by an expert in the interview, data is "an essential ingredient for intelligence, but hard to trust that it's handled responsibly," indicating concerns users' trust and awareness of data collecting during the use of IoT wearable technologies. Thus, it is worth emphasizing and being mindful of creating a transparent data-processing mechanism, designing an interpretable process, and conceiving an understandable and user-friendly interface for delivering data usage information as well as building trust between IoT wearable technologies and users.

Consider Personal Data Privacy and Security. According to the pre-survey results (Fig. 4), experts were divided in their degrees of comfort with having data collected through IoT wearable technologies stored and shared in the cloud. Only 13.8% of experts indicated that they feel comfortable and are willing to share and store their data on the cloud via IoT wearable technologies. Synthesized from expert interview outcomes, most IoT wearable technologies need data and inputs from users to understand behaviors, routines, lifestyles, and preferences. Therefore, capturing user data in an ethical and transparent way, and utilizing non-invasive and secure ways of collecting and using data are becoming increasingly important.

Enhance Users' Data Awareness. "Due to the enormity of this issue, we need to learn better ways to collect and extract data that will enable us to develop greater rubrics and or opportunities to identify problems that need to be solved that would not fall into the same category as what marketing entities call innovation," said one expert. Data awareness has been discussed by nearly one-third of the experts. Helping users to better understand the use of data, including questions about what types of data will be captured, where

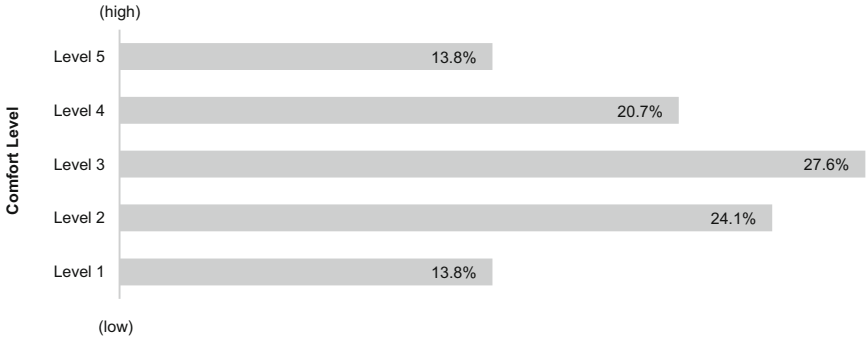

Fig. 4. The result of the experts' comfortable level for data to be shared and stored on the cloud through IoT wearable technologies (n = 31)

the data will go, if the data will be further distributed, if their data is treated securely, as well as data ethical issues are all crucial in the design of IoT wearable technologies, especially for the aging population. "Data should be used in a more human-centered way, and not make users think they are tracked or their data is collected for the business purpose". It is significant to design and deploy user-friendly ways of informing the usage and distribution of data to ensure user's right to know where their data will go and how it will be used.

4 Society

Inclusiveness of Product Features. As shown earlier in Fig. 3, when asked to indicate the ways in which the experts think IoT wearable technologies can help them achieve in life, the top choices were to make life convenient (75.9%), to improve work efficiency (62.1%), and to optimize time (62.1%), which are all connected to the functional aspects of IoT wearable technologies. In the interviews, experts discussed that using IoT wearable technologies can streamline people's work and life in terms of convenience, efficiency, and optimization. Whereas the emotional side such as users' feeling, a feature of inclusiveness of product for the aging population is lacking, which experts were also emphasized less.

Design for Sustainability. Applying a human-centered approach needs to not only consider the lens of users but also design IoT wearable technologies in the context of the industry. One expert who's a design entrepreneur shares his view that "Every time I will consider the consequences if I need to create a new IoT device. We need to think about the issue in the context of the global environment since we only have one earth." Currently, most IoT wearable technologies design is based on its platform/system different from brands to brands. As for designers, when we create a new type of IoT wearable technologies for the aging population, we need to consider its product lifecycle and eco-system in order to make not only the business but also the environment sustainable.

5 Discussions and Conclusion

This paper mainly focuses on the non-technological part of the design of IoT wearable technologies from the dimensions of product, data, and society. According to expert interviews, these three dimensions are parts of technology acceptance of the public, especially the aging population, and potentially reveal the challenges we will come across during the implementation of IoT wearable technologies. Thus, it is not only vital to know about the technological aspects of IoT wearable technologies to improve the design of products, services, and experiences, but also important to consider issues related to individuals' needs, societal impacts, and data ethics.

For further study, we want to re-consider the following questions in the process of conducting interviews: How do people use IoT wearable technologies to increase the interaction among people? How do users such as the aging population feel being cared for with the help of IoT wearable technologies? How do we value the design team's role and responsibilities while creating human-centered IoT wearable technologies for people and with people? For the next generation of IoT wearable technologies design, it helps the design team think comprehensively in planning, designing, executing, and refining in regard to target users, especially for the aging population.

Future research can apply the result of this study as fundamental resource and conduct more expert interviews targeted to specific fields with our interview flow (Fig. 2). Also, the methodology can be applied to interviewing potential end users' interviews to get more practical insights and perspectives toward IoT wearable technologies. From the practice perspective, the study can be interpreted from three angles: (1) the results can serve as a checklist for the IoT wearable technology design team, including designers, developers, and engineers to consider the non-technological and human-centered aspects; (2) the results related to data privacy, security and societal implications can serve as resources for policymakers and regulatory bodies to set up ethical standards around the collection and use of data; and (3) the results can be utilized by generally target users (e.g. aging population) to evaluate the positive and negative impacts of IoT wearable technologies on their life.

Since IoT wearable technologies consist of a relatively wide range of products, service, and techniques as well as methodologies, future research can take a more comprehensive approach to address dimensions and aspects of IoT wearable technologies design. A possible approach is to invite experienced industry experts from diverse fields and target discussions in specific domains, such as wearable devices to enhance aging population well-being or wearable products for communication. Moreover, interviews and surveys with a larger group of diverse stakeholders, including end users, need to be conducted to incorporate different perspectives and voices into the research process and obtain deeper insights into IoT wearable technologies design and application.

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