Undergraduate Thesis Prospectus

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

(technical research project in Biomedical Engineering)

The Struggle for Simpler Interfaces for Users with Cognitive Disabilities

(sociotechnical research project)

by

Julia Yi

October 27, 2022

Technical project collaborators:

Felix Donis Barrera
Patrick Lee
Laura Livingston
Saoirse Teevan-Kamhawi

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Julia Yi

Technical Advisor: Timothy E. Allen, Department of Biomedical Engineering

STS advisor: Peter Norton, Department of Engineering and Society

General Research Problem

How may the disadvantages of cognitive impairments be mitigated?

Cognitive impairment is defined as a mental impediment in independent function due to issues with memory recollection, behavior, emotional feelings and learning. Numerous forms of cognitive impairment exist in varying severity from mild cognitive impairment (MCI) to dementia. As a severe case, dementia indicates an inability to recall, think, or perform simple cognitive tasks that impede daily life (Alzheimer's Association, 2022a). As of 2019, dementia and related cognitive diseases exist in over 6 million Americans (CDC, 2019). With no accurate method of determining early onset of dementia for preventative measures, cognitive impairments are a rising cause of death in the United States. Due to its complexity and variability, there is no cure for dementia and current treatments can only mitigate symptoms and progression. Most pharmaceutical drugs and cognitive behavioral therapies are temporary treatments, as they have no effect on the underlying alterations of the brain structure due to the disease (Alzheimer's Association, 2022b). Specialized drug therapies that target biomarkers for disease onset are rare as despite their efficacy, the medications require accurate identification of the disease prior to treatment.

Acoustic Stimulation to Mitigate Cognitive Decline

How can auditory stimulation enhance Slow-Wave Sleep (SWS) Therapy in geriatric patients with Alzheimer's Disease?

Within the Biomedical Engineering Department of the University of Virginia, under the advisors, Joshua Blair and Spencer Shumway of Sequoia Neurovitality LLC., I am working with

Felix Donis Barrera, Patrick Lee, Laura Livingston and Saoirse Teevan-Kamhawi for this technical capstone project.

Alzheimer's disease (AD) is a degenerative brain disease in older populations that introduces neurocognitive decline - generally in the form of memory loss. AD accounts for 60-80% of all dementia cases, with 5.8 million people expected to be diagnosed from the aging baby boom generation (Alzheimer's Association, 2019). Despite this rising quantity, the complexity of the neurocognitive disease and causation from multiple factors at a time has led to limitations in treatment options and consequent lack of a cure.

A contributing factor to AD is a decrease in cerebrospinal fluid (CSF) activity in the brain with age. CSF, mainly active during deep sleep, cleanses the brain and removes waste in the form of amyloid-beta plaques and tau tangles (Han et al., 2021). In geriatric patients, reduced CSF activity leads to brain plaque accumulation, resulting in deterred cognitive function. Auditory stimulation during sleep is a promising therapy as it increases slow-wave activity (SWA) in older adults (Papalambros et al., 2017). SWA occurs in non-rapid eye movement (nREM) deep sleep and is associated with memory consolidation. Therefore, through a device that delivers acoustic pulses to the brain during sleep to amplify slow-waves, the aim is to increase CSF activity to clear plaque accumulation associated with cognitive impairment in AD.

Currently, few projects exist within the biotechnical industry to advance sleep therapeutic devices. The Philips SmartSleep is a headpiece system that administers auditory stimulation in sleep-restricted individuals. Philips states in their product details that the headwear is not for prolonging deep sleep and is for individuals with regular sleep-wake schedules (Philips, 2022). These conditions exclude the CD audience from using the device as deep sleep is the most prospective stage of sleep for cognitive improvement. Some devices are capable of analyzing

sleep data but are unable to deliver direct therapeutic solutions. The Dreem product is currently unable to evoke any external stimuli and solely reads and scores polysomnographic data for suggestive feedback on improving sleep conditions based on those measurements (Dreem, 2022).

This project expands on existing hardware from an external vendor to gather electroencephalogram (EEG) data. As it is marketed as raw wires and electrodes, the initial stage of the project is to design the outer case to host the naked hardware. The external shell should be easy, obvious, and aesthetically fitted for use by older populations. Interviews of the design and clinical trials of the device function amongst geriatric patients will be tested. Software using Labview, Python, and MATLAB platforms will be established for signal analysis and administration of pink noise. Self-administration of the audio is determined by a phase locked loop (PLL) system with machine learning that can predict when upstate phases in the slow-wave oscillations occur. The upstate phase is a point in the wave oscillation where stimulation results in the most responsive reaction. A key constraint is the limiting population of voluntary geriatric patients that we are able to interact with to receive input and clinical testing of the product.

At the end of this project is the marketing of a sleepwear device specialized to geriatric patients with Alzheimer's disease, providing results in mitigating cognitive decline. Concluded by the development of a system that monitors polysomnographic activity while amplifying SWA via live auditory stimulation.

The Struggle for Simpler Interfaces for Users with Cognitive Disabilities

How are advocates for populations that require simpler device interfaces promoting their agendas?

The technological divide highlights the imbalance between users and non-users. Ayon & Dillon (2021) indicate that disabled populations avoid the internet and associated technology at three times the rate of non-disabled users. Highlighting the need for updated development of assistive technology that will encourage regular use by disabled users. Participants are classified into cognitively disabled (CD) populations and technological developers, with activists that either advocate for change in the technological designs or assist adaptation to technologies between the consumer and producer parties.

In recent decades, political campaigns have shifted to depend on communication technologies at a national level. Candidates are expected to engage in social media platforms to interact with supporters and relay information. The Americans with Disabilities Act (ADA) prohibits discrimination against disabled individuals of any form in any employment field, participation, or service. Cork et al. (2016) describes the impediment of disabled populations in participating in political activities due to the digital barrier. With limited accessibility to the resources to input their right to vote, Cork et al., accentuates that "the largest minority group in the United States" (p. 4) is underrepresented and the social gap between disabled and non-disabled populations is increasing as a result.

CD communities for health or age-related reasons, are non-users as they express difficulty in using high-tech devices (Tanis et al., 2012). Technological devices are not usually engineered to be inclusive towards CD users with their complex forms following an ability to contain a multitude of functions. While favored by non-disabled users, this complexity augments the divide, discouraging inclusion of CD consumers. Tanis et al. "found that cell phone use by people with IDD was 27% compared with over 60% of the population." due to the design and cognitive complexity of recent phones. Correspondingly, Chalghoumi et al. (2019) interviewed

older adults with CD, finding complaints of deficient accessibility in IT design. Findings were summarized into three obstacles: limited IT access and use by seniors with CD, unmet needs in design accessibility and use, and a lack of consideration for caregivers and supportive assistance. In response, Schepens Niemiec et al. (2022) defines “soft technology strategies” to reference advocacies for change in design details - customization, sensitivity, specialized features and adjustments that can elevate engagement by CD users. Subsequently resulting in more inclusive access addressing collectively desired needs.

Manufacturers that design, produce, and sell devices promote convenient but high-tech products. If at all when addressing CD groups, they provide simpler, basic interfaces with no complex settings or integrate specialized features to assist in certain tasks. RAZ Mobility advertises a smartphone that performs the minimum necessities for CD populations (RAZ Mobility, 2022). The RAZ Memory cell phone introduces an “Easy-to-use, groundbreaking cell phone for people with memory loss, dementia, Alzheimer’s or seniors who prefer a simple experience.” The product boasts an unique ability to remotely manage the device through an app or online portal for caretakers to support the CD user. RAZ Mobility appears to focus completely on simplicity, getting rid of most functions besides a one-touch dial, gallery options, emergency service, and battery settings. With only one screen available on the picture phone and minimum function, the phone design regresses to the original purpose of a phone as a form of contact rather than as a source of modern entertainment.

Activists that press for more accommodative changes in product development and design aim for changes in the product by directing their agendas towards manufacturers rather than the CD population. Often through research and development practices, changes in public policies, and informing companies of CD audience feedback. Within the National Institute on Disability

Independent Living and Rehabilitation Research (NIDILRR) is the Rehabilitation Engineering Research Center (RERC) that promotes the development of technological interfaces to incorporate CD needs (RERC, 2021). Program agendas include the generation of new knowledge to modify existing standards or to produce assistive technology for CD populations. State Protection and Advocacy Systems (P&As) exist within the department to represent and advocate for equality rights on behalf of CD communities (P&A Programs, 2022). P&As have the legal authority to litigate federal, state and local laws, provide input on services and legal rights, and inform policy makers and stakeholders on CD-related reforms. Agenda advancements are done by decreasing segregation towards disabled individuals using the 1999 Olmstead v. L.C. Supreme Court case.

Other activists advocate by supporting adaptation to the unchanged, complex devices through learning and assistive procedures towards CD populations. The Senior Planet Exploration Center, a branch of the American Association of Retired Persons (AARP), focuses on providing courses in digital tutorials (Senior Planet, 2022). Digital classes for seniors are claimed to mitigate social isolation by forming connections between the senior user and a device that enables contact with family, friends, and healthcare professionals or caretakers (KSAT 12 News, 2022). By instructing seniors both with and without cognitive impairments in digital literacy and technological services, the AARP works to support the adoption of advancing devices. Representing the interest of the group in promoting inclusivity of CD senior populations through adaptive services with modern trends in technology.

References

Alzheimer's Association (2019). Association, A. (2019). 2019 Alzheimer's disease facts and figures. *Alzheimer's & Dementia*, *15*(3), 321–387. doi.org/10.1016/j.jalz.2019.01.010

Alzheimer's Association (2022a). Alzheimer's Disease and Dementia. alz.org/alzheimers-dementia/what-is-dementiaAlzheimer's Association (2022). Alzheimer's Disease and Dementia. alz.org/alzheimers-dementia/what-is-dementia

Alzheimer's Association (2022b). Alzheimers-facts-and-figures.pdf. (2022). www.alz.org/media/Documents/alzheimers-facts-and-figures.pdf

Ayon, V., & Dillon, A. (2021). Assistive Technology in Education: Conceptions of a Socio-technical Design Challenge. *The International Journal of Information, Diversity, & Inclusion*, *5*(3), 174–184. JSTOR.

CDC (2019). The Truth About Aging and Dementia | CDC. (2019, August 20). Centers for Disease Control and Prevention (CDC). www.cdc.gov/aging/publications/features/Alz-Greater-Risk.html

Chalghoumi, H., Gauthier-Beaupre, A., Wang, R. H., Chu, C. H., Auger, C., & Sun, W. (2019). Access and use of information technology by persons with cognitive disabilities: Perspectives of older adults and their caregivers. *2019 7th International Conference on Ict & Accessibility (Icta)*. Web of Science.

Cork, S., Jaeger, P. T., Jette, S., & Ebrahimoff, S. (2016). The Politics of (Dis)Information: Crippled America, the 25th Anniversary of the Americans with Disabilities Act (ADA), and the 2016 U.S. Presidential Campaign. *The International Journal of Information, Diversity, & Inclusion*, *1*, 1–15. JSTOR.

Dreem (2022). Scientific research for the Dreem Headband. (2022). Dreem. dreem.com/en

Han, F., Chen, J., Belkin-Rosen, A., Gu, Y., Luo, L., Buxton, O. M., Liu, X., & Initiative, the A. D. N. (2021). Reduced coupling between cerebrospinal fluid flow and global brain activity is linked to Alzheimer disease–related pathology. *PLOS Biology*, *19*(6), e3001233. doi.org/10.1371/journal.pbio.3001233

KSAT 12 News (2022). KSAT 12 News: "These digital literacy classes can help older adults connect to people, resources." (2022, August 22). Senior Planet from AARP. seniorplanet.org/news/2022/08/22/ksat-12-news-these-digital-literacy-classes-can-help-older-adults-connect-to-people-resources

P&A Programs (2022). P&A Programs | ACL Administration for Community Living. (2022, July 27). acl.gov/programs/pa-programs

Papalambros, N. A., Santostasi, G., Malkani, R. G., Braun, R., Weintraub, S., Paller, K. A., & Zee, P. C. (2017). Acoustic Enhancement of Sleep Slow Oscillations and Concomitant

Memory Improvement in Older Adults. *Frontiers in Human Neuroscience*, *11*. www.frontiersin.org/articles/10.3389/fnhum.2017.00109

Philips (2022). SmartSleep Deep Sleep Headband. (2022). Philips. www.usa.philips.com/c-e/smartsleep/deep-sleep-headband.html

RAZ Mobility (2022). RAZ Mobility | Next Generation Assistive Technology. (2022). www.razmobility.com

RERC (2021). Rehabilitation Engineering Research Center (RERC) Program | ACL Administration for Community Living. (2021, October 25). acl.gov/programs/research-and-development/rehabilitation-engineering-research

Schepens Niemiec, S. L., Lee, E., Saunders, R., Wagas, R., & Wu, S. (2022). Technology for activity participation in older people with mild cognitive impairment or dementia: Expert perspectives and a scoping review. *Disability and Rehabilitation: Assistive Technology*, *0*(0), 1–22. doi.org/10.1080/17483107.2022.2116114

Senior Planet (2022). Our Purpose—Tech for Older Adults. (2022). Senior Planet from AARP. seniorplanet.org/about/our-purpose

Tanis, E. S., Palmer, S., Wehmeyer, M., Davies, D. K., Stock, S. E., Lobb, K., & Bishop, B. (2012). Self-Report Computer-Based Survey of Technology Use by People With Intellectual and Developmental Disabilities. *Intellectual and Developmental Disabilities*, *50*(1), 53–68. doi.org/10.1352/1934-9556-50.1.53