A Mobile Augmented Reality Game to Encourage Hydration in the Elderly

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Abstract. Dehydration among the elderly is associated with numerous negative health outcomes that result in increase hospitalization, institutionalization, and burden to caregivers. Older adults with dementia are physically capable of fluid intake, but fail to drink due to multiple cognitive deficits, including poor initiation, decreased motivation, and amnesia. We are interested in looking at the use of mobile smartphone technologies to help ensure adequate hydration in older adults with cognitive impairment or dementia. Our approach uses everyday consumer smartphones paired with appropriately designed augmented reality (AR) game that will remind, motivate, guide, and track hydration in older adults with dementia. Our hypothesis is that our system will not only improve hydration, but also that the improvements in hydration will result in improved cognition and mood in community-dwelling older adults with cognitive impairment. This paper describes the design of a feasibility study for an electronic reminder application for older adults.

Keywords: Computer-aided cognition · Reminder system
Older adults · Hydration

1 Introduction

There are currently approximately five million Americans living with dementia today. As the older adult population increases (21.7% of the total United States population is estimated to be older adults by 2040), the number of people suffering from dementia is expected to grow. The exorbitant health care costs associated with this trend are a significant concern for the United States, as well as other countries with similarly changing demographics [3,50]. One of the primary causes of this high cost of care is the difficulty for older adults with dementia in completing everyday tasks. Which leads to increase caregiver burden.

Developments in computing technology have led to the creation of an *Internet of Things* (IoT) [29]. This is an environment where everyday objects such as

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refrigerators, cabinets, and so on, are embedded with computational intelligence, and networked together. We can harness these new developments to build new systems to help dementia patients live more independent lives. This form of **computer-aided cognition** is especially promising, given the fact that older adults are increasingly computer literate, and will have likely had grown up with these types of technologies.

We approach this computer-aided cognition paradigm by examining a specific everyday activity and how an existing commonplace smartphone device can be used to help older adults. The everyday activity we look at is ensuring adequate hydration. Dehydration is associated with numerous negative health outcomes, including acute confusion, urinary and respiratory infections, medication toxicity, pressure ulcers, muscle weakness, falls [43], constipation, and death [5,7,53]. Dehydration also increase the risk of thrombosis, cardiac arrhythmias, and death. These negative health consequences may result in hospitalization, institutionalization, and increased caregiver burden and/or increased cost of care. In 1996 the estimated medical costs associated with dehydration in the elderly exceeded $1 billion [24]. However, many acute illnesses (e.g., pneumonia) or injuries (i.e., falls) may be caused by dehydration, and hospitalizations for dehydration in older adults have increased by 40% from 1990 to 2000 [56]; therefore, it is likely that the true costs associated with dehydration in older adults is actually much higher in 2016.

In this paper, we will first discuss the challenges faced by older adults with dementia and water intake. Section 3 will discuss our planned study and prior work in this area, and Sect. 4 concludes.

2 Elderly and Hydration

Dehydration in older adults with cognitive impairment is a complex, multidimensional problem. Most older adults are physically capable of fluid intake, but fail to drink due to multiple cognitive deficits, including poor initiation, decreased motivation, and amnesia (i.e., impaired episodic memory) [33]. A review study by [18] suggested that elders in some residential settings who were not fully dependent on caregivers for mobility and activities of daily living and appeared to be capable of obtaining their own fluids were at a somewhat higher risk for dehydration, suggesting that cognitive factors play a meaningful role in dehydration in ambulatory older adults. Based on our review of the extant literature on dehydration and cognitive and functional disability in dementia, we have identified four cognitive targets for improving hydration in the elderly with cognitive impairment.

Poor Initiation. Older adults typically understand that they must drink and know how to attain water, but they may fail to initiate a search for water for at least two reasons. First, the ability to recall an intention (i.e., prospective memory) is a complex cognitive process that involves a network of brain structures, including the prefrontal cortex, parietal cortex, and thalamus [6]. Decline in prospective memory is observed even in healthy older adults and it is impaired

in older adults with dementia [15]. In addition to prospective memory impairment, older adults with cognitive impairment may also fail to initiate the search for water, because their experience of thirst, which serves as a salient cue in healthy people, may be blunted due to brain changes [2]. The sensation of thirst is controlled through receptors in the hypothalamus that are sensitive to the fluid balance in the body. Neuropathology affecting the hypothalamus may perturb the natural physiological reminders to drink for older adults with dementia [22].

Lack of Motivation. Because of degraded taste and smell, drinking may not be as pleasurable or rewarding for older adults. Functional neuroimaging studies with healthy participants have demonstrated that the pleasantness and reward associated with drinking when thirsty is linked to activation of the medial orbitofrontal cortex [12,27]. Subtle changes (i.e., thickening) in the orbitofrontal cortex have been reported in healthy older adults and marked dysfunction in this region has been observed in individuals with frontotemporal dementia [46]. Thus, without the natural pleasure and reward that follows drinking, drinking behaviors will not be as strongly reinforced and may decline over time in older adults with dementia.

Unreliable Memory/Poor Monitoring. Older adults may fail to drink because they cannot reliably recall whether or not they have consumed liquid earlier in the day. Episodic memory impairment, a hallmark feature of dementia [32], is associated with degeneration of the hippocampus and surrounding temporal lobe tissue [20]. Episodic memory impairments are associated with problems in a range of everyday tasks (e.g., forgetting to pay bills, forgetting to turn off the stove, etc.) [49]. Even in the early stages of decline episodic memory impairment create difficulties recalling everyday events. Regarding hydration, failure to recall whether or not one has consumed a drink would preclude the accurate monitoring of fluid intake in older adults with dementia and could lead to a reduction in drinking behaviors.

Premature Decay of Intention to Drink. Errors in everyday tasks are sometimes due to the premature decay of an intention [41]. The decay of an intention is more likely if an activity unfolds over an extended period of time or if there is distraction between the time at which the intention was activated and the goal state is achieved. The *doorway effect* or *location updating effect* are terms used to describe the loss of intention that people sometimes experience upon entering a new room [39]. Although this phenomenon has been largely studied in healthy young participants, it is widely noted among clinicians and caregivers that older adults with dementia become quickly distracted and derailed when moving about and searching for objects to achieve even simple everyday goals. For people with dementia, the location of objects (e.g., cup, water) in the home may require more time because of confusion or forgetfulness, thereby increasing the time during which they may become distracted and derailed. Thus, the premature decay of action intentions over time may contribute to the failure to maintain adequate hydration in older adults.

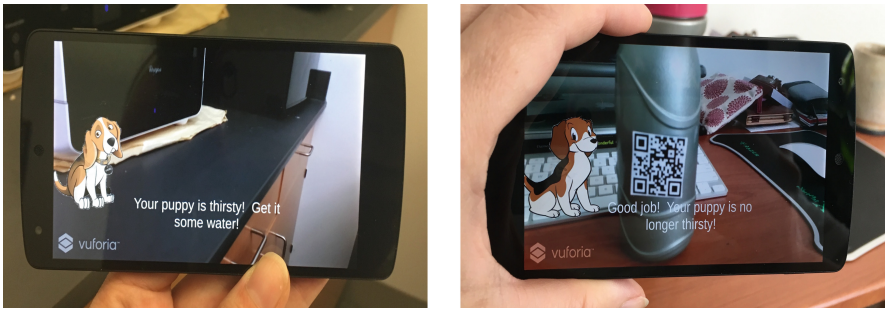

Fig. 1. Illustration of game rewards to motivate participant. Left figure is a prompt to reminder the participant to hydrate. Right figure is the reward after the participant has completed the hydration task.

3 Proposed Study Design

A reminder system is a form of computer-aided cognition that delivers cues to perform daily tasks, such as drink water or take medication. The objective of our proposed study is to understand how older adults, especially older adults with dementia, respond to reminder systems of varying complexity. This is an important preliminary step since it is known that the elderly often face barriers when using technology [25,34,38].

A simple reminder application design is a mobile app running on a smartphone that is programmed to set off an alarm at pre-defined intervals to remind the older adult to drink water. However, a simple alarm-type reminder application may not be suitable for older adults with dementia. People with dementia require simple interfaces and more explicit instruction to circumvent the multitude of cognitive challenges that preclude successful task recall and completion. For example, when responding to a timed alert, individuals with dementia may become distracted while moving to a different room to begin the task; they may fail to initiate or complete the task due to apathy, inability to perform the accurate sequence of task steps, and so on.

A complex mobile app can make use of the additional processing capabilities of the smartphone to overcome these difficulties. We have designed a complex mobile app that addresses the four cognitive targets for improving hydration. The hydration reminders are delivered to the user based on the caregiver's predefined schedule, which address the older adults failure to recall the intention to drink due to cognitive decline. The gaming aspect is designed to promote engagement with the system and provide some motivation for older adults, who may not feel inherently thirsty, to hydrate. The intent is to encourage users to care for themselves by placing the emphasis on caring for something else. Figure 1 shows snapshots of the game "reward".

We address the problem of poor monitoring of water consumption, by reminding the user to take a photograph of the cup before and after water consumption as a means of recording water consumption for the user and caregiver. Finally,

to address the issue of distraction and premature decay of intention, the application will also help the user to complete the drinking task by prompting and reminding the user to find the drinking vessel (e.g. cup or water bottle) by using the smartphone's camera to scan and locate the appropriate vessel. This recognition is done by having the caregiver affixing QR stickers onto the user's commonly used drinking cups and water bottles. Table 1 summarizes the basic and advanced versions of our reminder application.

Table 1. Summary of different features of the basic and advance versions of the reminder application

Objective	Basic app	Advanced app
Poor initiation	Auditory alarm and text of goal at predefined times	Auditory alarm and text of goal at predefined times. A delayed alarm will be played if participant does not complete hydration task within allocated time
Unreliable memory or poor monitoring	Participant instructed to keep paper logbook	Participant is instructed to take a photo of the cup as part of the game to earn points
Lack of motivation	None	Points are awarded as photos are collected into the photo log; at the end of the day bonus points are acquired for completing both tasks
Premature decay of intention to drink	None	Screen shows customized photo of the objects needed or the scene where the target task must be completed. A written reminder of the task goal is presented along with the photo. The camera can be used to help identify cup affixed with QR stickers

We plan to conduct testing of the basic and advanced versions of the reminder apps in a feasibility study modeled after the Memory for Intentions Screening Test (MIST). The study includes two conditions (Unprompted and Prompted), each lasting one hour.

In the Unprompted Condition participants are instructed to walk to a nearby kitchen to retrieve a very small glass of water every 15 min, such that they must go the kitchen on four different occasions by the end of the Unprompted Condition. Participants will be shown the laboratory kitchen at the start of the Unprompted Condition, and the condition will not begin until the participant is able to repeat the task directions. The experimenter will not provide reminders or cues about the task objective during the Unprompted Condition. All participants will engage in standardized secondary tasks with the examiner during the hour-long, Unprompted Condition.

In the Prompted Condition, participants will undergo a brief tutorial on how to use the reminder application. Participants will be told that they will be prompted by the phone to retrieve a glass of water in the laboratory kitchen on four occasions within one hour. As in the Unprompted Condition, participants will be engaged in standardized secondary tasks with the examiner; however unlike the Unprompted Condition, the participant will be carrying the smartphone in a belt case or lanyard, depending on the participants preference, to receive the system prompts.

All participants will complete both the Prompted and Unprompted Conditions in a two-hour testing session. To control for order effects, the conditions will be counter-balanced across participants. The following dependent variables will be collected separately for each condition: (1) number of drinks consumed (max = 4); (2) time at which drink was consumed = (i.e., minutes before or after each 15-min mark at which a drink was consumed). The participants will be asked to rate their overall experience with the system, using a simplified and modified usability questionnaire to determine the likability of the reminder application.

While participants are completing the tasks, their caregivers will work with a second research assistant who will demonstrate the reminder application using a standardized script. Following the demonstration, caregivers will be asked to rate their impression of the system usability on both a standardized, closed-ended usability questionnaire, and an open-ended interview. Additional information regarding the participants current drinking schedule and preferences also will be obtained during a structured, open-ended interview.

4 Related Work

Simple prompts and environmental adaptations have been successful for increasing fluid intake in older adults in residential care facilities [51]. For example, significant benefits were reported in a sample of 51 nursing home residents following a five-week intervention that incorporated a hydration plan, caregiver education, environmental changes (e.g., adding color to cups and a colorful beverage cart), and increasing beverage options [45]. The goal of the intervention was for participants to drink two additional 8-ounce beverages per day (mid-morning and mid-afternoon). When compared to a two-week baseline prior to the intervention, participants showed a significant increase in total body water as measured by skin impedance testing, reduction in falls, increase in the number of bowel movements, decrease in laxative use, and a decline in the care cost of associated negative outcomes.

Augmented reality technology has been incorporated into many different areas [4], including education [36,44], retail [11], environmental monitoring [54], navigation [19,35,42], security [30], safety [40], and so on. Within the healthcare area, augmented reality applications include systems to promote healthy diet [1], exercise [28], supplement traditional nursing programs [13], and aid in childhood cognitive and motor development [9,23]. Our system falls under this category of AR applications.

Applying virtual or augmented reality specifically for adults with cognitive decline is also an emerging field of research [14,16,31,47,55]. These include training-type applications [17,57], systems to help driving automobiles [26,48], systems that help with physical rehabilitation [21], and so on. These prior work demonstrate the utility of AR systems to help older adults. We take the approach of make full use of commercially available smartphones to make WaterWatcher feasible for wider deployment.

Researchers have also considered usability issues of mobile devices and the elderly [34,52] to identify specific design concepts that would appeal more to older adults [37,58]. Others have also looked at gamification to motivate older adults to use mobile applications [8,10]. While our preliminary design draws upon this prior research, none of these usability studies have targeted older adults with cognitive decline. We will expand the knowledge of this group of little studied users as part of this project.

5 Conclusion

We propose a novel complex smartphone app to promote hydration in older adults with cognitive impairment. The app has many advantages over existing reminder apps. The entire app is designed to target the cognitive impairments that prevent hydration, and incorporates gaming to increase motivation. Our system can be used with commercially-available, and relatively inexpensive, smartphones. Our testing plan includes a feasibility study that will compare the complex app to a more basic app to determine whether the additional features of the complex app are needed to promote hydration in cognitively impaired older adults. Data obtained from this feasibility study will be used to inform a larger, randomized controlled trial in participants' homes to test the effectiveness of the app.

The reminder application described in this paper is designed to increase hydration in older adults, which is expected to have positive effects on cognition and general health. However, the system may be modified to promote a wide range of healthy behaviors and everyday activities with diverse clinical populations (e.g., brain injury, stroke, Schizophrenia, etc.).

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