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SMARTWATCHES AS AN ASSISTIVE TECHNOLOGY FOR ARAB ELDERLY: A CASE STUDY

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Abstract

There has been a continuous rise in life expectancy in most countries over the past century. This rise has led to an increase in the percentage of the aging population. Forgetfulness and falls are common complaints among elders. Therefore, the need for caregivers continues to grow. However, caregiving requires most of the caregiver time and attention. Nowadays, smartwatches technologies can provide interesting solutions that help the elderly live independently. This paper introduces a smartwatch application, which aims at helping Arab elderly doing their daily important tasks independently. The current study is conducted as a proof of concept on a small sample size of users of different categories (Arab elderly people and caregivers) to ensure appropriateness of the application for the target audience and to take an insight of the usefulness of the application that can be further evaluated in the future work. The results revealed a great potential for the proposed application in improving elderly quality of life.

Keywords: Accelerometer, Assistive technology, Elderly people, Fall detection, Smartwatch, Wearable computing.

1. Introduction

There is a considerable growth in the older population that is occurring worldwide. For instance, there is an expected increase of 40% of people aged from 65 to 80 over the next 20 years. This increase can be related to the improvements in public health, nutrition, and medicine [1, 2].

The increase in life expectancy comes with a price. As people age, their physical and mental health usually weaken. Elderly have difficulties with their daily activities, such as performing hobbies or finances, taking medication, and handling emergencies [3-5]. However, memory loss is different from Alzheimer's disease, although there is a probability of progression from memory loss to Alzheimer's [6].

Many of the elderly prefer to stay at home and rely on family members to provide help rather than moving into a long-term care facility [7]. Very often, the family members can become preoccupied with their jobs and their own families. In this case, some can seek out other companionship services (caregivers) for their elderly parents. The caregivers can help the elderly take care of their basic daily activities, such as medication reminders, housekeeping services, personal hygiene, etc. However, the cost of a long-term care service is high, and most families cannot afford such a service especially if they are under constrained budget conditions.

Advancement of technology has an impact on improving the quality of human daily lives. In recent years, home-based care models and assistive technologies have been proposed to improve the quality of care services offered to people with certain conditions, such as illness and aging [8, 9]. For instance, the use of wearable devices [10] and smartwatches could be a promising tool to support and improve the independent well-being of the elderly, as well as to support caregivers by reducing their responsibilities towards their elders.

This paper describes the design and the development of a smartwatch application, which we called "Smartwatch Assistant for Elderly (SAE)". The application aims at enhancing the life of Arab elderly. It acts as a personal assistant during the elderly’s everyday life. SAE reminds the elderly of their daily medication and prayers. The prayer alert is quite different as it is based on the name of the prayer rather than the usual Adhan sound. Adhan is the Islamic call for prayers. Another important and novel feature of SAE is that it reminds the elderly of the number of current Rakaa in the prayer. Rakaa is a single unit of Islamic prayer. Moreover, it detects the elderly falls and notifies the caregiver about the fall event.

The rest of the paper is organized as follows. Sections 2 and 3 describe the background and related work respectively. Section 4 presents the system design and its details. Next, section 5 describes the user requirements. Section 6 discusses the experimentation and results obtained, while the paper is concluded in section 7. Finally, Future improvements of our work are presented in section 8.

2. Background

2.1. Moto360 Smartwatch

There are different types of smartwatches that can be used for our application, such as Apple watch, LG watch, and Samsung galaxy gear but we decided to go with Moto360 smartwatch from Motorola Company [11] for two reasons. First, Moto360 has the ambient light sensor feature. This sensor is used as an effective solution to determine the number of the current Rakaa in the prayer as it optimizes the smartwatch screen brightness and allows gesture controls such as covering the screen by the palm of the hand [12]. Second, Moto360 is lightweight and has a comfortable fit on the average-sized wrist. Figure 1. [11] shows the Moto360 smartwatch.

In addition to the ambient light sensor, Moto360 has the typical sensors expected in a smartwatch, such as an accelerometer, gyroscope, and a heart-rate sensor. It also has Bluetooth 4.0 Low energy and dual microphones. Moto360 is compatible with smartphones running both Android and iOS. It is connected to a mobile device using the Android Wear app from the Google Play store on Android devices. This application lets the user customize settings in Moto360. It could be also used to access the connected mobile device's features [11].

Fig. 1. Moto360 smartwatch.

2.2. Islamic Prayers

Prayer (which we usually call Salat) is one of the five pillars of Islam. It is an obligatory religious duty upon every Muslim (male, female, and children aged ten and over). It is performed five times a day at very specific times as follows [13]:

- Salat alfajr: it is the morning prayer and starts after dawn, before sunrise.
- Salat aldhuhr: it is the early afternoon prayer and starts at midday after the sun passes its highest.
- Salat alasr: it is the late afternoon prayer and starts in the late part of the afternoon.
- Salat almaghrib: it is the sunset prayer and starts just after sunset.
- Salat alisha: it is the early night prayer and starts when twilight has disappeared and ends before midnight.

Each prayer or Salat consists of the repetition of a unit called Rakaa. Each Rakaa includes prescribed actions and words. The number of Rakaas in each Salat varies from two to four according to the time of day. For instance, Salat alfajr consists of two Rakaas, Salat aldhuhr, alasr, and alisha consist of four Rakaas, and Salat almaghrib consists of three Rakaas [13, 14]. Figure 2 illustrates the series of actions required to complete one Rakaa. As can be seen in Figure 2 (b), hands should be folded across the chest at the start of each Rakaa. We used this posture to help us count the number of current Rakaa in the performed prayer.

(a) The beginning of the Salat.

(b) The start of each Rakaa in the Salat.

(c) Ruku.

(d) The raise from Ruku.

(f) Sujud (end of Rakaa).

Fig. 2. Illustrations of the actions required to complete one Rakaa[1].

3. Related Work

This section will present a brief overview of the different types of the smartwatch applications related to our study and we will address their features and limitations.

MyPrayer [15] is a prayer time alert application that calculates Muslims prayer times using the phone's location (latitude and longitude). Location can be found automatically using the Network, GPS, or manually by searching on the Internet. The app supports many Prayer calculation methods adopted by many Muslim countries such as Umm Al Qura University and Muslim World League. It also calculates the time between the previous and next prayer. However, the midnight time is not accurate, because they do not use the local midnight time based on the sunrise and the sunset. My Prayer wear app for smartwatch does not have a notification feature for each prayer. Notification is only on phone app. The application can be used in both languages, English and Arabic. It is a free app for Android Smart Phones as well as Android smartwatches [15, 16].

[1] All images are taken from http://www.wikihow.com/Pray-in-Islam

MediSafe Meds and Pill Reminder [17] is a pill reminder and medication management application. It helps patients to take medicine safely and on time. It also allows Med-Friend to help with pills taking. The family member or caregiver is notified if the patient doesn’t check in. In addition, the app will remind patient when a refill is due. The patient can also record all medication dosages and measurements and send a report to the doctor. This application can synchronize reminders with the Android Wear smartwatch. It can also synchronize family members' devices with the application [17, 18]. However, the app does not support the Arabic language. Furthermore, it can by mistake mark medication as taken if a reminder happens while users are moving their wrist or walking since the application detects that a user took the medication by his/her wrist shake.

PrayWatch application provides alert for each prayer by Adhan sound with an option to snooze the alert. It displays on the screen all prayer times with a different color display of the current prayer. Internet connection is only required the first time the app tries to access location; then prayer time’s formulas work completely offline. The app can also find the nearest mosque. Besides, it includes the Qibla compass, which indicates the direction of AlKabah [19]. However, ParyWatch does not support Arabic language and automatic calculation of prayer times is not accurate.

RxRemindMe is a reminder application for medications or anything else needed for everyday life tasks. The application manages medications. It allows follow up doctor recommendations and advises the patient to maintain his /her health. The user can add any number of reminders in a day. The notifications will be displayed on the iPhone and Apple watch. Moreover, the user can set the amount of dosage for each medication [20]. However, RxRemindMe is not free and does not support Android platform and Arabic language.

Easy Pill is a medication tracker and reminder application. It will make a reminder schedule based on user's medication information. You have to determine the medication name, dosage per week, dosage per day, and the duration of medication in weeks. Easy Pill uses a unique color-coded interface to keep track of the medication. It can save the history of the taken medication and print the medication at any time [21]. However, Easy Pill does not support Android platform and Arabic language.

A comparison has been made between the previous smartwatch applications and SAE. A summary of the main features of previous applications and SAE is presented in Table 1. It is observed that most of the studied applications are either medication or prayer reminders and are free. However, they do not support Arabic language, and they do not notify the user for the prayer by the name of the prayer as most of them use Adhan sound notification, as well as they do not remind the user of the number of current Rakaa in the prayer, and finally they do not support the fall detection feature.

In order to compete with the related existing smartwatch applications, SAE application contributes to three main features that, to the best of our knowledge, are not yet found in the existing smartwatch applications in the market. The main feature is the reminder of the number of the current Rakaa in the performed prayer. This will be very helpful as older adults tend to forget and lose concentration during the prayers. The other feature is the notification sound of the prayer, which is based on the name of the prayer rather than the typical Adhan sound for the sake of removing any uncertainty the elderly have about the current prayer name. The third feature is that SAE combines four different assistance services to the Arab elderly in one application.

Table 1. Comparison between SAE and the existing smartwatch applications.

Feature	Applications					
	My Prayer	MediSafe Meds and Pill Reminder	Pray watch	RX Remind Me	Easy pill	SAE
Prayers time alerts	√	X	√	X	X	√
Notification by name of the prayer	X	X	X	X	X	√
Reminder of # of current Rakaa in the prayer	X	X	X	X	X	√
Medications time alerts	X	√	X	√	√	√
Sending alert with fall event	X	X	X	X	X	√
Free	√	√	√	X	X	√
Supporting Arabic language	√	X	X	X	X	√
Android platform	√	√	X	X	X	√
iOS platform	X	√	√	√	√	X

4. System Overview

The proposed system is made up of two main subsystems, an Android Wear smartwatch, which acts as an input device, and a smartphone with Android OS, which acts as a hub for the system.

To get the full experience of SAE application, the smartwatch must be paired with the smartphone. This can be done through the embedded firmware in the smartwatch that connects it to the smartphone via a Bluetooth radio. Once connected, all smartphone applications become instantly Android Wear smartwatch applications too. That is, all notifications and alerts that have been set in the smartphone will appear on the smartwatch automatically [11].

Generally, most of the processing and programming are performed on the smartphone. For this purpose, the Android Software Development Kit (Android SDK) provides an extensive set or library of Application Programming Interfaces (APIs) that acts as a middleware for accessing the smartwatch display, showing notifications on it, and reading its sensor data. The architecture of the application hardware and software can be seen in Figure 3.

SAE supports the Arabic language. SAE application includes Moto360 Smartwatch and Samsung Note 6 Smartphone. In SAE, the elderly can view medication information and prayer times from the smartwatch screen. Figures 4 and 5 show the medication page and the prayer times page respectively on the smartwatch. The caregiver is the admin of the SAE application. Figures 6 and 7 show the edit and the delete medication pages respectively on the smartphone.

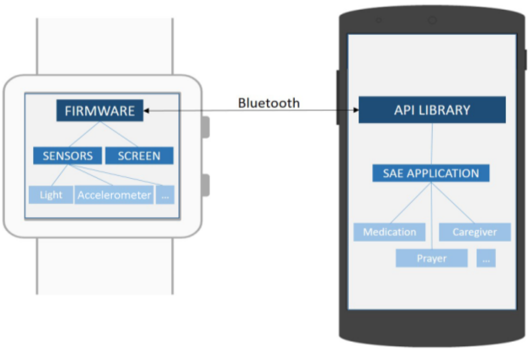


Fig. 3. The architecture of the app hardware and software.

Fig. 4. Medication page on smartwatch screen in Arabic.

Fig. 5. Prayer time page on smartwatch screen in Arabic.

Fig. 6. Edit medication page on smartphone screen in Arabic.

Fig. 7. Delete medication page on a smartphone screen in Arabic.

4.1. Determining the number of current Rakaa

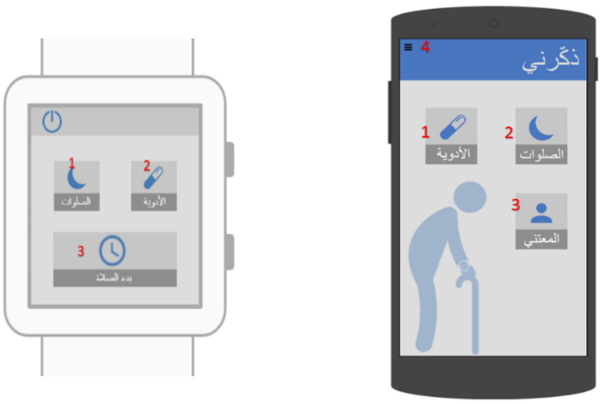
For determining the number of current Rakaa in the prayer, the elderly must press the start button on the smartwatch screen signaling the beginning of the prayer. Figure 8 (a) shows the home page on the smartwatch, where choice 3 represents the start button of the prayer. As we mentioned earlier, we will take advantage of the posture of keeping the hands folded across the chest at the start of each Rakaa to cover the light sensor in the smartwatch.

The old person triggers the light sensor of the smartwatch by covering it with the palm of the right hand at the beginning of each Rakaa, as shown earlier in Figure 2 (b). The person should cover the smartwatch for at least 15 seconds, which is the minimum time duration required for each Rakaa. The system will then be awakened by this action and will start tracking the number of each Rakaa in the performed prayer. The outcome of this process is connected to the person through a notification sound saying for example "the first Rakaa", "the second Rakaa", etc. Once the person completes his prayer, he can then press the finish button indicating the end of the prayer. Figure 8 (b) shows the home page on the smartphone.

4.2. Fall detection

Most of the current fall detection systems are based on the usage of smartphones and/or smartwatches taking advantage of the motion sensors on both. In research, there has been much more focus on fall detection systems with implementations and programming performed on smartphones rather than smartwatches or wrist-worn sensors. Nowadays, simple smartwatches are very powerful and have a set of sensors that can be used to detect a fall. However, the number of publications developing smartwatch-based fall detection systems is very few as in [22]. Commonly, a fall event is recognized by a sensor detecting a strong vertical acceleration. There are different methods that can be used to detect the fall such as fixed thresholds, acceleration patterns, fuzzy logic, and artificial intelligence methods [23].

In our study, we have implemented an accelerometer-based fall detection system, which works independently on the smartwatch and incorporated the threshold method for detecting the fall event. The value of the accelerometer sensor will be monitored. When the sensor detects a fall, an instant message will be sent directly to the mobile phone of the caregiver.



(a) The home page on a smartwatch. **(b) The homepage on a smartphone.**

Fig. 8. The home page of SAE on smartwatch and smartphone.

5. User Requirements

Certain elderly user requirements should be taken into consideration [24, 25] to increase compliance with the usage of SAE application. The design of SAE should fulfill the elderly and caregivers need. It should be simple and suits the elderly in terms of familiarity and ease of use. Therefore, we have selected the smartwatch wearable as it is quite familiar to the elderly due to its similarity to ordinary watch. In addition, its use is not complex or stigmatizing. Another important requirement is that no new learning should be required on the part of the elderly. The above-mentioned user requirements encouraged us to build an application that is composed of a standard off-the-shelf smartphone and a smartwatch, in which the elderly are likely to integrate on their everyday routine without introducing any burden or discomfort.

6. Experimental Results and Discussion

SAE application was implemented in Java using the Android Studio environment (v 1.1.0). SAE is composed of three layers as shown in Figure 9:

- XML layer: contains the XML files that represent the interfaces for the user on the smartphone and the smartwatch. This layer links the user with the application.
- Java layer: contains the Java classes that process user requests coming from XML files and send them to PHP layer.
- PHP layer: executes the received requests from Java layer and then converts them to MYSQL queries. The database itself is MySQL. It then executes the queries in the database and returns the result to Java layer.

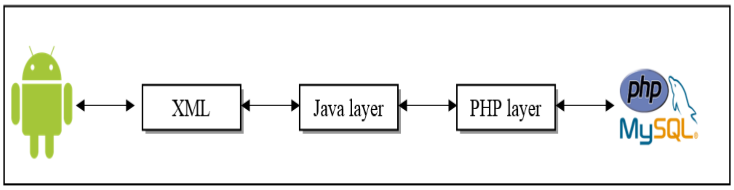


Fig. 9. The SAE structure.

To evaluate the reliability of the proposed application, a variety of real scenarios were conducted with Arab elderly and caregivers. The participant volunteers were 6 elderly people (3 male and 3 females aged between 60 and 70) and 6 potential users who will act as the caregivers in our application (3 male and 3 females aged between 19 and 25), who are familiar with the use of mobile applications. The experiments were performed with healthy participants.

Although the size of the sample in our study is limited by 12 participants, we made sure to keep this number in a reasonable range (between 12-30) based on Caine [26] similar qualitative works. In addition, we considered a balanced sample with respect to gender and age group to obtain a thorough viewpoint from various angles of the study. We acknowledge that this study is an initial step for further analysis and evaluation for future work. The useful insights we were able to gain in this study can be applied to a much larger context and can be used to improve and refine our future work.

Before conducting the experiments, we presented the concept of SAE application to participants through a video that demonstrates the four main functionalities of SAE. Participants could watch the video demonstrations as many times as they liked. At the end of the experiments, participants were interviewed about their satisfaction with SAE.

The caregiver participants, who will be using the SAE application on a smartphone, were asked to perform the tasks (C1 to C10) as shown in Table 2. The elderly participants, who will be using the SAE application on the Moto360 smartwatch, were asked to perform the tasks (E1 to E4) as shown in Table 2.

To measure the usability of the proposed application, all three aspects of usability should be assessed, which are: efficiency, effectiveness, and user satisfaction with the application [27].

Table 2. Tasks of the caregiver (C1..C10) and elderly (E1..E4)

Task #	Task description	Task #	Task description
C1	Register in the application	C6	View medicine on mobile
C2	Log in	C7	Add medicine
C3	Log out	C8	Delete medicine
C4	View his/her profile	C9	Edit medicine
C5	Edit his/her profile	C10	View prayer time on mobile
E1	View medicine on a smartwatch	E3	Start counting Rakaa
E2	View prayer time on a smartwatch	E4	Stop counting Rakaa

6.1. Efficiency of SAE

Efficiency is measured in terms of task completion time. Table 3 displays the average time (in minutes: seconds) required for the participants (caregiver and elderly) to accomplish their required tasks. Task C7, which is added medicine, is the longest time-consuming task for the caregiver. This is due to the full information required to be entered into the application for a new medicine. The other remaining tasks, for the caregiver and elderly participants, were completed quickly as seen in Table 3. This reveals the elderly's ability in completing their tasks easily, quickly, and without assistance.

Table 3. Average completion time in (minutes: seconds) for the tasks of caregivers and elderly

Task #	Average time in min: sec	Task #	Average time in min: sec
C1	1.5	C6	0.04
C2	0.3	C7	2.1
C3	0.05	C8	0.2
C4	0.09	C9	0.6
C5	0.7	C10	0.04
E1	0.08	E3	0.4
E2	0.08	E4	0.1

6.2. Effectiveness of SAE

Effectiveness is the measure of the quality of the solution. We measured the effectiveness of SAE application by calculating the average number of errors made by the participants (elderly and caregivers) while performing their required tasks. Tables 4 displays the average number of errors of the performed tasks by caregivers and the elderly. We noticed from the results in Table 4 that the caregiver participants made some mistakes when performing the longest tasks, which are: tasks 5, 7 and 9. However, the average number of errors was zero in the remaining tasks for the caregivers. As for the elderly participants, we observed from Table 4 that they only made some mistakes when they want to start counting the Rakaa in the prayer (task E3) and this is because they forget to press the Start button, which indicates the start of the prayer. Surprisingly, the elderly participants committed fewer errors than the caregivers while doing their tasks. This signifies that the elderly did not encounter any difficulties when conducting the experiments.

Table 4. Average number of errors for the tasks of caregivers and elderly.

Task #	Average Number of Errors	Task #	Average Number of Errors
C1	0	C6	0
C2	0	C7	0.4
C3	0	C8	0
C4	0	C9	0.2
C5	0.2	C10	0
E1	0	E3	0.3
E2	0	E4	0

6.3. User satisfaction

In order to evaluate the end-user satisfaction of SAE application, participants were interviewed after they have actually tried using the application and performed the tasks. The caregiver participants found the application easy to use and very useful for their aged relatives and for themselves. This is because SAE can provide the required assistance to the elderly during those hours that are not covered by the caregivers' visit. The majority of the elderly participants gave positive feedback to SAE. They thought that it was easy to use due to its simple interface. In addition, they found it very supportive of their independent living. The most favorite feature for them was the sound alarm that reminds them of the number of the current Rakaa in their prayers as it will help them perform their prayers properly. However, among the twelve interviewed participants, only one elderly aged over 65 was reluctant to use SAE due to the fear that this application could replace the human (caregiver) assistance.

6.4. Evaluation of fall detection

For the safety of the elderly, several experimental falls were conducted with the caregiver participants using a crash mat to measure the feasibility of the proposed accelerometer-based fall detection system. SAE was able to detect the fall and trigger an action in the system (a fall is detected—caregiver is informed) each time the experiment was conducted properly, i.e. the acceleration of the simulated fall is similar to real-life fall. Generally, falls generate higher accelerations than other activities. However, there are some activates that have similar acceleration patterns such as jumping and sitting or standing up quickly. This could cause some inaccuracies when trying to detect a fall. Yet, this case does not apply to our study since the movement of older people is usually slow. The participants were interviewed after the experiments. The caregivers found that the fall detection system gave them a great sense of reassurance for their elderly. The older adults found the use of a fall detection system gave them a great feeling of security and enabled them to remain safe at home.

7. Conclusion

The major goal of SAE application is to assist the elderly to live independently and safely at home and to reduce the burden and responsibilities of the caregiver during the non-visit hours. In this paper, we propose the design and the evaluation of SAE, which is based on the combination of a mobile phone and a smartwatch. SAE focuses on the most important daily activities in the life of the Arab elderly, such as medication and prayers. The alert of the prayers is quite novel as it is based on the name of the prayer rather than the usual Adhan sound that is generally used by most of the prayer notification apps. Another important and novel feature of SAE is that it alerts the elderly with the number of the current Rakaa during the performed prayer as the elderly tend to miscount it. Moreover, SAE provides a safety service to the elderly by detecting their falls and sending an instant message to the caregivers notifying them of the fall event. The fall detection is designed to run independently on the smartwatch. A range of real scenarios has been conducted involving real end users. The experiments demonstrated that the SAE application has a potential to be an appropriate assistant tool for Arab elderly population.

8. Future Work

In the future, we would like to improve the robustness of the fall detection strategy using other approaches, such as Artificial Intelligence. Another aspect that could improve the usability of SAE is to assign more than one caregiver for each elderly person. This would boost the safety of the elderly and enhance the care service provided by the application. A compatible version of SAE for iOS-based devices is also suggested, to maximize reach and potential downloads. Moreover, we are currently concentrating on developing an English version of SAE, which would allow for its prevalence among non-Arabic speakers.

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Abbreviations

API	Application Programming Interface
App	Application
iOS	iPhone Operating System
Moto	Motorla
OS	Operating System
SAE	Smartwatch Assistant for Elderly
SDK	Software Development Kit

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