Thesis Project Portfolio

Title of Technical Report

The Use of Acoustic Stimulation to Increase Slow-Wave Activity in Alzheimer's Disease Patients

Title of STS Research Paper

Designing Care Robots for use by Alzheimer's Dementia Patients Using a Person Centered Care Model

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Patrick Lee

Spring, 2023

Department of Biomedical Engineering

Contents of Portfolio

Executive Summary

Alzheimer's Disease (Alzheimer's or AD), a currently incurable degenerative brain disease that progressively affects patients' memory, thinking, and behavior over time, affects 6.5 million Americans over the age of 65. In 2022, the cost of care for people 65 and older with Alzheimer's and other related dementia conditions was $321 billion. 65% of that cost came from Medicaid and Medicare and a quarter came from out-of-pocket (*2022 Alzheimer's Disease Facts and Figures*, 2022). Currently, there are only five FDA-approved medications that attempt to treat AD, four of which only target symptoms and all of which have undesired symptoms (Yiannopoulou & Papageorgiou, 2020). Due to the scope and difficulty of treating AD, alternatives have emerged to treating AD which revolves around medical devices. One category of devices is brain-computer interfaces (BCIs), but more specifically, this project revolved around auditory stimulation devices during deep sleep to prevent the onset of AD in patients with mild cognitive impairment (MCI). Another category of device is care robots which attempt to counteract the negative social, cognitive, and physical consequences of living with AD. This project aims to understand how we can design these devices to best suit their respective target populations. By designing technologies that fit the needs of people living with Alzheimer's, we could see better health outcomes for residents, higher standards of living, and higher standards of care.

With the emergence of care robots entering the dementia care space, their role and future are uncertain. To determine the technology's potential success and wider adoption, person-centered care (PCC) was chosen to be a framework from which to analyze care robots. PCC has been the most dominant and successful theoretical framework for caring for patients with dementia for the past few decades. Therefore, this research asks how compatible are care

robots within this framework. A literature review on PCC found these core themes: shifting away from medical treatment, the autonomy of the patients, nurturing relationships, and flexibility/personalization. These themes were used to analyze the compatibility of care robots in a PCC framework. Then, an extensive literature review of care robots used in the dementia care space was done to collect data on the design features of individual robots. Caregiver and patient perspectives on care robots were also found in this literature which was supplemented by customer reviews of the care robot NeCoRo. Findings showed that many robots lacked dynamic systems such as machine learning to meet the individual needs of users leading to a failure to meet up to the theme of flexibility/personalization in the PCC framework. Findings also showed the need to understand caregivers as maintainers of devices. This is because caregivers can understand the patients they care for on a level care robots are unable to and caregiver involvement may encourage the use of care robots, enhancing their positive effects. Though there are some incompatibilities between care robots with PCC, there are even more gaps. Filling these gaps may lead to wider adoption of the technology leading to health benefits for users.

Another part of this project was designing an auditory stimulation device for use during sleep. Research has shown that auditory stimulation during deep sleep is an effective method of improving cognitive function and memory and may prevent the onset of AD in people with MCI. This project focused on designing a form factor that would be worn on the head and would house all the electrical components including circuit boards, wires, and electrodes. The design process included listing technical constraints by understanding the mechanisms of auditory stimulation, ideation, prototyping using computer-aided design (CAD) and 3D printing, and understanding target population perspectives through surveys of caregivers and older adults as well as an interview with an AD expert. A major technical constraint found was the need to align the form

factor to run on top of specific standardized electrode lead placements on the head. Other constraints revolved around choosing materials so the wearable device would be lightweight and comfortable. Findings from surveys showed that the device would need to be effective with only 3 hours of sleep at a time since many older adults take frequent naps or sleep short hours during the night. Finding also showed the difficulties of wide adoption of our device due to the general rejection of wearing similar items such as sleep masks as well as the need to primarily convince caregivers and doctors over users. This project has shown that design considerations for medical devices targeted towards older adults are especially important for their adoption by potential users but it is also important to design and market towards caregivers as they will be the ones adopting new technologies for our target population.

This research project analyzed care robots through the framework of PCC and found the technology in general to be lacking many features needed to be successful in a dementia care space where PCC is dominant. However, this research analyzed care robots across the world and failed to consider cross-cultural perspectives of either care robots, dementia, or PCC in other countries. The next steps for care robot developers/researchers would be to consider cross-cultural perspectives and design needs. The design element of this project focused primarily on the form factor of the device and understanding the context in which we are designing. The next steps would be to circle back to previous stages in the design process to incorporate lessons learned from the surveys and interviews. The initial goal of the project was to develop a fully functional device which was not achieved this year but is a future goal.