Robin: Enabling Independence For Individuals With Cognitive Disabilities Using Voice Assistive Technology

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Abstract
Individuals diagnosed with dementia are often most concerned about loss of independence, defined as the ability to continue living in one's own home. Currently, assistive technologies that provide in-home cognitive support for those with degenerative brain diseases have not been widely adopted, and individuals often rely entirely on informal caregivers to aid them in planning and performing the daily activities that allow them to continue living independently. To help these individuals, we designed Robin, a conceptual context-aware assistive application that supports independent living for users with cognitive impairments by providing temporally and physically appropriate audio prompting for the routine tasks that are most important for health outcomes and life satisfaction.

Author Keywords
Dementia; cognitive impairment; assistive technology; voice assistant; cognitive aid, context-aware; routine management, task management.

ACM Classification Keywords
H.5.2 User Interfaces: Natural language; H.5.3 Group and Organization Interfaces: Computer-supported cooperative work

Dementia
"Dementia is not a specific disease. It is a descriptive term for a collection of symptoms that can be caused by a number of disorders that affect the brain. People with dementia have significantly impaired intellectual functioning that interferes with normal activities and relationships. They also lose their ability to solve problems and maintain emotional control…" [6]

Facts & Figures
46.8 million people have dementia worldwide and 9.9 new cases of dementia are diagnosed each year [12].

By 2018, the worldwide cost of dementia is estimated to exceed a trillion dollars. These costs include health care, but also the lost wages and productivity of dementia patients and their caregivers, who contribute unpaid work valued at $500 billion dollars annually [6].

Introduction

There is a growing need to support people experiencing dementia and other cognitive disabilities, but the existent assistive technologies that provide in-home cognitive aid are either not yet commercially available or have not been widely adopted [4, 10]. In our interviews with caregivers and healthcare providers, we found no instances of adoption of assistive technologies for cognitive function, but a strong interest in such interventions.

For people experiencing symptoms of dementia, many express a desire to remain in their current home and maintain as much independence in their daily activities as possible [13]. In support of these goals, we focused our research on cognitive aids to support daily living. We found that while there are currently many successful adaptations for physical impairments, the products that exist to aid in activities affected by cognitive impairments, such as task execution, are often expensive or inflexible, catering to very specific tasks. However, in one prior study, an electronic memory aid significantly improved patients' prospective memory [11], and our expert interviews also stressed the importance of routines and reminders for patients living with dementia. The collaborative design process of Nugent et. al confirmed both the interest in these types of interventions on the part of caregivers and patients with early-stage dementia, and the utility of supporting dementia patients in both remembering and performing daily life activities [9]. Drawing on this work, Meiland et. al recommended that technological assistants for dementia focus on supporting both daily living and meaningful and pleasurable activities10]. In this intervention, we aim to support both necessary activities (such as taking medication) and quality-of-life activities using a newly-available voice assistant technology.

Research Process

Expert Interviews
We conducted interviews with two healthcare providers who specialize in degenerative brain diseases (one physician, one nurse). These interviews, which we conducted in four sessions over the course of the project, helped us both narrow the scope of our intervention and identify the key breakdowns for those living independently with dementia. Additionally, we interviewed five informal caregivers for elders with dementia. These caregivers cared for elders with Parkinson's (1), Alzheimer's (2), and Lewy Body Dementia (2).

Forums
To learn about the perspective of those who have recently been diagnosed with Alzheimer's and other forms of dementia, we read online forums that contained postings by people who had recently been diagnosed [1]. We manually logged instances where users mentioned trouble performing certain tasks, dividing these into task-types. We later returned to these same forums to validate our design assumptions with a four-question survey for individuals that identified themselves as having trouble completing tasks.

Competitive Analysis
We reviewed interventions that are currently on the market, and found that the majority of successfully-adopted technologies were aids that helped with the physical impairments that co-progressive with cognitive impairment [4]. We also found that emergency

1	No cognitive decline
2	Very mild cognitive decline (forgetfulness)
3	Mild cognitive decline (noticeable forgetfulness, difficulty finding words)
4	Moderate cognitive decline (difficulty with complex tasks, increased forgetfulness, difficulty concentrating)
5	Moderately severe cognitive decline (major memory deficiencies, needs help completing daily tasks)
6	Severe cognitive decline (extensive memory deficiencies, requires help for most tasks, possible personality changes)
7	Very severe cognitive decline (essentially no ability to speak or perform tasks)

Table 1.
The Seven Stages of Dementia [14].

response devices were widely used by elders living on their own, both with and without dementia.

Secondary Research
We conducted a literature review, focusing on interventions that are currently in the research phase. Here, we found a number of technologies that aimed to assist with routine tasks, but many relied on custom technologies that were not market-ready [4].

Matchmaking
In our final research stage, we conducted additional research on technologies that could be adapted within this domain. We investigated mixed reality technologies, wearables, and location-based technologies (GPS, RFID).

Key Findings

Importance of Routines
We found that the majority of those with dementia wished to stay in their homes but began to have difficulty performing the routine tasks of daily living as their disease progressed. For those who did stay at home after they began experiencing impairment, we found that daily routines were widely used, and that adherence to routine increased as the disease progressed. We also found that small deviations from routines such as missed meals or medications often led to negative health events, including hospitalizations and increased mortality. In studying these routines, we found that crucial tasks generally have several steps, and happen both at a particular time of day and at a particular place. As such, a routine-assistance system would ideally use both spatial and temporal data and provide step-by-step prompts as required.

Stages of Dementia
We identified the first four stages of dementia as the most promising for in-home intervention (average duration of stages 3 and 4 combined: 9 years). From the Alzheimer's message board, we found that in these early stages of the disease, many people are proactive and wish to learn about interventions that could help them maintain their independence [1].

The Importance of Customization
While we found that impairment caused by dementia progresses in a consistent order, we also found that the exact manifestations of these impairments varied greatly. While routines are immensely important for health outcomes and life satisfaction, the manifestations of these routines would need to be customizable for each user. We also found that as the disease progressed, the assertiveness of the intervention would need to increase, following what one doctor characterized as the "reverse Piaget" of dementia. Finally, we found that the rate of abandonment of technological assistants was high among our target population, making ease of setup and customization paramount.

Design Requirements

Based on our research findings, we drafted design requirements for our product, deciding it should:

- Support successful routine management
- Enable the user to live in his/her own home
- Be customizable and adjustable over time to align with changes in cognitive function
- Be inexpensive and readily available

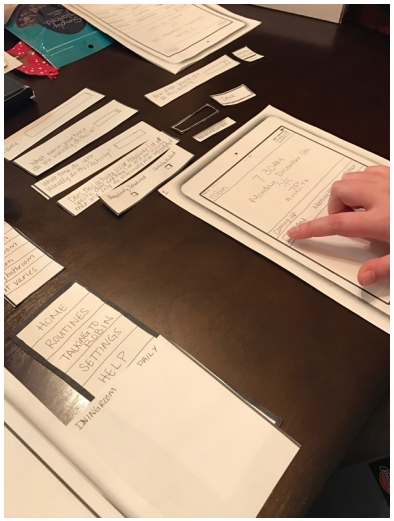

Figure 1.
Think-aloud usability testing with a paper prototype of the screen interface.

- Utilize voice commands, but support multiple means of interaction with a visual interface

Design Process

Scenarios of Use

We began the design process by imagining scenarios in which a routine-based intervention would aid in an early-stage dementia patient's daily activities, using a dementia patient and a primary informal caregiver as user personas. After generating 30 scenarios of use, we identified three primary types of routine prompting: necessary intervention (e.g. ensuring medication is taken), step-by-step guidance (e.g. how to perform a task), and quality-of-life improvements (e.g. proposing activities that user enjoys). These three types of prompting correspond to the most promising areas of assistive technology development [10].

Storyboarding and Speed Dating

We storyboarded three scenarios and used them in speed-dating sessions with caregivers and healthcare providers. Each speed-dating session was accompanied by a debrief and a collaborative ideation session in which caregivers were invited to share scenarios that they believed could most benefit from intervention. From these sessions, we learned the following:

- While some dementia patients may be reluctant to acknowledge their condition, many are eager to adopt technologies that will help them maintain independence.
- Because eating and medications are key activities, the kitchen and the bathroom are important sites within the home for maintaining healthy routines.
- Interactivity was crucial, but because there are significant physical impediments for using touchscreens, voice interaction was perceived as more accessible.

Usability Testing

Using low-fidelity paper prototypes, we performed four think-aloud usability tests, which allowed us to quickly iterate and address usability issues with our mobile application interface. We then iteratively designed a digital prototype of the application interface, performing four additional think-alouds as we iterated on the digital version. We then performed a heuristic evaluation using website heuristics for older adults [5].

Validation

We returned to the forums that we had studied in our research phase and using a three-question survey, asked users who had trouble with task execution if they would be interested in using a voice assistant for task guidance. 65% of respondents indicated that they would be interested in trying such a device.

Final Design Solution

Our final design solution is Robin, a conceptual prototype of a mobile and web application that provides voice prompts and task guidance to users.

Enabling Technology

We prioritized working with existing technology that is both inexpensive and readily available. Robin is co-operative technology that communicates with and modifies a voice-activated platform. Robin's mobile application currently works by creating and editing "Skills," which are built-in capabilities that Amazon

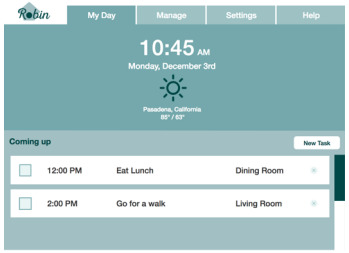

Figure 3.
Clickable prototype (CP): daily tasks screen.

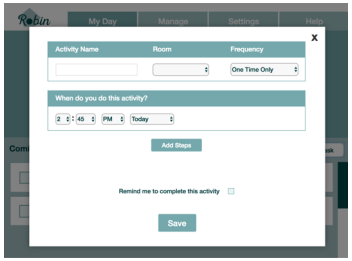

Figure 4.
CP: new task screen.

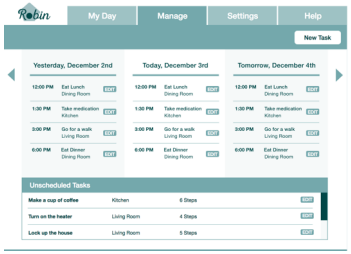

Figure 5.
CP: manage tasks screen.

Alexa products use to provide users with certain commands.

A user can input routine tasks via the Robin mobile application or by giving voice commands via an Amazon Alexa-enabled product. As the user becomes more comfortable using a voice-activated device, they can add greater detail to their tasks by speaking to Robin or editing their routines within the Robin mobile application. For example, the initial task input of "make breakfast" could be expanded to include the steps to make a specific breakfast.

User Experience

We chose to use a voice-activated platform because it could provide a ubiquitous assistive environment without the need to carry around a mobile device. There are several solutions currently which constrain the user to a device (e.g. mobile phones, smart watches must be worn constantly). By using a voice-activated assistant, the user can be anywhere in their home within range of the voice assistant to receive aid.

To set up the application, users, with the help of their caregivers as needed, first provide core information about their daily routine through the Robin application. The initial input of tasks requires few details; the task name with the approximate time that it is conducted (e.g. "lunch around noon every day") will suffice.

As they go about their day, the user may choose to interact with Robin in a few distinct ways. First, the user can proactively ask for assistance ("Alexa, ask Robin what I usually do at this time.") and, using the programmed schedule, the voice-activated device would suggest a task ("You usually go for a walk at this time"). Second, Robin can provide complex step-by-step information about a programmed routine. If the user is having trouble completing a task because they cannot recall the procedure, Robin can provide the sequence of steps ("Alexa, tell Robin I need help making eggs"). Finally, Robin orients users within their daily routines. If the user forgets a task in their routine, the device can prompt them by asking the user if they have completed a certain task. The user can communicate with Robin and check off completed tasks ("Alexa, tell Robin I'm finished with lunch").

One concern is that users may have difficulty remembering the utterances for the speech interface. This may be true at the onset, but as our solution targets early-stage dementia, asking Robin for help using certain keywords will become habitual over time.

Customizability

As the user's condition progresses, caregivers are able to input more tasks or add more detail to tasks that the user has difficulty with, allowing Robin to be adaptable to each individual by addressing the specific problems in their daily routine. Because the manifestations of dementia are varied, Robin is designed to be a reactive assistant to the various symptoms that an individual may face.

Accessibility

Designing for elders, we used online resources from Resene and UXmatters [3, 15]. To create a welcoming tone with high legibility, we chose to use pastel colors with a high contrast between text and background color. For the same reason, we used a sans-serif font.

Use Cases

Reactive Assistance

When a user is unsure of steps to take in a particular task, Robin can offer assistance by providing the proper sequence. For example, Sue is making breakfast and stops during her routine because she cannot remember what to do after she cracks the eggs into the pan. She can say "Alexa, tell Robin I'm making eggs and I can't remember all the steps. Help." Robin can then relay the instructions step-by-step to assist Sue.

Proactive Assistance

The system can also help users in a proactive manner, by prompting them to do tasks in their programmed schedule. Sue may have forgotten to take her morning medication. One hour over her regular medication time, Robin can prompt "Sue, you are an hour overdue for your morning medication. Did you take it?" Sue can then take her pills and say, "No, I'm doing it right now", allowing Robin to keep track of her routine.

Benefits

Robin empowers people living with degenerative brain diseases by prolonging their independence for as long as possible. It also lessens the burden on caregivers, who experience both heavy economic and emotional burdens as a result of caregiving [7].

Because the technologies that we incorporate are currently available to the general public and affordably priced, our solution is highly accessible for the intended users. As of January 2017, Amazon offers a smaller model of voice-activated assistants called the Dot, which are priced at less than $50 each.

Lastly, Robin offers an intuitive and simple user experience. Individuals only need to input their daily routine before interacting with Robin. Afterwards, they update the system on an as-needed basis with tasks that they require help remembering.

Conclusion & Future Work

We have designed our system to work with Amazon Alexa because it is currently the only hands-free speaker system that allows third-party app integration. Alexa is poised to allow proactive push notifications within the next year, which will enable Robin to prompt the user without the user's evocation [2]. These proactive push notifications will allow a full working prototype of Robin to be built. As other services like Microsoft Cortana, Apple Siri, and Google Home open their platforms, Robin can be expanded to those devices as well.

Since adaptability is a key feature of Robin, we predict that future developments will integrate machine learning, which would allow Robin to learn when and where a user completes certain tasks, minimizing the need for manual programming. Encouragingly, GreenPeak Technologies recently released an emergency response sensor system with machine learning to determine deviations from a senior's normal routine [8].

Currently, our present interaction design still stands as a simple yet effective routine management solution for those with early and middle stage dementia. Moreover, Robin will alleviate the pressure on caregivers to be continuously available for day-to-day assistance and extend the duration of independent living, leading to a higher quality of life for patients and their caregivers.

References

1. ALZConnected Discussion Board: I have dementia. (2016). Retrieved December 23, 2016, from https://www.alzconnected.org/discussion.aspx.
2. Amazon Preps Push Notifications for Alexa. (n.d.). Retrieved January 1, 2017, from https://www.theinformation.com/amazon-preps-push-notifications-for-alexa?unlock=yG-iZum3DXA&token=1azGlK4Q9GnAkkb8rFza3g.
3. Atkinson, Carolyn. (2004). Colors for living and learning. Retrieved January 2, 2017 from http://www.resene.co.nz/homeown/use_colr/colours-for-living.htm.
4. Bharucha, A. J., Anand, V., Forlizzi, J., Dew, M. A., Reynolds, C. F., Stevens, S., & Wactlar, H. (2009). Intelligent Assistive Technology Applications to Dementia Care: Current Capabilities, Limitations, and Future Challenges. *The American Journal of Geriatric Psychiatry, 17*(2), 88-104.
5. Chisnell, D. E., Redish, J. C., Lee, A. (2005). New Heuristics for Understanding Older Adults as Web Users. *Technical Communication*, 53(1), 39-59.
6. Dementia Information Page. (n.d.). Retrieved January 11, 2017, from https://www.ninds.nih.gov/Disorders/All-Disorders/Dementia-Information-Page
7. Family Caregiver Alliance. (2016). Caregiver Statistics: Demographics. Retrieved December 02, 2016, from https://www.caregiver.org/caregiver-statistics-demographics.
8. Links, C. (2016). Sensara Senior Lifestyle, a new Internet of Things application, enables seniors to live longer independently at home!. *GreenPeak White Paper*. Retrieved December 23, 2016 from http://www.greenpeak.com/Press/PressKit/2015GreenPeakWhitepaperSeniorLifeStyle.pdf.
9. Nugent, C., Mulvenna, M., Moelaert, F., Bergvall-Kåreborn, B., Meiland, F., Craig, D., Davies, R., et al. "Home Based Assistive Technologies for People with Mild Dementia." In *Pervasive Computing for Quality of Life Enhancement: 5th International Conference On Smart Homes and Health Telematics, ICOST 2007, Nara, Japan, June 21-23, 2007. Proceedings*, edited by Takeshi Okadome, Tatsuya Yamazaki, and Mounir Makhtari, 63–69. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007. doi:10.1007/978-3-540-73035-4_7.
10. Meiland, F., Innes, A., Mountain, G., Robinson, L., Van der Roest, H., García-Casal, J. A., Gove, D., Thyrian, J. R., Evans, S., Dröes, R., Kelly, F., Kurz, A., Casey, D., Szcześniak, D., Dening, T., Craven, M. P., Span, M., Felzmann, H., Tsolaki, M., Franco-Martin, M. (2017). Technologies to Support Community-Dwelling Persons With Dementia: A Position Paper on Issues Regarding Development, Usability, Effectiveness and Cost-Effectiveness, Deployment, and Ethics. JMIR Rehabilitation and Assistive Technologies, 4(1), 1-21. Retrieved February 1, 2017, from http://rehab.jmir.org/article/viewFile/rehab_v4i1e1/2
11. Oriani, M., Moniz-Cook, E., Binetti, G., Zanieri, G., Frisoni, G. B., Geroldi, C., De Vreese, L. P., Zanetti, O. (2003). An electronic memory aid to support prospective memory in patients in the early stages of Alzheimer's disease: A pilot study. Aging & Mental Health, 7(1), 22-27. doi:10.1080/1360786021000045863
12. Prince, M., Wimo, A., Guerchet, M., Ali, G., Wu, Y., Prina, M., Chan, K., Xia, Z. (2015, October). World Alzheimer Report 2015 The Global Impact of Dementia An analysis of prevalence, incidence, cost and trends. Retrieved December 02, 2016, from https://www.alz.co.uk/research/WorldAlzheimerReport2015.pdf.
13. Roger, K. S. (2008, September 03). Priorities for people living with dementia: education, counseling, research. Retrieved December 10, 2016, from

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2682387.

14. Seven Stages of Dementia | Symptoms & Progression. (2016). Retrieved December 05, 2016, from https://www.dementiacarecentral.com/aboutdementia/facts/stages.

15. Six, Janet M. (2010). Designing for Senior Citizens. Retrieved January 2, 2017 from http://www.uxmatters.com/mt/archives/2010/05/designing-for-senior-citizens-organizing-your-work-schedule.php.