Towards Designing Information System of Health-Monitoring Applications for Caregivers: A Study in Elderly Care

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På Väg Mot Utformning av Informationssystem för Hälsobevakningsapplikationer för Vårdgivare: En Studie i Äldreomsorg

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ABSTRACT

With the increasing elderly population and longer life expectancies, smart wearable technologies are playing an important role in facilitating caregivers to monitor elderly people remotely. Aifloo’s wristband is one smart wristband which can collect various data, predict activities and detect abnormalities to enable elderly people to live independently at home. However, too much information and poor visualizations will cause huge difficulties for caregivers to interpret the data. Six caregivers were interviewed in this study to investigate what data is relevant to monitor elderly people and how they interpret the different designed displays. The main results show that alarms, fall incidents and medication compliance are the most important. Besides, caregivers place a greater emphasis on holistic views of data and they want to highlight abnormal behaviors and alerts. In the end, design guidelines for the information system to present data meaningfully and intuitively are generated.

ABSTRAKT

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ABSTRACT
With the increasing elderly population and longer life expectancies, smart wearable technologies are playing an important role in facilitating caregivers to monitor elderly people remotely. Aifloo’s wristband is one smart wristband which can collect various data, predict activities and detect abnormalities to enable elderly people to live independently at home. However, too much information and poor visualizations will cause huge difficulties for caregivers to interpret the data. Six caregivers were interviewed in this study to investigate what data is relevant to monitor elderly people and how they interpret the different designed displays. The main results show that alarms, fall incidents and medication compliance are the most important. Besides, caregivers place a greater emphasis on holistic views of data and they want to highlight abnormal behaviors and alerts. In the end, design guidelines for the information system to present data meaningfully and intuitively are generated.

Author Keywords
Elderly people; caregivers; health monitoring; Aifloo’s wristbands; data visualization.

INTRODUCTION
The world is facing an increasingly serious aging situation where there will be almost 20 percent of the world’s population over 65 years old by 2050 [16]. Elderly people are so fragile that we need to pay more attention to protect them from various situations, such as falling incidents [8], deterioration in health status [21] and so on. With an increasing elderly population and longer life expectancies, we have to spend more resources and time on elderly care. The report conducted by The Health Service Executive of Irish hospitals shows that nearly 87% of the patients remaining in hospitals were elderly [13]. On the other hand, elderly people prefer living in their own homes for as long as possible to staying in hospitals or nursing homes [25]. In order to resolve this problem, we need to facilitate elderly people with assisting tools to enable them to live independently at home.

During the last decades, there have been a rapid development of smart wearable technologies which can facilitate caregivers to monitor elderly people, promote the elderly’s independence and increase their quality of life through early detection of health problems and dangerous situations [5]. Among the smart wearable technologies, the smart wristband is very common and popular. It can offer caregivers an unobtrusive monitoring of elderly people by gathering various health data over time at home. Furthermore, smart wristbands are widely accepted and used to help elderly people improve their health [15]. Aifloo is a Swedish startup company which designs and develops a self-learning e-health system assisting elderly people to live independently at home. Aifloo’s system consists of three different elements: a motion sensitive wristband that collects various data such as indoor location, steps and movements; a cloud server that analyzes collected data and secures a continuous connection; and an information system that presents data for caregivers to monitor elderly people. By analyzing and processing collected data, Aifloo’s wristband can predict activities and catch something unusual or out of the ordinary, e.g. he/she does not get up from bed at a relatively normal time or if he/she goes to the toilet too many times. As elderly’s daily activity patterns are closely related to their health status [1], it is very important for caregivers to monitor elderly’s daily activities, notice the deviations and receive alerts in the information system easily and quickly, thus offering help to elderly people immediately.

It is obvious that caregivers want to gather as much data as possible to monitor elderly people sufficiently and accurately. However, the large amount of different and complex information could overload caregivers, including collected sensor data and detected changes in various activities. Putting all data in the information system will cause difficulties for caregivers to search for information they need. Besides, caregivers are so busy that they would like to interpret and get insight from this information easily and quickly. Hence, it is necessary and important to explore caregivers’ needs and preferences regarding what information is important to them, and how they would like to view this information.
LITERATURE OVERVIEW

Smart wristbands

Although it is a relatively new concept to monitor elderly people’s health status through smart wristbands, related research and products develop so fast [8]. There are some mature smart wristbands in the current market: falling detection smart wristbands [26], measuring specific pathology medical smart wristbands [3] or tracking GPS wristbands for elderly with dementia [11]. Anliker [3] explains the main concepts of AMON, which is likely the first wrist-wearable multiparameter medical monitoring and alert system. AMON consists of collection of multiple vital signs, emergency detection and a cellular connection to a medical center. With the unobtrusive wrist-worn enclosure and aggressive low power design technology, it allows caregivers to conduct continuous monitoring of patients’ daily activities without restricting their mobility. Angelini et al. [8] present the design process of a smart wristband which aims at enhancing the quality of elderly people’s life. The smart wristband can monitor health status and facilitate daily activities, including alerting abnormal conditions, reminding the wearer to take medicine and digital payment. However, most of this research is about the aesthetic design of the wristband, how to collect data by sensors, or how to transform and analyze data. There is a lack of research about the information system: what data to present and how to present it intuitively.

Health monitoring system

Health monitoring systems can monitor and report the elderly’s health and their daily activity patterns automatically [11]. There are wearable and/or embedded sensors collecting data in health monitoring systems. According to Suryadevara et al. [23], it is very important to analyze the data from a huge data base to learn and recognize the daily activity patterns. In order to detect deviations and send alerts to caregivers, the health monitoring system should know what the normal activity patterns of elderly people are. Furthermore, health monitoring systems can predict the potential diseases [11]. For example, staying in kitchen for longer time may indicate the dementia; increasing eating, drinking, toileting and decreasing weight may indicate the diabetes. Therefore, understanding the normal activity patterns and detecting abnormal behaviors are the key to the sufficient and successful health monitoring system. The Center for Advanced Studies in Adaptive Systems [27] designs and develops a health monitoring system to collect various data and recognize activity patterns, including nutrition, sleep, hygiene, socialization, medication, fall detection, etc. Git et al. [15] suggest that the focus of health monitoring should concentrate on regular living aspects which have a relationship with wellbeing, e.g., sleeping, eating, etc.

Data visualization

Poorly visualized interfaces will lead to potential misunderstandings and misinterpretations of information generated from ambient assisted living services for elderly people [14]. The information system should present normal activity patterns succinctly and highlight deviations. The proper and intuitive data visualization can minimize the cognitive load for caregivers to interpret this information system. Mulvenna mentions that different users e.g. caregivers, technical staffs, and care recipients have different needs and requirements for the information system. It means that it is the key for designing a successful information system to understand the needs of the specific user group- caregivers. Shaehan and Skubic [22] analyze and redesign the interactive web-based interface for presenting the in-home data from motion, bed and gait analysis sensors, because the design and usability of the web interface greatly affect the effectiveness of the clinical decision support system. They focus on designing a user interface that supports the health alerts as a means of early detection of health change and functional decline such that early interventions are possible. They start from analyzing the information system for inconsistencies and potential user frustrations, and then make improvements on time navigation, visual controls and multi-device friendly. There are some existing information systems presenting sensor data using text-based visual elements, colored tables and charts [14]. Caregivers prefer easily interpreted information independent of skill level and prior knowledge [12]. Also, compared with the daily status, they show more interest in the trends over long period. Therefore, in order to design the best visualization of data, it is necessary and important to ask the caregivers for their opinions regarding which visual methods can convey the information they need and minimize cognitive load [6].

METHOD

There are two aims of this study: (1) to investigate what data from Aifloo’s wristbands is important for caregivers to monitor elderly people, and (2) to explore caregivers’ preferences for visualization of each kind of data. In this study, the data will be limited to what Aifloo’s wristband can collect: firstly, Aifloo’s wristband can collect the elder’s movement and location at home; then through self-learning process and artificial analysis, it can predict activity patterns and detect abnormalities. For example, when the elder is close to the medicine cabinet and behave like taking something out from bottles, putting something into mouth and drinking water, it will predict that the elder is taking medicine. However, other information like what medicine the elder is taking, what food the elder is eating and bio data: heart rate, blood pressure, and body temperature are not included in this study due to the lack of such sensors.

There are five phrases in the procedure: 1. interview caregivers to identify what data they need to monitor elderly people; 2. design different visual displays for various data based on prior research and results of interviews; 3. conduct first-time user tests with the same caregivers interviewed before to get feedbacks about visualizations of data; 4. redesign some visual displays.
based on the results of first-time user tests; 5. go back to do the second-time user tests.

Participants
In order to get a good match between the developed technology and end users, it is necessary and significant to involve end users at the beginning of the process [24]. The end users are people who use the technology directly, in this study, caregivers. Besides, knowing the requirements of caregivers is the key to the success of designing the information system to visualize data for caregivers intuitively.

Six caregivers from two nursing homes were selected for the semi-structured interviews. They all had a good understanding of Aifloo’s smart wristbands and strong interests in e-health technology after the introduction of this study.

Interviews with caregivers
Six semi-structured interviews with caregivers were held at the nursing home to explore what data collected from elderly people through Aifloo’s wristbands should be presented in the information system. Each caregiver was interviewed with a card sorting task individually for around 60 minutes. Card sorting is a technique in user experience design and a useful approach for designing information architecture [20]. Closed card sorting was used in this study, where each caregiver was given cards with different data and information identified from Aifloo’s wristbands’ functions and previous research. They were also asked to combine cards into subgroups for combined information they wanted to see and to prioritize them in order of relevance. They could write down data/information on empty cards, which they thought were relevant to monitor elderly people and not given yet. After the card sorting task, they were also asked about why and how they wanted to view this information.

The interviews were voice recorded and transcribed for further analysis.

Design process and first-time user tests
Based on the results of the six semi-structured interviews and prior research regarding caregivers’ preferences and requirements for visualizing data, different visual displays for various data were designed using principles derived from cognitive theories [4, 17]. Then user tests were conducted to interview the same caregivers about the visualizations of data, including how they processed and interpreted each visual information, their preference within different visual displays, and the possible improvements.

Redesign process and second-time user tests
Based on the results of the first-time user tests, some visual displays were redesigned, e.g., change the visualization methods, polish the charts or add some other data. Then second-time user tests were conducted to get more feedback.

Qualitative data analysis
For the qualitative analysis of the interviews and user tests, inductive coding was used. The transcripts were analyzed to identify labels and sublabels. Based on the content of the interviews and the labels that were identified, a coding scheme was made. The transcripts were coded, where quotes were grouped into labels and sublabels according to similarity. Based on the results of qualitative data analysis, the guidelines of designing the information system for caregivers to present health data intuitively were concluded and given.

RESULT
The results of this study consist of participants’ demographics, results of interviews with caregivers, results of design and first-time user tests and results of redesign and second-time user tests.

Participants’ demographics
Basic information of caregivers is shown in Table 1. There were five females and one male in the respondent group. They have an average age of 33.2 ranging from 27 to 45 years old. All of them are experts with technology. Their care experience years range from 3 to 23 years.

<table>
<thead>
<tr>
<th>Alias</th>
<th>Gender</th>
<th>Age</th>
<th>Experience with Technology</th>
<th>Care Experience (years)</th>
</tr>
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<tbody>
<tr>
<td>P1</td>
<td>F</td>
<td>45</td>
<td>Expert</td>
<td>23</td>
</tr>
<tr>
<td>P2</td>
<td>F</td>
<td>42</td>
<td>Expert</td>
<td>20</td>
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<tr>
<td>P3</td>
<td>F</td>
<td>29</td>
<td>Expert</td>
<td>8</td>
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<td>P4</td>
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<td>P5</td>
<td>F</td>
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<td>Expert</td>
<td>4</td>
</tr>
<tr>
<td>P6</td>
<td>F</td>
<td>28</td>
<td>Expert</td>
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Table 1. Demographic Characteristics

Interviews with caregivers
The results of interviews with caregivers were organized by different themes which emerged from interviews that helped to describe their overall needs of data. These themes focused around important activities of daily living (ADL), delivery of the data and additional data.

Activities of daily living (ADL)
Medication compliance. The most important thing caregivers wanted to see in the information system was medication compliance. All the caregivers wished to know whether the elderly people took their medicine on time. When an elder forgot his medicines, the most important thing was that the caregivers should receive an alert on the
mobile phone so that they can remind him to take medicine immediately. Also, three caregivers (P1, P2, P5) thought that it was relevant and necessary to record how often the elderly forgot their medicine, because it could be used to notice and predict dementia. P4 mentioned that it should record the time they forgot to take medicine which was one useful context data. However, P3 described her worry:

"Not only did the elderly need to take the medicine on time, but also they should take the medicine properly, not less or not more, otherwise it could result in serious health concerns. However, it looks impossible to know it accurately through Aifloo’s wristbands by now."

Nutrition. One of the most relevant ADLs concerning enabling elderly people to live independently was nutrition. All the caregivers wanted to know whether the elderly had enough nutrition every day. Aifloo’s wristband can distinguish when and whether the elderly are eating or not, but it can not correctly indicate what kind of food they consumed and how the quality of food was. P1 and P3 pointed that it was still necessary and meaningful to record the eating time and frequency, because they always followed their own eating routines. Caregivers should be noticed when there were deviations.

Location at home/Routines. It is important for all the caregivers to see the elderly’s location at home which is closely related to their routines. A healthy elder should follow his routine every day. P1 said that if an elder had his dinner at 10 pm, it may not be an unhealthy indicator, but simply his routine. On the contrary, if a break from his routine happens, it always indicates that there is something wrong with his health. The information system should highlight all the irregular behaviors, like spending more time in kitchen and sitting in sofa longer (P1, P3, P4).

Sleep pattern. All the six caregivers agreed that many aspects of sleep pattern were relevant and important to monitor elderly people. These include bedtime, wake-up time, how many times they waked up at night, how long and how often they slept during the day time, and whether the sleep apnea happened. P1 thought the location of sleep was also important because some elderly people forgot to go to bed but slept on a chair in living room.

Physical activity. Some said that this was not so important because the elderly were too old to be physically active anymore (P5, P6). Others thought it was relevant to monitor elderly. On the one hand, the elderly were less active when they were not feeling well (P1, P2, P3). On the other hand, the physical activity was related to other data, for example, the elder had more risk of falling down if he had a big increase of physical activity (P4). The trend of physical activity over a long period (week/month) had more meaning than the separate activity amount of each day.

Toilet. There was not much use of the toilet time and duration period because they were strongly related to personal habit (P2, P5). However, it was still meaningful to record the toilet frequency because the urinary infection could be predicted when the toilet frequency was abnormal (P1, P3, P4).

Hygiene. Four of the six caregivers thought it was important to record the shower frequency (P1, P2, P4, P5). It would damage elderly’s health if they took the shower too much or too seldom. Besides, three caregivers wanted to know if the elderly brushed their teeth every day (P1, P3, P6), because it played an important role in influencing their oral health. P2 and P6 also wished to know whether the elderly lived in a clean environment and whether they wore the clean clothes, although they knew it was too difficult for Aifloo’s wristbands to detect these correctly. P4 mentioned that:

"If the elder needed help in the shower and had the preference of caregiver’s gender, it should mark it so that we can help him/her properly. I was refused by one lady when I tried to help her with shower because she preferred female caregivers, but I did not know it in advance and it caused the waste of time."

Fall incidents. All the caregivers agreed that it would be a disaster for elderly people if they fell down and nobody noticed that. Therefore, when there was a fall incident, the information system should alert caregivers immediately to offer help. They all thought it was better to prevent fall incidents than to offer help to the elder once he/she fell down. It was important to find out the reasons behind the fall incidents. P5 and P6 mentioned that the time of the fall incident was also useful, because it could be analyzed and connected to other contextual factors, like getting up at night or walking too much. Four caregivers said it was useful to record how often the fall happened to check if it was an increasing problem, because some elderly people got up by themselves and did not report it to caregivers (P1, P2, P4, P5).

Alarms. All the caregivers always wanted to have an alert on their mobile phones so they could offer help as soon as possible. Four caregivers also found it so important to see when and how often the elderly raised an alarm that they could recognize patterns and anticipate on that (P1, P3, P4, P5).

Delivery of data
Alerts. All the caregivers said they wanted to receive an alert on their mobile phones that they could check it and offer help immediately. However, they did not want to receive too many alerts which would prevent them from doing their job. It should send alerts when there was a critical situation happening, like alarms, fall incidents, forgotten medicines and other serious deviations.

Modifiability. All the caregivers appreciated the function that it allowed them to set threshold for change and then be alerted if the criteria were met. They also wanted to select what information to be presented and what information to be hidden based on the health background of
the elderly people. Otherwise, presenting irrelevant data would cause information overload for caregivers. What’s more, the potentially relevant information in the future should be added into the system although they were irrelevant now (P2, P6).

Sharing data. All the caregivers agreed that it was necessary and important to share data, because it always happened that several caregivers took shift to take care of the same elder. P1 mentioned that: “It would be great if we can connect this information system to that one of hospital. Then we could know all the health records of the elder.”

Quick visualization. P1, P3 and P5 said that they preferred the overview of each elder, because they were so busy and wanted to know what to do in a short time. P2, P3, P4 and P5 suggested that it would be great that they could draw information they needed after just taking a glance of the visual displays. P6 mentioned that it should not require special knowledge to understand the visual displays.

Additional data
Caregivers were asked to write down additional data on empty cards which was not given but still relevant to monitor elderly people in their opinions. Four caregivers wanted to know if the elderly had enough social contacts (P1, P2, P3, P6). Three caregivers cared about the emotional wellbeing of the elderly (P1, P4, P6). P5 mentioned that it was relevant to know whether the elderly had enough groceries.

Design process and first-time user tests
Based on the results of the interviews with six caregivers and the design principles from previous research, two different charts for each important data were designed and shown to caregivers during the user tests. They were encouraged to say anything about the charts, including how they processed and interpreted each visual information, their preferences for different visual displays, and the possible improvements.

Summary of health. A summary of health where all relevant information was provided at one page would be valuable for caregivers. There were two different visual displays of summary (Figure 1-1 and Figure 1-2):

Figure 1-2. List of summary of health
Caregivers were not very enthusiastic about the hGraph (Figure 1-1), because they could only see if something was abnormal, but couldn’t directly see why it was abnormal. It was difficult to distinguish various data in hGraph. On the contrary, they preferred the list of summary of health (Figure 1-2), because it was easier to read and they could see if there were any problems on specific aspects at a single glance. But too many texts would distract caregivers’ attention.

Location at home. Three caregivers (P1, P3, P4) agreed that they preferred the line visualization (Figure 2-1) which is the more extended version of the location at home.

Figure 2-1. Line visualization of location at home
In this line visualization, they could see daily patterns and abnormalities within these daily patterns like the sleeping pattern, frequency of going out of bed, etc. They were very content with all the information that was visible in the line visualization. The line visualization showed more information than the pie chart that only gave the percentages of the occupancy per room (Figure 2-2).
Other caregivers found the pie chart (Figure 2-2) relevant, because they could easily see a shift in daily patterns like more time spent in the bedroom for example. Besides, they thought it took long time to understand the line visualization especially when there were many different rooms and changes.

Sleep pattern. Five of the six caregivers (P1, P2, P3, P5, P6) preferred the horizontal bar chart (Figure 3-1), because it was simple and easy to see the bedtime, wake-up time, and interruption time. It could show the trend and difference in bedtime and wakeup time during a period.

“Not only the length of sleep time but also the quality of sleep are important factors to be measured in sleep pattern. Some elderly people often sleep during day time and wake up during night. (P2)”

P4 liked the vertical bar chart (Figure 3-2) where the trend of sleep hours could be easily shown and other details would show up when clicking one specific date.

Frequencies. There was some data where frequencies were important factors to be measured, like toilet visits, taking shower, forgetting medication, fall incidents, etc. Taking the toilet frequency as an example, there were two different designed figures: line chart (Figure 4-1) and bar chart (Figure 4-2).

All the caregivers found it more relevant to see this in a line chart than in a bar chart. They did not pay much attention to the times on one day, but they cared about the trend of frequency and the abnormal points in long period. Besides, it should allow caregivers to select specific date ranges.

Redesign process and second-time user tests
Based on the caregivers’ feedback and suggestions from the first-time user tests, these visual displays were redesigned, e.g., apply different visualization methods, polish the charts and add the visualization of “Physical Activity”. Then second-time user tests were conducted to get more feedback.

Summary of health. Doughnut was used to present the summary of health to replace hGraph. It used icons to represent different activity patterns instead of words. Besides, different color could show the status whether it
was normal or not. Here were two new visual displays of summary of health (Figure 5-1 and Figure 5-2):

![Figure 5-1. Doughnut of summary of health](image)

![Figure 5-2. List of summary of health](image)

Most of the caregivers preferred the list of summary of health (Figure 5-2) because they were so busy during work and wanted to know what happened on the elderly people specifically at a single glance (P1, P2, P3, P5, P6). From the doughnut chart (Figure 5-1), they could only see what was normal and what was abnormal, but they did not know the details. On the contrary, the list of summary could help caregivers understand the overview health status of the elder easily. It used a meaningful text to tell caregivers why certain aspects were abnormal. Besides, it put the most seriously abnormal activity pattern on the top so that caregivers could notice that simply and take action immediately. P4 liked the doughnut chart:

“I appreciated the idea that showing the grade of the elder’s health status in the center. Usually, we took care of more than one client and sometimes, they needed help at the same time. Based on the grades, we could make a decision quickly and offer help to that one with the lowest grade. What’s more, it should present more details if I clicked the red status.”

**Location at home.** P5 and P6 agreed that the pie chart (Figure 6-1) was easier to understand. They could know the percentages of the occupancy per room and see the daily pattern like more time spent in the living room for example.

![Figure 6-1. Pie chart of location at home](image)

Other caregivers liked the line visualization (Figure 6-2) because they could get more information from it.

![Figure 6-2. Line visualization of location at home](image)

From the line visualization (Figure 6-2), they could know how the elderly spent the whole day at home and also get some hints of the abnormalities. Using different colors for different rooms made it simpler and easier to distinguish.

“It was abnormal that the elder spent half of the day in the living room but only 20 percent in the bedroom. We could not analyze the reason based on the pie chart. However, from the line visualization, we could guess the elder forgot
to sleep at the bedroom because he/she stayed at the living room at night. (P1)"

Sleep pattern. Four caregivers (P1, P2, P4, P5) thought the doughnut (Figure 7-1) was better because they could see almost all the information they needed about sleep pattern, including bedtime, wake-up time, wake-up times during sleep, how often and how long the elder slept during day time. What’s more, it indicated light sleep and deep sleep.

P3 and P6 liked the bar chart (Figure 7-2) where the trend of sleep hours during day and night could be easily shown. They suggested that it would be better if specific details would show up after clicking one date.

Physical Activity. In the first-time user tests, P1, P2 and P3 mentioned that physical activity was important and should not be missed. Area chart (Figure 8-1) and pie chart (Figure 8-2) were designed to show physical activity of the elderly.

All the caregivers preferred the area chart to the pie chart. They all agreed that there was no use to know the details of physical activity on one day. But the trend of physical activity over time was relevant. For example, when there was a decreasing trend, it always indicated that the elder was not feeling well. They suggested that it should allow them to select the period (week/month) to see the trend (P2, P3, P4).

DISCUSSION

Interpretation of results
This study sought to find answers to two questions: 1) what data from Aifloo’s wristbands is relevant for caregivers to monitor the elderly people and 2) what are the preferences and wishes of caregivers for the visualization of data? From the results of the six semi-structured interviews with caregivers, it can be seen that the caregivers were interested in almost all the regular living aspects which have a relationship with wellbeing. This was also found in previous research [15]. However, there is a significant risk that due to the large amount of data generated by Aifloo’s wristbands, caregivers will have difficulties in searching for information they need. In their opinions, alarms, fall incidents and medication compliance are the most important. It can be easily understood because critical situations largely are perceived as the most important to know. They also mentioned some relevant data Aifloo’s wristbands can not collect at the present time, like the quality of food and the elderly’s emotional wellbeing, but it
can provide suggested functional requirements for the future development of Aifloo’s wristbands. They placed a greater emphasis on holistic views of data and wanted to highlight abnormal behaviors and alerts. Due to the pressure of work, they wished to interpret the data and know what to do next at a single glance. In the meantime, they found values in component based views of data which allow identification of trends in overall health. Monitoring trends over time allows caregivers to observe activity patterns and identify deviations. They all agreed that it should be possible for them to modify the data presented in the information system. On the one hand, different elderly people have different needs based on their health backgrounds. It should present the relevant information and hide irrelevant information to avoid data overload. On the other hand, there are some potentially relevant data which will emerge with the elder’s increasing age. It should allow caregivers to add it to the information system in the future. It was also necessary and important to share the data among different caregivers to achieve better collaboration, because they often took shifts to take care of the same elder.

Although the above results are mostly consistent with Zulas et al. [12] about the caregiver’s needs from elder care assistive Smart Homes, there are many differences in the methodology. First of all, Zulas et al. explored caregivers’ general opinions of needs for sensor information. However, this study focused on caregivers’ needs of the specific data collected from Aifloo’s wristbands. It also discussed some important and relevant data which is not possible to collect at the moment, but it provided suggestions for the directions of Aifloo’s future research. Besides, Zulas et al. designed the visual displays of data firstly and then explored the preferences and needs of caregivers. On the contrary, caregivers were involved at an early stage of this study. Visual displays were designed based on the results of interviews with caregivers about their needs and preferences of visualizing data. Then first-time user tests were conducted with the same caregivers to get feedbacks about how they interpreted these visual displays, their preference within different visual displays, and the possible improvements. Based on the feedback collected from first-time user tests, visual displays were redesigned and evaluated in the second-time user tests. Understanding caregivers’ needs and preferences can significantly meet their requirements and increase the prospect of their engagement.

It could be seen from the results that the caregivers overall had a positive attitude towards remotely monitoring the elderly through Aifloo’s wristbands to enable them to live independently at home. On the one hand, it saves a lot of money and resources from not arranging the elderly to live in hospital or nursing homes. On the other hand, it can reduce the workload of caregivers and avoid unnecessary visits. The intuitive information system can help caregivers prevent being stuck in data overload and offer accurate and timely help to the elderly. In the future, the families can also check the elder’s conditions through designed information system based on their needs and preferences, thus no need to pay visits or make calls to enquire the elder’s current health status.

At the moment, most of the caregivers in elderly care are female. But the extensive usage of health-monitoring applications may influence the percentage of male caregivers in the future. There may be differences in the preferences for information system of health-monitoring applications between male and female caregivers. But it is difficult to draw any conclusion regarding gender in this study because there is only one male participant.

The caregivers also had the worries about the reliability, safety, and privacy of the data. Although this data was relevant and important for them to monitor elderly people, it nevertheless posed ethical challenges which allow for a serious threat to personal integrity. Using health-monitoring applications would certainly decrease the elderly’s physical contacts with caregivers, which might lead to their social isolation.

**Reflection on methodology**
This study aims to provide design guidelines for the information system of health-monitoring applications to present data collected from Aifloo’s wristbands by the means of interviewing caregivers. However, there are only six caregivers involved in this study due to the challenges of scheduling interviews from their busy work. Despite the small sample size, these six caregivers are from two nursing homes and the same one geographic area, which could cause a consensus among them. The elderly people they take care of might have similar health backgrounds, which has great influences on caregivers’ needs and preferences of visualizing data. More caregivers with various care experiences should be involved in the future study. Apart from that, another limitation of this study is that the coding process is performed by one person and others may analyze and interpret the data differently.

**Design guidelines**
The results of the six semi-structured interviews and user tests can provide design guidelines for the information system of health-monitoring applications to present data intuitively which helps caregivers monitor the elderly people living independently at home. These generated design guidelines include:

- Alarms, fall incidents and medication compliance are the most important aspects to be monitored. Besides, it should send alerts to caregivers’ mobile phones if any of these three happens, so that caregivers can check the elder’s health status and offer help immediately.

- It should allow caregivers to modify the presented data based on their needs.
● Any changes or deviations should be highlighted, including sudden and gradual changes over time.
● It should allow caregivers to set threshold for change and then be alerted if the criteria are met.
● It should provide the summary of health which can help caregivers see where to focus time and attention at a single glance.
● Visualizations should be easy to read and interpret without requiring prior knowledge or consuming long time.
● It should avoid presenting too many texts to protect caregivers from distraction.
● It should use icons and different colors appropriately to help caregivers understand data.
● It should allow caregivers to see the data in both short-term (day) and long-term (week/month) through interactive visualizations.
● It should support collaborations among caregivers by sharing data.

CONCLUSION
In conclusion, this study provides some design guidelines for the information system of health-monitoring applications to present data in a meaningful, holistic, intuitive but concise way. We can see from the results that caregivers are interested in the regular living aspects, especially these three most important ones: alarms, fall incidents and medication compliance. Besides, they prefer holistic summary of health status which helps them know where to put attention and time. Abnormalities and alerts should be highlighted and be sent to their mobile phone, then they can check the elder’s status and offer help immediately. They also want to modify presented data, set threshold for change and share data for collaborations.

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