Caring Companions: A Novel AI-Enabled Social Robot and Companion App for Enriching the Lives of People with ADRD and Their Caregivers.

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Abstract

One out of every three seniors succumb to Alzheimer's disease or other related dementias (ADRD). ADRD adversely affects an individual's memory and decision-making capabilities. Regrettably, there is currently no known cure for ADRD. Nonetheless, there exist both medical and non-medical interventions and programs designed to enhance cognitive performance and slow down the disease's progression. In the initial stages of dementia, some individuals can maintain a certain degree of independence with minimal supervision However, as symptoms worsen, they inevitably require more comprehensive care, eventually necessitating round-the-clock assistance. To address this growing need, socially assistive robots have been developed to support caregivers in delivering care to those affected by ADRD. This paper delves into the collaborative efforts of a diverse and experienced team comprising experts in healthcare robotics, artificial intelligence, human-centered design, cybersecurity, and biomedical research. Together, they meticulously considered the ethical implications, functionalities, and accessibility factors while working closely with both healthy older adult caregivers and individuals with ADRD. Their joint efforts culminated in the creation of an AI-powered socially assistive robot named "FRED" (Friendly Robot to Ease Dementia) and a companion caregiving application.

Introduction

In 2022, more than 11 million Americans dedicated over 18 billion hours to unpaid caregiving (Alzheimer's Association, 2023). Projections suggest that from 2020 to 2030, an additional 1.2 million caregivers will be required to meet the needs of the expanding population of individuals living with Alzheimer's disease and related dementias (ADRD) (Alzheimer's Association, 2023). These statistics are both alarming and indicative of the pressing need for innovative caregiving solutions.

A promising solution gaining increasing support and research attention involves the development of socially assistive robots (SARs) specifically tailored to individuals living with ADRD. These SARs leverage cutting-edge artificial intelligence (AI) technology, aiming to assist caregivers in delivering care, assume certain caregiving tasks, and enhance the overall well-being and mental health of both people with ADRD and their caregivers.

Research has demonstrated the effectiveness of SARs endowed with human-like characteristics, such as Pepper and NAO, in providing therapy for people with ADRD, improving their communication and motor skills, language abilities, and cognitive functions (Pu et al., 2019). Additionally, robotic companions like PARO and AIBO have been found to have positive impacts on the emotional well-being of people living with ADRD, resulting in reduced stress and loneliness (Miller, 2017). However, these solutions often come with substantial price tags.

An interdisciplinary team, consisting of healthcare researchers, designers, computer scientists, engineers, caregivers, and individuals living with ADRD, has collaborated to create a socially assistive robot called FRED (Friendly Robot to Ease Dementia) and a companion caregiver application. FRED has been designed to fulfill the role of an affordable companion and support tool for individuals with ADRD and their caregivers. The goal is to create an effective SAR priced under $300, enabling people with ADRD to enjoy daily companionship and entertainment while allowing caregivers to set helpful medication and event reminders and facilitate communication between the person with ADRD and their loved ones.

Figure 1: Image of users interfacing with FRED

Standing at just 14" tall, FRED harnesses the power of artificial intelligence (AI) through automatic speech recognition (ASR) and Conversational AI, and is specifically designed to enhance the quality of life and mental well-being for both individuals living with ADRD and their caregivers. FRED is exclusively powered by a Raspberry Pi, where the

Pi manages both the operating system and the LED face via its GPIO pins. FRED can be interacted with by voice or through its touchscreen tablet, built into its chest cavity. The software designed for FRED is Python-based, and the user interface (UI) is crafted using the Kivy and KivyMD libraries. To enable natural conversation, FRED employs Google's speech-to-text and text-to-speech capabilities. Additionally, the generation of conversational responses to user speech is facilitated using the OpenAI API in Python, specifically leveraging the "text-davinci-002" GPT-3 model.

Friendly Robot to Ease Dementia

FRED aids both caregivers and patients by handling routine tasks such as scheduling appointments, providing medication reminders, facilitating basic communication with care partners and family members, and engaging in brain-stimulating games. To enhance communication, FRED will periodically check in with the individual throughout the day, asking about their well-being, and proactively initiating conversations and game activities. These functionalities aim to alleviate the sense of isolation often experienced by individuals living with ADRD and promote cognitive engagement to keep their minds active. By serving as a tool to stimulate and engage the person with ADRD, FRED can also provide caregivers with more personal time.

FRED represents a comprehensive solution to ensure that no ADRD patient faces the disease alone. Leveraging AI and robotics techniques, FRED contributes to cognitive enrichment, ultimately enhancing the daily lives and overall quality of life for individuals with ADRD and their caregiving partners. FRED can store user mood data and usage information, which caregivers can later access through a dedicated care companion application. Importantly, this application can be accessed remotely, eliminating the need for the caregiver's physical presence to activate essential functions within FRED.

FRED's open-ended AI facilitates natural conversational interactions, enabling patients and caregivers to communicate as they would with a trusted companion. FRED has been intentionally designed to feel like an extension of the patient's trusted caregiver, establishing a strong bond between the patient and the robot-caretaker pair. Additionally, for those without a trusted caregiver, FRED's 24/7 availability ensures it can partially fulfill that role, providing continuous support and companionship.

Ethics of AI Interventions for ADRD Care

AI technologies hold immense potential for enhancing the health and well-being of individuals with ADRD and their caregivers. However, due to the utilization of machine learning in AI, it is crucial to involve both caregivers and individuals with ADRD in the development process. This involvement is essential to mitigate the risk of AI technology reinforcing stereotypes, biases, or discrimination. The World Health Organization's published Policy Brief, titled "Ageism in Artificial Intelligence for Health," underscores the concern that even when AI designers intend to create technology tailored to older individuals, they may inadvertently base their design on misconceptions about how older people live, engage with technology, and desire to use AI for health-related purposes. Specifically, in the context of designing AI technologies for older adults, the brief emphasizes:

> When we design for people rather than with people, this leads to inflexible uses of AI technology, and, if such technologies become standard in care, older people may have to adapt to prevailing technological approaches instead of drawing upon their own life experiences. (WHO, 2022).

In the domain of AI-powered robotics, the inclusion of the individuals we are designing for is not merely an ethical consideration but an essential mandate. It reflects the core principles of responsible AI development, acknowledging that technology should ultimately serve the well-being and interests of its users. By actively engaging end-users in the design process, we recognize the intricacy and diversity of human experiences and needs.

Foremost, involving the people for whom SARS are intended fosters a sense of agency and empowerment. It ensures that the technology is not imposed upon them but is instead tailored to align with their preferences, values, and requirements. This inclusivity results in more user-centered designs that are not only more effective but also ethically sound. Furthermore, it helps uncover potential biases, stereotypes, or unintended consequences that may arise from a developer-centric approach.

Through collaboration with target users, developers gain deeper insights into the unique challenges and intricacies of their lives, enabling the creation of AI systems that genuinely enhance their quality of life, safety, and independence. In essence, the active involvement of end-users in the design process not only upholds ethical standards but also yields AI-powered robots that are more respectful, inclusive, and finely tuned to the needs and desires of those they are intended to assist or engage with.

Co-Designing An Ai-Powered SAR

To ensure that AI technologies effectively support caregiving for individuals with ADRD, our team actively engaged

caregivers and people with ADRD throughout the entire design process. In total, 12 individuals (n=12) participated in our participatory focus groups for developing FRED. This group comprised seven people living with ADRD, four caregivers, and one participant who did not specify their role.

Upon arrival, all attendees completed a demographic survey. In addition to the standard questions, individuals identifying themselves as caregivers were presented with a supplementary set of inquiries. These included: 1. Duration of their caregiving responsibilities for individuals with Alzheimer's Disease and Related Dementias (ADRD), 2. Whether they were compensated or unpaid for their caregiving role, 3. If they were concurrently employed while providing caregiving, 4. The types of support they currently utilized in their caregiving role, 5. The support they felt they needed in relation to caregiving for individuals with ADRD.

After everyone arrived, we initiated our focus group sessions by breaking the ice with an introductory question. Subsequently, we delved into a range of topics concerning individuals living with ADRD, the daily responsibilities of caregiving for ADRD patients, the role of technology in caring for individuals with ADRD, and the utilization and ethics of robotics in caregiving among others.

To facilitate these discussions, a team of five facilitators were present. One facilitator was responsible for posing the questions, while the remaining four diligently recorded the participants' responses. Following an hour of open-ended inquiries, we provided participants with a brief 20-minute lunch break during which no notes were taken.

After the break, we reconvened for an additional hour and a half, during which we divided the participants into smaller groups, each with a specific focus. These smaller groups spent 20 minutes in each room with a dedicated facilitator and rotated between rooms to attend the various sessions.

Two breakout rooms were equipped with tablet screens, allowing participants to interact with and engage with FRED solely through the touch screen. In the third room, we had the complete FRED robot available, affording participants the opportunity to interact with FRED at their leisure. Following the breakout sessions, the entire group reconvened into our large room and talked more in-depth about what they liked / disliked about the current FRED design.

The 3-hour long participatory focus group sessions provided a platform for candid discussions with open-ended questions. When asked if they would trust a social robot to assist with caregiving, all participants expressed their willingness to do so. When inquired about their trust in AI, they generally replied positively, although some raised concerns about data security and its usage. Many participants stressed the importance of designing FRED to be user-friendly and accessible. Some caregivers mentioned concerns about their digital literacy but indicated that they would be more likely to use FRED if it were easy to operate.

Among the challenges identified by our focus group participants, time and financial constraints emerged as the most significant burdens in caregiving. All caregivers in our focus group were unpaid family caregivers juggling multiple responsibilities. They relied on tools like Google Calendar, although one person living with ADRD preferred a printed calendar. Participants expressed a desire for FRED to assist with reminders, as well as the ability to engage in games and meaningful conversations.

The caregivers expressed the ability to sync their calendars into FRED and suggested that they could control its functions through a companion application. There was also concern about needing internet to be able to use FRED, as one participant and their caregiver lived in a remote area where internet was not available.
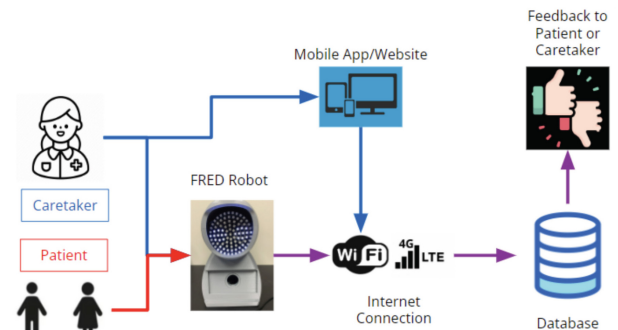

Figure 2: Technical Approach Diagram

To date, we have conducted two participatory focus group sessions as part of our research efforts, with more sessions planned for the near future. These initial sessions provided valuable insights into various aspects of our AI-powered robot's development. Moving forward, each upcoming focus group session will be dedicated to specific topics of interest. These topics may encompass the design and functionality of the user interface, the configuration of the robot's physical body, voice preferences, AI interactions, and responses, among others. By structuring our focus groups in this manner, we aim to ensure a comprehensive exploration of critical design elements while actively involving our target users and caregivers in shaping the development of our technology. Their input and feedback will continue to be instrumental in creating an AI-powered robot that truly caters to their needs and preferences.

Friendly Robot Companion Application

Caregivers emphasized the importance of maintaining remote communication with FRED, enabling them to monitor the mood of individuals with ADRD, view and update shared calendars, manage reminders, and engage in video calls with them. To facilitate this seamless interaction, it became imperative for both the companion application and the social robot to share a common database.

Our team opted for a web application framework for the companion app, ensuring its accessibility from any device with a web browser. This flexibility was highly sought after by caregivers, given their hectic schedules, and allowed for efficient data access and manipulation in their caregiving responsibilities.
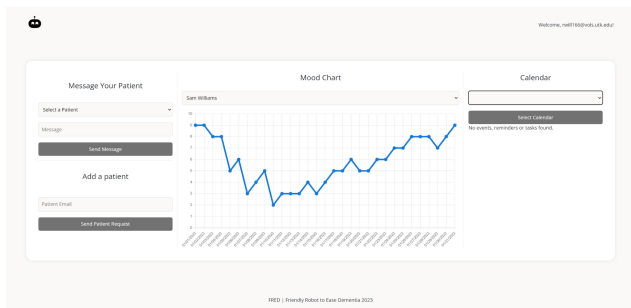

Figure 3: Mood Tracking Chart In The Companion App

After logging into the companion app, the caregiver gains access to a central hub dashboard, as depicted in Figure 3. This dashboard provides an overview of the daily mood assessments, seamlessly integrates with Google Calendar to assist the caregiver in managing crucial events and indicates whether the patient has confirmed the intake of any necessary medications.

The caregiver's level of control and oversight over the AI and function of the social robot is of paramount importance. While AI technology serves as a valuable aid, it is crucial to recognize that the caregiver should maintain a substantial degree of control. The AI should act as an empowering tool that enhances the caregiver's capabilities, rather than overshadowing their role. This dynamic ensures that caregivers can tailor the robot's interactions and functions to the specific needs and preferences of the individual with ADRD, offering a customized and responsive caregiving experience. Ultimately, the caregiver remains at the helm, with the AI as a supportive ally, collectively working to improve the quality of care and overall well-being of those they are caring for.

Security and Access

Our team engaged cybersecurity experts to establish a secure connection between the companion app and FRED. We implemented Firebase Authentication to safeguard user access, ensuring that only authorized individuals could use the system. Firebase Authentication adheres to industry-standard protocols like OAuth 2.0 and OpenID Connect, effectively thwarting unauthorized access to user accounts.

The utilization of Firebase Database, a serverless database, eliminated the need for a backend server, reducing the risk of server-side vulnerabilities and bolstering overall sys-

tem security. This database also offered real-time data monitoring, enabling us to promptly identify and address security threats.

Furthermore, the integration of Google OAuth into the project ensured a secure and efficient user authentication process, leveraging a trusted third-party authentication service familiar to users. These robust security features and protocols collectively contributed to the development of a secure and privacy-conscious final product.

To address internet connectivity concerns, we incorporated a battery backup and a SIM card solution. The backup battery ensures uninterrupted operation in case of power outages or if FRED is disconnected from the wall socket. The SIM card enables FRED to access cellular service and connect to the internet independently, obviating the need for a separate modem or router, thus enhancing its connectivity resilience.

Conclusion

AI-powered Socially Assistive Robots hold great promise in alleviating the challenges faced by caregivers in providing care for individuals with ADRD. The growing number of ADRD diagnoses, coupled with a shortage of available caregivers, is poised to become a significant crisis.

To fully harness AI's capabilities and utilize its functionalities for the creation of socially assistive robots aimed at improving the health and well-being of individuals living with ADRD and their caregivers, we should place significant emphasis on actively involving people with ADRD and their caregivers in the design process. By actively involving people with ADRD and their caregivers, we ensure that the technology aligns with their specific needs, preferences, and experiences, ultimately creating AI-powered companions that can offer meaningful support and enhance the quality of life for those affected by ADRD.

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