AdBo: A Mobile Application to Boost Adherence of Physical Exercises for Elderly Suffering from Cognitive Decline

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Abstract. *According to the UN, the number of elderly people over the age of 60 will reach 2 billion by 2050. Aging is accompanied with functional and cognitive decline that impact elderly independence and quality of life. This often results in issues such as forgetting, fall, and depression. Physical exercises can help. However, only 16% of elderly above the age 65 years do enough exercise to meet HHS (Department of Health and Human Services) physical activity guidelines for Americans. Several barriers impact the elderly's adherence to physical exercises. In this paper, we discuss the barriers and proven strategies that can be used to overcome them. Then, we discuss the development of the AdBo smartphone application, which aims to increase the elderly adherence to physical exercises. The application will guide the elderly though appropriate exercises, measure cognition ability before and after the exercises regimen, and track cognitive improvement over time.*

Keywords: Elderly, cognitive impairments, physical exercises, persuasive, design science, app, mobile health.

1 Introduction and Problem Definition

Major cognitive decline begins after the age of 60 [1]. Cognitive decline is sometimes noted as a syndrome of functional decline that appears in 12% of the elderly people every year [2]. There is evidence that cognitive impairment is a functional decline risk factor [3]. Another study found that there is an association between the severity of cognitive decline and ADL (Activities of Daily Living) and IADL (Instrumental Activities of Daily Living) [4]. We can conclude that both cognitive decline and physical decline are two major issues that are associated with aging.

Exercises can improve both cognitive and functional status in the elderly. According to the NIA (National Institute on Aging), exercising is one of the important things that the elderly need to adhere to, given the fact that only 16% of elderly above 65 years old do enough exercise to meet HHS (Department of Health and Human Services) physical activity guidelines for Americans. NIA also mentioned the need to new approaches to bring physical activity and exercise to the remaining 84% [5]. In addition, there is a need for other interventions that complement the role of health

care and motivate the elderly to exercise [6] . Those new approaches are needed more if we know that 50% of the sedentary elderly have no intention to start exercises, and 50% of those who started exercises stop during the first 6 months [6]. More efforts are required toward the elder population since there is clear evidence that physical activities can improve physiological and performance capacities [7]. However, large numbers of the elderly already suffer from cognitive and physical decline, which becomes a barrier to adherence to physical exercises, in addition to other barriers. Therefore, a technology designer who is trying to solve this issue must aim at preventing further decline without forgetting the large number of the elderly who already suffer from cognitive and physical decline as a targeted group.

Efforts have been done in the context of aging and exercises such as CAMMinA that uses virtual coins to motivate the elderly to do exercise [8]; some solutions focus on narrower types of exercises such as fall prevention [9]. In this paper, we focus more on the cause of the issue by addressing the question what prevents the elderly from doing exercises? How can we motivate them, and how can we suggest the right variety of exercises that is suitable for them?

In order to empower the elderly to do exercises using digital technology so we can improve their physical and cognitive health, we need different things. First, we need to understand cognitive and physical barriers that prevent the elderly from doing exercises. Second, apply proven mechanisms/strategies that can be used to overcome those barriers in the design process. Third, we need to capture both physical and mental progress over time since there is a relationship between exercises and physical and cognitive status, and both are important when it comes to the elderly and exercises. To address this issue, we propose the Adherence Booster (AdBo) system. AdBo is a smartphone application designed to overcome the barriers that prevent the elderly from adhering to physical exercise, with a focus on cognitive and physical ability in the design and the objectives of the app.

2 Research Approach

In general, this study will use the design science research (DSR) approach. Since the main focus of this paper is to assist and change the elderly's behaviors, DSR is the best choice among different approaches. It is stated that " We also recommend using design science such as the DSRM process model (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) as a methodical tool for developing effective behavior change and assistive technologies" [10]. DSR is defined as a research methodology in which a researcher or designer answers questions relevant to human problems by creating innovative artifacts [11]. DSR has three cycles: the relevance cycle in which the design and its environment are bound together, the rigor cycle in which the design is grounded on and contributed to the knowledge base, and the design cycle which is the actual building and evaluation of the artifact [12]. In this research-in-progress paper, we will focus on defining the problem and detailing the design elements. In the near future, we will evaluate the application based on real-user feedback, and determining

the feasibility of the intervention in terms of improvement of adherence to physical exercises.

Fig. 1 highlights the components of AdBo system with numbers indicating the flow of events. Numbers 1 and 2 show how aging and cognitive decline among the elderly create barriers to adherence (see section 3). Number 3 indicates how those barriers are considered in the design of AdBo (see section 4). Number 4, 5, and 6 show how the interaction with AdBo can help the elderly overcome the barriers and adhere to exercises. Finally, AdBo will track improvement in adherence to exercises, and assess the cognition overtime to give insights for physicians and caregivers.

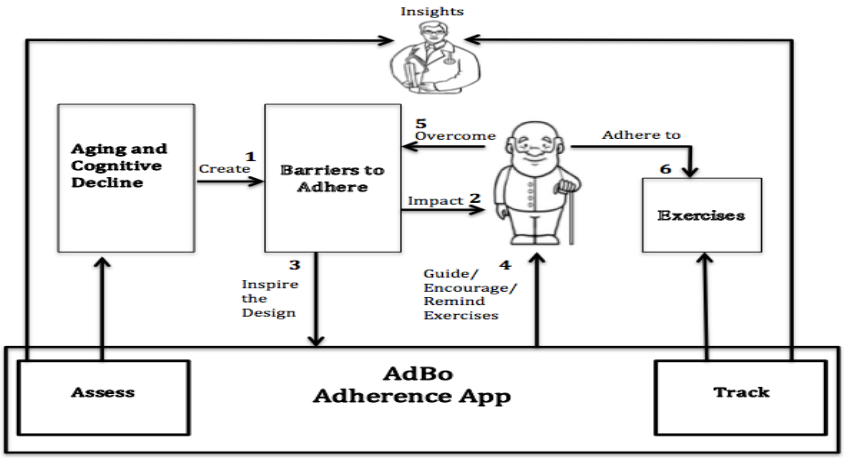

Figure 1. Conceptual Design of AdBo Stages.

3 Barriers and Mechanisms

To design an effective solution, we have to understand the nature of barriers that prevent the elderly from doing exercises, and then define the mechanisms that should help the elderly overcome those barriers. Those mechanisms should be implemented as design specifications in the produced artifact. Regarding the barriers, social cognitive theory can help in explaining two barriers that prevent the elderly from adhering to physical exercises. The two main concepts in social cognitive theory are self-efficacy and outcome expectation [13]. Self-efficacy is the person's belief that he is capable of performing an action, and outcome expectation is the belief that this action can produce desired results. Both self-efficacy and outcome expectation are two factors that influence adherence among older adults with cognitive impairments [14]. Four mechanisms can enhance self-efficacy: 1) performance accomplishment or enactive mastery experience (successful experience), 2) verbal persuasion (encouragement and feedback), 3) vicarious experience (observing someone else performing a similar task), and 4) physiological states (such as anxiety) [13]. High arousal weakens performance, and performance accomplishments and vicarious experience can eliminate anxiety [13]. Those four mechanisms should address the self-efficacy barrier.

Outcome expectations is another important barrier related to elderly adherence [14]. Education is one strategy that increases adherence in which information about the regimen is a necessary first step [14]. The elderly must comprehend the benefit of the regimen before they make the adjustment in lifestyle. In addition, "show and tell" is mentioned as an effective strategy [14]. In "show and tell," the elderly are provided with each exercise, and then told what this exercise is for and how is it performed.

Cognitive impairment should be improved by exercises, but it is also an exercise barrier by itself. The impact of aging on adherence is mediated by cognitive impairments [15]. It is possible to skip doing exercises or forget how the exercises are performed because of memory decline. Despite the prevalence of medically-explained cognitive impairment among the elderly such as dementia or Alzheimer Disease, Medically Unexplained Memory Loss (MUML) and Cognitive Impairment No Dementia (CIND) have prevalence ranging from 10.7%-26.6% according to different studies in different countries [16], [17], [18]. One of the strategies to increase adherence in people with memory or general cognitive impairment is via automated reminding service [19].

Table 1. Barriers to adherence and overcoming strategies.

Barriers	Overcoming mechanisms/ strategies
Self-efficacy	• Performance Accomplishment • Verbal persuasion and encouragement • Vicarious experience • Improving psychological State
Outcomes expectations	• Education • Show and tell
Cognitive Decline	• Reminding system
Physical Decline	• Appropriate Exercises

The physical decline described above justifies the need for elder-friendly exercises. In fact, we should differentiate the type of the elderly's exercise from other younger age-group exercises [6] . "Appropriate exercises" is an important factor that influence exercises adherence among the elderly. The National Institute on Aging defines four types of exercise that are necessary and appropriate for older adults (endurance, strength, flexibility, and balance) [20]. Therefore, choosing the appropriate exercises is an important mechanism or strategy to improve the elderly's adherence to physical exercises. Table 1 summarizes the elderly's exercises adherence barriers and the corresponding strategies to overcome each barrier described in this section.

4 Design and Build of Artifact

From the DSR perspective, Adherence Booster (AdBo) is an instantiation. AdBo is a system that consists of: 1) an iPhone application designed for the elderly to increase

adherence to exercises, 2) a server that stores the data collected by the app, supports user login, and handles push notification, and 3) a messaging system. The app will guide the elderly through appropriate daily exercises, monitor their daily progress, remind and encourage them to exercise, and measure their short-term memory at the beginning and the end of a predefined exercise regimen. Each exercise will have a simple description (using images and videos) about the benefits and performance instructions.

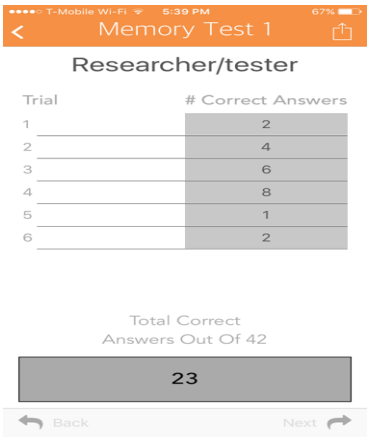

Fig. 2. Initial memory Score.

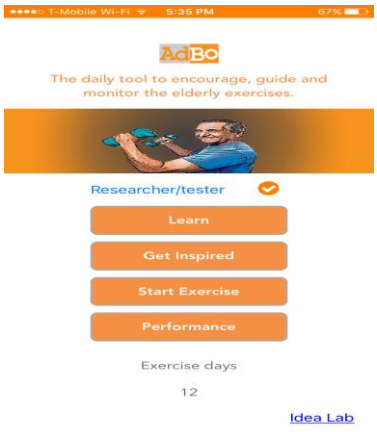

Fig. 3. AdBo's home screen.

The AdBo is in the testing stage of development now. In this section, we will illustrate how the application works. After downloading the application, the user will have to register with a name and password, and he is optionally asked to add an email or a phone number that can be used later by the user to share his progress with peers (another elderly user) or caregivers. During the registration, a video will popup that explains the next screen which is a short memory test consisting of six trials (based on University of Washington Short-Term Memory Test). This memory test is part of the registration. In the memory test, the user will be shown two letters in the first trial for 3 seconds, then those letters will disappear and the user will be asked to type the letters he remembers. The test will get harder in the next trials by increasing the number of letters to remember in the thee-second period. At the end, a score will be assigned to the user based on his performance in the memory test to benchmark his cognitive ability (Fig. 2).

After that, the user will be transferred to the home screen, which consists of four features (Fig. 3). The first feature is "learn," in which a video will explain the four types of exercises in this application and their benefits. This easy and attractive educational video about the application and the exercises should address the outcome expectation barrier of exercise adherence in an easy way using a video. The second feature is "get inspired," where several videos show how peers are doing similar or more difficult exercises with some motivational massages. Some contain verbal mes-

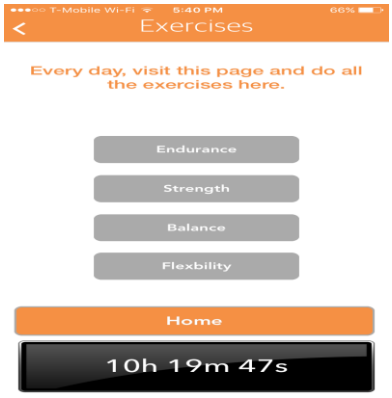

Fig. 4. Four types of exercises each user should go through every 24 hours.

Fig. 5. A video that explains and demonstrates one exercise.

Fig. 6. Collecting data after each exercise.

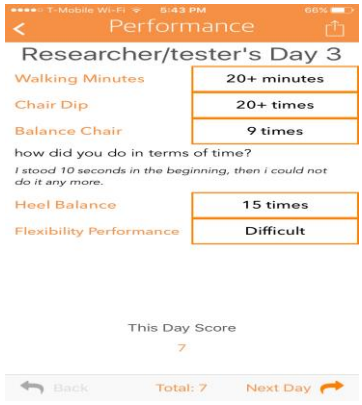

Fig. 7. The third-day performance report.

sages from physicians as well as success stories. This part of the application is inspired by "verbal persuasion" and "vicarious experience" strategies that improve self-efficacy. Users of the app can also share their performance via SMS or email to motivate each other.

The third feature is "start exercises," which is the heart of the application. In this part of the app, the user will go through 7 daily exercises covering the four types of recommended exercises, which are endurance, strength, balance, and flexibility (Fig. 4). Before each exercise, a video that contains a description about the exercise and a demonstration performed by a certified trainer will be shown (fig. 5). Those exercises are adopted from the National Institute on Aging, and they consider the elderly's physical ability. After each exercise, the app will collect two types of data that answer

whether each exercise has been performed or not on that day? How many times did the user do the exercise and for how many minutes? It also asks how difficult is that exercise (see Fig. 6)? The reason we collect this data is to use it in the evaluation part of this project and to build daily progress and achievement reports.

The fourth feature on the home screen is "performance," in which we show the previously collected data and the daily progress report (Fig. 7). This report should address the self-efficacy barrier via performance accomplishment mechanism. The user can see his achievements every day and can share it. The app will continuously send push-notification messages to the user with encouraging text to motivate and remind them to do the exercise. This reminding system should address the memory decline barrier. Finally, the app will ask the users to play the memory game at a certain interval of time to assess their short memory. Both physical progress and memory assessment can be shared via email or SMS using the app share feature.

5 Future work

At this point, we are in the final stages of the application development. The next step will be the evaluation of this application on elderly subjects, in which we will address two important things. First, we will gather the requirements of the next iteration based on the elderly feedback. Second, we will answer the questions whether an easy to use application that overcomes the previously mentioned barrier can improve adherence, and does it have impact on cognitive tests performance? A pre-post learning using paired t-test and post-hoc analysis will be used to accomplish the evaluation. Subjects are being recruited at this time. We anticipate that our strategies could help to improve adherence in different domain such as medication adherence.

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