Challenges for Deploying IoT Wearable Medical Devices Among the Ageing Population

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Abstract. The phenomenon of ageing population is raising substantial pressure to the national health and welfare systems of many countries in the world, and can be a potential threat to social stability and economic development. IoT wearable medical technologies have the potential to aid this struggle, but anecdotal evidence showed that large-scale deployment of IoT wearable devices among the ageing population could be fraught with challenges, which have not been well reported in academic literature. Therefore, this paper aims to address this knowledge gap by reporting on an exploratory study that firstly investigated older people's user requirements towards wearable medical devices and secondly explored potential challenges and difficulties for large-scale deployment of such devices. Five focus groups were conducted to collect insights and opinions respectively from five families (i.e. each contained 1–2 elderly members, accompanied with 2–4 family members who held caring responsibilities). The data collected was analyzed by using a thematic analysis approach. The results showed that elderly people have complicated and diverse user requirements towards IoT wearable medical devices, and that a range of challenges related to hardware providers, caregivers, legal regulations and technical features can affect large-scale deployment of such devices. The paper concluded that these identified user requirements and challenges should be carefully considered by wearable hardware designers, system developers, and service providers if they want their innovative products and services to be accepted and deployed among the ageing population globally.

Keywords: Wearable devices · Healthcare · Ageing population
User requirements · Challenges

1 Introduction

Ageing population as a global grand challenge has received increasing attention from governors, practitioners, academics and the general public worldwide. According to the United Nations, the global share of older people (aged 60 years or over) increased from 9.2% in 1990, to 11.7% in 2013, and will continue to grow and reach 21.1% by 2050. Globally, the number of older people is expected to more than double, from 841 million people in 2013 to more than 2 billion in 2050. In light of this trend, the old-age support ratios (i.e. number of working-age adults per older person in the population) will significantly and continuously fall in the coming decades. This is leading to substantial

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pressure to the national health and welfare systems of many countries, and can be a potential threat to social stability and economic development.

Consequently, there is an imperative need for countries to seek for innovative, reliable and convenient solutions to provide better healthcare services to the ever-increasing ageing population, with less workforce, over distance [1]. The concept of IoT wearable medical devices has thus become increasingly important in recent years. Besides being lightweight and portable, this kind of device allows the provision of health monitoring and caring over distance, and so reduces the burden of commuting that many older adults experienced when visiting a healthcare facility for a regular checkup [2].

However, anecdotal evidence showed that large-scale deployment of IoT wearable devices among the ageing population could be fraught with socio-technical challenges, especially considering that older people have very different health and medical conditions and their caring needs may not be easily satisfied by technological means over distance. In the current literature, a large number of studies about wearable devices focused on the contexts of fitness and leisure (e.g. [3, 4]). There are also other studies, from a developer and technical perspective, that look into functionalities and monitoring capabilities of wearable devices for health and medical purposes (e.g. [5–9]). Nevertheless, there is currently very limited understanding and study on the views of older adults towards using wearable medical devices as well as potential difficulties and challenges for large-scale deployment of such technologies. Therefore, this paper aims to address this knowledge gap by reporting on an exploratory study that aims to answer two research questions:

- What do older people really need from IoT wearable medical devices?
- What are the socio-technical challenges in deploying such devices among the ageing population?

The results derived from this study will be of importance to city governors, service providers, IT practitioners and researchers who are interested in not just the development of IoT wearable medical devices but more significantly in large-scale deployment of such technology among the ageing population. The rest of this paper is structured as follows: the next section presents the research methodology adopted by the research. Subsequently, the findings derived from the study are presented and discussed, followed by a discussion of the implications of the results, with conclusions drawn.

2 Methodology

Owing to the exploratory nature of this study, a qualitative research approach was adopted. Merriam and Tisdell describe qualitative research as studies that interpret people's experiences and behaviors to contribute to knowledge [10]. The researchers initially planned to use interview to collect data in the study. However, it was soon recognized that elderly people may often not have sufficient understanding on novel technologies like wearable medical devices, so normal one-to-one interviews may not lead to the best output. On the other hand, when using wearable medical devices, elderly people may often seek help from their younger family members, especially

who have caring responsibilities. Therefore, it was deemed that the views of elder people could be better complemented by the opinions of their family members. These considerations pointed the researchers to select focus group rather than individual interview as a more suitable method of data collection for the study. In particular, a focus group will allow the researchers to involve both elderly people and their family members to have an open and interactive discussion on the issues and phenomena under investigation. It was hoped that the use of focus group could trigger a more in-depth conversation that covers the angles of different relevant stakeholders, and so lead to a richer set of data and findings that may not be easily explored by using other methods [11].

Consequently, five face-to-face focus groups were conducted respectively with five families. As shown in Table 1, each focus group in this study involved a family that contained 1–2 elderly members plus 2–4 younger family members. In order to provide a more comfortable and protective environment for elderly people and their families, all focus groups took place in their respective homes with a pre-booked appointment. Each focus group lasted for 40 min to 1 h, and was recorded by using a digital camera. The resulted transcripts were sent to the corresponding participants to double-check the correctness of the recorded contents.

Table 1. Summary of focus group participants

Family ID	Number of 60 + people	Number of family members	Total
Focus group/family 1	1	2	3
Focus group/family 2	1	2	3
Focus group/family 3	1	2	3
Focus group/family 4	2	4	6
Focus group/family 5	2	2	4

Subsequently, the focus group data was analyzed by using a thematic analysis approach. Thematic analysis is one of the predominant techniques for analyzing qualitative data. Braun and Clarke described it as data-driven inductive approach "for identifying, analysing and reporting patterns (themes) within data" [12]. Following guidelines given by Braun and Clarke, the thematic analysis conducted in this study consisted of five stages, as shown in Table 2 [12].

In order to organize and represent concepts and findings derived from the analysis, a concept map was established. As shown in Fig. 1, irradiating from the center of the map are the three identified categories/themes, which are linked to specific user requirements and deployment challenges raised by the elderly people and family members during the focus groups. This concept map provides the structure for reporting the research findings in the next section.

Table 2. Five stages of the thematic analysis

Phase	Description
1. Getting familiar with the data	The transcripts that resulted from the focus groups and interviews were read multiple times for clarification and a better understanding of the participants
2. Coding the data	Coding the textual data in a systematic fashion across the entire data by using NVivo
3. Connecting codes with themes	Classify codes based on potential themes, collecting and gathering all data have relationships with each potential theme
4. Reviewing themes and developing concept maps	Make sure each theme is identified properly considering relevant coded quotes and the entire data set; integrate concept maps of the analysis
5. Reporting findings	Final analysis of selected quotes, considering of the analysis to the research question, producing a new section to report the findings

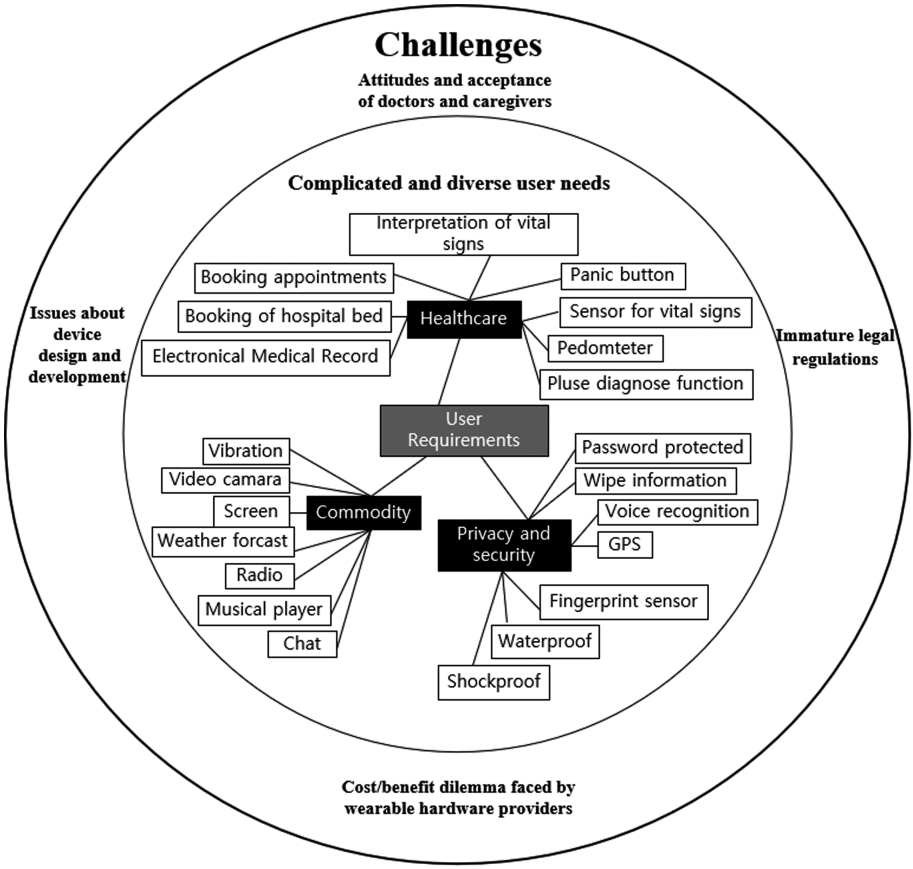

Fig. 1. Concept maps of focus group findings

3 Results and Findings

The results of the focus groups identified that elderly people have complicated and diverse user requirements towards IoT wearable medical devices, and that a range of other challenges related to hardware providers, caregivers, legal regulations and technical features can affect large-scale deployment of such devices, as detailed below.

3.1 Complicated and Diverse User Needs

It emerged from the focus group data that user requirements of elderly people for wearable technologies contain three main categories, namely healthcare, data privacy, and commodity requirements. In terms of healthcare needs, the participated elderly people and their families raised a number of essential hardware and software functions to be ideally included in wearable medical devices, such as:

- Having a panic button exclusively for medical emergencies;
- Having embedded sensors that automatically monitor vital signs (e.g. blood pressure, pulse, heart rate, blood oxygen), measure steps and sleep duration;
- Having additional sensors that can accurately measure and support pulse diagnosis (i.e. a disease measurement method used commonly in traditional Chinese medicine);
- Allowing creation of electronic medical record, booking of hospital beds, booking of medical appointments, interpretation of their vital signs, and medical recommendations and medicine reminders through mobile app.

It is apparent that these types of functions could be particularly useful to elder people with chronic diseases (e.g. Hypertension, High Cholesterol, Diabetes, Ischemic Heart Disease, Dementia, Parkinson's disease, Heart Failure), which do not necessarily require hospitalization but need long-term monitoring and treatment [13, 14].

Further to healthcare requirements, the focus group participants also raised the importance and needs of data privacy protection. Specifically, many participants expressed the fear that personal information collected from wearable medical devices may not be strictly protected and may even be misused by device manufacturers, service providers, and/or caregivers. In other words, device and service providers will need to establish and follow efficient data usage policies to protect data privacy, if they want to gain trust of prospective users and maximize sales.

The third category of identified requirements dealt mainly to commodity and entertainment features (e.g. video camera, chatting tools, social media, location maps, traffic conditions, radio, games) that older adults and their family members will like to have on a wearable device. In fact, the findings showed that older people with or without chronic diseases can often still remain socially active with friends and family members. Previous research also reinforces that older adults with better social connection and interaction tend to have a healthier lifestyle as well as a lower chance of getting depression [15].

By further examining these identified user requirements, it became clear that as physical and psychological conditions of elderly people can vary significantly, their monitoring, caring and entertaining needs can be very complicated and different, and so

cannot be easily supported by a universal model of wearable device. In other words, the above identified user requirements and functions will need to be customized to fit the needs of particular individuals in practical terms.

3.2 Issues About Device Design and Development

The complexity and variety of user requirements as discussed above will inevitably raise issues and difficulties when designing and developing wearable medical devices.

In particular, in order to monitor physical variables (e.g. movements, steps, and motion) and various vital signs (e.g. blood pressure, pulse, heart rate, blood oxygen, etc.) of elderly people, different types of sensors will need to be used [16–18]. The ideal solution will be to integrate all the needed sensors into one single device. This was supported by the focus group participants, who stated that they "*want an integrated piece of tool rather than wearing too many different devices" (Focus Group 3). This* however can lead to severe technical challenges regarding accuracy, stability, battery lifetime, size, and weight of the wearable device. Specifically, when too many sensors need to be embedded into one single device, its internal circuit and structure will become very complicated. When device manufacturers try to reduce and compress the size of the device, its accuracy and stability can often be affected [19, 20]. Faced with these problems, some manufacturers may then try to reduce the size of the device battery in order to leave more space for other crucial components, but this solution can in turn reduce battery lifetime and so lead to inconvenience to the users [16, 19]. Owing to these technical issues, the weight and size of an integrated wearable medical device may not be reduced easily, and so can cause discomfort to elderly people when they wear a relatively large and heavy piece of device on a daily basis [21].

On the other hand, the focus group participants also raised their concerns about how these medical devices may look like and be worn on their body. In fact, many wearable devices for fitness and sport purposes (Fitbit Alta HR, Samsung Gear Fit 2 Pro, Steel HR) are currently designed as a bracelet or watch. But in order to collect more accurate data, wearable medical devices may be designed into different forms. For example, Holter monitor is a well-established piece of wearable healthcare device for monitoring electrocardiography (or ECG) heart activity, and can be particularly useful for elderly people with heart-related diseases [22]. However, these devices require the usage of a series (normally 3–8) of electrodes attached to the user's chest. An elderly person involved in the focus groups cogently stated that "*we are getting old, but we do not want to wear devices that make us look like aliens*" *(Focus Group 4)*. In other words, the current design of wearable medical devices will need to be carefully reviewed and revised by considering the feeling and opinions of their intended users.

3.3 Cost/Benefit Dilemma Faced by Wearable Hardware Providers

The complicated list of user requirements and associated design and development challenges is leading to a cost/benefit dilemma to wearable device providers. On one hand, the global market of wearable medical devices is getting increasingly competitive. If any device manufacturers want to play successfully in the market, they need to make a

greater endeavor to satisfy the identified needs and requirements of the elderly people [23]. Failure in doing so will inevitably reduce use acceptance and diminish the value and usefulness of the developed wearable devices, and so affecting competitive advantages of the product in the market. But on the other hand, overcoming the design and development challenges associated with these user requirements (e.g. especially to have a highly integrated, reliable, stable, light and long-lasting wearable device with all the needed functions) will require very substantial R&D investment. Such high R&D cost can then lead to high selling price of the device, which may not be affordable to many elderly people and their families. From a customer perspective, the focus group participants reinforced that for most wearable medical devices available in the market, "*the affordable ones often did not contain all the functions they need, and the ones that can satisfy their requirements are always far too expensive for them to buy*" *(Focus Group 2)*. This dilemma will inevitably affect large-scale deployment of IoT wearable medical devices. In order to resolve this, device and service providers will need to seek for new business models, which do not simply reply on the selling of the device itself, but allow a cheaper device selling price that can be compounded by add-on service charges in the long run.

3.4 Attitudes and Acceptance of Doctors and Caregivers

IoT wearable medical devices are not just simply monitoring tools. In fact, vital signs and other essential data collected by the device will normally be sent through wireless network to a back-office cloud system, which will process, store and analyze the data and then generate warnings and disease predictions in due course [24]. These analytical results can be used by elderly people and their family members to take proper actions if needed. More importantly, these data and analytical results can be constantly and remotely monitored and reviewed by doctors and medical caregivers to provide necessary treatments to the elderly people. For those with chronic diseases, this type of remote monitoring and caring will be particularly useful and can reduce the need of hospitalization [13, 14].

However, the focus group participants worried that it might not be easy to get involved a large number of doctors and medical caregivers in public hospitals in the caring end of wearable devices. This view has actually also been reported in other studies. Specifically, Kornreich et al. [25] highlighted that doctors and caregivers in hospitals already have a lot of pressure and very tight daily schedules, and so may not be willing to take any additional remote monitoring/caring duties. Kroll et al. [26] echoed that medical professionals might also have concerns about the accuracy, validity and currency of the data collected and sent by wearable devices, and so might not be willing to carry diagnosis and make medical decisions based on these data. The focus group participants added that "*the scenario will become even more complicated when considering the very strict regulations and rules of hospitals, which may not allow doctors to accept and use data supplied by different wearable devices used by elderly people*" *(Focus Group 3)*.

3.5 Immature Legal Regulations

Last but not least, the focus group results showed that elderly people and their family members had serious doubts about current legal regulations associated with the usage of wearable medical devices. For instance, the two elderly people in focus group 5 questioned that "*if we use these wearable devices on a regular basis, but things did not go well, such as, the device did not measure my heart rate accurately and so wrong treatment is provided to me, who should be legally responsible for it*". In fact, the failure of wearable devices and related services can be caused by a mixture of potential reasons, including hardware issues (e.g. inaccurate and unstable measurements), software flaws (e.g. inadequate data processing and analysis), irresponsible caring professionals (e.g. wrong diagnosis and decisions made by doctors), and even inappropriate user behaviors (e.g. the elderly person does not charge and/or wear the device properly). Consequently, when medical accidents happened to the device users, it could be difficult to identify clearly whether the accident is owing to hardware, software or human reasons. As such, it will be hard to draw a clear answer to tell who the responsible parties are. Because local regulations and legal rules often have not been developed sufficiently to resolve these conflicts, device manufacturers, software developers and medical service providers may try to find excuses to avoid being responsible for the accident. The participants in focus group 1 cogently concluded that "*when a wearable medical device fails, the elderly person who uses it can face severe risk and even become a truly victim*".

4 Further Discussions and Conclusions

Faced with the global grand challenge of ageing population, the evolution of wearable healthcare technologies has attracted increasing interest from the society. However, the adoption of wearable devices among the ageing population is still in an infancy stage. This paper reported on a study that aimed to explore potential socio-technical challenges affecting large-scale deployment of IoT wearable medical devices. The results showed that elderly people with different health conditions can have very complicated and diverse needs towards the usage of wearable devices. These needs and requirements may not be easily satisfied with current technical constraints. In addition, the findings also showed that elderly people and their family members have many concerns about the current medical and legal systems, which were deemed to be insufficiently prepared to enable large-scale deployment of wearable medical devices in the society.

Overall, it can be concluded that technology is important but not the only determinant for the success of IoT wearable medical devices. In order to realize the benefits promised by these devices and achieve a high level of adoption and penetration rate, device designers, service providers, governors and medical practitioners need to make a stronger endeavor together to resolve the identified socio-technical challenges as well as to provide a better business, medical and legal environment that can support long-term development of the wearable medical device market. Finally, it should be highlighted that as an exploratory study which was limited by time and resources, this research has an apparent weakness. That is, only a limited number of stakeholders were

involved in the focus groups of this study. Therefore, further research on this topic is strongly recommended.

References

1. Fan, M., Sun, J., Zhou, B., Chen, M.: The smart health initiative in China: the case of Wuhan. J. Med. Syst. **40**(3), 1–17 (2016)
2. Li, B., Chen, S.: A study of residential condition and satisfaction of the elderly in China. J. Hous. Elderly **25**(1), 72–88 (2011)
3. Fritz, T., Huang, E.M., Murphy, G.C., Zimmermann, T.: Persuasive technology in the real world: a study of long-term use of activity sensing devices for fitness. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 487–496. ACM (2014)
4. Buttussi, F., Chittaro, L.: MOPET: a context-aware and user-adaptive wearable system for fitness training. Artif. Intell. Med. **42**(2), 153–163 (2008)
5. Zheng, Y.L., et al.: Unobtrusive sensing and wearable devices for health informatics. IEEE Trans. Biomed. Eng. **61**(5), 1538–1554 (2014)
6. Pantelopoulos, A., Bourbakis, N.G.: A survey on wearable sensor-based systems for health monitoring and prognosis. IEEE Trans. Syst. Man Cybern. Part C (Appl. Rev.) **40**(1), 1–12 (2010)
7. Appelboom, G., et al.: Smart wearable body sensors for patient self-assessment and monitoring. Arch. Public Health **72**(1), 28 (2014)
8. Zheng, J., et al.: Emerging wearable medical devices towards personalized healthcare. In: Proceedings of the 8th International Conference on Body, pp. 427–431. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), Networks (2013)
9. Chang, Y.J., Chen, C.H., Lin, L.F., Han, R.P., Huang, W.T., Lee, G.C.: Wireless sensor networks for vital signs monitoring: application in a nursing home. Int. J. Distrib. Sens. **8**(11), 685107 (2012)
10. Merriam, S.B., Tisdell, E.J.: Qualitative Research: A Guide to Design and Implementation. Wiley, Hoboken (2015)
11. Morgan, D.L.: The Focus Group Guidebook. Sage publications, Thousand Oaks (1997)
12. Braun, V., Clarke, V.: Using thematic analysis in psychology. Qual. Res. Psychol. **3**(2), 77–101 (2006)
13. Prince, M.J., et al.: Ageing 2. The burden of disease in older people and implications for health policy and practice. Lancet **385**(9967), 549–562 (2015)
14. Wang, Z., Li, X., Chen, M.: Catastrophic health expenditures and its inequality in elderly households with chronic disease patients in China. Int. J. Equity Health **14**(1), 8 (2015)
15. Moak, Z.B., Agrawal, A.: The association between perceived interpersonal social support and physical and mental health: results from the national epidemiological survey on alcohol and related conditions. J. Public Health **32**(2), 191–201 (2010)
16. Lo, B., Yang, G.Z.: Key technical challenges and current implementations of body sensor networks. In: Proceedings of 2nd International Workshop on Body Sensor Networks (2005)
17. Otto, C., Milenkovic, A., Sanders, C., Jovanov, E.: System architecture of a wireless body area sensor network for ubiquitous health monitoring. J. Mob. Multimedia **1**(4), 307–326 (2006)
18. Baig, M.M., GholamHosseini, H., Moqeem, A.A., Mirza, F., Lindén, M.: A systematic review of wearable patient monitoring systems–current challenges and opportunities for clinical adoption. J. Med. Syst. **41**(7), 115 (2017)

19. Khan, Y., Ostfeld, A.E., Lochner, C.M., Pierre, A., Arias, A.C.: Monitoring of vital signs with flexible and wearable medical devices. Adv. Mater. **28**(22), 4373–4395 (2016)
20. Prasad, D., Chiplunkar, N.N., Nayak, K.P.A.: Trusted ubiquitous healthcare monitoring system for hospital environment. Int. J. Mob. Comput. Multimed. Commun. (IJMCMC) **8**(2), 14–26 (2017)
21. Hung, K., Zhang, Y.T., Tai, B.: Wearable medical devices for tele-home healthcare. In: 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, IEMBS 2004, pp. 5384–5387 (2004)
22. Glaros, C., Fotiadis, D.I.: Wearable devices in healthcare. In: Silverman, B.G., Jain, A., Ichalkaranje, A., Jain, L.C. (eds.) Intelligent Paradigms for Healthcare Enterprises Studies in Fuzziness and Soft Computing, vol. 184, pp. 237–264. Springer, Heidelberg (2005). https://doi.org/10.1007/11311966_8
23. Gao, Y., Li, H., Luo, Y.: An empirical study of wearable technology acceptance in healthcare. Ind. Manag. Data Syst. **115**(9), 1704–1723 (2015)
24. Chan, M., Estève, D., Fourniols, J.Y., Escriba, C., Campo, E.: Smart wearable systems: current status and future challenges. Artif. Intell. Med. **56**(3), 137–156 (2012)
25. Kornreich, Y., Vertinsky, I., Potter, P.B.: Consultation and deliberation in China: the making of China's health-care reform. Chin. J. **68**, 176–203 (2012)
26. Kroll, R.R., Boyd, J.G., Maslove, D.M.: Accuracy of a wrist-worn wearable device for monitoring heart rates in hospital inpatients: a prospective observational study. J. Med. Internet Res. **18**(9), e253 (2016)