

Evaluation of a Technology Enabled Garment for Older Walkers

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Abstract— Walking is often cited as the best form of activity for persons over the age of 60. In this paper we outline the development and evaluation of a smart garment system that aims to monitor the wearer’s wellbeing and activity regimes during walking activities. Functional requirements were ascertained using a combination of questionnaires and two workshops with a target cohort. The requirements were subsequently mapped onto current technologies as part of the technical design process. In this paper we outline the development and second round of evaluations of a prototype as part of a three-phase iterative development cycle. The evaluation was undertaken with 6 participants aged between 60 and 73 years of age. The results of the evaluation demonstrate the potential role that technology can play in the promotion of activity regimes for the older population.

I. INTRODUCTION

The trend of the population growth coupled with falling birth rates has resulted in an ever-increasing older population [1] with one in three suffering from at least one chronic condition [2]. The World Health Organization defines health as “a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity” [3]. This paper presents the details of a research study, which aims to promote and maintain the physical and mental fitness of older walkers in the age range of 60-75 years of age. Walking in later life is considered to significantly reduce the risk of preclinical disability and increase aerobic capacity and physical function [4].

II. BACKGROUND

There is an increasing awareness for the need to engage in regular physical activity in order to maintain health and wellbeing [5]. This can be illustrated by the vast number of personal health monitoring devices currently on the market. The Nike+ [6], Garmin Forerunner [7] and Adidas MiCoach [8] are three such devices that use various sensors (Heart rate, GPS and accelerometers) to record and monitor both physical activity and personal wellbeing.

The aforementioned devices cater specifically for younger users and have not been designed for use by members of the older population. Characteristics such as diminished eyesight and hearing, memory loss and reduced dexterity are common in older people [1] and hence this cohort find these devices difficult to use.

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A number of research projects have explored the use of wearable sensors integrated with textiles to produce wearable health systems. Examples include the WEALTHY project [9], which aims to couple textile sensors with wearable technology to provide real-time health and wellbeing monitoring. The eCAALYX project aims to monitor the health of older persons with multiple chronic conditions, at home and on the move, using Smartphone technology and textile electrodes [10].

The Design for Ageing Well project [11] aims to address the issue of autonomy of the older population using smart clothing and wearable technology for the active ageing [12]. One of the main objectives of the Design for Ageing Well project is the development of a set of garment designs that conform to the changing body shapes and sizes of the older population.

III. METHODS

In this Section we present an overview of the user centered design process adopted by the project in order to elicit the system requirements. In addition to the elicitation process a technology mapping exercise was undertaken which resulted in the development of a prototype system, which was subsequently evaluated.

A. User Centered Design

In order to develop a functional system, which is deemed as being acceptable by the target cohort, a user centered design methodology was adopted. Users were involved in a range of different workshops that included garment design, textiles, colour and technology appraisal. In the early stages of the project a number of questionnaires were disseminated to walking groups throughout the United Kingdom and the University of the Third Age. The aim of the questionnaires was to elicit an initial set of functional requirements for older walkers [13] shown in Table I.

TABLE I. SUMMERISED LIST OF USER REQUIREMENTS ELICITED FROM DISTRIBUTED QUESTIONNAIRES (N = 50)

Requirement	Walker %
Tell me where my group members are	26.2
Help me navigate	54.8
Call for help should I fall	52.4
Tell me the distance covered already	54.8
Monitor my health for medical reasons	16.7
Interact with my mobile phone	35.7

To supplement the results of the questionnaires two user workshops were organized with an average of 10 participants in each workshop. These workshops enabled researchers to obtain more detailed feedback on each requirement.

Following the elicitation of the user requirements a technology mapping exercise was undertaken [13]. This exercise resulted in the identification of available technologies which could be used to meet the needs of the users.

B. Prototype Development

The main technology components of the system were an Android Smartphone (HTC Desire) [14], Shimmer [15] sensor mote and Fibretronic Bluetooth Module (BTM) [16]. The Smartphone acts as the main processor and feedback mechanism of the system. The Shimmer sensor connects via Bluetooth to the Smartphone, transmitting a single Lead ECG and tri-axis accelerometer data.

The functionality of the prototype aimed to address all of the requirements elicited from the target cohort. The system records and presents the user's heart rate, obtained using a variant of the Pan Tomkins algorithm [17], in addition to the amount of activity undertaken in the form of a step count. In order for the users to understand the context in which their heart rate appears, the heart icon on the screen changes colour according to their heart rate. If their heart rate is less than 60% of their maximum, the icon will be green. Between 61-89% yellow and $\geq 90\%$ red. These thresholds are preset and not configurable at this stage and in future will conform to the Karvonen formula [18].

The Fibretronic BTM also connects to the Smartphone via Bluetooth. This device allows the user to interact with textile switches, located on the sleeve of the jacket, in order to interact with the Smartphone to retrieve health and activity information and to initialise an emergency call.

Using the Smartphone's Global Positioning System (GPS) hardware the following parameters can be recorded, distance traveled, direction of travel, speed and altitude. This information, coupled with heart rate and step count, is stored on the Smartphone for review at a later stage. If the user so wishes, the system has the ability to transmit their location to a central server for storage and a list of their friends' locations may be returned using GPRS. This will be utilized to display the location of their friends on the map screen on the Smartphone in addition to the distance to that particular friend.

The user has the ability to maintain contact with their friends using a 'Contact' screen, which displays the contents of their address book. By processing the Shimmer accelerometer data, the system can detect a sudden downward acceleration, coupled with a change in device orientation i.e. face up and identify a fall. The system then initialises an automated call to a pre-defined emergency contact.

It is important that the User Interface (UI) of the system is simplified to reduce the cognitive load placed on the users. In order to provide 'on demand' feedback to the users regarding how well they are doing, the system uses the Android's Text To Speech (TTS) engine to provide audio feedback. The users press a button on their sleeve, and the system 'speaks' their current heart rate, step count or distance traveled. An additional button is dedicated as an emergency call button. When pressed the system automatically places a call to the

user's predefined emergency contact. Each of these functions do not require the user to interact with the Smartphone, which can remain in a pocket or rucksack. Figure 1 presents each of the main technology components included in this iteration of the prototype in addition to the application UI.

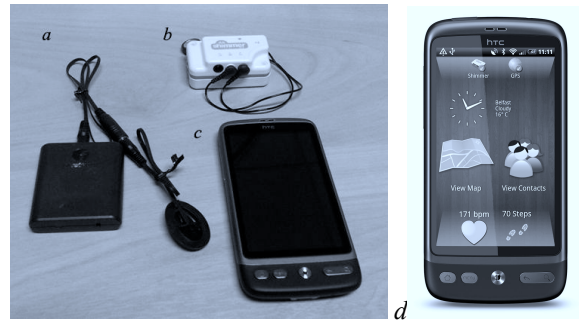


Figure 1. Prototype components used for user evaluations. a) Fibretronic BTM with Microphone, b) Shimmer sensor mote, c) Smartphone and d) User Interface of Smartphone Application.

An additional application has been developed to be run on the user's home computer that enables the configuration of the system and subsequent reviewing of the recorded data. Figure 2 shows the review screen of the 'Desktop Viewer' software.



Figure 2. User Interface of the Desktop Viewer software showing an interactive map with recorded data overlaid and health and activity information.

The configuration screen allows the user to enter their personal details, such as age (which is used to define a maximum heart rate) and sex. They can define their emergency contact details in addition to choose which functions the system should perform and hence support a degree of personalisation.

IV. EVALUATION

The tasks that the participants were asked to perform whilst evaluating the prototype, are enumerated. This procedure follows on from an evaluation of a previous iteration of the prototype [19]. This evaluation includes a more robust system and additional interaction and feedback modalities i.e. soft-switches and Text-To-Speech, respectively.

A. Evaluation Procedure

The user evaluation consisted of 6 (3 male & 3 female) users, aged between 63-73, using the prototype during a

walking exercise in order to ascertain functional, aesthetic and UI feedback. Participants were asked to wear, for males, custom made base layers and females custom made bras both consisting of textile electrodes and a small pocket for the Shimmer device (Figure 3). All participants wore a modified outer layer (water proof jacket), which included a Fibretronic soft-switch, headphones and a microphone.



Figure 3. Custom made male base layer and female bra. Each include two textile electrodes, male snaps and a pocket for the Shimmer sensor.

There were three main stages to the evaluation:

1) Configuration

During the configuration stage participants were asked to connect the Smartphone to a laptop and enter some information onto the system using the *Desktop Viewer*. This information consists of name, age, sex, emergency contact name and number. This information is used to ascertain a maximum heart rate (based on age) and a phone number to contact in the event of an emergency. Other information to be entered included, Shimmer sensor ID, desired services for the participant, destination(s) to walk to and milestones to be fed back to the participant e.g. the system will automatically update the user when they walk a certain distance or number of steps.

2) Activity

For the Activity phase of the evaluation, participants were asked to wear a custom-made base/skin layer and attach the Shimmer sensor. A middle layer of the participants choosing was then put on over the base layer/bra (fleece, shirt etc). Finally participants wore a modified outer layer. This outer layer consisted of a waterproof jacket with integrated textile switches, headphones and microphone.

Once the garments were in place, participants were asked to turn on Smartphone and start the Design for Ageing Well application, which connected automatically to the Shimmer sensor. After this, all users went outside to perform a walking activity which lasted approximately 30 minutes.

3) Review

Once the participants returned from their walk they were again asked to use the *'Desktop Viewer'* software to view their walk. This allowed the participant to review the number of steps taken, the highest, lowest and average recorded heart rate and distance travelled. A route of where they walked can also be presented on a map.

Upon completion participants were asked to complete a questionnaire for information ranging from the technology they currently have and use, to how they use these pieces of technology, to the overall usability and functionality of the

current system. The results of these are presented in the following Section.

V. RESULTS

All participants were asked, as part of the post evaluation questionnaire, whether they liked using the system and what in particular they did or did not like about the system. This feedback is presented in Table II.

TABLE II. PARTICIPANT POST EVALUATION QUESTIONNAIRE FEEDBACK REGARDING THEIR FEELINGS TOWARD THE CURRENT ITERATION OF THE PROTOTYPE

Sex	Like the system?	Likes	Dislikes
M	Yes	<i>"Easy to use. Simple"</i>	-
M	Yes	<i>"Everything"</i>	-
M	Yes	-	<i>"I could not get feedback from using the two buttons"</i>
F	Don't Know	<i>"Liked the audio feedback"</i>	<i>"Still not intuitive – possibly due to bugs & inconsistent icon – could rely on images rather than text."</i>
F	Yes	<i>"It records the walk and could make current walks more challenging"</i>	-
F	Don't Know	<i>"Would like to become more familiar with the system before deciding"</i>	-

When asked all 6 participants thought the system did improve their walking experience. Four participants answered 'Yes' to this question and the remaining 2 answered 'A Little'. The participants in general thought the system was easy to use, with one participant stating the system was 'Troublesome' (*'At this stage'*), 2 participants answered with 'OK' responses a further 2 answered 'Easy' and only 1 participant thought the system was 'Very Easy' to use.

A. Participant's Additional Comments

Participants were provided with the opportunity within the questionnaire to add any comments, suggestions or criticisms of the system. Below are the comments they wrote:

1) Participant 1

"Ear communication sometimes comes out. The 'Tell my friends where I am' is the least used. Is it worth the 'effort' in electronic terms. Other functions were much more useful."

2) Participant 5

"I am not happy using headphones – earpieces fall out but I'm assured it would be built into the jacket hood. The technology interests me and I feel it is or will be useful for my age group in particular. Could also give confidence to younger people with health problems and help towards greater independence and levels of fitness."

3) Participant 6

"The system should be as simple as possible to use, and less obvious shimmers."

B. Post Evaluation Discussion with Participants

After the initial evaluation was complete a researcher initiated a conversation with the participants. From these conversations it was noted that all the participants liked using the system, however, in varying ways. This is reflected in Table 1 as two participants remarked that they 'Don't Know' if they liked the system, but actually did like specific features. Some participants considered using it further beyond the trial.

C. Further Observations

On one of the walking activities the researcher accompanied the participant to observe how they used the system when walking outside.

Over the course of the two-day evaluations, all participants performed the walking activity in bad weather conditions, principally rain, some hail. When walking with the participant the researcher noticed that the participant was worrying about interacting with the phone due to the weather conditions and subsequently damaging the Smartphone. Other issues noted that may have affected the participants' perceived usability of the system was the position the participants were holding the Smartphone. On one occasion the participant was trying to activate a function on the Smartphone screen, however, their action was not performed. What transpired to be the problem was that the participant was trying to activate the function with their right index finger, however, whilst holding the Smartphone in their left hand their left thumb was touching the 'Notification' area of the screen hence negating the touch event being performed by the right index finger. Other issues similar to this were the use of a fingernail to activate the functions. This was a problem because the screen was capacitive and needed to be activated by touch. It is anticipated that these issues would be addressed with extended use of the technology.

VI. CONCLUSION

The aim of this evaluation was to ascertain the usability and performance of the developed prototype. During the same evaluation period, Cleland *et al.* evaluated the reliability of the custom made base layers, bras and textile electrodes with the Shimmer sensors [20] ascertaining that the custom skin layers did not perform accurately whilst performing tasks involving movement of the trunk and limbs.

Based on this initial written and verbal feedback the system may be viewed as being beneficial to the users. All of the participants enjoyed using the system and described it as usable. A particular feature that all participants liked was the use of audio feedback.

All but one of the participants had no previous experience with touch screen mobile devices. This led to a number of usability issues with the Smartphones, which could not be remedied by application development. Nevertheless, these will become less of an issue when the participants become familiar with the technology.

From a functionality perspective, the technology performed well, with no major issues. Performance of the

'Maps' screen could be improved by reducing the frequency of the calls to the server for updated friends' locations as the current frequency makes requests before the previous request has been completed.

As a result of the feedback, it was determined that the current functionality of the system did not require significant amendments, however, it would be prudent to improve the efficiency and performance of the prototype in general.

The next stage in the project will be a longitudinal evaluation of the system as a whole including a complete clothing system.

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