Technology and Aging: Users' Preferences in Wearable Sensor Networks

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ABSTRACT

Population aging is a global phenomenon. It is also enduring: we will not return to the young populations that our ancestors knew. It is hence crucial to use any possible means, including sensing technology, to improve the quality of life of older adults, as well as their relatives and caregivers. In this paper, we study acceptability and usability of a system for silent monitoring with sensors hidden in wearable objects, which record data and send it to a server for further elaboration. The server collects and stores information, and gives an alert in case of danger. The goal of such a system should be to improve the safety and independence of end users with a technology as little intrusive and visible as possible. For this reason, we conducted a survey to understand the system's features required for its market release.

CCS CONCEPTS

• **Human-centered computing** → *Ubiquitous and mobile computing systems and tools*;

KEYWORDS

aging, technology, wearable sensor networks

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1 INTRODUCTION

In 2001, a report from the United Nations [5] evidenced that the population aging is unprecedented, without parallel in the human history. It has profound implications for many facets of human life, deeply affecting the management of family life.

Population aging also implies age-related diseases. Dementia, with a particular emphasis on the Alzheimer's type of the pathology, affects an increasing number of seniors. Mild cognitive impairment (MCI) is a medical condition reflecting the border between an expected cognitive decline, following a normal process of aging, and dementia. It is characterized by an impairment in at least one cognitive domain and subjective concerns of the patient about the deterioration in the cognitive performance [19]. However, the independence in performing activities of daily living is fairly well preserved.

In this paper, we investigate acceptability and usability of a system for silent monitoring of elderly people or people affected by age-related diseases. The system is composed of a *Wearable Sensors Network (WSN)*, a set of sensors, hidden in the everyday objects, which record data and send it to a server for further elaboration. The server collects and stores information, and gives an alert in case of danger (e.g., falls).

The goal is to improve the safety and independence, not only of the patients, but also senior population in general. Therefore, we conducted a survey in order to understand the system's features required for its acceptance and success.

Even though remaining cognitive resources of older adults with a cognitive decline may still allow them to conduct most of the everyday life activities by themselves, the subjective sensation of lack of competence can cause a feeling of anxiety [19]. An assistance based on (non-intrusive) wearable sensors can, therefore, increase their sense of safety and independence.

Even if the system components are hidden in everyday life objects, the patients could feel uncomfortable with being monitored. For this reason, we asked our possible target group and their caregivers about their opinions on the system. We used three different surveys, each addressed to the elderly, their relatives and the medical staff, respectively.

The paper is organized as follows: Section 2 discusses related work, whereas Section 3 presents two case studies. Section 4 and Section 5 discuss the survey methodology and the obtained results. Finally, conclusions are drawn in Section 6.

2 RELATED WORK

The use of sensor networks is growing rapidly in recent years. This technology finds an application in a wide range of areas, such as: fitness and wellness [13], military services [16], home and office, logistics and transportation, tourism and leisure, or health-care [1].

There are plenty of examples of commercial devices that incorporate sensors to monitor physiological data. Fitness bands and smartwatches are good examples of this kind of products [14]. They became popular among sport enthusiasts due to the possibility to, not only track the physiological data, but also record their personal

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performance. We can also find some proof-of-concepts in the literature: in [17] the authors proposed a wearable training system that supports athletes in learning correct movements during their training sessions, while [9] presents a safety service for children which consists of a vest equipped with wearable sensors.

The application of wearable devices in the medical field is substantial. They can be used to monitor life parameters, body position or location of a patient. Due to their capabilities to analyze and transfer data in real-time, they can be an invaluable help for the family and physicians taking care of the elderly [1]. One of the issues affecting dementia patients is spatial navigational difficulties [18], i.e., problems with determining and maintaining the right trajectory of movement from one point to another [11].

A growing body of research focuses on the application of wearable technology in monitoring patients' spatial navigation skills. Grierson *et al.* [7] proposed a tactile wayfinding device aiming to facilitate navigation for persons with dementia. A wearable belt with four small vibrating motors provides users with a tactile signal indicating the direction to their destination. A similar device was designed by Rosalam *et al.* [15]. The authors investigated the reaction of the patients to the proposed wearable device and its applicability to assist them in wayfinding. In the initial stage of the study, they also administered a preliminary survey in order to understand the design preferences of the users.

Understanding the needs, preferences and acceptability of wearable devices among the end users is essential for their practical employment. As already mentioned above, fitness bands and smartwatches gained popularity among sports enthusiasts and athletes, but what attitude the elderly people have towards them? Some research studies have been conducted in this domain. The authors of [12] face the problem by comparing British and Japanese perception of a wearable ubiquitous monitoring device. They investigated parameters such as perceived privacy invasion and the attitude of participants towards the technology application. Unfortunately, the sample of participants includes only a limited number of seniors.

In this study, we aim to investigate how elderly people, their relatives and medical staff perceive the utilization of WSNs in improving the quality of life of seniors and patients affected by dementia. To reach to goal, we created and administered a survey which inspects, not only the technical and aesthetic preferences of the participants, but also their perception of the crucial issues, such as safety and privacy.

3 CASE STUDY

In this section we present two possible scenarios of the application of our WSN for the elderly population.

3.1 Healthy older adults

The first use case presents the application of our WSN in a group of healthy older adults. Due to demographic changes, there has been a growing number of the elderly population. Currently, a quarter of European population [6] is composed of people aged 60 or above. Elderly people, even if they are healthy, often require assistance or surveillance in order to prevent life-threatening situations, e.g., accidental falls.

This aging phenomenon brings new challenges to families. To support older adults in maintaining a safe independence in their everyday-lives and to minimize the need for a permanent presence of a caregiver, the wearable technology can be applied.

Seniors can decide to wear their sensors in a wide variety of clothes and accessories. Due to the small size of the devices, they can be placed in jewellery, handbags or any piece of clothing. A user can share the access to the collected data with relatives or other indicated individuals, or be the only one connected to the WSN infrastructure. In this way the information about user's vital signs (heartbeat), unexpected or abnormal movements (e.g., falls), real-time position or chosen destination with a programmed, best fitted pathway can be either available only to the user or also to the specified person. If a senior using the WSN chooses to go to the bank, he/she inserts the location in the smartphone application which sends an alert if his/her behavior presents some significantly unexpected pattern.

3.2 Dementia patients

In the second scenario, the WSN is applied to the clinical settings. A common problem associated with dementia is wandering behavior. In a study conducted in 2006 [20] the authors reported that one in five patients affected by dementia wander. The rates vary from 17.4% [10] to 63% [8] depending on the source. Although one explicit definition of wandering is still missing, it is commonly understood as aimless or disoriented behaviors based on attributes of walking and locomotion [3][4], with a repetitive, temporally-disordered, and/or spatially-disordered nature that is manifested in lapping, random, and/or pacing patterns some of which are associated with eloping, eloping attempts, or getting lost unless accompanied [2].

As wandering is one of the most frequently reported problems regarding care services for dementia patients, our system can be very helpful. The system can be used during the initial stage of the disease to control silently where the patient goes, thus preserving their independence. Then, we aim to apply our WSN to hospitals, nursing homes and other assisted living facilities: the possibility to locate the patients in real-time guarantees a higher level of safety to the patients and provides a convenient and reliable tool for the medical staff to take care of the patients.

The sensors can be sewn into the clothes as well as placed in the shoes or in accessories like a bracelet, a necklace or a watch. Patients equipped with items containing sensors can move freely around the facility without the threat of undetected falls or alarming alterations in the vital signs. The information collected and recorded by the sensors can be accessed anytime by the medical staff through the web server specifically designed for this purpose.

4 SURVEY METHODOLOGY

The aim of this study is to investigate the level of acceptability, usability and functionality of our WSN applied to the population of elderly people with a specific emphasis on patients with dementia.

We conducted a survey that targets three different groups of participants: older adults, their relatives and health practitioners. The total number of participants who took part in the study is 146: 44 elders, 51 relatives and 51 health professionals.

	Elderly	Relatives	Medical Staff
Participants	44	51	51
Males	25%	29,4%	31,4%
Females	75%	70,6%	68,6%
Age range	60 to 97	24 to 67	26 to 64
AVG age	76	44	40
SD age	8,53	6,69	11,73

Table 1: Demographic data of the participants

After a short description of the purpose of the study and an introduction of our research group, the survey was divided into four parts presented in the following subsections.

4.1 Personal information

The first section of the survey was dedicated to the personal data of the respondents. We collected the information about the age and gender of all the participants (Table 1). The elderly people and relatives were also asked about their level of education. The majority of older adults (71%) obtained a primary education. Among the relatives two most frequent answers were consecutively a high school (31%) and a secondary school (29%) diploma. The survey addressed to the health professionals included a question about their specialization. As reported in Figure 1, nurses made up 43% of the respondents from the medical staff group. Other professions are distributed as follows: 27% of doctors, 16% of psychologists, 12% health-care assistants. The remaining 4% was composed of educators and physiotherapists.

4.2 Familiarity with technology

Since the WSN users are meant to be older adults and their relatives, we consider highly relevant the information about participants' familiarity with technology. It allows for the prediction of what problems we may encounter, what is the most suitable communication channel and to what extent our technology can be applicable.

4.3 Wearable sensors: description and preferences

To help the respondents understand what is the WSNs and what are their possible applications, this segment starts with a description of the system. We explain what kind of data can be collected and recorded, what is the size and other physical characteristics of the sensors and how it can be inserted into the items of everyday use. The description is followed by several questions which differ depending on the targeting group.

The older adults – being end users – are asked both about their personal preferences regarding different types of accessories and a the possible placement of the sensors. They express their opinion about the items in which our sensors can be hidden, the utility of proposed technology, the acceptability of the system and their own willingness to use it. They are also asked to predict the increment of the sense of safety.

The relatives are requested to give their opinion on the utility of the WSN both from the perspective of the elderly and their caregivers. They evaluate to what extent this technology can improve the quality of life. Additionally, they are asked about the best possible placement of the sensors and predicted acceptability of the technology among their older family members.

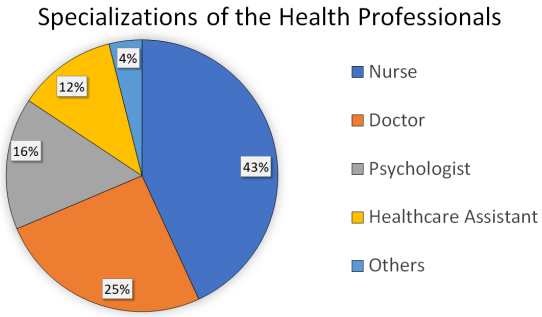

Figure 1: The distribution of specializations of the health professionals

The survey addressed to health professionals includes a section in which participants are asked to share their own ideas of possible applications of the WSN in the clinical settings and types of patients that would benefit from the implementation of this technology. In addition, they answer the same general questions about the utility and placement of the sensors as the rest of participants.

4.4 Shareability of information

The last section of the survey was dedicated to the privacy issue, as it is considered to be one of the main concerns in wireless sensor networks applied to the medical field [1]. Health related data are very sensitive by nature, so we aimed to understand, which information and with whom our target group is willing to share.

The medical staff and relatives are asked to indicate, which data collected by the sensors might be useful for them. They also express their opinion on with whom the information should be shared and if the end users should have the possibility to decide, which data they want to make available for others.

The elderly respond to the questions regarding the level of control they would like to have over the shareability of information, the influence of the usage of our system on their well-being and the extent to which they would feel monitored by the ones they decided to share the data with.

5 RESULTS

Obtained results will be presented in subsections corresponding to previously described segments of the surveys.

5.1 Familiarity with technology

We investigated what kind of technological devices are most commonly used among the respondents. Irrespectively of the group, mobile phones appeared to be the most widespread technological tool (see Figure 2). In the groups of health professionals and relatives also a computer seems to have a wide appeal - 84 and 63 percent of participants, respectively, admit to use it frequently. In respect of the age range of the elderly group, it is not surprising that a quarter of respondents claim not to use any of the listed

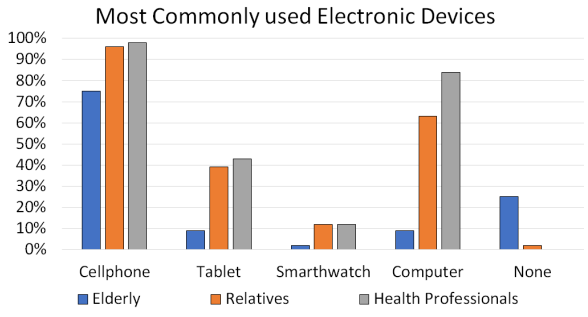

Figure 2: Electronic Devices most commonly used by each group of the participants

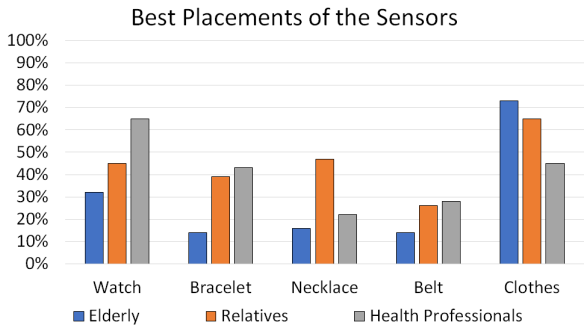

Figure 3: Best placement of the sensors according to each group of participants

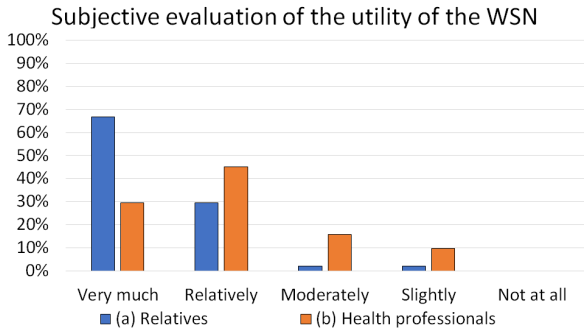

Figure 4: Subjective evaluation of the utility of WSN for: (a) the family members and (b) health professionals, estimated by the two groups respectively

devices. 63% of the health practitioners, 78% of the relatives and 59% of older adults admitted that they have at least one of the above mentioned devices with them at all times.

The results obtained from the question about the most frequently used functions of the technological devices showed some significant differences between the elderly people and two other groups of participants. As both relatives and health professionals indicate text messages (SMS, WhatsApp or similar) to be the main feature they use, only 25% of older adults admit to employ this function frequently. Unlike the medical staff or relatives, they are also not used to utilize services like Google Maps, music platforms or audio/video applications. Only 6%, 3% and 14% of the elderly, respectively, indicated to use these functions. On the contrary, over 94% of older adults admit that they are making phone calls on an everyday basis.

An overall familiarity with technology is lower among the elderly (with 52% of the group claiming to have only a little knowledge of this area), in respect to the health professionals (55% evaluate their knowledge as good or very good) and relatives (31% claim to have either an average or very good knowledge of the field).

5.2 Wearable sensors: description and preferences

To understand where the sensors should be inserted to be worn most frequently, we asked the group of seniors what accessories they usually wear. The most commonly appearing answers were: a watch (39%), a bracelet (39%), a necklace (36%) and a bag/waist bag (25%). A direct question, with a multiple choice, regarding the best items for the sensors to be placed in was asked to all of the three groups of participants. As reported in Figure 3 both the elderly and relatives believe that sensors sewn into the clothes would be the most practical solution. For the health practitioners, on the other hand, inserting the sensors inside a wristwatch appears to be even more functional.

70% of the elderly respondents evaluate the proposed technology as highly useful, whereas 82% of health professionals admitted it would be relatively (35%) or very useful (47%) for the family members or caregivers of older adults and patients. A subjective estimation of the utility of the system for their own purposes is reported in Figure 4a. The majority of the relatives consider WSNs as highly useful both for their loved ones requiring assistance (73%) and for themselves as caregivers (67%, see Figure 4b).

An additional part of the survey addressed to the medical staff asked them what kind of patients would benefit the most from a WSN and what possible applications it may have. The most commonly appearing answers for the first question were: older adults (especially if living alone and being relatively independent), dementia patients with different types of neurodegenerative diseases (with most common reference to Alzheimer's disease), patients suffering from chronic diseases, such as diabetes or cardiovascular diseases, psychiatric patients and individuals with physical disability. Among the most frequently mentioned applications of the system, there were: locating the position of patients affected by the wandering behavior, monitoring vital signs and falls prevention.

5.3 Shareability of information

We aimed at understanding whether the expectations of the relatives and health professionals about the data accessible to them meet the willingness of the elderly to share them. Therefore, we asked the first two groups what kind of information might be useful for them, and the group of older adults what data they would agree to make available to others. Each person could have indicated more than one option. As reported in Figure 5a the majority of seniors agree to share all of the outputs that the relatives and medical staff consider relevant (see Figure 5b and 5c respectively). According to 78% of the health practitioners and 67% of family members, the best

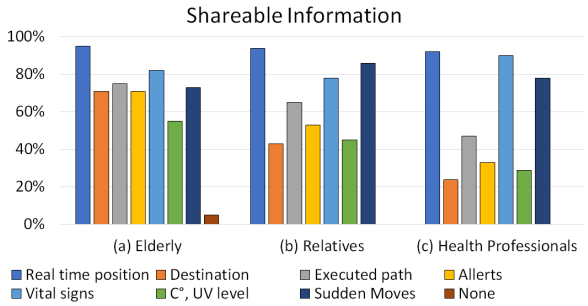

Figure 5: Shareable Information: Information that the elderly would agree to share (a), Information the relatives (b) and health professionals (c) would like to have an access to

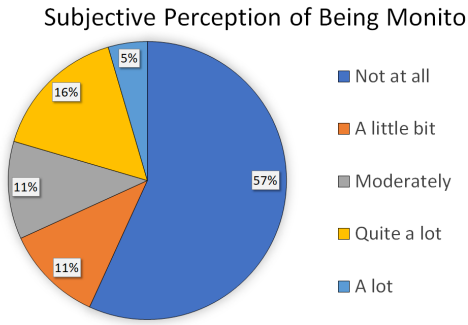

Figure 6: The extent to which older adults would feel monitored using WSN

receiver of the alerts and records in case of an emergency would be an emergency contact specifically indicated by the end user. Most of the older adults state their willingness to decide what kind of data they share (91%) and when (93%). 82% of the medical staff and 69% of the relatives agree that the elderly should be in control of what information to share.

In oder to make sure that our target group would not experience any kind of discomfort using the proposed technology, we asked the respondents to what extent they would feel monitored. As reported in Figure 6, 68% of the participants answered either 'not at all' or 'a little bit' to this question (57% and 11% respectively), which shows that an actual level of discomfort experienced by the elderly is even lower than estimated by the relatives or medical staff.

6 CONCLUSION

Older adults are generally excluded from the discussion of modern technology as they are rarely considered to be a target audience of new technological solutions. However, our study suggest that this might be a misconception. Even though an average level of familiarity with technology among the elderly respondents was claimed to be low, the vast majority of them expressed their willingness to use the proposed WSNs in their everyday lives. Clearly, the technology should be as little intrusive and visible as possible to be applicable; sewing the sensors onto the piece of clothing could be the solution.

Based on obtained results we can state the elderly do not consider as an issue sharing their data collected by the system with their relatives or health professionals. However, having control over the privacy settings would be a highly appreciated feature. All in all, our WSN was met with a general approval. All groups of participants perceive the proposed technology as an innovation that may positively influence their lives.

Obtained results also confirmed that our WSN can have a wide range of applications in the medical field. Possible employments suggested by the health practitioners are in line with our initial assumptions about the utility for patients affected by cognitive decline, dementia and the population of older adults in general.

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