Assistive AI for Coping with Memory Loss

Libby Ferland and **Ziwei Li** and **Shridhar Sukhani** and **Joan Zheng** and **Luyang Zhao** and **Maria Gini**
Department of Computer Science and Engineering, University of Minnesota, Minneapolis, MN 55455

Abstract

Living with memory loss presents many challenges for patients and caregivers alike. Intelligent assistive technology can help address care gaps. Our core objective is to develop an assistive device that can be used at home by individuals experiencing memory impairment. We propose an assistant, based on existing and widely used voice activated consumer technology, as a tool to help patients and caregivers cope with issues common to cognitive impairment. Our long term objective is to develop a cognitive assistant that can do what is told to do, but also reason and be proactive in interacting with its users.

Introduction

One of the hallmarks of aging is sensory change associated with physical changes in the brain occurring as the body grows older. Issues such as decreased motor control, difficulty hearing, and worsening vision are often reported in elderly patients. These issues can be especially noticeable in patients on the memory loss spectrum, as the cognitive impairment associated with the progression of memory related diseases can also cause diminished language processing capability. As a result, a number of elderly people require some increased amount of care either inside or outside the home, and these sensory issues can cause a lot of difficulty and frustration in the care process and day-to-day life, from the standpoint of patients and caregivers alike. This is an issue of increasing and critical concern as the world population continues to trend older, and so far human resources to support aging people have not kept pace.

Technology has often been proposed as an additional means of supporting elders. Developing technology for this domain is challenging, however. There are multiple subpopulations among the elderly, and each group (and indeed individual) has unique challenges and needs for technological support. One of the groups that stands to benefit most from assistive gerontechnology is people with memory disorders, including amnestic mild cognitive impairment (MCI). Patients with amnestic MCI have memory gaps that interfere with their day-to-day lives, but are often capable of remaining largely independent with appropriate support.

Many technologies have been proposed for this population – robots in the home (Robinson, MacDonald, and Broadbent 2014), ambient monitoring systems (Peetoom et al. 2014; Acampora et al. 2013), social agents (König et al. 2016) – but there are still gaps in the solutions available versus the needs of the population.

In this paper we describe some critical needs for patients with in amnestic MCI that our intelligent assistant technology can help address, both on the caregiver and patient side. Next, we will briefly outline our proposed approach and current prototype. Finally, we will discuss immediate and long-term future work.

Background

Mild Cognitive Impairment. Mild cognitive impairment (MCI) encompasses a variety of symptoms that can be subdivided into several types. Amnestic MCI is characterized by memory loss at a degree slightly greater than the patient's demographic, and is often a precursor for more severe disorders such as Alzheimer's disease and dementia. It is estimated that 15–20% of people age 65 or older have some form of MCI, and a significant number of those will develop the more severe disorders (Gauthier et al. 2006).

Cognitive Resources and Coping. Neurological disorders such as MCI are often accompanied by increasingly limited cognitive resources due to chemical and physical changes in the brain (Bäckman et al. 2000). Cognitive resources describe our capability to respond to and engage with tasks, from routine daily activities to emotional labor to novel situations. Even in a healthy brain, the amount of cognitive resources available is finite, and so the more resources are devoted to routine daily tasks, the fewer resources are available for other processes. This is especially significant in MCI patients as memory loss issues are often comorbid with anxiety and depression, and in fact unmanaged anxiety has been shown to be a predictor for increased and more rapid cognitive decline (Beaudreau and O'hara 2008). Technological support for routine tasks can free up cognitive resources for higher-level tasks, such as engaging in cognitive rehabilitation and the emotional labor of coping with anxiety, depression, and memory loss itself, that are vital to successfully treating, managing, or even slowing cognitive decline (Lindenberger et al. 2008;

Beaudreau and O'hara 2008).

Caregiver Burden. Caregiver burden is an important, but often overlooked, issue for providers of long-term care, both inside and outside the home. Caregiver burdendescribes various ill-effects that occur as a result of long-term or high intensity care. Caregivers often experience mental, physical, emotional, or even financial strain over the course of caring for others. This is especially true for caregivers of adults with memory or cognitive impairment (George and Gwyther 1986). Many of the behaviors that occur with memory loss that are a source of stress for caregivers, such as repetitive questioning, are also a source of anxiety or embarrassment for the patients themselves (Hawkey et al. 2005).

Proposed Approach

Successful technologies for memory loss patients generally fall into three broad categories: day-to-day life management, increasing patient engagement in activities and social life, and supporting professionals and systems involved in patient care (Meiland et al. 2017). Our proposed application falls under the first category.

We have focused our efforts so far in developing a personal assistant specialized in handling calendars and scheduling tasks (e.g., (Berry et al. 2011; Yorke-Smith et al. 2012)). Effective time management is acknowledged as a significant tool in coping with memory loss, though time management applications designed for this population are still noticeably lacking (Meiland et al. 2017). Many people suffering with MCI struggle with keeping track of time, and this can cause a great amount of stress among both patients and caregivers (Hawkey et al. 2005). A system capable of answering scheduling questions and keeping track of day-to-day activities could therefore have a significant impact on both patient and caregiver quality of life.

User Population and Identified Need

Our target user population is individuals with early amnestic MCI who are considered at-risk for more progressive memory impairments, as well as their caregivers. Appropriate support for these patients can help arrest or slow disease progression, allowing them to stay independent longer.

This population stands to benefit immensely from assistive technologies. Standard treatment plans for MCI patients involve training in compensatory strategies, including using organizers, calendars, and journals to stay oriented and involved in day-to-day life. Evidence suggests that maintaining calendars and organizers can help increase patient performance on certain types of memory tasks. Just as importantly, patients participating in both paper-based (Greenaway, Duncan, and Smith 2013) and electronic calendar studies (Imbeault et al. 2014) reported positive mood effects as well as increased feelings of confidence and empowerment. Caregivers also reported similar effects, both in self-assessment and in assessing their care recipient.

Smart Home Devices: Feasibility

Our approach builds on existing smart home devices. We considered both Google Home and Amazon Alexa devices as platforms, both of which have features uniquely suited to this application. In evaluating available consumer devices, we focused on the following: adoption, multi-user support, voice recognition and language processing capabilities, and commercial support/portability. Based on this evaluation we have chosen to base our application on the Amazon Echo with Alexa voice services, though many features have been tested on both platforms. Alexa skills are also easily ported to Google actions, which still leaves us a great amount of flexibility in future development. Table 1 contains a comparison of key features of Amazon and Google platforms.

	Amazon Alexa devices	Google Home
Distribution	8 million+ units	200,000+ units
Account access	Google accounts, iCal, Exchange, etc	Google accounts
Users recognized	Single user voice recognition (multiple users under development)	Multiple users suppported
Notifications and Alerts	Multiple types supported	Dialogflow (API.AI)

Table 1: Comparison of key features in Amazon Alexa devices and Google Home.

We have chosen voice as a primary mode of interaction because it allows us to overcome the greatest number of deficits a user may have. Users that are hard-of-hearing can connect their devices to speakers or headsets. Low vision users do not have to read input prompts or calendar data (e.g., readability problems with an electronic calendars were reported in (Holthe, Hagen, and Bjorneby 1998). Users with motor control issues do not have to type or write any information, or interact with small touch screens. Most importantly, users will have a constantly accessible, non-judgmental source of information to answer questions and take notes.

Application

Our pilot application (also known as Google action or Alexa skill in deployment) is a scheduling assistant that will be able to sync with a variety of cloud-based calendar services. Multiple studies have shown the value of using a calendar and other activities to support memory (Jean et al. 2010). Specifically, the use of a calendar/notebook significantly improved adherence and functional ability in people with moderate MCI (Greenaway, Duncan, and Smith 2013). Using a cloud-based service, such as Google Calendar, would also make it possible to share calendars between patients and caregivers. A shared calendar that can be accessed and updated easily by both patients and caregivers may make communication about scheduling much easier and help reduce misunderstandings, which in turn would reduce stress and increase quality of life.

The assistant we are developing can interpret a number of speech commands to add, delete, or modify calendar events, as well as remind users of upcoming events or set alarms.

We have tested proof-of-concept application features on both an Amazon Echo Dot and a Google Home device. The Google Home application uses PullString, a basic chatbot service, to interpret user speech and respond to prompts. Our main goal with this application is to evaluate the feasibility of storing, querying, and communicating calendar data that have not been synced to a calendar service, and then syncing to a calendar service independently of user input. To do this we needed to assess the following capabilities for each device: ease of data storage and access, including querying stored data, ease of integration with different cloud services accounts, any existing feature gaps, and conversational ability based on supported chat agent interfaces. Table 2 details some of the supported user commands and identifies the key platform requirements being tested. All calendar actions are done on local calendar data, which can then be pushed to a calendar service as a workaround to gaps in voice command support for both the Google Home and Alexa devices. Independent data representation and syncing has proven to be a challenge, and development and testing of this feature is ongoing.

Command	Natively supported	Requirements tested
"Add yoga class to my calendar on Tuesday at 4:00pm"	Yes	Data storage, queries
"Remove lunch tomorrow from my calendar"	No	Data storage, queries; account access; feature gap
"Change the 10 am appointment today to 11 am"	No	Data storage, queries; account access; feature gap

Table 2: Sample commands supported by our prototype, matched with identified feasibility requirements. Actions shown in bold are not natively supported by either platform.

Key Features

The key to our application is to enable the users to interact with the assistant agent through voice communication. We will include basic support for verification of the correctness of the commands given (e.g., an event not in the calendar cannot be removed, an event cannot be added if it conflicts with another already scheduled event). Verification by itself is not sufficient, we want the agent to be able to start an appropriate conversation with the user to clarify the situation. This requires conversational ability in the agent.

A conversational agent is difficult to design in general, and so at this point we have constrained our efforts to the calendar application itself. However, even limited conversational ability allows us to circumvent issues that are common sources of frustration. We can exploit the capabilities of API.AI to learn better vocal prompts or cues from users, which will gives us better predictive ability so that we can avoid issues like stonewalling users with frustrating fall back phrases when speech recognition fails. ("I didn't understand that."). Basic conversational features, like contextual prompts, help decrease user frustration and increase adoption and long-term usage rates.

Challenges and Shortcomings

Development to date has yielded a number of challenges, which are critical for our application and target user base.

- Native calendar support. Neither of the platforms evaluated support voice modification or deletion of calendar events. This makes it necessary to create a local representation of calendar data and then sync data at regular intervals as a workaround. This means that calendar data may not be available outside of the home immediately. Appropriately storing and syncing calendar data from voice interactions has proven to be a significant challenge.
- Voice activation. At this time neither Google Home nor Amazon Echo support activation (wake) phrases aside from the default ("Hey Alexa," or "Ok Google"). This may present a serious barrier to usability and is under ongoing investigation.
- Device storage and web hosting. Neither device allows data to be stored locally. Any data that needs to be stored must go through a hosting service, so any calendar data that is not immediately synced to a calendar would need to be stored externally. Voice commands must also go through a hosting service.
- Privacy. In order to respond to voice commands, devices must be listening at all times. To facilitate better learning, all user commands are recorded and stored on external servers. However, these voice clips also include seconds of conversation before a wake phrase is detected, and it is not transparent how users can access or delete these clips. This presents not only a usability barrier but may also cause issues due to the nature of the user population – namely, the possibility of sensitive (e.g., health) data being stored externally.
- User adoption rates. Technology adoption rates are typically low for our target population for a number of reasons. However, many studies have identified that one of the greatest barriers to adoption is the lack of user involvement in the design and testing process. Another predictor of adoption is whether or not a caregiver is also using the technology (Meiland et al. 2017). We are addressing this challenge with a variety of user studies, including planned beta testing in-home with potential users (patients and caregivers).

Future Work

The work presented here is intended as groundwork for a more comprehensive assistive agent. In order to build this agent, we have several future directions planned.

Patient Involvement. Many assistive devices proposed to assist in elder care are based on assumptions as to what patients or caregivers actually need instead of on requirements elicited from users themselves. This is an important gap in designing and deploying this type of gerontechnology – not least of which because eliciting user input and incorporating it into product design often leads to increased user satisfaction and higher adoption rates.

We have planned user requirements studies and acceptance testing. The first study, asking users and their caregivers about their day-to-day lives and existing tool usage, has been approved by IRB and will start shortly. We hope that this will give us insights on how to improve our planning and scheduling assistant as well as further capabilities to include in the future. Subsequent studies will ask users to actually interact with the agent and give feedback about their experience.

User Modeling and Customization. The calendar tool we are building by itself is not a personalized assistant. A key feature of the agent we want to build will be its customizability to the preferences of its user. There is a rich literature on creating customized planning agents (Pollack 2005) and conversational agents to support calendars for group meetings (Berry et al. 2011). Since the primary mode of interaction with the agent will be through voice, we will be building a user model based on speech input. We will develop a training set of different user interactions to build a model of user preferences, habits, and intents. The model could be enriched by the caregiver or the final user with default information. From these training data we will build a user model, and use it to drive the conversation and fill in missing information. We hope also to be able to extract a more general user model that can be used as a wireframe to simplify the customization process for other users.

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