Tongue Driven Wheelchair for Quadriplegics

Exploring Assistive Technology's Impact on Those with Disabilities

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

By
Nicholas Talton

October 27, 2023

Technical Team Members:
Dhruv Batra
Michael Kinsel
Yeabsira Mekonnen

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.

ADVISORS

Rider Foley, Department of Engineering and Society

Adam Barnes, Department of Electrical and Computer Engineering

Introduction

According to the National Library of Medicine the global impact of spinal cord injuries (SCI) with respect to the years lived with disability (YLD) and annual age-standardized years lived with disability (ASYR) was estimated to be about 6.2 million cases worldwide (Ding et al., 2022). In addition to this, about 76 in 100,000 people contribute to this statistic. SCI impacts more than 17,800 Americans each year, with an estimated 294,000 Americans concurrently experiencing such injuries (Lasfargues et al., 1995). Accoridng to the U.S. Department of Health and Human Services (2023), Spinal injuries lead to a multitude of physical and neurological impairments such as Paraplegia, Quadriplegia, chronic pain, and respiration issues to name a few. Spinal cord injuries primarily hinder the motor functions of a person therefore minimizing or even removing the usage of their limbs to move and communicate with other people (Kuriakose, D. C. & SpinalCord.com Team, 2022).

Most traditional wheelchairs use a joystick for movement freedoms, but for those that are less fortunate to move their upper body, that becomes problematic for the user to try and move a joystick, thus the user is forced to use their mouth and head for movement, but from Newsome | Melton (2019) it was observed that not all individuals who suffer from quadriplegia are able to move their neck muscles. According to the Cleveland Clinic (2022) a quadriplegic can be defined as someone who suffered a SCI where the impacted vertebrae are between C1 and C8**,** indicating that a SCI pertaining to the neck region has a high chance of resulting in quadriplegia. The most traditional method that quadriplegics use to move around is a technological innovation that uses sipping and puffing characteristics. This device offers movement for an individual at a tradeoff of it being difficult to learn, and tiring from continuously using facial and throat muscles to perform movement (Menon et al., 2015).

The goal for this project is to provide a different perspective of movement for an individual by using a magnet fastened to the tongue to cooperate with a series of sensors external from the mouth that will send data to a microcontroller to process and send to a wheelchair for movement commands. This capstone project seeks to revolutionize the existing technology system employed by individuals with spinal cord injuries by offering a more intuitive, efficient, and less physically demanding method of mobility. The ultimate goal of this project is to empower users, providing them with enhanced independence and a greater sense of personal freedom.

Tongue Driven Wheelchair for Quadriplegics

The current technology that is commonly accepted as the traditional way for quadriplegics to move is the sip and puff method where a series of sips and puffs serve as data for a particular command for the wheelchair (Jeff, 2023), but new solutions are being created to compete with the traditional method. The first method is from Izzuddin and his fellow researchers where they used a system that uses a Electroencephalography (EEG) signal processing headset that reads electrical body signals and then classifies the signal into a movement command by using machine learning to objectively qualify the signal being sent to the system for the wheelchair (Izzuddin et al., 2015). In a different approach, researchers came up with using a magnet on the tongue to send data to a retainer in the mouth where the retainer would send information of how to move the wheelchair, essentially using the tongue as the joystick (Lund et al., 2010; Lontis et al., 2010). Similarly, Jain and Joshi wanted the system to focus user comfort and be somewhat discreet to external observers, so they used an array of sensors that were external of the mouth that captures data which is processed by a

microcontroller using a control algorithm which is then used to simulate a wheelchair in a program (Jain & Joshi, 2014). Wanting to focus on user feedback, technical, and social actors, Kim and Lu both focused on a voice-controlled assistive device project, which prioritized language inclusivity and explored facial movements for control (Lu & Chen, 2012; Kim et al., 2013). This research highlighted the significance of user feedback in designing assistive devices that improve mobility and minimize social challenges. All of these ideas and solutions provide a benefit in some aspect to help assist an individual who may benefit from assistive technology, but my capstone project aims to make a solution that is both intuitive, discreet, and affordable.

The capstone system will be positioned externally outside the mouth, so it still uses a magnet to manipulate magnetic sensor fields for movement inputs. This cost-effective system comprises three subsystems and a testing phase: 3D modeling/electrical sensors, microcontroller programming, simulations, and testing. The workflow begins with a customizable headpiece equipped with prongs containing magnetic sensors along the inside, parallel with the user's cheekbones. This headpiece serves as the mounting point for sensors, which relay data to the microcontroller, defining objective movements for the wheelchair. The microcontroller handles system calibration and data processing. It processes serialized data from the sensors, calibrating cardinal directions and generating a continuous datastream for simulation. The simulation emulates wheelchair movement, receiving data from the microcontroller. This project separates itself from the rest of the projects made previously because it is attempting to provide an efficient product for quadriplegics while still maintaining affordability so that even those who are less economically inclined are still able to experience the same freedom as those who have a better system. The control algorithm is very bare bone and processing speed of the microcontroller is slow, but but still provides command data to the simulation within 100ms while still being under

$100 for the entire system, which is a fairly good tradeoff to allow for inclusion of a larger subset within those who suffer from quadriplegia. Although my capstone project hopes to create a better living situation for the people who may benefit from it, it may also impose newfound struggles that we did not think of initially such as relevant surgery, assistance with the headset, and calibration systems requiring constant checks to name a few.

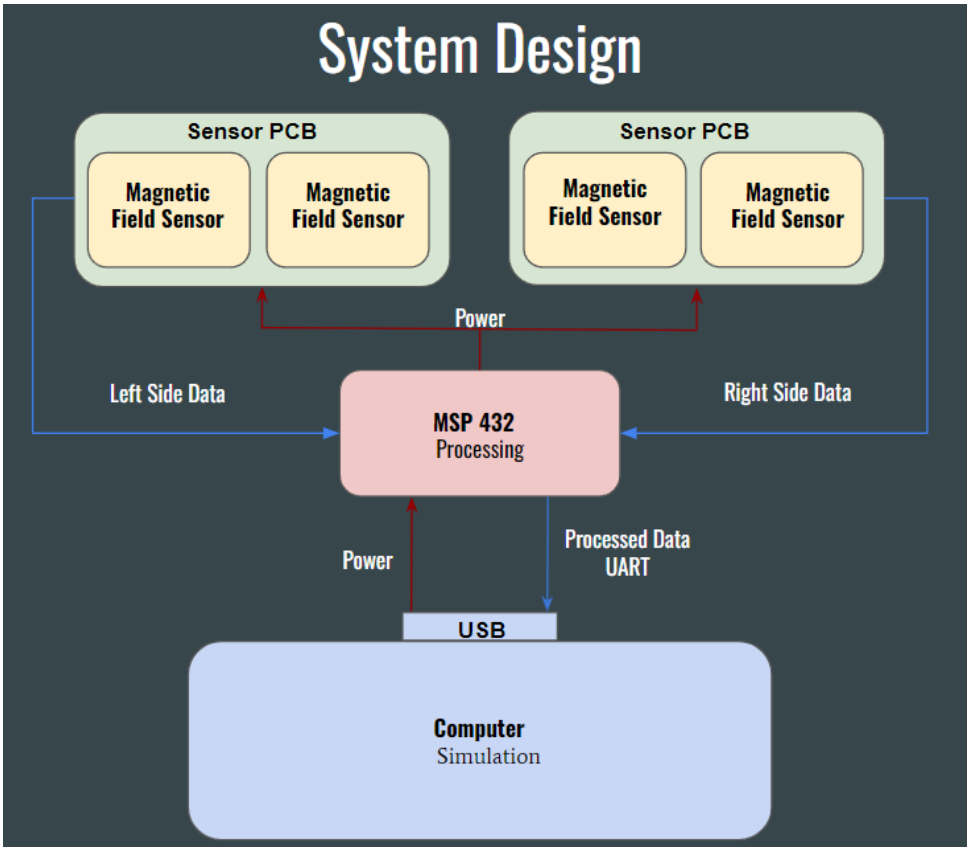

Figure 1. Image of the System design (Source: Talton, 2023)

Exploring Assistive Technology's Impact on Those with Disabilities

Assitive technology is a field of engineering that aims to improve the quality of life of certain groups of people based on their needs by focusing on an aspect of their current life that needs more assistance than another part. One of the most important aspects of the impact of

assistive technology is how society and politics perceive it. Francis provided a discussion upon a previous study researching how able-bodied people perceive disabled people with and without bionic devices (Francis, 2022). She asserted bionic assistive devices can lead to more positive perceptions by able-bodied individuals and that perhaps in the future the competency gap will be bridged between people with and without disabilities. Although assistive technology is meant to be a supporting device that is able to help people with everyday tasks, we know from Latour that when we choose to assign a non-human actor something of value, it is able to impose new values onto the human actors (Latour, 1992). Latour's concept of symmetry challenges the idea that assistive technology devices dont just assist but also exert its own influence on the human actor in a way such that the device could influence social perception resulting in the user's identity to be impacted. With respect to the sociotechnical aspects of how assistive technology impacts those with disabilities, Bijker and Pinch's framework becomes relevant in this case because one of their most important points from the Social Construction of Technology framework was the multidirectional model which implies that different groups of people perceive some set of technology differently from another group (Bijker & Pinch, 1987). Consider the case of quadriplegics, multiple groups of people solve the same problem to assess a new solution that could provide a benefit to quadriplegics in a newly perceived way be it with brainwaves or with magnetic fields. Hughes closely aligns with Bijker with assistive technology because Hughes' main points are that technology is influenced to improve upon itself such that it is always being influenced by factors such as innovation, reverse sailents, and competition. Assistive technology is impacted by these factors such that reverse salients provide the initial push for innovation which in turn inspires more groups of people to try and compete for a new assistive technology to be the traditional device in the future (Hughes, 1987). Hughes's assertions align closely with

Star's input on infrastructure. Star highlights that infrastructure is not easily defined as a single entity but rather a conglomerate of multiple aspects of infrastructure that generates an ethnography of some larger source of technology be it to be built on an installed base, where the fundamentals of some technology is intertwined with a previously established technology (Star, 1999). An additional aspect of infrastructure is learned by membership by a particular group of people, in this case assistive technology is a membership prioritized to those who would benefit from it but in some cases like in Francis' discussion with society perceiving assistive technology, this landscape has potential to encompass a larger group eventually. From all of the frameworks and cosndierations of relevant Science Technology and Society (STS) components, assistive technology and its impact on disabled people imposes a relevant, multifaceted, and evolving field of study. The influence of technology on user identity, societal perception, and the larger technological landscape highlights the need for ongoing research and dialogue within the field of assistive technology and beyond. With this in mind, I ask the following question: How has assisitive movement technology impacted those with physical limitations?

Research and Methodology

This question is important because it pertains to relevant aspects of STS where engineers may not perceive all valuable actors on a technological advancement, so this question opens a dailogue between the engineer and then individual. To begin exploring the aspects of this question we must decide on some type of data acquisition to gather data to analyse. One of the best ways to gather personal and relevant data for this research would be through interviews with people with physical limitations who use assistive technology and those who do not. Some of the questions I would ask them to gauge the data would be: How do you feel assistive movement

technology has improved or hindered your independence and mobility? Is there any aspect of your life that has challenged you more now than it did before you acquired assistive technology? How has the introduction of assistive technology influenced your self-identity and the way you interact with others? Are there any particular aspects of assistive movement technology that you find most valuable or areas that you believe need improvement? Do you believe that there is a need for greater awareness and acceptance of assistive movement technology among society at large? If so, how do you think this can be achieved?

These questions provide relevant information for every aspect of importance from independence, newfound identity, assistive technology values, and how society perceives assistive technology from the user's perspective. In addition to this research, sending out surveys would be beneficial for a general consensus about their views on assistive technology. The questions on the survey would be more focused on a gauge of agree to disagree questions similar to the questions asked as if it were to be an interview.

Conclusion

People with physical limitations, especially quadriplegics, need more user-friendly, discreet, and affordable assistive technology solutions. Traditional methods are often challenging and limit independence of the impacted user. The impacts of the solution in mind from my capstone will hope to enhance the level of independence of a user as well as making it more inclusive and affordable by all people so that everyone is able to have their own mobile independence and freedom regardless of physical limitations. Being able to address the relevant assiitve technology limitations can result in increased positive perceptions of society on those with disabilities. This paper aims to address or at least shed light on the relevant factors that

shape the multifaceted relationship between assistive technology, the individual, and society with hopes that lead to a more inclusive and empowering future for those with disabilities.

References

Bijker, W. E., & Pinch, T. J. (1987). The social construction of fact and artifacts. *Philosophy of technology: the technological condition: an anthology, 107-139*.

Cleveland Clinic medical. (2022). *Quadriplegia (tetraplegia): Definition, causes & types*. Quadriplegia. https://my.clevelandclinic.org/health/symptoms/23974-quadriplegia-tetraplegia

Ding, W., Hu, S., Wang, P., Kang, H., Peng, R., Dong, Y., & Li, F. (2022). Spinal cord injury: The global incidence, prevalence, and disability from the global burden of disease study 2019. *Spine*, *47*(21), 1532.

Francis, N. (2022). *Novel EMG-IMU Sensor Array for a 5-DOF Wearable Robotic Upper-Limb Exoskeleton; Examining the Politics Surrounding Assistive Devices*. Charlottesville, VA: University of Virginia, School of Engineering and Applied Science, BS (Bachelor of Science). https://doi.org/10.18130/0fb2-bb76.

Izzuddin, T. A., Ariffin, M. A., Bohari, Z. H., Ghazali, R., & Jali, M. H. (2015, November). Movement intention detection using neural network for quadriplegic assistive machine. In *2015 IEEE International Conference on Control System, Computing and Engineering (ICCSCE)* (pp. 275-280). IEEE.

Jafar, M. R., & Nagesh, D. S. (2023). Literature review on assistive devices available for quadriplegic people: Indian context. *Disability and Rehabilitation: Assistive Technology*, *18*(6), 929-941.

Jain, M., & Joshi, H. (2014). Tongue Operated Wheelchair for Physically Disabled People. *International Journal of Latest Trends in Engineering and Technology (IJLTET)*, *4*.

Jeff. (2023, April 28). *Understanding assistive technologies: What are SIP-and-puff systems?*. WCAG Audits, ADA Accessibility Audits & Section 508 Audits. https://www.boia.org/blog/understanding-assistive-technologies-what-are-sip-and-puff-systems#:~:text=The%20system.

Hughes, T. P. (1987). The evolution of large technological systems. *The social construction of technological systems: New directions in the sociology and history of technology*, *82*, 51-82.

Kim, J., Park, H., Bruce, J., Sutton, E., Rowles, D., Pucci, D., ... & Ghovanloo, M. (2013). The tongue enables computer and wheelchair control for people with spinal cord injury. *Science translational medicine*, *5*(213).

Kuriakose, D. C. & SpinalCord.com Team, & (2022). *Quadriplegia & Tetraplegia: Definition, causes, symptoms, and treatment*. Quadriplegia & Tetraplegia: Definition, Causes, Symptoms, and Treatment. https://www.spinalcord.com/quadriplegia-tetraplegia.

Lasfargues, J. E., Custis, D., Morrone, F., & Nguyen, T. (1995). A model for estimating spinal cord injury prevalence in the United States. *Spinal Cord*, *33*(2), 62-68.

Latour, B. (1992). Where are the missing masses? The sociology of a few mundane artifacts. *Shaping technology/building society: Studies in sociotechnical change, 1, 225-258.*

Lontis, E. R., Bentsen, B., Gaihede, M., Biering-Sørensen, F., & Struijk, L. N. A. (2021). Wheelchair control with inductive intra-oral tongue interface for individuals with tetraplegia. *IEEE Sensors Journal*, *21*(20), 22878-22890.

Lu, Y., & Chen, Y. (2012). Prototyping potential control systems to assist complete quadriplegics. In *The 5th 2012 Biomedical Engineering International Conference* (pp. 1-5). IEEE.

Lund, M. E., Christiensen, H. V., Caltenco, H. A., Lontis, E. R., Bentsen, B., & Struijk, L. N. A. (2010). Inductive tongue control of powered wheelchairs. In *2010 Annual International Conference of the IEEE Engineering in Medicine and Biology* (pp. 3361-3364). IEEE.

Menon, S., Nambiar, A., Pariyarathu, A., & Krishnamoorthy, M. (2015). Tongue Driven System. *International Journal of Engineering and Technical Research, 3(4). ISSN: 2321-0869.*

Newsome | Melton (2019). *Quadriplegia: Types of paralysis: Brain and Spinal Cord Injury Information*. Newsome | Melton. https://www.brainandspinalcord.org/quadriplegia/#:~:text=A%20patient%20with%20complete%20quadriplegia,control%20over%20their%20hand%20movements.

Star, S. L. (1999). The ethnography of infrastructure. *American behavioral scientist, 43(3), 377-391.*

Talton, N.R. (2023) Midterm Design Review. Available at: https://docs.google.com/presentation/d/1kjzTwNK050S2tOjSgDINawHokvu5CVhypJNLhkQpeJs/edit#slide=id.g28ba5c15421_1_0.

U.S. Department of Health and Human Services. (2023). *Spinal Cord Injury*. National Institute of Neurological Disorders and Stroke. https://www.ninds.nih.gov/health-information/disorders/spinal-cord-injury