Undergraduate Thesis Prospectus

Decreasing memory loss: An acoustic stimulation device to enhance slow wave sleep

(technical research project in Biomedical Engineering)

Future of walkable communities: Universities as models for walkable urban design

(sociotechnical research project)

by

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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.

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General Research Problem

How can we reduce memory loss in older adults in the US?

Alzhiemer's, a degenerative brain disease that affects patients' memory and cognitive ability, affects 5.8 million Americans over the age of 65 (Matthews, 2018). Currently, pharmaceutical treatments only try to mitigate symptoms as the disease progresses (NIA, 2021). Using advanced therapeutics, researchers focus on high-tech tools to combat Alzhiemer's Although these tools are useful, we must also consider low-tech tools that could tackle the root of the issue and still have similar effects on Alzheimer's. Improving the quality of life in US cities through urban design could be a possible tool that could decrease the number of older Americans with memory loss. The biggest issue in most US cities is low-walkability due to its car-centered urban design. By implementing walkable urban design, community members show increased health benefits, such as improved sleep quality. Sleep has been shown to improve memory consolidation, which correlates with long-term memories (Rauchs et al., 2005). Implementing walkable urban design could then further slow down memory loss in older adults.

Decreasing memory loss: An acoustic stimulation device to enhance slow wave sleep

Using acoustic stimulation, how can slow wave sleep be enhanced to reduce memory loss in older adults?

This is a capstone project within the department of Biomedical Engineering. The technical advisors are Joshua Blair and Spencer Shumway from Sequoia Neurovitality, a biotechnology start-up providing projects to UVA biomedical engineering students. The capstone project team consists of Laura Livingston, Patrick Lee, Saoirse Teevan-Kamhawi, Julia Yi, and Felix Donis-Barrera. The project is to decrease memory loss in older adults by designing

and testing a device that can monitor brainwave activity during sleep while also amplifying slow wave activity via auditory stimulation. Alzheimer's disease is characterized by a decrease in cerebrospinal fluid (CSF) activity in the brain as people age. Due to disrupted sleep cycles CSF activity decreases and plaques can build up within the brain, leading to slower connections and a loss of brain function (Han et al., 2021). This device will create a novel tool to slow down the progression of Alzheimer's. The first project goal is to design a wearable device that is both comfortable to sleep in and simple to use for older adults. The second goal is to develop and test the device's detection capability for slow wave sleep and implementing auditory stimulation at appropriate times. An unusual constraint is that we use hardware from other companies, therefore it may take a few iterations to develop a wearable device compatible with the hardware in use. This also means there will be unknown periods of time when there won't be material available to work with.

Currently there are several companies within the brainwave technology space, one being Neurosity. Their device, the Crown, uses acoustic stimulation to improve concentration during usage (Neurosity, Inc, n.d.). The Crown is recommended for working on short-term projects that require higher concentration. Although it does increase concentration during wakefulness, it fails to create a comfortable device to use while sleeping and doesn't decrease memory loss in the long term. Another company, Lucid Dreamer, uses similar technology to enable lucid dreaming with mild electrical stimulation during sleep (Neuromodulation Technologies, 2016). They have created a semi-comfortable wearable device that improves creativity during sleep, but doesn't decrease memory loss. This capstone project will use both previous established device components while implementing novel components to create the final product.

The capstone team will be using AutoCAD to create a computer-aided design and then prototype using the Unicorn Naked BCI (g.tech medical engineering, n.d.). Python coding language will be used to create a code that detects slow wave sleep and implements acoustic stimulation at appropriate times. Then 20 participants, from Johns Hopkins Alzheimer's Disease Research Center, Memory Disorders Clinic, and the Artificial Intelligence & Technology Collaboratory registry list, above the age of 60 will be interviewed to determine general consumer population wants and needs, device comfortability, and usability. The results from these interviews will help further ideate the wearable device.

The successful completion of this capstone project is characterized by the creation of a wearable device that can detect slow wave sleep and implement auditory stimulation at appropriate times. It also means the device would have been tested using patient interviews and clinical studies. This would mean patients with mild cognitive impairment or Alzheimer's onset could use this device to further slow down memory loss progression. The next steps include improving device user interface and editing aesthetics to improve marketability.

Future of walkable communities: Universities as models for walkable urban design

In the U.S., how are proponents of walkable communities using the University of Pennsylvania, George Washington University, and Northeastern University campuses as testbeds and models for walkable urban design?

When people imagine the US, they envision highways, parking lots, and traffic. This is due to an imbalance in American cities, where cars are the main focus over pedestrians and cyclists. Jacobs (1961) stated that "Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody." Car-centered cities,

like the ones Jacobs mentioned, provide unwelcoming and unsafe environments for pedestrians and cyclists. They also tend to cause a disconnect between people and the city itself. As this crisis within cities worsen, interest grows in unconventional tools with which to respond. New urbanism is such a tool that "aspires to be – a guide force for urban development at all scales: a blend of architectural styles, anti-sprawl 'smart growth', and transit-oriented sustainable urbanism" (Marshall, 2003). New urbanism influences can be seen through university campuses, such as the University of Pennsylvania, George Washington University, and University of Minnesota, which can serve as models for walkable urban design. This is evident through the university campuses' routes, which are composed of 90% walkable routes, including sidewalks, crosswalks, and curb cuts (King et al., 2020). In turn, walkability has health benefits such as physical activity and other non-obvious, such as quality of sleep. Sleep is known to improve memory, therefore can be used as an indirect tool to decrease memory loss within older adults (Malkani & Zee, 2020). Another example of this can be found in low income communities, which tend to have low walkability, also tend to have lower sleep duration and efficiency due to perceived safety (Troxel et al., 2018). Universities' urban design provides a low-technical tool to increase sleep and decrease memory loss in older adults, therefore acting as testbeds and models for urban walkable design.

Proponents and adversaries of walkable communities both play a role in how the stated universities are used as testbeds and models for walkable urban design. Automakers defend status-quo highway engineering standards because they promote the utility and profitability of their product at public expense. For example, Toyota promotes battery-electric passenger cars as a means of decreasing vehicular emissions without considering means of alleviating unsustainable car dependency (Toyota, 2018). After graduation, many former university students

miss the walkability they enjoyed on campus and seek to promote it elsewhere (Reed, 2021). They value meaningful experiences such as quality time with friends and family, which become more accessible through walkable communities. America Walks is an advocacy group that advances walkable and accessible places in US communities through policies and legislation changes (Spielmaker, 2022). For example, they joined forces with the California Bike Coalition to advocate for the Freedom to Walk Act in California, which decriminalizes safe street crossing, when traffic permits, whether or not a pedestrian is within a marked/unmarked crosswalk. Smart Growth America is another national initiative that advocates for improving lives by improving communities, which includes the health benefits of walkability (Smart Growth America, n.d.). Penn Sustainability is an initiative within the University of Pennsylvania, to promote sustainable practices within their university. They implement sustainable actions through university policies, such using large walkable and biking areas to reduce emissions throughout their campus (UPenn Sustainability, n.d.). These policies also introduce walkable urban design to the surrounding communities, further advancing the UPenn Sustainabilities ideas. Civil engineering firms, such as Moody Engineering, promote walkability through their construction projects. Dennis (2018), from Moody Engineering, recommends cities that want to become walkable to "consider investing in mixed-use land with pedestrian connections and greater street / sidewalk connectivity." Their values lie within improving infrastructure, but also indirectly benefiting from the extra projects that walkable urban design may bring. Some American tax-payers may argue that it's just a ploy to increase taxes for urban planning, but Moody Engineering responds with research-backed articles to support their motives and values.

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