Alzheimer's Disease Rehabilitation using Smartphones to Improve Patients' Quality of Life

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Abstract—Alzheimer's Disease (AD) is an incurable disease that causes dementia. Rehabilitation efforts of this disease focus on slowing down the rate of progression and improving the quality of life of the patients by enhancing their ability to engage with the environment and society surrounding them. In this paper, we present an integrated application (ADcope) that utilizes mobility and advanced communication features of smartphones to rehabilitate AD patients. ADcope integrates quality of life enhancing modules such as the memory wallet, calendaring, and NFC enclosure content tagging, and dementia exercising modules that incorporate audio assisted memory training and spaced retrieval exercises. Initial trials of the ADcope application with AD patients confirm that the benefits of previously proposed AD tools and exercises can also be achieved using a smartphone application. The simplicity of using the ADcope application can increase the rate of adoption of AD tools in dealing with AD patients.

I. INTRODUCTION

Alzheimer's disease (AD), named after the German psychiatrist and neuropathologist Dr. Alois Alzheimer in 1906, is an irreversible, progressive brain disease that slowly destroys memory and thinking skills, and eventually even the ability to carry out the simplest daily tasks. Currently, there is no cure for the disease, which worsens as it progresses, and eventually leads to death. The Alzheimer's Association estimates that one in eight older Americans are living with Alzheimer's disease totaling around 5 million Americans [1].

Alzheimer's disease is the most common cause of dementia among older people. Dementia is the loss of cognitive functioning including thinking, remembering, and reasoning and the loss of behavioral abilities, to such an extent that it interferes with a person's daily life and activities. Dementia ranges in severity from the mildest stage, when it is just beginning to affect a person's functioning, to the most severe stage, when the person must depend completely on others for basic activities of daily living [2].

Health care professionals have tended to overlook the needs and the requirements of Alzheimer's individuals for physical exercises and activity programs. Because of the memory retention problems, many health care professionals feel that the majority of persons with AD have little, if any, rehabilitation potential. Besides retention problems, many clinicians also take the "They're just going to get worse anyway" approach in their clinical decision making [3].

Recent studies [3] have shown that people with AD may actually benefit from physical exercises and rehabilitation processes. Studies showed that rehabilitation would also add value in making the day for an individual with AD a little less foggy, less frustrating, less isolated, less stressful for as long as possible. In addition, rehabilitation helps the individual with AD on living as fully as possible with whatever time he has. In general, rehabilitation is about the quality of life; it adds life to the years not more years to the life.

For individuals with AD, rehabilitation should focus on people's abilities, rather than their disability. The goal is to maintain as high a quality of life as possible for as long as possible [3]. This may help to enhance people's ability to take part in meaningful activities within their environment and enjoy family events.

In recent years, mobile phones have improved rapidly in processing power, embedded sensors, storage capacity, and network data rates. Mobile phones of today have evolved from merely being phones to full-fledged computing, sensing, and communication devices. These advances in mobile phone technology have paved the way for exciting new applications. Smartphones can be used as medical devices for measuring blood pressure, measuring Glucose levels, performing portable ultrasounds, and even testing for STDs.

In this paper, we propose using smartphones to enhance the quality of life for individuals with AD. Based on best rehabilitation practices proposed in [3], we developed an integrated application (ADcope) that includes several modules that target individuals with AD. The goal for ADcope is to maximize the patients remaining capabilities and avoid excess disability, improving their overall quality of life.

The focus of our work is to improve people's abilities to perform activities of daily living and hence to promote independence and participation in social activities. Our work also aims for reducing the burden on caregivers by increasing the AD patients sense of competence and ability to handle behavior problems.

The remainder of this paper is structured as follows. In Section II, we present the application (ADcope) that integrates the various modules that target improving the quality for life for Alzheimer's patients. Section III summarizes the results of our work. In Section IV, we discuss related work and describe how our work differs from previous related activities. We conclude with final comments in Section V.

II. APPROACH

Alzheimer's disease is currently an incurable disease and worsens progressively. Our approach in dealing with this

disease focuses on two aspects: Finding ways to help the patient cope with the disease; and slowing down the pace of decline in quality of life as the disease worsens. A combination of advanced smartphones equipped with NFC and NFC tags will be used to meet the challenges of the two focus areas. Smartphones running the Google Android OS have been selected since currently most phones supporting NFC are running the Android OS.

A. General requirements in dealing with AD patients

Our approach will be based on general standards recommended when dealing with people with dementia [3]. This includes:

- Using simple language when interacting with AD patients.

- Repeating instructions several times.

- Instructions should be broken into simple steps and given one at a time.

- Allow the AD patient ample of time to respond or react.

- All messages should be as short as possible.

B. Helping the patient cope with the disease

Since AD is not a curable disease, our approach focuses on maintaining the quality of life of AD patients as high as possible. An application, named ADcope, with several modules is developed on smartphones to support this approach. Figure 1 is a block diagram of the application showing the modules and phone interfaces. The application and its modules are designed to help the patient in many aspects of the daily life. The continuous interaction of the patient with the smartphone as he moves through his daily life ensures that the patient does not forget about utilizing the smartphone. In addition, ADcope provides an option to remind the AD patient to use the smartphone.

The first module is a memory wallet as suggested by Bourgois et al. [4]. She suggested the use of a wallet that contained 30 pictures and sentences about familiar persons, places and events. The patients managed to learn to use the wallet to improve their conversations by making more accurate factual statements. The module allows the user to take photos of the familiar people, places and events. The patient is then given a chance to tag the photos with phrases that reminds him of the subject of the photo. Photos of people can also be tagged with voice samples of the person in the photo. The patient can go back to the wallet as frequently as needed to be reminded of these people, places and events. The memory wallet also use the tagged voice samples to automatically play back the photo and tagged phrases anytime the voices in the background match the tagged voice samples helping the patient to refer to the wallet to instantly get help on recognizing the people around him without having to sift through the wallet.

The second module is a calendar with reminders of all daily activities that need to be performed. The events can refer to information in the memory wallet such as photos to help the patient recognize the person he needs to talk to or the place he needs to go to. The calendar also includes the recurring event to review the memory wallet.

The third module utilizes NFC tags that are placed on various things including drawers and doors. As the person touches these with the smartphone, the smartphone displays a list of content of the drawer or room. This saves the person from having to open them for inspection when looking for something. This can also be used by a new caretaker to facilitate fetching items requested or needed by the patient since they may not have prior knowledge of how things are arranged.

C. Exercising the patients memory

Although AD is an incurable disease, some memory exercises may help in retaining critical information longer. Researchers have identified several exercises and training techniques the patients with dementia should perform periodically. The exercises include Audio Assisted Memory Training as identified by Arkin [5] and Spaced Retrieval which was first described by Landauer and Bjork in 1978. In Audio Assisted Memory Training an audio cassette recorder was used to playback narratives of biographical information then interactive quizzes are performed to exercise the retrieval process. This technique has resulted in substantial learning with most patients. The Spaced Retrieval exercises are based on asking a questions and requiring an immediate response. The questions are then repeatedly asked with the time between each repetition systematically lengthened until the patient demonstrates the ability to recall information in every day life [6]. This technique has been increasingly used with AD patients to teach important information and skills needed to improve daily life.

These exercises have been integrated into the ADcope application as separate modules. The Audio Assisted Memory Training module replicates the audio cassette recorder approach by playing back audio files of the biographical information and quizzing the patient regarding the information. The targeted answers are very short and mostly consist of one or two words. The simplicity of the answers is critical for successful exercises based on the general recommendations when dealing with AD patients. The simplicity of the answers also enables the use of voice recognition techniques to automatically validate correctness of responses.

The Spaced Retrieval exercise module has been designed to execute in two phases; an assessment phase and a training phase. During the assessment phase, the current memory recall ability is assessed by presenting a piece of information, and then the patient is quizzed about it at a later time. If the recall fails, the information is reiterated, and quiz repeated again later. The length of time between quizzes is reduced until memory recall is successful. The final duration between information presentation and successful recall is stored as the basis for initial duration in future training. The second phase is the training phase in which the module follows the Spaced Retrieval recommendations for training recall of information. The module starts with the duration of time between information presentation and quizzing as determined in the first phase and the length of time between information presentation and quizzing is lengthened with every successful retrieval and maintained with every failure.
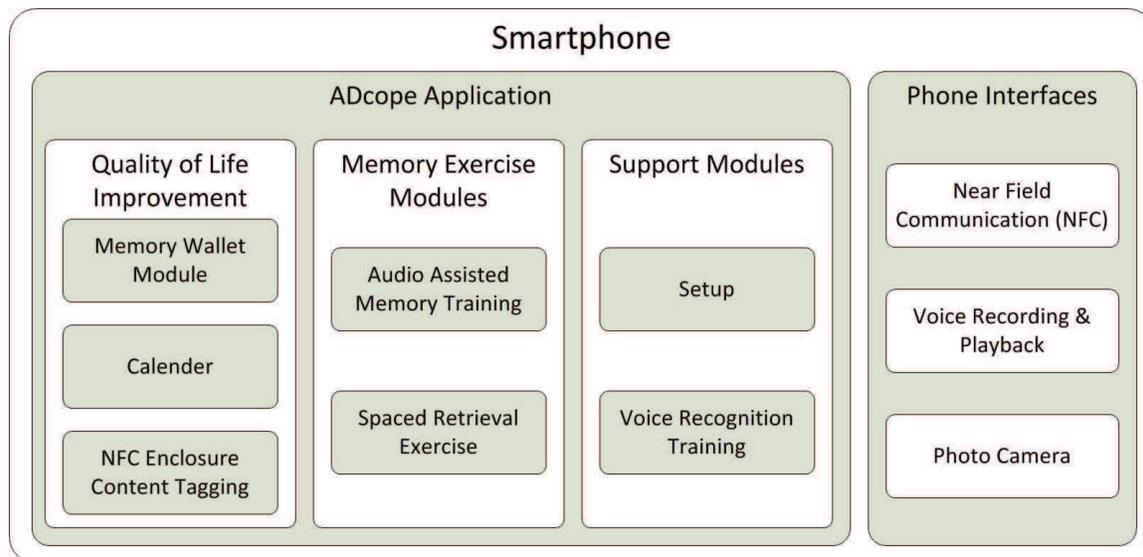
Fig. 1: ADcope modules and interfaces

D. Supporting Modules

The modules described in the previous sections require substantial setup and training. The ADcope application includes a setup module which will guide the caregiver (or patient if he is able to) through all of the setup steps. This includes:

- Recording audio files of biographical data: The user is asked to narrate the desired biographical phrases and signal the termination of recording. The user can record several audio files that are randomly played back in the Audio Assisted Memory Training module.

- Recording of biographical quiz questions and answers: The user is repeatedly asked for questions which are recorded. After each question, the user is asked to type in the correct answer. The answers are currently limited to numbers (such as age, year, and quantities) or single words due to the limitation of the voice recognition libraries used in the development of the application.

- Spaced Retrieval Exercises: The ADcope application has some built in spaced retrieval exercises based on general knowledge facts. However, the setup module allows the user to add additional fact-question pairs. The user also has the option to setup the Spaced Retrieval module to exclusively use the user-added facts.

- Memory Wallet initialization: The user is asked to take photos of people, places and events and type in a word or a phrase for each one. The user can also optionally tag the photo with a voice sample of the person in the photo. The user is allowed to defer this part of the setup to later and build the memory wallet as he meets people or visits places.

- NFC tagging: The user is asked to enter a note that describes the item being tagged. This could be contents of drawers for example. The user is then asked to place the smartphone next to the tag and the ADcope application utilizes the internal NFC writer of the smartphone to write the information to the tag.

- Calendar: In the last step of the setup procedure. The user is asked to enter recurring calendar event with optional photos for each event.

The application needs to be able to recognize voices and match voice replies with correct answers. The ADcope application includes a separate module for training the voice recognizer. The module displays words and asks the patient to read them. A spectral analysis is then done on the words and stored for future voice recognition.

III. RESULTS

Initial evaluation of the ADcope application has been performed using trials with few AD patients. The initial trials confirm that the benefits of using the manual methods to conduct the AD exercises can also be achieved using a smartphone application. The integration of all of the modules into a single application simplified the ability to conduct all of the exercises with patients.

AD patients need to be convinced that learning to use the ADcope application in early stages of the disease will help them cope with the disease in advanced stages. It would be difficult to learn how to use ADcope at late stage. Using ADcope at early stages of the disease guarantees the integration of its use into the patients daily activities. In addition, using ADcope at early stages helps in getting modules like the memory wallet well trained for being used as the disease progress.

IV. RELATED WORK

Many researchers have focused on using smartphones and social networks for monitoring elderly patients by relatives and health professionals [7], [8], [9]. Chan et al. citeChan2008 investigated the use of smart homes for elderly where intelligent

devices including sensors and assistive robotics are implanted into their homes for continuous mobility assistance and non-obtrusive disease prevention.

Other research has focused on games targeting Alzheimer's patients to help slowing down the decline in their abilities. Benveniste et al. [10] suggested using video game based music therapy to improve patients' self-image to reduce behavioral symptoms. Makedon et al. [11] proposed ZPLAY, a game-based, web-based user interface system which is designed to provide intervention therapy for AD patients. Guidelines for designing and implementing effective serious games targeting silver-aged and Alzheimer's patients to help slowing down the decline in their cognitive abilities has been proposed in [12].

Some researchers proposed various devices to help AD patients to cope with the symptoms. Imbeault et al. [13] proposed using an electronic organizer to help individuals with Alzheimer's disease to organize their daily activities. Tapus suggested using socially assistive robotic (SAR) system that aims to provide a customized protocol through motivation, encouragement, and companionship for users suffering from cognitive changes related to aging and/or Alzheimers disease.

Many researchers suggested using NFC tags to help caring for AD patients. Bravo et al. [14] suggested using NFC tags placed on patients, places, devices and applications to help caregivers manage information easily. They have also suggested using NFC to enable simple touches of services' catalogs to make shopping, catering, calls, and mobile pre-scriptions easier for AD patients [15]. ía-Vázquez et al. [16] proposed an Ambient Information Systems (AIS) that support strategies relevant to enable elders to effectively manage their medication through remind (Remind-Me AIS), guide (GUIDE-Me AIS), and motivate (CARE-Me AIS) them to medicate.

V. CONCLUSION

Alzheimer's disease is the most common cause of dementia among older people causing the loss of cognitive functioning including thinking, remembering, and reasoning. Currently, there is no cure for the disease, which worsens as it progresses, and eventually leads to death. In this paper, we have presented ADcope, an integrated smartphone application that targets re-habilitation of Alzheimers disease patients. ADcope integrates various modules to improve patients quality of life and improve their remaining abilities. ADcope aims for enhancing AD patients ability to take part in meaningful activities within their environment and enjoy family events. Initial results indicate that ADcope simplifies the use of AD tools and exercises. The simplicity of ADcope would increase the adoption of the AD tools and exercises for rehabilitation of AD individuals.

For future work, we plan to conduct a complete usability study on ADcope. We would like also to perform experiments to quantify the benefits of using ADcope with comparison to the classical manual approaches.

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