MemAid - A Therapeutic Application for Dementia Patients and Caregivers

Dept. of CIS - Senior Design 2014-2015

Jonathan P. Chen
jonchen@seas.upenn.edu
Univ. of Pennsylvania
Philadelphia, PA

Jinesh Desai
jdesai@seas.upenn.edu
Univ. of Pennsylvania
Philadelphia, PA

Vishwa Patel
vishwa@seas.upenn.edu
Univ. of Pennsylvania
Philadelphia, PA

ABSTRACT

MemAid is a mobile application focused on assisting patients with cognitive disabilities and improving the quality of life of their caretakers. MemAid provides a variety of tools to assist patients with memory rehabilitation as well as reminders and safety features for the patient’s well being.

1. INTRODUCTION

Dementia is the blanket term for the class of brain diseases characterized by neurological degradation and memory loss. Common and well-known subclasses of dementia include Alzheimer’s Disease and Huntington’s Disease. These diseases are also neurodegenerative, meaning that the damage they cause to the central nervous system is irreversible. The mental condition (and consequently quality of life) of a dementia patient worsens gradually until death. To date, there is no known cure but a variety of treatment techniques to nullify symptoms.

Symptoms of dementia can be drastically different from patient to patient, but common ones include:

- Forgetting events/appointments
- Repetition of phrases
- Forgetting the names and faces
- Wandering aimlessly
- Hallucinations
- Becoming angry or frustrated easily

Essentially, most forms of dementia affect a patient’s retrospective memory, or their long-term memory. The two components of retrospective memory that we are concerned with are the autobiographical memory, or the memories of one’s past experiences, and the semantic memory, or the facts, concepts, and general ideas in one’s memory.

47% of people over the age of 85 suffer from dementia. This translates to about 5.2 million people in the U.S. alone who have some sort of dementia, and a mortality rate of half a million every year from Alzheimer’s Disease alone. As people live longer and longer, the number of people who suffer from dementia is also increasing dramatically. [7] By 2050, the amount of people living with Alzheimer’s and related dementias may hit 13 million. [12]

Dementia is a significant social issue. Dementia patients gradually lose their ability to lead independent lives, beginning with simple absent-mindedness that impairs their ability to meet obligations and eventually deteriorating to the point where they fail to remember to perform basic functions such as eating or avoiding pain. They require caretakers to help them maintain their day-to-day lives and in some cases even assist with basic tasks like personal hygiene.

Dementia has also proved to be the most monetarily costly disease in America. For Alzheimer’s Disease alone, the estimated cost of care and treatment amounts to $214 billion. With the growth of dementia and amount of the senior population, cost of care is estimated to be at $1.2 trillion by 2050.

Studies have shown that helping dementia patients reinforce associations between observations and retrospective memory can help dementia patients maintain retrospective memory, specifically reviewing photographs has been shown to stimulate memory for past events and also to prompt general memories about the stimulus present in the photographs [9]. Essentially, if the memory of a dementia patient is routinely subjected to a stimulus that the patient associates with their retrospective memory, the patient is more likely to
when Oriani et al. ran a pilot study to observe the effects of dementia patients using an electronic memory aid from a prospective memory standpoint. Prospective memory deals with planning and future decisions, such as running out to buy food from the grocery. Their electronic aid was a device which allowed vocal recordings that contained instructions or reminders of tasks and allowed the user to set a date and time. On the specified date and time the device would alert and remind the user of the upcoming task. In their study, this group of researchers used three different testing conditions: recall based on just memory (free recall), recall using a physical list of things to do, and recall using the electronic memory aid. Initially, out of the 5 patients they were observing, only one patient was able to remember a few tasks in both the free recall and the physical list recall settings and none of the other 4 patients could remember a single task. However, with the electronic memory aid, all 5 patients performed excellently. In fact, one of the patients who could not recall a single task in the other two settings was able to match the score of the single patient who did well in the other two settings. This experiment drew two interesting conclusions, although, it is important to note that a sample size of 5 patients may not be indicative of significant progress. First, electronic memory aids seem to actually improve the prospective memories of dementia patients. Second, physical memory aids appear to be equivalent to having no memory aids at all. Physical memory aids are not effective because they are an additional object that patients have to remember to carry around and, more importantly, unlike eletronic memory aids, they do not have the ability to actively notify the patient of upcoming tasks and events. [1]

In 2006, Hodges et al. wanted to explore the avenues for growth in the field of wearable eletronic cameras and to study the effect of their recordings on autobiographical, retrospective memories of patients suffering from memory disorders. They named their system SenseCam. SenseCam is designed to capture a series of photographs and a log of sensor data from a user’s day. The researchers believed that by reviewing their daily activities through snapshots of significant moments the patients could strengthen their retrospective memories. SenseCam is a custom-hardware camera that is designed with a small form factor and it can be attached to a lanyard and worn around one’s neck while it hangs on one’s chest. The camera contained an internal SD card which could store up to 30,000 photos. In order to validate their hypothesis, the researchers studied a woman suffering from amnesia in a clinical trial and the following graph from their paper highlights the dramatic benefits of this aid. [4]

A survey done in 2008 outlined the current state of technologies for dementia care. They found that most assistive techniques migrated to engineering and computer science fields. Among clinical, engineering, and computer science fields, they found 58 assistive technology devices that provided care. Out of the 58, they found that there were 11 cognitive orthotics, 15 environmental sensors, physiological sensors, and 22 advanced integrated sensor systems [12]. As of 2008, the most attention had been spent on memory recall: there were six concurrent studies of memory aids (the most out of all areas of care). From artificial intelligence to biosensors, and memory glasses to customizable multimodal displays, researchers were experimenting with a wide variety of both software and hardware to find the most effective

2. RELATED WORK

The use of technology for therapeutic applications, known as “assistive technology”, has been more prominent in the last decade, and more research is being invested into developing useful technology to facilitate aid. The first case of success in this specific area of dementia research was in 2003 when Oriani et al. ran a pilot study to observe the effects of dementia patients face difficulties in their duties due to the nature of the patients. These include:

- Overwhelming emotions as [the patient’s] capabilities lessen
- Fatigue and exhaustion as caregiving demands increase
- Isolation and loneliness as independence disappears
- Financial and work complications as costs rise and resources are challenged

"[10] We are not focusing our application solely on the dementia patients, but also the caregivers as well, who are responsible for much of the daily functions of the patients.

This paper presents an application that leverages retrospective memory association techniques and the power and accessibility of modern-day mobile technology to help dementia patients better retain key elements of their retrospective memories. The application also provide tools that can be used to facilitate the care and observation of dementia patients. Finally, it addresses the challenge of designing an interface that is intuitive to use for both dementia patients and their caregivers.

2. RELATED WORK

The use of technology for therapeutic applications, known as “assistive technology”, has been more prominent in the last decade, and more research is being invested into developing useful technology to facilitate aid. The first case of success in this specific area of dementia research was in 2003 when Oriani et al. ran a pilot study to observe the effects of dementia patients face difficulties in their duties due to the nature of the patients. These include:

- Overwhelming emotions as [the patient’s] capabilities lessen
- Fatigue and exhaustion as caregiving demands increase
- Isolation and loneliness as independence disappears
- Financial and work complications as costs rise and resources are challenged

"[10] We are not focusing our application solely on the dementia patients, but also the caregivers as well, who are responsible for much of the daily functions of the patients.

This paper presents an application that leverages retrospective memory association techniques and the power and accessibility of modern-day mobile technology to help dementia patients better retain key elements of their retrospective memories. The application also provide tools that can be used to facilitate the care and observation of dementia patients. Finally, it addresses the challenge of designing an interface that is intuitive to use for both dementia patients and their caregivers.
treatment.

A study done by Peterson et al in 2012 focused on the rift between the technologies developed and the actual needs of caregivers and patients. They categorize assistive technology into four categories:

1. Prevention and engagement
2. Compensation and assistance
3. Care support
4. Enhancement and satisfaction

[13] The paper asserts that all state-of-the-art technology focuses on one or a couple of the above categories, but does not address all of them. They hypothesize that the most effective caregiving is only possible when the specific conditions and symptoms are fully understood. According to the paper, the main purpose of assistive devices is to simulate the tasks performed by a human caregiver, including the ability to recognize and detect changes, communication, medical management (including nutrition and hydration), and home safety [13]. All innovation should move towards those goals, and the use of smart devices or “smartphones” should minimize activity for the patient and be evaluated under uniform standards. Borson et al, however, believe that most effort should be spent on screening and surveillance methods, to bolster preventative measures [14].

Prasad et al, delineated unique criteria to assess improvements in dementia symptoms. Rather than assessing based on progress on performance tasks, they suggest factors to measure quality of life. [15]. Even as of 2010, there were a lack of assessment factors that could be used to gauge the well-being of patients. The framework they ultimately provide to measure quality of life include a variety of personal and environmental factors including, self-esteem, attachment, security and privacy, physical and mental health, and freedom. They also advocate electronic assessments to classify domains and quantitatively measure improvements in quality of life [15].

We agree with the conclusions of Peterson et al, that the most effective form of care addresses all four of the classes they delineate. Though we would like to focus specifically on memory recall, we also are addressing care support, enhancement, and monitoring. While we think that both SenseCam and the electronic reminder aid mentioned earlier have great potential as therapeutic tools, we are focusing on using everyday tools, such as smartphones and tablets. This reduces the additional hardware patients would have to acquire and set up, in addition to reducing the work of the caretaker. SenseCam, due to its design, makes patients stand out in public places and forces other people to fear being recorded, thus hindering good conversations between the patients and others who might not know the patient. Since most people possess some sort of smart device they they use regularly, our use of the Android platform to incorporate smartphones and tablets will allow us to be more flexible in the patients we target, as well as reducing the cost of accommodating caretakers in their duties.

3. SYSTEM MODEL

The benefits of electronic memory aids for patients suffering from dementia are evident throughout the research quoted in the previous section. However, we believe that with the ubiquitous nature of smartphones in our world, our system would work best by harnessing the wide reach and the powerful features afforded by smartphones. Our project has culminated in the production of an Android application named MemAid. MemAid is comprised of three core features:

1. Memory Game
2. Reminders
3. REALERT or Real-time Location Alert System

3.1 Memory Game

The memory game is the central feature of MemAid. The game has one core mechanism: the patient is presented with a visual or aural stimulus and the patient can press a button to activate the speech recognition system and then he or she can name the object in the stimulus. These stimuli can be uploaded by the caregiver of the patient or the patient’s doctor. We developed a framework for allowing the upload of either of two things:

- An image along with its corresponding name which is recorded via our speech recognition system
- An audio recording, which could be a question identifying a particular name or object, along with its corresponding correct response which is recorded via our speech recognition system

The speech recognition system then converts this speech into text and presents us with a list of possible results, these results are compared to the list of results generated by the speech recognition system when the caregiver uploaded the correct response to the stimulus using our custom string matching algorithm, which will be described later. If a positive match is found between the two lists of responses then the user is presented with a positive congratulatory message and the player’s score is updated on the screen and in our database. If a positive match is not found then the patient is allowed to try again or he can choose to skip the current stimulus.

The speech recognition algorithm we use takes speech input from the user and compares it with the list of possible correct responses stored when the caregiver uploaded
the stimulus. If the keyword is close enough then we assume there is a match. We have found that this algorithm works well for proper nouns too because, intuitively, speech recognition services for Android have progressed to the point where almost anything that is spoken can be picked up with reasonable accuracy, and our way of accounting for the small margin of error is the edit distance algorithm which we will describe in great detail in the implementation section.

Figure 4: Memory game with a visual stimulus

Image/audio uploading

We use a native Android SQLite database to store the stimulus and the correct responses to the stimulus. We created a simple interface to allow the user to upload images, audio, and audio-based responses for the stimuli. We initially intended to allow only visual stimuli, but we realized that by allowing the caregiver to upload audio-based descriptions of people and objects would provide them with greater flexibility. We also decided to allow audio keyword uploads (as opposed to the standard text-based keywords) to help with the correctness of words speech recognition might have trouble analyzing accurately. This way, we can use the edit distance algorithm on the results of the keyword audio checked against the audio input of the patient.

3.2 Reminders

The reminders feature’s goal was twofold.

Our first goal to allow patients to achieve greater independence and the ability to manage their lives better by creating a system which would allow them to ensure that they are able to keep track of things they need to do and places they need to be without needing the support of the caregivers.

Our second goal was to create a system which would allow the caregiver to remind the patient to play the game at a prefixed interval. This would ensure that the caregiver could track how often the patient actually played the game. One of the key problems with such therapeutic games is that dementia patients often forget to play them because of a lack of memory.

3.3 REALERT or Real-time Location Alert System

Statistics show that 6 out of 10 Alzheimer’s patients suffer from wandering as a symptom of their disease [16]. A person with Alzheimer’s may not remember their personal details like their home address or, in certain cases, their own name. This can be incredibly dangerous because they could potentially end up in location that could cause them harm. We believe that REALERT helps the caregivers by allowing them to locate the patient very accurately and very quickly, two things that matter a lot when a missing person is being located.

The way REALERT is designed allows us to notify the caregiver in real-time if we suspect that the dementia patient might be wandering. If the patient consents to sharing their location with their caregiver when the patient first logs into the application, their phone sends out a location beacon or a location update to our server every 10 minutes. These location updates allow us to construct a location history of the patient. This location history proves incredibly valuable in the unfortunate event when the patient goes wandering. Their phone continues to send beacons and the caregiver can view the location history of the patient over the last 24 hours or more and the caregiver is presented this information on a Google Map with a line tracing the movement pattern of the patient along with the time at which the location was recorded. The caregiver can provide this information to the police or any other authority that is tasked with finding the patient.

Additionally, we also designed a framework which allows the caregiver to be even more careful in case the dementia patient has a severe history of wandering. We conceptualized the idea of ‘safe zones’, which are basically, regions or geo-boundaries where the patient can be assumed to be safe. These could be areas like the patient’s house, the patient’s gated community, the patient’s hospital, the caregiver’s location etc. The caregiver can touch a location on a Google Map and then he or she has to define a radius for the safe zone depending on the estimated size of this area. Whenever
the patient leaves this region, our system automatically trig-
gers an SMS to the caregiver’s phone with the information
about where the caregiver currently is and a short message
which says ‘X might be wandering because they have left
their safe zone’ where X would be the name of the patient.

Our technical approach to tackling this problem is to use
the native Android SpeechRecognizer system to actually
record the data and responses of the patient to the stimu-
lus and gather their responses to the stimulus. As a result,
this will allow us to measure how effective our application
is at helping patients remember the names of the people
or objects being presented to them. Additionally, we have also
implemented speech recognition which will complement the
stimulus upload feature by allowing us to present the user with the stim-
ulus and gather their responses to the stimulus. As a result,
this will allow us to measure how effective our application
is at helping patients remember the names of the people
or objects being presented to them. Additionally, we have also
implemented a basic version of the reminders feature that is
aimed at relieving some of the responsibilities of the care-
takers such as reminding the patient to take their medicine
at a particular time etc.

The technical underpinning of our speech recognition, au-
dio capture system is the Android Intent system. Intents are
asynchronous messages that can be passed either between
different components of the same application or between dif-
ferent applications entirely. Intents allow an application to
communicate with another application and request a spe-
cific feature that is exposed by the other application. This

Figure 6: Location history of patient with movement
pattern traced

4. SYSTEM IMPLEMENTATION

The platform we have chosen to implement our solution
is Android. At this point in time, we have implemented the
basic framework of an application which allows users to up-
load stimuli that are either in the form of visual images of
people/living things or even inanimate objects that might
be relevant in the lives of dementia patients or in the form
of audio clues which can trigger memory associations in the
minds of the patients and, thereby, help them remember the
object being described orally. We have also implemented
speech recognition which will complement the stimulus up-
load feature by allowing us to present the user with the stim-
ulus and gather their responses to the stimulus. As a result,
this will allow us to measure how effective our application
is at helping patients remember the names of the people
or objects being presented to them. Additionally, we have also
implemented a basic version of the reminders feature that is
aimed at relieving some of the responsibilities of the care-
takers such as reminding the patient to take their medicine
at a particular time of the day, reminding the patient to eat
their meals at a particular time etc.

The backbone of our idea and our application is the speech
recognition system that will allow us to record the responses
of the patient to the stimuli. We are faced with an inter-
esting problem here because we are not simply dealing with
recognizing English proper nouns or even English names of
common objects, instead, we have to account for the possi-
bility that the names of the stimuli might not be common
English words, an example of this would be the name of a
person of Indian origin such as Vishwa, or Jinesh.

Our technical approach to tackling this problem is to use
the native Android SpeechRecognizer system to actually
perform the recording of both the stimulus and the response
of the patient to the stimulus and then, if a perfect match
is not found between the two results, to use the minimum
string edit distance or Levenshtein distance algorithm to
compute the minimum number of edits required to trans-
form one of the two strings into the other, where edits refers
to insertions of characters, deletions of characters or substi-
tutions of characters.

The problem with using the native Android SpeechRec-
ognizer is that even though it is very efficient at recognizing
common names and English words, it is unable to accurately
convert, from speech to text, words that are not from the
English language or commonly used in the English world.
Our intuition, with the minimum edit distance algorithm
is to essentially use the minimum edit distance as a cor-
rection factor for the flaw of the SpeechRecognizer we just
described, so as to allow some degree of failure in the results
of the SpeechRecognizer. However, an interesting challenge
here is to determine what we set as the threshold for the per-
missible minimum edit distance between two strings, since
if we do not have a threshold, any string can be transformed
into another string through N edits, where N is the length of
the longer of the two strings being compared because if two
strings A, of length M, and B, of length N, differ completely
by every character, the shorter string, say string A, can be
edited to transform it into string B by replacing all its char-
acters to match the first M characters of string B and then
by the insertion of the remaining (N - M) characters from
string B.

An interesting technical aspect of the the Android SpeechRec-
ognizer is that, upon recognition of sound, it does not return
only one recognized result, instead, it can result a list of
strings that could potentially be the correct answer. Our
approach is such that once the caretaker uploads a stim-
ulus and speaks the correct name of the stimulus, we will
store all the possible matches returned by the SpeechRecog-
nizer in our embedded Android SQLite database and then
when the patient responds to the stimulus the SpeechRec-
ognizer provides us with a list of possible results. The next
step in our algorithm involves comparing every result stored
from the input of the caretaker with every result returned
by the SpeechRecognizer when the patient says the name of
the stimulus. Essentially, we are performing a set in-
tersection between the two sets of results generated by the
SpeechRecognizer and checking if the intersection contains
elements. However, if this fails, we then move on to
perform a similar comparison between all pairs of elements
between the two sets while measuring the minimum edit dis-
tances between the two strings in a pair and checking if that
distance is below our specified threshold, and if we find at
least one such pair, we have determined that we have found
a successful match and the name the user entered is correct.

The technical underpinning of our speech recognition, au-
dio capture system is the Android Intent system. Intents are
asynchronous messages that can be passed either between
different components of the same application or between dif-
ferent applications entirely. Intents allow an application to
communicate with another application and request a spe-
cific feature that is exposed by the other application. This
grants application developers the power ability to reuse existing functionalities from other applications. Specifically, we used the Android system intents to send messages to the Android system to ask it to start the speech recognition service and upon completion of the specified task, the Android framework triggers an asynchronous function call in the context of our application and provides us with the requested information, which, in this case, is the list of results recognized by the speech recognition service.

The next part of our application is the reminders feature. The reminders feature was a monumental challenge.

The first task we faced was to construct an interface that would allow patients to, with minimal hassle, input the details of an event or task in the future. One major hurdle we had to overcome for this part of the application was that we needed to design an interface that elderly dementia patients, many of whom are relatively new to smartphones and unfamiliar with the intricacies of their use, would proactively use. The way in which we accomplished this was designing custom datepicker and timepicker UI components, which we designed to be extremely intuitive. The datepicker was simply a calendar, and the patient can tap the day they want on the calendar. Similarly, the timepicker allowed the patient to swipe upward or downward to scroll through the hours and choose a time. The remaining parts of the form were designed to involve minimal text entry.

Next, we needed to create the infrastructure necessary to notify the patients at the appropriate time. In order to do this, we extended Android’s AlarmManager library. We created a custom handler class for alerts from the reminders part of the application, and using AlarmManager, designated a custom Intent which would notify Android to set off an alarm at the time and date specified by the patient. The custom handler was also responsible for creating a customized notification for each reminder, which would include the reminder’s title and a button to indicate acknowledgement of the reminder.

Finally, we had to build the feature responsible for notifying the caregivers when the patients acknowledged their reminders atop the aforementioned infrastructure. We were able to achieve this using a similar mechanism to the one we used when creating the reminder alerts. We used custom intents to notify the caregiver’s application whenever the patient acknowledged a reminder. This custom intent also passed along information such as when the patient acknowledged the reminder and what the reminder was.

REALERT was implemented using Google’s location tracking service which combines the GPS with the location of the patient determined through their data connection and fuses this information to provide a more accurate result. The patient’s location history is presented on a Google Map and this was implemented using the Google Maps Android API v2. The location markers with the custom infowindows allowed us to specify not just the movement pattern but the exact time at which the patient was tracked at that spot.

5. RESULTS

5.1 Methodology

Our basic methodology was to test functionality and robustness. To test the former, we conducted rudimentary tests across a wide variety of dictionary words in order to ensure that the algorithm processed the speech properly and sent the information to the backend, which would then keep track of the user’s score. The caretaker suite testing was done by carrying the device across from a source to a destination within a given time frame and assessing if the returned data of the timestamped trip was accurate. To test robustness and consistency, we recorded the results of twenty of our peers among common proper nouns and common dictionary words from four major word roots. Since none of the test users had dementia, the score was immaterial; only the algorithm’s performance was assessed, rejecting wrong answers and accepting right answers.

5.2 Speech Recognition Algorithm

The results of our memory game are shown in the graph below. We decided to test our speech recognition algorithm by attempting to get it to recognize text-based matches of proper nouns describing names of people of different ethnicities in order to ensure that a majority of names are correctly recognized by the algorithm.

![Figure 7: Performance of recognition algorithm on words of different origin](Image 329x441 to 544x579)

The algorithm performs extremely well on Anglican or English names with a success rate of over 95%, and decently with names of foreign origins with a success rate of over 70%. We can observe that there is a slight dropoff from Latin to Chinese names as well. We obtained different results by tweaking the edit distance threshold, and found that it was possible to set it such that the algorithm would match even names that were phonetically far from English. This seems to be because most languages have speech an be mapped to some letter in the English alphabet, with the exception of some cases. For example, in Spanish, the “r” sound is rolled, but the remainder of the word is still pronounceable in English, and even uses the same Romanized alphabet. The only execution would be non-Latin based languages such as Chinese, whose pronunciation of “sh” and “x” are identical, but spelled differently in Chinese. Adjustments to this algorithm post-testing will be discussed in the Future Work section.

It is important to note a phenomenon that is not visible from the graph; the algorithm seems to have perfect success in rejecting false positives. All the errors the algorithm made is reflected in false negatives, or failing to recognize the correct answer. This is because the app is simply attempting to test recognition, not correct pronunciation, and if the patient correctly recognizes the stimulus, it does not
matter if they mispronounce the keyword slightly. On the flip side, it is extremely unlikely that the user would say an incorrect word, but one that is similar phonetically enough to the correct word such that the algorithm would recognize it. Since all the stimuli are cues that the patient should know, there should be no false positives in practice.

5.4 Reminders Feature

The reminders feature allows the user to input important tasks throughout the day, and MemAid will notify the user when those tasks need to be done. From expert and user feedback, some automated tasks by default are programmed in such as charging the phone every night and playing the memory game three times a day. Of course these can be changed as the caretaker or doctor see fit. The reminder does not go away until it is acknowledged by the user. If a reminder is not acknowledged, the caretaker receives a notification asking them to check up on the dementia patient. This has been rigorously tested across multiple devices and is flawless.

5.5 Feedback

Feedback from patients, caretakers, and medical experts is perhaps among the most integral components to our evaluation process, since prior studies have already shown the effectiveness of electronic memory aids. We met with the cognitive fitness group at the Penn Memory Center as well as the caretaker support group in order to fully gauge their opinions and experience with MemAid. Overall, feedback was very positive with 100% of the users saying that they were willing to use the application and ask their doctors to prescribe it as treatment if it were deployed. We also solicited constructive feedback which is specifically outlined in the “Future Work” section below. Because are the caretakers and patients we surveyed were all elderly people, many were afraid of the technological barriers from using the application. Others were afraid that they would not be able to process the reminders even when they were shown on the screen. The issue of privacy was brought up involving what information was visible to the caregivers and the doctors. MemAid was developed with privacy concerns in mind, so no patient information besides their score on the memory tests are submitted to their doctors. This information is not concerning since it would be known by their doctors anyway with any other treatment.

Some members in the cognitive fitness group who acted as both caretakers and patients themselves (their dementia being not as severe) were concerned about the benefits and additional hassle. It was suggested that MemAid be tied to lower insurance premiums to motivate widespread use among patients. Of course this would be a long term goal, but it is still crucial to the long term success of MemAid as a mainstream treatment method.

6. FUTURE WORK

Consulting with medical professionals and gathering feedback from both patients and caretakers has directed much of the future work. In addition to technical adjustments, there are a plethora of logistical components must be discussed before MemAid can make its way into the hands of dementia patients.

6.1 Technical Implementation

MemAid is a self sufficient mobile application and can be deployed at its current state and run independently from any external client. However, from ongoing communication from medical experts and actual patients, there are features and improvements that can be made on the technical side. This can be broken down into three components: the algorithm, the game, and the utility suite. Of course, these changes are
subject to further feedback and testing as this application becomes fully deployed.

As shown in the results, the algorithm that we develop performs satisfactorily at 85% overall, but not perfectly. The accuracy also drops as words move away from English or Anglican roots. This limits the outreach of our application, as we would like to target all patients of different ethnicities, and eventually target patients around the world who do not speak necessarily speak English. Ideally, the accuracy of recognizing names and proper nouns across the board should be over 90%. It is a fair threshold level in which most speech recognizing devices today operate at, and it does not prevent the user from being able to play the game and get accurate results. Because the results reflect the patient’s mental health, minimizing the natural error from the algorithm is of utmost importance. Fortunately, dementia patients, as opposed to patients with strokes for example, have no impairment of speech, so no extra considerations need to be made regarding dementia patients versus healthy users.

To improve recognition results for English words, patients can be asked to repeat their answer multiple times and an average be taken among them. However, since the drop in accuracy is with non-English words, the language base in which the algorithm is operating would need to be expanded. For example, if the algorithm could map certain speech patterns common to different languages such as rolling an “r” to a recognized letter in the English language, then accuracy can be improved substantially.

On a broader scale, the memory rehabilitation games can be modified as well. We focused much of the game on personalization so that the user could relate to all the stimuli and be able to recall the important names and places of their daily lives. However, a caretaker we met with suggested using globally recognized stimuli, such as city names or the President of the United States. Further development would increase a dimension to the game, allowing users to select from globally recognized names and personal names. In the global version of the game, the user could put in the decade in which they were born in, and the game would use stimuli from their time period as well as stimuli from modern day. This would allow patients to have exercises with both relevant information from their past as well as staying up to day with current affairs. From a medical perspective, this would allow doctors to assess which aspects of a patient’s memory such as cued recall or free recall needs improvement. The game itself could also quantitatively track the progress of the patient’s performance over time and return analytics regarding his or her progress. This would motivate patients to take initiative to play the game and improve their memory if they could track their own progress, and perhaps even have some sort of goal to reach.

During a preliminary session, patients had no trouble understanding and navigating the utility suite, but suggestions were made for those with more serious onsets of dementia that they would not be able to process or receive notification reminders, even if the phone were to go off or vibrate. Incorporating MemAid with a smartwatch component would address this issue, since most people have their watches on at all times even if they leave their phone at home. Also, the location tracking feature was viewed as potentially too intrusive, even for those who would like to have their caretakers notified should they go missing. To facilitate this, as mentioned earlier, we have developed designated “safe-zones” in which a person’s whereabouts are not monitored until they leave such an area. Further adjustments can be made to the location tracking feature such as specifying certain time intervals where a person would like to have their location monitored and other times where it would turn off (such as in the morning and at night). Similar to the safe zone concept, patients can also specify “danger zones” or areas where the caretaker should be notified if the patient wanders into them. For example, Penn is generally extremely safe during all times, but wandering west of campus may be unwise at certain times during the day. These minor adjustments would help compromise the balance between safety and privacy.

6.2 Treatment Integration
In order for MemAid to be successfully integrated with treatment plans that doctors prescribe patients, there must be ways for the doctor to respond to and verify the legitimacy of the information being sent by the patient. Because there are inherent privacy concerns with patients uploading aspects of their personal lives to a server, all stimuli both audial and visual are only stored locally on the patient’s device. Though this prevents third parties from gaining unrestricted access to this information, it also prevents doctors from compelling a patient to do a certain type of exercise with certain types of stimuli. It is also very difficult for them to verify that the patient is indeed following the mandate. Remote access of patient information would be an integral part of the results and feedback from doctors. Doctors would be able to check up on all their patients without having to directly engage with the devices, and patients would not need to be concerned that their private information may be eavesdropped by third parties. While it was not in the scope of the project to build a secure backend that complied with HIPAA regulations and allowed doctors to remotely access the patient data, remote access would drastically facilitate the ease of use for doctors to access data. remote access of patient information

6.3 Health Insurance
To motivate patients to use MemAid, doctors and hospitals could negotiate with health insurances that cover dementia patients to offer a lower premium for those who are on an electronic memory aid treatment. There has been overwhelming evidence for the positive effects of electronic memory aids in dementia care. Not only would this spur the growth of MemAid in the cognitive impairment field, but insurances would benefit from the lowered safety and health risks that MemAid provides. This step would naturally come after widespread use in treatment plans across hospitals, but nonetheless stands as an important consideration for the future of MemAid.

7. ETHICS
Any health-care treatment is inherently prone to ethical subjectivity. In order to address the various ethical pitfalls of using the application, it is important to view the issue from all perspectives in order for future integration to be successful. From a caretaker or doctor perspective, the system gives user constant information throughout the day, including the location of the user (if they so comply). This wealth of information can be abused by a caretaker, as they can easily monitor the daily activities of the patient as
well as see the progress of the patient’s activities throughout the day. Caretakers often have multiple patients they watch over and though monitoring provides a convenience, there is an inherent potential abuse of power on the side of the caretaker to track his or her patients. From a patient’s perspective, there is also risks of moral misconduct. For example, if there were insurance or medical incentives to perform better on the memory aid’s tests, the patient can manipulate the stimuli in the tests to skew towards better results. Because the stimuli that the patient uploads is private, the doctor would not be able to verify the validity of a malicious patient. Because there are gray areas on both sides of the application, there must be a certain degree of professionalism and honor on both sides.

Privacy regarding the memory rehabilitation exercise is related to general online privacy with applications that store user information. The treatment involves assessing user performance and data, and therefore, collects information of the patient. To facilitate this, our application allows the user to select their preference of if they would like their location to be tracked for the purpose of their caregiver, and if they would like their personal data to be recorded. Since the mobile application would most likely be used in conjunction with other treatments with most users having some sort of caretaker or doctor, their information is shared with their own medical experts. There is less privacy concerns over a patient’s results since it is only being shared with his or her doctor, as would be the case without an electronic memory aid. However, caution must still be exercised in order to prevent the private information from leaking or being misused by third parties who would benefit from knowing patient information.

Finally, if the success of online applications eventually becomes integrated with insurance premiums as suggested in future work, then there are ethical risks regarding patients manipulating the applications for their own benefits or insurance companies pressuring doctors to use certain memory treatments over others. Of course, the pressure doctors and hospitals face for certain treatment plans falls under a wider umbrella of the moral code of health care and is not unique to electronic memory aids.

8. CONCLUSION

Through extensive user testing, robustness testing, and quality assessments, MemAid serves as a foundation for mobile applications to assist patients with cognitive disorders. Memory Aid uses prior research in the success of electronic memory aids to assist in memory rehabilitation and provides an entire caretaker suite, designed for the purpose of facilitating the patient and the caretaker’s needs. The speech recognition algorithm in the memory exercises performs with an accuracy of 85.5% across all names and words. The utility suite has received positive feedback from the dementia patient community as well as the caretaker community.

There is an increasing trend of research into the use of technology in health care, especially with cognitive disorders. In addition to mobile and web applications that focus on patient health, specific applications geared towards disorders are used by doctors and hospitals to treat patients. With the prominence of smart devices among the population, medical electronic applications are now easier to access for across all ages. The integration of technology and health care is an inevitable process; MemAid only scratches the surface of the potential of technology in mental health treatments and health care as a whole.

9. REFERENCES


