Wearable Stroke Rehabilitation Upper-Limb Exoskeleton
(Technical Project)

Effect of Community Perspective on Stroke Rehabilitation in Ghana and United States
(STS Project)

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 Mechanical Engineering

By
Caroline Nealon

October 21, 2023

Technical Team Members: Alison Butcher, Samar Bahrami, Caroline Flanagan, Kathryn Zimnick

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

MC Forelle, Department of Engineering and Society

Sarah Sun, Department of Mechanical Engineering

Introduction

Stroke is a leading cause of death and disability in the worldwide adult population that occurs when either blood flow to the brain is stopped, or sudden bleeding in the brain (*About Stroke,* n.d.). Even though a recovery is possible for survivors, full or even partial rehabilitation is not a given. Disability caused by stroke can manifest in a range of ways, from requiring a full-time caretaker, to living and working independently with small accommodations. Typical effects of stroke include significant loss of mobility, speech, vision, and memory, as well as behavioral changes (*About Stroke,* n.d.). The degree of rehabilitation depends on many factors; a significant amount of time and effort is required for therapies to work, and a major roadblock to reaching recovery is access to these resources (Alawieh et al., 2018). While stroke rate is reducing in America, other populations' stroke rates are increasing including the countries in Sub-Saharan Africa (Sarfo et al., 2018). The full recovery rate for survivors is suppressed due to lack of access to stroke care, and stroke survivors end up depending on others for support in living their daily lives.

My technical project will address the accessibility of upper-limb stroke rehabilitation physiotherapy by producing a soft, wearable exoskeleton that performs repetitive motion following the technique of repetitive task training used in hospitals for rehabilitation (Thomas et al., 2017). By prioritizing the design's ability to adapt to financial, physical, and time constraints, I address the problem of accessibility to rehabilitation therapy. The bot will be cheap, used at home, and allow for consistent and frequent physiotherapy of both fine-motor skills and flexion and extension of the elbow. My intention is for any stroke survivor that could benefit from upper-limb rehabilitation would be able to obtain the device and improve their chances at recovery.

However, these are not the only factors that limit rehabilitation chances; hospital treatment delays, quality of care, home support, and much more contribute to a person's ability to achieve a full recovery (Alawieh et al., 2018). I seek to understand the various ways in which public perception of stroke affects access to rehabilitation in Ghana, a country with a growing stroke rate, versus the United States (Donker et al., 2014). Utilizing existing quantitative and qualitative studies on stroke rehabilitation, I will do a literature synthesis to better understand the relationship between societal awareness and stroke rehabilitation in the two nations. By establishing themes and differences across vastly different countries, I intend to highlight systemic barriers in stroke treatment that healthcare infrastructure hides. My findings from the sociotechnical research will inform my technical project and allow me to take more factors into consideration to meet my goals for reducing stroke disability for diverse populations.

Technical Project

A high percentage of patients recovering from stroke have upper-limb disability, including fine motor movements in the hand, like grasping, and larger functions like flexion and extension of the elbow (Van der Lee et al., 1999). Fortunately, these impairments can be significantly reduced or even negated with repetitive task training in which the patient undergoes the same simple motion continuously as a means of relearning the motion, gaining muscle, and most importantly reestablishing the mind-muscle connection (Langhorne et al., 2011). Due to the repetitive nature, robotics and technological approaches to rehabilitation mechanisms are common in stroke care units in America. Currently, these robotic rehabilitation machines are found in hospitals and clinics, requiring the patients to be at the same location as the stationary devices.

However, the nature of repetitive task training requires the patient to commit to exercising the motions frequently and consistently; it can take months before progress is seen. Recurrent, lengthy outpatient visits to therapy can be time consuming, expensive, and often not possible. So, a better system for upper-limb rehabilitation is needed to remedy these issues with the current standard.

To address this, I intend to design a soft exo-suit for the upper limbs with multiple degrees of freedom to help stroke patients perform thorough physiotherapy from home. The design's adaptability to patient circumstance counteracts the main issues facing the standard robotics used for rehabilitation. By eliminating the need for outpatient visits, the cost of rehabilitation and the physical barrier to accessing therapy is reduced. In addition, the textile nature of the exo-suit would make it comfortable to be worn for longer periods of time, and more regularly.

More specifically, the exo will repeat one motion: flexion of the elbow while the hand clamps into a fist, and extension of the elbow as the hand stretches back out. This combination of fine and large motor skills is another important component of the at-home rehabilitation exo that is missing in current practice. Combining these two motions saves time, as well as expands the applications of the machine itself. To understand how the design functions, it is important to understand our priorities while developing a prototype; low cost, low weight, comfort, portability, and ease of use are the goals for this project. Only four components will come into contact with the wearer: a small runners backpack, an upper arm cuff, a wrist cuff, and a compression glove. By using textiles, traditional use of hard plastics and metals to provide structural support is not necessary; instead, Bowden cables controlled by small motors in the backpack and glove will direct the movements. Inertial measurement units in the cuffs will

determine angles of flexion and extension to ensure the biomechanics of the design is safe and to control the motors through a programmed microcontroller chip. Using small DC motors and microcontrollers allows the design to run independently of any computer and light enough to carry in a backpack, making it fully portable.

Once the preliminary exoskeleton has been completed, we will complete several in-house evaluations to investigate how well we met our goals. With our own teams' arms, we will test that we correctly computed the amount of torque, and that we created a comfortable ergonomic design. Battery life, weight, portability, and cost of production will be compared to our original goals to quantify how accessible the design will be. Finally, we will determine its functional utility for stroke rehabilitation by presenting the upper-limb rehabilitation exo-suit to local stroke professionals who can give us qualitative assessments of our device. Further studies coming from the target population could include IRB approved studies used with actual stroke patients.

STS Project

To understand how extensively the wearable rehabilitation exoskeleton could be used to help stroke patients, I choose to analyze rehabilitation methods in two markedly different cultures. As previously introduced, a universal challenge facing successful rehabilitation is accessibility, manifesting as policy constraints, cultural and religious values, financial burdens, and more that block individuals from obtaining the help they deserve (Lynch et al., 2017). While healthcare efforts and general stroke awareness have resulted in decreasing stroke rates in the United States, there are places where rates of stroke are rising—namely in Sub-Saharan Africa, a phenomenon partly attributed to the public's lack of awareness of the disease (Donker et al., 2014; Patel et al., 2019). However, as someone committed to designing a broadly applicable

rehabilitation device, my interest goes beyond stroke incidence to analyze how these different societies address the needs of stroke victims within the theme of public awareness. How do societal perceptions of stroke affect stroke rehabilitation differently in Ghana versus the United States?

To compare the unique socially motivated factors affecting stroke rehabilitation, it is important to understand the physical factors that allow for the best chance at rehabilitation. The time it takes for the stroke patient to receive hospital care after symptom onset is crucial, as longer wait times negatively affect a person's chance at recovery (Lee et al., 2021). Residual stroke disability often manifests itself as a lack of motor control, although severed neural pathways can be reconnected through physiological, occupational, and psychological therapy. However, these programs only work under the circumstances of frequent and long-term practice, as the nature of neural relearning requires these rehabilitation therapies to be consistent (Langhorne et al., 2011). Although seemingly straightforward, looking more closely into these predictors of rehabilitation reveal socio-technical aspects deeply rooted in the infrastructure that is healthcare systems.

The first group whose perceptions I will unpack is the general public. As previously mentioned, shorter time taken to get to the hospital after stroke onset is a positive indicator for recovery ability. The main relationship between this time and social awareness of stroke is how well members of the community can recognize stroke symptoms. If someone can identify these tells on themselves or others, action can be taken sooner. Recognition of symptoms is not the only factor affecting the time to get hospital care; interpretation of these symptoms is just as important. In both countries, an ambulance or the emergency room is often not a person’s first response, but variance lies in who is consulted initially (Baatiema et al., 2021). The public's

perception of stroke also reaches practices of rehabilitation itself. In the early stages of life after a stroke, full time caretakers are required, and untrained, non-healthcare worker relatives in both countries often take over this task. In addition to general unpreparedness, cultural beliefs that stroke is caused by curse often encourage family caregivers to resort to traditional and spiritual medicine as rehabilitation in Ghana (Watkins, 2020). Whereas in America, the lack of understanding usually manifests in caregiver burnout that is due to "feelings of uncertainty, emotional distress, and the need for training and information" (Lutz et al., pp. 881). Caregivers with mental and physical health issues are coincident with worse stroke survivor outcomes (Lutz et al., 2016).

Finally, insurance policy makers' understanding of stroke affect financial barriers. While stroke is a main cause of disability in Ghana, coverage for rehabilitation by the country's provider, National Health Insurance Scheme (NHIS), is restricted to physiotherapies. This leaves out occupational and psychotherapies, two resources proven to be imperative to making a full recovery (*Benefits Package*, 2023; Langhorne et al., 2011). In addition, the NHIS's limited outpatient visits discourages patients from pursuing the necessary rigorous treatment schedule aforementioned. Medicare, the main healthcare insurance for stroke victims in the United States, provides a financial barrier in a different way. Without a physician referral, Medicare will not cover stroke rehabilitation treatment, yet another roadblock for stroke survivors to overcome to receive rehabilitation services (Cook et al., p. 6). In both situations, insurance policy makers demonstrate a lack of understanding about the high stroke risk population they are catering to, as well as stroke rehabilitation itself.

Ultimately, perceptions of stroke yield unique barriers to recovery chances in each country. Sources will be gathered from previous examinations of stroke rehabilitation in Ghana

and the United States. This includes interviews with healthcare professionals, community members, and stroke-impacted individuals, as well as statistical quantitative data from related research. Due to the large amount of literature on stroke rehabilitation in both the USA and Ghana, I will limit my literature synthesis to information from the last fifteen years, with data being gathered from peer-reviewed journals and policies of healthcare corporations. By framing stroke rehabilitation in America and Ghana as two sociotechnical imaginaries (Jasanoff, 2015), I will outline my comparison by highlighting the narratives, practices, and collective identity of each country's public perception of stroke.

Conclusion

By working on these two projects simultaneously, they will inform each other and improve both. My technical project will appeal to a broader population and address more accessibility issues as an upper-limb wearable exoskeleton. Fine motor motion as well as flexion and extension motions will be repeatedly performed by the bot, mimicking repetitive task training normally done in a hospital. Typical barriers facing stroke victims, including costs, frequency, and distance of hospital visits, are overcome by a design that stroke survivors can use in their own home.

Through my design project, I will be able to do more productive and informed research for my socio-technical report. My report will deliver an increased understanding of factors standing in the way of recovery rates in two culturally different places. Policy makers, health care workers, and families of stroke survivors can use my research to understand ways in which recovery rates can be increased, and areas in each community where there are information gaps. Combining these two unique projects, I will bring more perspective to the stroke community on how to accommodate diverse obstacles facing stroke rehabilitation.

Works Cited

About Stroke. (n.d.). www.stroke.org. Retrieved November 15, 2023, from https://www.stroke.org/en/about-stroke

Alawieh, A., Zhao, J., & Feng, W. (2018). Factors affecting post-stroke motor recovery: Implications on neurotherapy after brain injury. *Behavioural Brain Research*, *340*, 94–101. https://doi.org/10.1016/j.bbr.2016.08.029

Baatiema, L., Sanuade, O., Kuumuori Ganle, J., Sumah, A., Baatiema, L., & Sumankuuro, J. (2021). An ecological approach to understanding stroke experience and access to rehabilitation services in Ghana: A cross-sectional study. *Health & Social Care in the Community*, *29*(5). https://doi.org/10.1111/hsc.13243

Benefits Package. (2023). National Health Insurance Authority. https://www.nhis.gov.gh/benefits

Cook, C., Stickley, L., Ramey, E., & Knotts, V. J. (2005). Variables Associated with Occupational and Physical Therapy Stroke Rehabilitation Utilization and Outcomes. *Journal of Allied Health*, *34*(1), 3–10.

Donkor, E. S., Owolabi, M. O., Bampoh, P., Aspelund, T., & Gudnason, V. (2014). Community awareness of stroke in Accra, Ghana. *BMC Public Health*, *14*(1), 196. https://doi.org/10.1186/1471-2458-14-196

Jasanoff, S. (2015). Future Imperfect: Science, Technology, and the Imaginations of Modernity. In S. Jasanoff & S.-H. Kim (Eds.), *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power* (pp. 1–33). The University of Chicago Press.

Langhorne, P., Bernhardt, J., & Kwakkel, G. (2011). Stroke rehabilitation. *The Lancet*, *377*(9778), 1693–1702. https://doi.org/10.1016/S0140-6736(11)60325-5

Lee, E.-J., Kim, S. J., Bae, J., Lee, E. J., Kwon, O. D., Jeong, H.-Y., Kim, Y., & Jeong, H.-B. (2021). Impact of onset-to-door time on outcomes and factors associated with late hospital arrival in patients with acute ischemic stroke. *PLOS ONE*, *16*(3), e0247829. https://doi.org/10.1371/journal.pone.0247829

Lutz, B. J., Young, M. E., Creasy, K. R., Martz, C., Eisenbrandt, L., Brunny, J. N., & Cook, C. (2016). Improving Stroke Caregiver Readiness for Transition From Inpatient Rehabilitation to Home. *The Gerontologist*, gnw135. https://doi.org/10.1093/geront/gnw135

Lynch, E. A., Cadilhac, D. A., Luker, J. A., & Hillier, S. L. (2017). Inequities in access to inpatient rehabilitation after stroke: An international scoping review. *Topics in Stroke Rehabilitation*, *24*(8), 619–626. https://doi.org/10.1080/10749357.2017.1366010

Patel, A., Fang, J., Gillespie, C., Odom, E., King, S. C., Luncheon, C., & Ayala, C. (2019). Awareness of Stroke Signs and Symptoms and Calling 9-1-1 Among US Adults: National Health Interview Survey, 2009 and 2014. *Preventing Chronic Disease*, *16*, 180564. https://doi.org/10.5888/pcd16.180564

Sarfo, F. S., Ovbiagele, B., Gebregziabher, M., Wahab, K., Akinyemi, R., Akpalu, A., Akpa, O., Obiako, R., Owolabi, L., Jenkins, C., & Owolabi, M. (2018). Stroke Among Young West Africans: Evidence From the SIREN (Stroke Investigative Research and Educational Network) Large Multisite Case–Control Study. *Stroke*, *49*(5), 1116–1122. https://doi.org/10.1161/STROKEAHA.118.020783

Thomas, L. H., French, B., Coupe, J., McMahon, N., Connell, L., Harrison, J., Sutton, C. J., Tishkovskaya, S., & Watkins, C. L. (2017). Repetitive Task Training for Improving Functional Ability After Stroke: A Major Update of a Cochrane Review. *Stroke*, *48*(4). https://doi.org/10.1161/STROKEAHA.117.016503

Van Der Lee, J. H., Wagenaar, R. C., Lankhorst, G. J., Vogelaar, T. W., Devillé, W. L., & Bouter, L. M. (1999). Forced Use of the Upper Extremity in Chronic Stroke Patients: Results from a Single-Blind Randomized Clinical Trial. *Stroke*, *30*(11), 2369–2375. https://doi.org/10.1161/01.STR.30.11.2369

Watkins, K. (2020). *What does upscaling stroke rehabilitation mean globally? A qualitative description of international variation in stroke rehabilitation and the influences on evidence-based practice* [Thesis, Master of Health Sciences, University of Otago]. http://hdl.handle.net/10523/10097