Review of User Interfaces for Caregivers in Ambient Assisted Living

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***Abstract*—As the world's population ages, Ambient Assisted Living becomes a topic of considerable interest. At present, multimodal user interfaces in Ambient Assisted Living systems are an important research area. The contribution of this paper is to ascertain the needs of caregivers and family members, pertaining to the activities of daily living information of the elderly, discuss how these needs are best presented, and analyse existing user interfaces in Ambient Assisted Living systems based on the identified criteria. This paper concludes by highlighting the scarcity of research in the area of user interfaces and outlining future work to enrich the design of user interfaces.**

Keywords–Ambient Assisted Living; User Interfaces for Caregivers; Activities of Daily Living.

I. INTRODUCTION

The world's population continues to age rapidly as people live longer. It is predicted that by 2050 the number of people aged 65 years and over will exceed the younger population for the first time in history [1]. In this context, Ambient Assisted Living (AAL) extends the time period during which the elderly can live independently in their homes using Information Technology and reduces the overall burden on family caregivers.

Numerous AAL projects facilitate independent living for the elderly. The User Interface (UI) is an integral part of these projects, as UIs facilitate interaction between the user and the AAL system. The majority of users' interaction with computing systems occurs through a graphical UI [2]. UI design that addresses the needs of caregivers is critical to technology acceptance, adoption and consumer satisfaction [3].

UI design requirements are dependent on the type of users for which the interface is intended. In AAL, several types of users, or stakeholders, are distinguished [4]:

- The elderly: people who need assistance to live independently. They are considered to have the greatest stake in the success of the AAL vision;
- The family members and the elderly person's loved ones: they act as informal caregivers. The responsibility for caring for the elderly often falls upon them;
- Formal medical caregivers: people who are paid to give care. AAL helps the caregivers to use their limited resources in a more effective manner.

The needs of the first group of stakeholders, the elderly, have been studied thoroughly. For example, Johnson and Finn [5] present an extensive study of age-related changes in vision, motor control, hearing, speech, cognition, and they offer UI design guidelines. Dodd et al. [2] identify the physical, cognitive, and computer-related issues the elderly experience with UIs created to assist them and review the existing solutions.

However, UI research is limited for caregivers/family members, even though caregiving is regarded as a complex or even stressful activity and can cause adverse physical and mental health consequences [6]. Therefore, these technologies for helping caregivers/family members require more attention, as they offer a technological aid which may enable them to concentrate on their unique health needs and achieve a healthier lifestyle.

This paper will concentrate on caregivers/family members and their needs in AAL UI design. The contribution of this paper is to review, evaluate, and critique UIs for caregivers/family members in AAL systems that present summarised Activities of Daily Living (ADLs) information in an effective way. This paper is organised as follows. Section II defines the kind of information caregivers/family members need for reassurance that their elderly loved ones are undertaking their daily routines. Section II further describes how these needs are best presented in UIs for caregivers in AAL. Section III presents the UIs in AAL systems that provide assistance to caregivers/family members of elderly people, and analyses them based on the criteria described in Section II. The conclusions and future work are outlined in Section IV.

II. ADL INFORMATION AND PRESENTATION METHODS FOR CAREGIVERS OF THE ELDERLY

The first subsection will discuss the needs of caregivers/family members pertaining to the ADL information that UIs in AAL present. The visual methods which can be employed to present ADL information will be discussed in the following subsection.

A. ADL Information for Caregivers/Family Members

ADLs are routine actions that are performed by individuals every day and are essential for independent life. Correct ADL measurement is significant for the management of healthcare in aging societies.

1) Sleep: Sleep is vital for overall health at any age. The elderly who do not acquire good-quality sleep can suffer from a range of sleep disorders, for example, insomnia and sleep apnoea. Family members wish to be aware of their loved ones' quality and quantity of sleep as poor sleeping patterns have health implications. If an elderly person experiences multiple consecutive nights of poor sleep, their family members want

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to be informed, so that they can intervene if necessary [7]. Poor quality sleep reduces mobility, communication, and social contact with other people. The duration of day sleep, the length of uninterrupted sleep at night, the number of times, and for how long the elderly person gets up in the night are characteristics of the quantity of sleep [8]. To collect sleep data the following information needs to be logged: time of day when alarm is set, scheduled wake up time, time of day when the elderly person goes to bed, sleep duration, sleep efficiency, amount of times alarm is set to snooze function, duration of snooze periods, and time of day when alarm is deactivated.

2) Medication adherence: A high percentage of elderly people recently discharged from hospital do not understand the purpose of their medications. Therefore, the increasing number of drugs prescribed at hospital discharge is correlated to low medication adherence or complete non-adherence. It creates a real problem, especially for the elderly person receiving multiple drugs to treat a single condition [9]. This highlights the importance of knowing about medication adherence as well as the elderly person's medication list and regime for caregivers [7]. Caregivers/family members are worried about health problems aggravated by elderly people forgetting to take medication, accidentally taking too much, or even taking someone else's medication. Medication tracking is difficult if the elderly person lives alone. There is no perfect solution to this issue at the moment [10]. Besides accessing adherence statistics and information about medications taken or missed, caregivers/family members will benefit from a refill reminder feature [11].

3) Activity and Physical Exercise: Aging is one of the risk factors of physical and cognitive decline and physical activity is an additional effective non-pharmaceutical measure against aging. The elderly who stay active have reduced risk of such diseases as ischemic heart disease, stroke and diabetes. There is no evidence of physical exercise having a negative impact on cognition [12]. The amount of activity and physical exercise undertaken by the elderly person is of interest to caregivers/family members. For example, they want to know whether the elderly in their care exercise sporadically or on a regular basis. Some caregivers add that it is important for them to know certain metrics of physical ability such as strength and balance [7]. To comprehensively present activity and physical exercise information, such features as activity type, its duration, frequency, and intensity need to be logged.

4) Falls: A fall is an emergency situation and a source of danger to the elderly. Falls are a leading cause of unintentional injury among adults aged 65 and over. Even ground-level falls can result in multiple severe injuries. There are additional dangers if the elderly person lives alone. Most caregivers/family members have to ask the elderly person to carry their mobile phone around the home. The current technology required to detect falls invades the privacy of the elderly person (for example, cameras) while motion sensors may have difficulties detecting falls [8]. A UI fall detection system needs to be able to register an event, correctly identify whether it is a fall, and alert the caregivers/family members if necessary.

5) Localisation: Localisation of the elderly is of high interest to caregivers/family members. They find it important to be aware of the elderly's location in the home and to be notified in case they leave the house unattended to avoid the issue of wandering. Wandering is a very problematic and dangerous type of behaviour of the elderly, which could aggravate possible risks of suffering serious injuries as a result of the disorientation. A series of interviews with family members and with professional caregivers established that both groups of stakeholders prefer to be notified if the elderly person leaves the home for any reason [10]. Despite the fact that a situation where an elderly person leaves the house is not an emergency, compared to a situation where a dangerous fall occurs, it can still lead to hazardous consequences. Additionally, family members, even those who have their elderly relatives living with them in their own homes, expressed an interest in being aware where their elderly relative was in their home at any given point in time. The reasoning behind this is the fact that some areas of the house are not safe (sharp objects in the kitchen, slippery tile floors in the bathroom, etc.) [8]. Thus, information about the elderly's location, duration of stay, and time of entering/leaving the location is essential in a UI.

B. ADL Presentation Methods

ADL data collected from multiple sources over long periods can be a challenge to present efficiently. Which types of presentation convey ADLs in the best way, and how to visualise the relevant information for caregivers/family members, is still relatively unexplored [13]. The goal of using visual displays is to reduce the cognitive load of information and allow users to easily interpret large amounts of data [14]. Modern methods for visually presenting summary statistics include tables, charts, and graphs. They subsequently divide into column, bar, and pie charts, to name but a few. These diagrams are designed to show a considerable amount of information in a concise way, that allows for quick interpretation and understanding [15]. All of these methods could be deployed for presenting ADLs in UIs for caregivers/family members.

Colour carries an important meaning and has an impact on people's cognition and behaviour. Red is implicitly associated with failure and danger [16] and can even undermine performance on challenging tasks that require mental manipulation and flexibility [17]. Yellow is commonly used to indicate caution (e.g., brake lights). Blue and green are associated with positive content and are thought to be experienced as relaxing or cool, encouraging a calm and stable action [18].

Differing fonts have specific emotional and persuasive aspects. In a UI the size and type of font influences its readability. 14-point fonts are found to be more legible, promote faster reading and thus are recommended for presenting online text to users aged 60 years and over. There is no significant difference between the readability of serif (Arial, New Roman) and sans serif (Verdana, Georgia) fonts [19].

Taking into consideration the fact that many caregivers are themselves older [20], a UI must be as easy and user-friendly as possible. Simple ways of delivering ADL information to caregivers/family members are essential.

1) Sleep: Caregivers/family members need to see a detailed sleeping profile which includes the average sleep, sleep efficiency, duration, states and events detected overnight. Additional information such as the number of sleep interruptions, wake-up time, and bedtime can even be switched to another display and different colours for day and night time can be used [21]. Actigraphy is a major assessment tool in sleep research since it can identify changes over time by recording time in bed, total sleep time, sleep efficiency and detect sleep patterns associated with specific sleep disorders [22]. In a UI actigraphy data can be visualised in multiple ways: data plot, velocity

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plot, acceleration plot, etc., however a typical display includes spikes to signify different activity levels over a horizontal axis which represents a specific time (e.g., 24 hours or a week). These activity levels can be highlighted in different colours, e.g., red to indicate the period when the elderly person is awake, blue to indicate movement while asleep, green as a start of a new event (going to bed or getting out of bed).

2) Medication adherence: An alert as a text message to a mobile phone of a caregiver/family member is a convenient means for informing them of the elderly person's medication adherence or non-adherence [23]. A nonintrusive alternative to a mobile text message is a UI reminder which does not have to be 'pushed', forcing caregivers/family members to interrupt their current activity, since missing a medication is not an emergency situation. Instead the UI can indicate that a reminder can be retrieved and read when it is convenient, so that caregivers/family members will be able to defer follow-up action after receiving such a reminder. Other medication adherence features in a UI, such as adherence statistics viewing and taken/missed medication tracking, can be presented as calendars or timetables with the days highlighted in different colours depending on the type of event. As timetables are used for managing scheduled tasks, it would be possible to check what medication needs to be taken and when it needs to be taken. Highlighting the missed medication in a different colour would allow caregivers/family members to track the adherence statistics. A refill reminder might be another useful feature [11]. It can be visualised as a pop-up text message similar to that of a missed medication.

3) Activity and Physical Exercise: Activity and physical exercise can be presented in several ways in AAL UIs. Traditionally charts, metaphors, and numbers are the most popular techniques to visualise physical activity information [24]. Daily activity can be visualised in the form of a calendar, which interprets the usual patterns of activity as normal, requiring minimal attention from caregivers/family members. If an unusual event occurs, it could be depicted by a different colour (i.e., red instead of green). For example, Tong et al. [25] describe examples of activity and physical exercise visualisation where the data is represented in the form of a clock dial with a circle representing a time span. Each circle represents one month of time and each ring within that circle represents a day. Rings are then divided into 5 minute slots. If the user is active, the slots corresponding to relevant time become brighter in colour. If a caregiver/family member points the mouse over a particular time slot, information on the exact physical activity undertaken, and the time of that activity, is displayed.

4) Falls: The primary UI response to a fall should be an alert to a caregiver/family member. The image-based fall detection system FEARLESS [26] alerts caregivers automatically and the elderly are not required to take any action. The fall detection system developed by Wu et al. [27] sends a fall alarm text which contains fall location URL. By clicking the URL, caregivers/family members will see a map in a web browser where the fall location is tagged. However, a text message might not be enough. A notification in the form of an alarm seems appropriate in this case. There is no doubt that it has to be intrusive and interrupt the current caregiver's/family member's activity, forcing them to take immediate action before returning to whatever they were doing. This alarm has to be actively 'pushed' to a caregiver/family member, rather than simply be made available, so that it is retrieved, or 'pulled', at the recipient's convenience. Moreover, the alarm has to continue until it is manually stopped, which ensures that the caregiver/family member is aware of the fall.

5) Localisation: One needs to distinguish between visualising outdoor and indoor localisation of the elderly. For outdoor localisation, Faria et al. [28] propose a mobile monitoring system for elderly people. Once the location of the elderly person is detected, the UI displays a web page and a caregiver/family member is able to see the corresponding geographical map, where a red asterisk marks the exact location. Indoor positioning should work continuously in real-time and provide the locations of the elderly person in indoor areas [29]. To capture and depict this data, the UI has to be updated on a minute-by-minute basis. One of the options to present visualisation is a line chart with different colour lines representing different locations along the X axis, which is the timeline. Caregivers/family members would be able to see daily patterns and abnormalities within these daily patterns, e.g., if the time spent in bed is unusually long, it will be depicted by a long line in the chart. A pie chart could be an alternative option to visualise the indoor localisation of the elderly. Pie chart slices could represent the different locations of the house, so that caregivers/family members will be aware how much time per day their elderly loved one spends in each room.

III. Comparison and Evaluation of UIs for Caregivers

In this section, the UIs for caregivers of the following AAL systems will be reviewed:

1) HealthKiosk [30],
2) An Intelligent System For Assisting Family Caregivers Of People With Dementia [20],
3) GiraffPlus [31][32],
4) A Home Health Monitoring System Designed To Support Carers In Their Caring Role [33], and
5) A Monitoring System That Provides Feedback Regarding Physical Functioning [34].

Each of these systems is aimed at facilitating the everyday life of the elderly and their caregivers/family members. HealthKiosk is designed by IBM Research in China. It is a family-based healthcare system for health monitoring. It provides continuous monitoring of patients via a user-friendly interface, and can potentially reduce the effort required from care professionals. The Intelligent System For Assisting Family Caregivers Of People With Dementia is designed by Fukuoka University, Japan. It is an easy-to-run and easy-to-maintain system that monitors dementia patients, assessing their activity. It enhances the caregiver's monitoring ability, memory, problem solving and mobility. GiraffPlus is a collaboration between Örebro University, Sweden, Malaga University, Spain, and Lund University, Sweden. It is a telehealth system which supports independent living by the elderly, by addressing a number of issues aiming to enhance their well-being and extend the period of time for which they can live independently. The Home Health Monitoring System is developed by Distance Lab in Forres, Scotland. It allows people to record, track, and share their physiological health, mood, and calendar events. It is intended for use within informal support networks. The Monitoring System That Provides Feedback Regarding Physical Functioning is developed by Maastricht University,

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the Netherlands, and by the Institute Charles Delaunay at the Université de Technologie de Troyes in France. It provides feedback to elderly people and to their caregivers/family members, regarding the elderly person's physical functioning.

Out of these five AAL systems, only two have been piloted and deployed: HealthKiosk at the Peking University People's Hospital, China and GiraffPlus in real homes in Sweden, Italy and Spain. The remaining three are prototypes in various stages of development.

Figure 1. HealthKiosk [30].

In HealthKiosk UI, blue colour is used as a main background (Figure 1). The size of the font is big enough to be convenient to read. It is white against a blue background, and it changes to blue or black if the background is white. On the welcome page, the names of the buttons for different options (settings, blood pressure, blood glucose, community, and healthy tips) are complemented by symbols, e.g., a heart symbol for blood pressure. HealthKiosk offers an easy-to-use UI to interact with the biomedical sensors. The welcome page provides a summary of the functions in a user-centric and service-oriented manner. Users can set their personal settings, take their blood pressure and glucose levels, and browse healthy tips and community suggestions. To view the blood pressure visualisation graphic, the user has to set start and end dates first. Blood pressure is presented as a line graph, with red and blue lines representing systolic and diastolic pressure.

Figure 2. An Intelligent System For Assisting Family Caregivers Of People With Dementia [20].

The web-based UI of the Intelligent System For Assisting Family Caregivers (Figure 2) is minimalistic. When set in the Monitoring mode, it displays a real-time depiction of user's room in the upper left corner of the screen. Clear text on the right states the type of event (e.g., fall) and the place it occurred. The text in the frame shows the pre-scheduled actions. The red bar at the top right displays the level of emergency; the longer the bar, the higher the level of emergency. Below the visual depiction, there are buttons to activate audio communication and to deactivate an alarm. The four buttons at the bottom switch the display window between the Setting, Monitoring and Review operation modes, and access the emergency contacts if necessary. Red or orange text is used for warning or alarm messages, whereas non-alarm messages are shown in green or black. The UI is designed to be easy to understand and to operate.

The Intelligent System For Assisting Family Caregivers provides automatic, unobtrusive 24/7 monitoring, records the elderly person's movement, and it monitors sleep as the sensor network includes a bed sensor. The system allows for medication reminders. It logs the activity of the elderly person, and allows caregivers/family members to view the information for a specified time interval (hour, day, month and year), in the form of graphic or raw data (time, place, activity, generated message). The system is able to detect falls. If a fall occurs, the UI displays a real-time visual of the event on the screen. A text describes the level of emergency and where the event happened. The options for caregivers/family members include activating audio communication with the elderly person, de-activating the alarm, and accessing the emergency contacts if necessary. The system provides monitoring of the elderly person with dementia in their room or flat. Caregivers/family members are able to establish real-time visual and audio communication with the elderly. They can see the frequency or duration of activities such as leaving the room, approaching the entrance door, visiting the toilet, or staying in bed for longer than normal.

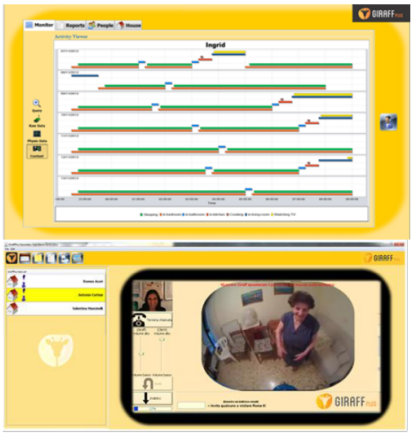

Figure 3. Giraffplus [32].

The UI of Giraffplus (Figure 3) has yellow as its dominating colour and a depiction of a giraffe as its logo. The menu tabs (Monitor, Reports, People, and House) are in the top left corner. The size of the font is quite small; the user would need good eyesight to read the text. The system allows video calls. A Skype-like interface is used: the caller sees the person they are calling, at the same time as seeing themselves on the same screen.

GiraffPlus is able to collect data and analyse long-term patterns in physiological parameters. Sleep and other activities in GiraffPlus are visualised using a line graph, where each activity is represented by different-coloured lines. The green line indicates sleeping, the orange line indicates the elderly person is in the bedroom, the light blue line indicates they are in the bathroom, the light red line indicates they are in the kitchen, the dark red line indicates the elderly person is cooking, the dark blue line indicates they are in the living room, and the yellow line indicates they are watching TV. Giraffplus does not have a medication reminder system, but it is able to present long term data that can show health

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deterioration. The system does monitor daily activities and the physiological parameters of the elderly person, and it presents a reliable view of their health status for caregivers/family members, as well as for the elderly person themselves. It is also able to detect falls, using its network of home sensors. If an event is recognised as a fall, the alarm is triggered. GiraffPlus detects where the elderly person is, whether he or she is sitting on the couch or lying in bed, using electrical appliances, opening cupboards or the fridge.

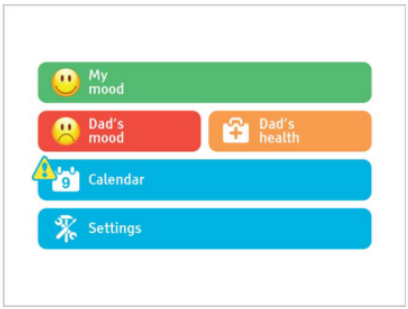

Figure 4. A Home Health Monitoring System Designed To Support Carers In Their Caring Role [33].

The Home Health Monitoring System is created to support family members (Figure 4). The UI consists of several pages; the home page gives an indication of the current mood and health status of the elderly person via an appropriate colour (red, amber, green) and a corresponding smiley face. It is also possible to access the calendar and the settings from the home page. Besides standard traffic-light coding colours, blue and grey are used as neutral colours. The buttons and font are intentionally large to promote quick readability. The system provides a health summary, which lists vital signs, along with the current day's notes. Users are able to enter new readings, view trends (history) graphs, and to compare graphs, which will allow the user to track mood and physiological health over time. The graphs show a week-to-view and plot the average value per day. The system includes a calendar where users can enter events by touching the relevant day. The repeat function can be used for events that happen on a recurring basis such as medication reminders.

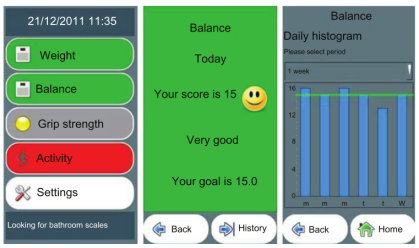

Figure 5. A Monitoring System That Provides Feedback Regarding Physical Functioning [34].

The UI for the Monitoring System That Provides Feedback Regarding Physical Functioning (Figure 5) was designed for a smartphone. The start screen has five large buttons (Weight, Balance, Grip Strength, Activity, and Settings). The text is clearly visible and easy to read. The navigation buttons (Back, History, Home) are clearly marked with appropriate symbols. The background colour of the UI is dark grey, and the buttons are of different colours: green, red, and white.

The UI of the system consists of three layers. The first layer, which is the start screen of the interface, consists of five buttons. When users touch one of the buttons, they enter the second layer, where they receive feedback regarding the measurement they performed. The History button represents the third layer, which provides an overview of the last six balance measurements in the form of a bar chart. The overview time can be set to 2 weeks, 1 month, 3 months, or 6 months, by touching the bar above the graph. When changes are positive, a green background and a smiley face accompany positive feedback messages. If changes are negative, an orange or red background is displayed, combined with an explanatory feedback message.

Out of the five AAL systems, sleep data is presented by the UIs of the Intelligent System For Assisting Family Caregivers, and by Giraffplus. Only the users of the Intelligent System For Assisting Family Caregivers can set reminders for taking medication. Giraffplus, the Intelligent System For Assisting Family Caregivers, and the Monitoring System That Provides Feedback Regarding Physical Functioning track physical activity. Physiological parameters are collected and displayed by the UIs of four systems with the exception of the Intelligent System For Assisting Family Caregivers. Out of these four systems, Healthkiosk, Giraffplus, and the Home Health Monitoring System monitor blood pressure and glucose levels, while the Monitoring System That Provides Feedback Regarding Physical Functioning measures weight, balance, and grip strength. Only the Intelligent System For Assisting Family Caregivers and Giraffplus recognise falls and alarm caregivers/family members. They also track the localisation of the elderly person, moreover, only these two systems are able to establish video communication between the stakeholders.

TABLE I. ADL UI USABILITY ASSESSMENT.

	Sleep	*Medic.*	*Act.*	*Falls*	*Loc.*	*Phys.Data*
HealthKiosk [30]						*X*
Intelligent Sys [20]	*X*	*X*	*X*	*X*	*X*	
GiraffPlus [31] [32]	*X*		*X*	*X*	*X*	*X*
Home Health Sys [33]			*X*			*X*
Monitoring System [34]			*X*			*X*

As can be seen (Table I), each UI of the evaluated systems delivers a set of functions. They coincide to a degree, but hardly include an exhaustive list of features that represents all the needs of caregivers/family members. Yet many people find themselves in a situation where an elderly relative living alone requires more and more attention. This forces the caregiver to look for a compromise, in order to combine their life (which typically includes working and raising children), and caregiving. Usually, personal development, hobbies, and social activities are sacrificed first of all. There exists an obvious demand for a UI which could comprehensively present ADLs, in order to provide a window into the elderly person's daily regime. By remotely visualising ADL information to the caregiver, the UI would provide reassurance that their elderly loved one is functioning normally, thus relieving the caregiver of constant worry about the elderly person's ability to continue living independently.

IV. Conclusion

As the world's population inevitably ages, various AAL systems facilitate the independent living of the elderly. They offer support to caregivers/family members, and help alleviate their burden, by presenting some of the elderly person's ADLs

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in a UI. This paper evaluates a number of UIs in AAL systems in order to compare the main features. The evaluation is based on identified criteria (sleep, medication adherence, activity and physical exercise, falls, localisation) and on the overview of methods that are employed to present ADLs.

It is outlined that the existing UIs meet caregivers'/family members' needs partially. Therefore, for their future work, the authors intend to propose a design of a personalised UI, specifically created to cater for their needs. This UI will be able to track the ADLs of the elderly person, and present them to the caregiver/family member in a simple but meaningful manner, so that they can be reassured that the elderly person is setting about their daily activities.

REFERENCES

[1] D. Monekosso, F. Florez-Revuelta, and P. Remagnino, "Ambient assisted living [guest editors' introduction]," IEEE Intelligent Systems, vol. 30, no. 4. IEEE, 2015, pp. 2–6.

[2] C. Dodd, R. Athauda, and M. T. Adam, "Designing user interfaces for the elderly: A systematic literature review," Australasian Conference on Information Systems, 2017, pp. 1–11.

[3] A. S. Hwang, K. N. Truong, and A. Mihailidis, "Using participatory design to determine the needs of informal caregivers for smart home user interfaces," in Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2012 6th International Conference. IEEE, 2012, pp. 41–48.

[4] M. J. O'Grady, C. Muldoon, M. Dragone, R. Tynan, and G. M. O'Hare, "Towards evolutionary ambient assisted living systems," Journal of Ambient Intelligence and Humanized Computing, vol. 1, no. 1. Springer, 2010, pp. 15–29.

[5] J. Johnson and K. Finn, Designing User Interfaces for an Aging Population: Towards Universal Design. Morgan Kaufmann, 2017.

[6] S. Reinhard, B. Given, N. Petlick, and A. Bemis, "Chapter 14: Supporting family caregivers in providing care," Patient safety and quality: An evidence-based handbook for nurses. Rockville, MD: Agency for Healthcare Research and Quality (US), 2008. http://www. ncbi. nlm. nih. gov/books/NBK2665 [Retrieved: September, 2018].

[7] S. S. Williamson, P. N. Gorman, and H. B. Jimison, "A mobile/web app for long distance caregivers of older adults: functional requirements and design implications from a user centered design process," in AMIA Annual Symposium Proceedings, vol. 2014. American Medical Informatics Association, 2014, p. 1960.

[8] A. L. Zulas, A. S. Crandall, and M. Schmitter-Edgecombe, "Caregiver needs from elder care assistive smart homes: Children of elder adults assessment," in Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 58, no. 1. SAGE Publications Sage CA: Los Angeles, CA, 2014, pp. 634–638.

[9] L. Pasina et al., "Medication non-adherence among elderly patients newly discharged and receiving polypharmacy," Drugs & aging, vol. 31, no. 4. Springer, 2014, pp. 283–289.

[10] A. L. Zulas and A. S. Crandall, "Assessing professional caregiver needs in assistive smart homes," Handbook of Smart Homes, Health Care and Well-Being. Springer, 2017, pp. 121–131.

[11] K. Santo et al., "Mobile phone apps to improve medication adherence: a systematic stepwise process to identify high-quality apps," JMIR mHealth and uHealth, vol. 4, no. 4, 2016, pp. 1–10.

[12] K. F. Felsted, C. Marquez, and D. M. Wischenka, "Benefits of physical activity on cognitive functioning in older adults," Annual Review of Gerontology and Geriatrics, vol. 36, no. 1. Springer, 2016, pp. 103–122.

[13] G. Demiris and H. Thompson, "Smart homes and ambient assisted living applications: from data to knowledge-empowering or overwhelming older adults," IMIA Yearbook, vol. 6, no. 1. Schattauer Publishers, 2011, pp. 51–57.

[14] L. Chittaro, "Visualizing information on mobile devices," Computer, vol. 39, no. 3. IEEE, 2006, pp. 40–45.

[15] K. Potter, H. Hagen, A. Kerren, and P. Dannenmann, "Methods for presenting statistical information: The box plot," Visualization of large and unstructured data sets, vol. 4. Citeseer, 2006, pp. 97–106.

[16] R. Mehta and R. J. Zhu, "Blue or red? exploring the effect of color on cognitive task performances," Science, vol. 323, no. 5918. American Association for the Advancement of Science, 2009, pp. 1226–1229.

[17] A. J. Elliot, M. A. Maier, A. C. Moller, R. Friedman, and J. Meinhardt, "Color and psychological functioning: The effect of red on performance attainment." Journal of experimental psychology: General, vol. 136, no. 1. American Psychological Association, 2007, p. 154.

[18] A. J. Elliot and M. A. Maier, "Color psychology: Effects of perceiving color on psychological functioning in humans," Annual review of psychology, vol. 65. Annual Reviews, 2014, pp. 95–120.

[19] M. Bernard, C. H. Liao, and M. Mills, "The effects of font type and size on the legibility and reading time of online text by older adults," in CHI'01 extended abstracts on Human factors in computing systems. ACM, 2001, pp. 175–176.

[20] V. Moshnyaga et al., "An intelligent system for assisting family caregivers of dementia people," in Computational Intelligence in Healthcare and e-health (CICARE). IEEE, 2014, pp. 85–89.

[21] T. Hao, G. Xing, and G. Zhou, "isleep: unobtrusive sleep quality monitoring using smartphones," in Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems. ACM, 2013, p. 4.

[22] A. Sadeh, "The role and validity of actigraphy in sleep medicine: an update," Sleep medicine reviews, vol. 15, no. 4. Elsevier, 2011, pp. 259–267.

[23] J. Thakkar et al., "Mobile telephone text messaging for medication adherence in chronic disease: a meta-analysis," JAMA internal medicine, vol. 176, no. 3. American Medical Association, 2016, pp. 340–349.

[24] C. Fan, J. Forlizzi, and A. K. Dey, "A spark of activity: exploring informative art as visualization for physical activity," in Proceedings of the 2012 ACM Conference on Ubiquitous Computing. ACM, 2012, pp. 81–84.

[25] X. Tong, D. Gromala, L. Bartram, F. Rajabiyazdi, and S. Carpendale, "Evaluating the effectiveness of three physical activity visualization-show people perform vs. perceive," IEEE VIS Electronic Proceedings, 2015, pp. 1–4.

[26] H. Weegh and M. Kampbel, "Acceptance criteria of ambient assistant living technologies," Studies of Health Technology and Informatics, vol. 217, 2015, pp. 857–864.

[27] F. Wu, H. Zhao, Y. Zhao, and H. Zhong, "Development of a wearable-sensor-based fall detection system," International journal of telemedicine and applications, vol. 2015, Hindawi Publishing Corp., 2015, p. 2.

[28] S. M. Faria, T. R. Fernandes, and F. S. Perdigoto, "Mobile web server for elderly people monitoring," in Consumer Electronics, 2008. ISCE 2008. IEEE International Symposium on. IEEE, 2008, pp. 1–4.

[29] Z. Wang, Z. Yang, and T. Dong, "A review of wearable technologies for elderly care that can accurately track indoor position, recognize physical activities and monitor vital signs in real time," Sensors, vol. 17, no. 2. Multidisciplinary Digital Publishing Institute, 2017, p. 341.

[30] C. H. Liu, J. Wen, Q. Yu, B. Yang, and W. Wang, "Healthkiosk: A family-based connected healthcare system for long-term monitoring," in Computer Communications Workshops (INFOCOM WKSHPS), 2011 IEEE Conference. IEEE, 2011, pp. 241–246.

[31] S. Coradeschi et al., "Giraffplus: a system for monitoring activities and physiological parameters and promoting social interaction for elderly," in Human-Computer Systems Interaction: Backgrounds and Applications 3. Springer, 2014, pp. 261–271.

[32] S. Coradeschi, A. Cesta et al., "Giraffplus: Combining social interaction and long term monitoring for promoting independent living," in Human system interaction (HSI), 2013 the 6th international conference. IEEE, 2013, pp. 578–585.

[33] A. Taylor, R. Wilson, and S. Agamanolis, "A home health monitoring system designed to support carers in their caring role," in eHealth, Telemedicine, and Social Medicine, 2009. eTELEMED'09. International Conference. IEEE, 2009, pp. 194–199.

[34] J. Vermeulen et al., "User-centered development and testing of a monitoring system that provides feedback regarding physical functioning to elderly people," Patient preference and adherence, vol. 7. Dove Press, 2013, p. 843.

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