LEVERAGING VOICE ASSISTIVE TECHNOLOGY 
TO ENHANCE HEALTH MONITORING OF OLDER 
ADULTS

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ABSTRACT

With the growing population of older adults, the need for mHealth to address specific aging features is also increasing. However, various research and usability studies on those mHealth applications indicate that mHealth is still not planned with older adults and their needs in mind. It is critical to gain insight into aging obstacles that affect the usability of mHealth as encountered by older adults in order to improve mHealth designs targeted at this demographic. Voice as a new interaction modality has been heavily emphasized in recent product launches such as Apple's Siri and Google's Voice Search. A user-centered design methodology was used to create a mobile health application to help independent living older adults keep track of their health and routine in this research. To help these individuals, I have designed CORE-Energy, a conceptual context-aware assistive application by integrating a language-technology-driven interface into mHealth. First, a Survey on mHealth was conducted to gather the opinion of various stakeholders. The functional design criteria used to direct the design were identified through an analysis of the data collected during this process. Integration of VUI, keeping track of Blood pressure, blood sugar, body temperature, and fitness tracking functionality was explored using a rapid prototyping method. The ease of use and perceived usefulness of the final prototype produced in this study were assessed. After conducting usability testing on 5 users, this application received a System Usability Scale (SUS) score of 75.4%, which indicates that the interface was found to be user-friendly in general. The application created during the research work can be extended to create a more diversified set of voice input to make the user experience even smoother.

KEYWORDS

mHealth for Older Adults, VUI, Elder Healthcare

1. INTRODUCTION

In recent years due to the rapid growth of digitization, health and medical organization have also increasingly begun to create digital tools supported by mobile (mHealth) technologies. Research shows that mHealth application can improve patients’ quality of life, patient’s health, and nutrition by providing real-time data to both patients and health care workers (Paiva, 2020). Agnihothri S. et all explored the use of mobile technology to manage chronic conditions and observed that patients who use mHealth observe improvement in their health (Agnihothri, 2020). Also, Elizabeth et all did experimental quantitative studies to support self-management for adult cancer survivors and found that mHealth interventions can improve pain and fatigue outcome among the users (Silva, 2019). Moreover, it is evident that access to timely information, assessment, and treatment are vital for patients in long-term conditions (Paiva, 2020). The quality and demand of mHealth applications have been incremented due to the high usage of mobile devices in clinical practice.

According to W3B Report from Fittkau & Maas Consulting, around 67% of the population uses Health or Fitness applications, but among them, only 18% are older adults (Fittkau and Maas Consulting, 2015). mHealth applications are prevalent among the younger population, but despite the technological advancement, the application developer failed to attract older adults as their end-user of the healthcare application. A usability assessment done by the University of Illinois for mHealth application for self-managing chronic health conditions states several usability issues like navigation, data entry, recovery from error, and Visualization in two of the major heart apps designated for older adults (Morey, 2017). The application users usually face a lot of issues with navigation between screens and scrolling within the application page. Besides, seniors often get
confused over providing new health-related data. The existing applications designed for older adults failed to provide clear direction for recovering from errors. According to the International Journal of Medical Informatics stated that Computer Literacy, Hand-eye coordination, Visual acuity, and various other factors which causes usability issues in major mHealth application for older (Wildenbos, 2018). Also, the text available in the GUI is very smaller to be readable for them. Besides that, the swipe concept in an application doesn't seem to grasp among older adults, which results in difficulty using an application for older adults.

Due to the popularity of Voice User Interface (VUIs), it could pave the way to connect the advantage of technology to older adults while accounting for age-related changes and the challenges posed by those changes. VUI allows for more efficient, hands-free, intuitive, and rich interactions than any other type of user interface (Ziman, 2017). Voice-controlled personal assistants will be leveraged to help older adults in an easier, hands-free voice interaction, which will provide their health information. Our planned technique is to produce continuous, on-demand health information to freelance living older adults employing a voice-assistant system.

In response, we have developed CORE-Energy, a high-fidelity prototype of a mHealth application to track blood pressure, blood glucose, body temperature, and various other health-related factors using voice command. Based on the research findings from some published guidelines (Ziman, 2017) (Ma, 2017) (Chung, 2018), the design requirement for the application are drafted. When creating this mobile application, the psychological and physical characteristics of the elderly were considered. Screen, touchscreen, text, information, keypad, function label, etc. are all being taken into considerations during the design process of the CORE-Energy application.

2. RELATED WORK

Mobile monitoring and care systems (MMCs), which incorporate observing and counseling systems for essential care, are being utilized to diminish the well-being care burden on open care offices and assist families looking after more seasoned grown-ups within the domestic environment (Malwade, 2018). In hospitals or healthcare institutions, they use diverse mobile monitoring devices and care systems to care for older peoples in need. But it not possible to always keep them in healthcare institutions and older adults always need constant care. In case of older adults, they are impossible to dependably connected with or carry savvy gadgets, and the often-overlooked burden of customary charging may posture an extra utilize challenge (Malwade, 2018). As such, there are one-of-a-kind physiological and mental boundaries hindering these individual’s get to and utilization of these technologies. Cognition function affects older adults by reducing the working capacity, semantic, procedural memory, and attention. Around 15% of men who aged above 65 are affected with moderate to severe cognitive impairment also, memory impairment affects 11% of women above 65 age (Wildenbos, 2018). The effect of aging is that each time, older people process fewer discrete information bits in a certain time and recall also decays faster. Also, physical impairment like arthritis, muscular dystrophy and heart disease, influence learning time, speed of performance, error rate, retention of time, and subjective satisfaction affecting technology use (Wildenbos, 2018).

3. METHODOLOGY

Various approaches were used in this research to understand the current condition of older adults better. However, activities such as literature studies, field studies, user activities, design, and development are ongoing and parallel activities that are cornerstone of this research project.

In the initial phase, a preliminary search was conducted to investigate other studies on what are the existing mHealth applications for older adults and how far it can attract them as their end-users. Requirement gathering and designing of the initial prototype of the mobile self-management software is being done in a parallel manner. Also, we have conducted a very in-depth survey to know how potential users view towards mHealth application. Most users of age above 50 participated in the Survey. For user who doesn't understand the Survey or doesn't own a smartphone, we have organized a telephonic meeting and asked the questions verbally. Participants were generally positive about the definition and script, with some suggesting that they planned to use a mHealth app that could be controlled by speech. Then we started the design process by imagining situations in which a voice-based intervention could help older adults with early-stage dementia with their
self-management. Self-health management entails keeping track of blood pressure, heart rate, and blood glucose level, as well as providing information on any deadly viruses and maintaining a health record, among other things. A formative usability approach was introduced to design and build the initial prototype with an understanding of how users are supposed to communicate with the mobile application.

3.1 CORE-Energy Application

Based on the information gathered in the questionnaire study, the mobile app (CORE-Energy) was designed and developed using the best possible frameworks and database. React Native using Expo was chosen to implement this mobile app as it is a cross-platform framework allowing the app to run on mobile devices with iOS and Android. For ease of implementation and storing vital health-related information of the user, we have used Firebase because it's a great way to create cloud-based functionalities that developers can use in their mobile apps. For the most critical function i.e. to integrate Voice User Interface, we have used a library called "Alan AI." Alan allows users to have real-time human-like interactions with mobile apps and websites, which are very effective. Figure 1 represents the architecture of the application.

![Architecture of the application](image)

It is evident that the primary purpose of the application is to record information. A user can easily record their blood pressure, blood glucose, and body temperature in the application. Also, the fitness-related information like heart rate, steps, and calories comes from the Fitbit device of the user. At the start of the application, an onboarding UI will be shown to the user where all the specifications of the application will be mentioned in an interactive manner. It is essential for the first-time user to get most of the application app by giving on-boarding information at the app startup. After the Onboarding UI, the user will be navigated to the Login/Sign up screen. A user can either sign up by creating a new account or login with social media option is also available.

![Screenshots of CORE-Energy application](image)

(a) Home Screen  (b) Blood Pressure Monitor  (c) Blood glucose Monitor  (d) To-do List

Figure 2. Screenshots of CORE-Energy application
The app takes to the home screen when someone opens it. This page functions as a dashboard that summarizes the data collected during the day and also as a platform for users to enter self-measured data. As seen from the home page of the application Figure 2(a), a user could choose to either operate via VUI or graphical interface. In the bottom right part of the screen is the Voice command button. When a user presses this button, it starts listening and acts accordingly. The top section is a mini dashboard that shows the user's most recent blood glucose, blood pressure, body temperature and average heart rate. The details for blood pressure and blood glucose entity are shown in Figure 2(b) and 2(c). In contrast to command-based modalities and/or one-turn exchanges, voice interfaces are now implicitly supposed to be conversational. There are a collection of training phrases for each purpose. The training phrases are made up of all the different ways a question can be phrased with the same intent. Designing a conversational interface entails influencing user requests and modeling our voice agent's responses.

The voice request has two layers:
- **Utterance**: A user utterance is what the user says. In simple terms, an utterance is a way a user expresses a request.
- **Intent**: This is the primary goal of any user request. It represents the actual task that a user wants to do. This phase also assists in identifying the 'slots' or 'variables' that are needed to complete the request. Variables are extra pieces of information or inputs that the user must have in order to finish the task.

The voice assistant needs to know the mandatory variables in order to complete the flow of requests. If a user asks for something which is not possible, it'll be treated as an invalid request. There are numerous voice commands supported in the CORE-Energy application, however, some of the elementary commands supported are listed above in table 1.

Table 1. Some of the supported commands in the CORE-Energy application

<table>
<thead>
<tr>
<th>Commands</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add blood pressure for today</td>
<td>The system will ask for blood pressure and add for today</td>
</tr>
<tr>
<td>Add blood glucose for yesterday</td>
<td>The system will ask for blood glucose and add for yesterday</td>
</tr>
<tr>
<td>Add body temperature for last Friday</td>
<td>The system will ask for body temperature and add it for last Friday</td>
</tr>
<tr>
<td>Go to Todo page</td>
<td>The routine management page will be loaded</td>
</tr>
<tr>
<td>Remind me to take medication</td>
<td>The system will ask for the date and time on which the user wants to add the task and then take medication will be added to the To-do list</td>
</tr>
<tr>
<td>Show my steps</td>
<td></td>
</tr>
<tr>
<td>What's my blood pressure yesterday</td>
<td>It'll tell yesterday's recorded blood pressure</td>
</tr>
<tr>
<td>How's my health</td>
<td>Gives a brief about the user’s blood pressure, blood glucose, and heart rate, etc.</td>
</tr>
</tbody>
</table>

The act of logging and reading blood pressure, blood glucose, and temperature occur on three different screens designated for these data. Figure 2(a) and 2(b) show the blood pressure and blood glucose monitoring page respectively. When the user clicks on any of the cards presented on the home screen, they will be directed to a new screen that will allow them to log their health information. On every page at the top right corner, there exists an 'Add' button which allows an individual to log the health information with respect to date. When a user clicks on that button, a pop-up will appear, and they can easily add the data by filling up the form. On each screen, an image is present to help the user with finding out whether their condition is suitable or not. Moreover, to help the individual with the information, the table cell is colored with a different pattern so that a user can quickly identify whether his condition is healthy or not. Figure 2(c) depicts the To-do list page of the application. The aim of this To-do List was to show the user what their day-to-day routine looked like at a glance. The idea is that a user can easily input their medication and other activities along with the date and time.
4. RESULTS

The overall aim was to explore whether a VUI-based mHealth application could be a valuable tool for older adults to support them in day-to-day life in keeping track of their health and self-management. So, we conducted the Usability Testing of the CORE-Energy app with 5 participants of age above 50 because according to Jeff Sauro of MeasuringU, testing with just 5 users would turn up around 85% of the problems in an interface (Martin, 2016). Every participant understands English and owns a smartphone. Overall, all of the testing were conducted in the same way. Each test lasted about forty minutes and audio recorded for later analysis. Because none of the participants owns a Fitbit device, the Fitbit device, which is used during the development, was provided to the participants. Participants were asked to complete a total of nine scenarios by engaging with the mobile application to learn more about the testing process. These tools were then used to assess tasks and conduct a thorough review of the participants’ results. The following information was evaluated for each participant: 1) task completion; 2) task completion time; 3) task error rate; 4) time to recover from an error 5) qualitative analysis notes and feedback, and 6) customer satisfaction questionnaire responses.

4.1 Measuring Usability

ISO 9241-11, a specification that includes detailed indicators on how well a consumer achieves specific goals, is one of the objective methods for determining usability which incorporates the basic concepts of user-centered design (UCD) (Georgsson, 2016). During the interactions with the user, we took feedback from them for heuristic evaluation. The resulting application may be considered to have reached an appropriate level of usability if the specified measurements of efficacy, performance, and satisfaction are met adequately. Each scenario is summarized and categorizes by user role in Table 2.

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Sign up</td>
<td>After installing CORE-Energy application, create your own account in there.</td>
</tr>
<tr>
<td>S2</td>
<td>Record Blood Pressure Information</td>
<td>You want to record today’s blood pressure reading. Open the app and record your blood pressure.</td>
</tr>
<tr>
<td>S3</td>
<td>Record blood glucose level</td>
<td>Your goal is to keep your Blood glucose in range. So, you’d like to record yesterday’s BG level in the app.</td>
</tr>
<tr>
<td>S4</td>
<td>Todo Page</td>
<td>You want to check what are the things you have to do further. Go to the To-do page to see all the tasks.</td>
</tr>
<tr>
<td>S5</td>
<td>Add Task to Todo List</td>
<td>You want to remember taking particular medication at a specific time. Add that to todo list.</td>
</tr>
<tr>
<td>S6</td>
<td>Register Body Temperature</td>
<td>You are recovering from flu, and you forget to input yesterday's body temperature. Input BT: 98.6°F for yesterday.</td>
</tr>
<tr>
<td>S7</td>
<td>Review recent data</td>
<td>Since it’s the end of the day, you want to have a look through your BP, BG, BT, Calories.</td>
</tr>
<tr>
<td>S8</td>
<td>Find steps</td>
<td>You took a walk-in street, find out how many distances you have traveled today.</td>
</tr>
<tr>
<td>S9</td>
<td>Upcoming Task</td>
<td>You want to know what's on your timetable next. Find that out.</td>
</tr>
</tbody>
</table>

4.1.1 Effectiveness

Task completion performance and the number of mistakes made during the interaction are two common ways to assess effectiveness. Figure 2 represents the effectiveness results of each scenario. Scenario one and two were the most difficult to complete with 50% and 18% failure rates, respectively (Here, assist is also considered as failure), but They completed the rest of the tasks flawlessly. Also, for the fifth task, some participants made similar mistakes, as it is very similar to task two. To get a better understanding of task success, the number of taps/gestures off the vital route to complete a scenario was considered. To put it another way, any participant
who completed a task with more taps than required was labeled a success with errors. Figure 3 below depicts the percent of participants that completed scenarios with no problems (green), with assist (orange), and failures (red).

Figure 3. Different level of task performance rate

4.1.2 Efficiency

Efficiency is measured by the amount of time and resources that the user must expend in order to accomplish a task in terms of precision and completeness (Georgsson, 2016). As observed from Fig. 3 scenario 4 and scenario 7 have the least task completion time with a mean value of 7. Scenario 4 was to navigate to the To-do page using voice command, and scenario 7 was to ask for a brief about your own health. Scenario 8 was to find out how many steps traveled today, which also participants did is seamlessly (average completion time 16sec). Whereas scenario 1 and scenario 2 consumed the most extended amount of time, as might be expected given the difficulty with task success and errors mentioned above.

Figure 4. Average time taken to complete the scenarios

4.1.3 Satisfaction

In the sense of usability, satisfaction refers to a user's subjective satisfaction with a method or result (Georgsson, 2016). Participants were given questionnaires at the start and end of the usability testing session. The pre-test questionnaire aimed to collect background information on participant's self-management routines and their level of comfort interacting with mobile devices whereas the post-session questionnaire was focused on evaluating the design's usability. The System Usability Scale (SUS) is a reliable “quick and dirty” method for assessing usability (Brooke, 1996). The System Usability Scale (SUS) is made up of ten usability-related sentences, half of which are positive and half of which are negative (Brooke, 1996). On a 5-point Likert scale, participants were asked whether they agreed or disagreed with the scheme. On a scale of one to five, users were asked to rate how realistic each of the scenarios was to them. Participants were then asked to provide open-ended feedback. Figure 4 depicts the SUS score of 75.4%, which is "Acceptable".
5. DISCUSSION

Overall, findings suggest that the CORE-Energy application is usable, acceptable, and relevant to older adults. Results from the focus groups indicated that the initial versions of the UI and modules were broadly good and uncovered helpful directions for making improvements. Participant feedback suggested that the application features are elementary to use and required less practice to get accustomed to the application. They also appreciated the graphics, amount of text, and Voice user interface environment. Another finding shows that seniors view the GUI and VUI differently in terms of learnability, accessibility, clarity, and usefulness. More precisely, the seniors polled thought the VUI was easier to learn and use, but the GUI was simpler to understand and more functional. In the end, the VUI was favored by the participants. However, they feel frustrated sometimes when they forget the command meant for executing specific tasks, but this could be further improved by adding more simplistic controls for VUI.

A few of the participants said that *It's very simple to use, the function provided are very straight forward and it's enjoyable to use.* All the participants were already using touch screen mobile devices for essential activities. As a result, they were able to grasp the application's functionality quickly. Two of the participants liked the To-Do list functionality in the application. They added that it’d be an excellent use to input their medication into the application so that they never miss it. Blood pressure monitoring was the most helpful feature for the participants. One of them even said *I usually keep track of my blood pressure every day and write it down in a notebook. But sometimes, I lost the notebook and commented how the application might help with that. They also wondered if it would be possible to connect their personal blood pressure machine with this application so that they don't have to input it into the application.* The participants also like Body temperature monitoring. He added that *Sometimes when I have a fever, our family doctor often asks me to record body temperature three times a day.* He said using this application he can keep track of it very quickly.

Also, the feedbacks from the participants suggested that older adults were not much interested in Fitness monitoring however these features are ‘nice to have’ but are not crucial to developing a functional application. A better GUI is also essential to increase the popularity of mHealth among older adults. Because some of our participants raised concerned about using the VUI outside of their respective house. Developers should consider the consumers’ technical ability, the type of data being collected, and the size of the mobile device display when designing the user interface. Developers could undertake design and usability studies, referring to users, in order to produce an easy-to-use application. Aside from that, our findings advise that the usage of keyboard should be limited, since it was discovered to be a time-consuming and error-prone chore for this user group. In order to improve the affordance of items, icons are used next to textual labels. From the usability testing we can conclude that older adults mostly tap on the icon.

The demography of the participants reveals no difference in terms of a task performance rate. Among the participants, one of the older adults was very acquainted with mobile devices, so he could complete every task very easily. So, it all comes to computer literacy while using the mobile application.

Throughout the project, there were several obstacles and challenging situations we have faced. The application's fitness monitoring feature was not completely developed. This was done on purpose so that experimental research into a fitness monitoring feature could be performed. Since no current smart wearable brands share their users’ data due to data privacy concerns, more research is needed to incorporate that functionality into the app. Also, when it comes to usability testing also only five participants were part of the user testing of the CORE-Energy application. So, it's still not clear how older adults who have dementia or physical disability will interact with the application.

6. CONCLUSION AND FUTURE WORKS

This study is the first step in a long-term design process where we have developed a VUI integrated mHealth application based on feedback provided in a focus group study and previous literature. The applications can store blood pressure, blood glucose, body temperature and provide on-demand health information to independent living older adults. Currently, the present interaction design still stands as a simple yet effective design solution for older adults for monitoring their health. However, more thorough tests in much bigger numbers should be conducted to gain statistical proof of its effectiveness. With more research, older adults can
benefit from supported self-care, equipping themselves with sufficient knowledge, skills, and the confidence to lead a relatively independent life at home.

Future research should involve a second iteration of the design that incorporates input from usability testing. Changes should be made explicitly to account for problems users encountered when communicating with the program. Fitness monitoring, VUI, and pairing with another smart wearable can all be reviewed, where the interaction mimics what it would be like to use a mHealth app in real life. Also, in recent years, hands-free, voice-activated assistants (VAAs) have gained popularity, thanks to the introduction of commercial products such as Amazon Alexa and Google Assistant. So, for further development, a voice-activated application which could provide on-demand health information to independent living older adults will make an even better option for those who don't even know the basic of a smartphone.

To conclude, there is an insatiable demand for innovative ways to assist independent-living older adults. It is hoped that this study will encourage potential researchers to come up with new and innovative ideas.

REFERENCES

Ziman R., 2017. ‘Factors affecting seniors’ perceptions of voice user interfaces’.