Upper Limb Exoskeleton for Rehabilitation Purposes

Factors Influencing Societal Acceptance of Exoskeletons

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
Hannah Rigby

December 1, 2023

Technical Team Members:
Clara Bender
Madeleine Deadman
Addison Hall
Kristen Pettit-Pokora

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

Joshua Earle, Department of Engineering and Society

Sarah Sun, Department of Mechanical and Aerospace Engineering

Introduction

The medical field is the application of technology and methods to improve human health and well-being. Medical technology and devices cater to diverse health needs and treat various ailments. A large part of medical care is devoted to preventive or curative efforts. Medical care is not only limited to treating existing diseases but also includes crucial efforts toward preventing and minimizing factors that lead to chronic diseases. These chronic diseases can significantly impact one's quality of life, so it is essential to focus on reducing risks and promoting healthy lifestyles (Bunker, 2001). While tried-and-true methods are widely accepted, and the healthcare field resists change (Krohn et al., 2017), ongoing research is developing and introducing newer technologies and methods. Rehabilitation is a subset within the medical field developing wearable technologies to improve the patient's recovery. These devices are worn on the body and designed to collect information to provide feedback to the user (Dias & Cunha, 2018). The proposed technical project aims to design and construct a soft or 3D-printed exoskeleton to aid upper limb movement for rehabilitation purposes for patients with neuromuscular diseases or limited mobility.

The integration of wearable technology into society is relentless in its advances. Wearable technology/devices are becoming more commonplace (Babič et al., 2021). It is seen in accessories and clothing like watches, jackets, and glasses. The use of wearable technology in the medical field is not new, as people have been living with medical devices such as pacemakers, cochlear implants, or prostheses for years. However, wearable technology still has numerous applications that companies and product designers can incorporate into products and services. As more wearable technology is developed and can be deemed as "radical" or "unconventional" in relation to the wearable technology available today, it is critical to delve into the dynamics between these technologies and societal acceptance. Wearable technology can profoundly impact numerous topics like user responsibility, perception of the user, privacy concerns, and policy-making.

Industry work, the military, and the medical field have used exoskeletons since the 2000s (Bengler, 2023). With their current development, exoskeletons can become devices incorporated into daily life, extending beyond their current sectors. The proposed STS research will explore the factors influencing the public's application and acceptance of exoskeletons.

Technical Project

For the technical project, an exoskeleton with two degrees of freedom will be designed to assist in rehabilitating individuals with neuromuscular diseases or injuries that result in limited mobility of their upper limbs. This exoskeleton will aid the flexion and extension of the wrist and elbow. This is one degree of freedom in the wrist and one degree of freedom in the wrist, which combines gross and fine motor skills. The wearable technology for this capstone will incorporate electrical and mechanical components as well as an understanding of the concepts of programming, kinematics, and biomechanics.

The body of the exoskeleton, which will support the electrical components and mechanical actuators, will be designed with soft material, 3D printed material, and ready-for-purchase support structures. The soft material allows for the exoskeleton to flex with the patient's movement more naturally. Relative to hard exoskeletons, which incorporate metal exteriors, this exoskeleton's soft and 3D-printed materials are low-cost. This is purposeful with the thought that this wearable technology can be made more accessible to a greater variety of patients. In order to fully incorporate the electrical and mechanical components comfortably and mold them nicely to the patient's upper limb, computer-aided design (CAD) will be used to design the body of the exoskeleton.

The exoskeleton's electrical side will integrate electromyography (EMG) and inertial measurement unit (IMU) sensors. When muscles are contracted or activated, they are controlled by motor neurons. These motor neurons give off an electrical signal that EMG sensors can detect and relay information to the coding program. This capstone will use surface EMGs, which are electrodes stuck onto the skin. It can tell when the patient is attempting to move their upper limb. Triggered by the EMG, the exoskeleton will assist the patient with moving their elbow in an upward bending motion and supporting the back and forth motion of the wrist. The IMU sensors will be used as a gyroscope to gain feedback on the current position of the patient's limb.

While the EMG senses the attempted muscular movement, a mechanical actuator is needed to translate the feedback from the EMG into natural movement. The mechanical actuator will assist in moving the patient's upper limb in a repetitive motion. For this capstone, two kinds of mechanical actuators will be incorporated. The elbow flexion and extension will utilize a pneumatic actuator, specifically a McKibben pneumatic artificial muscle (PAM). A servo motor, a rotary actuator, will aid the wrist flexion and extension. A unique code will be developed to control the motion of the actuators based on the EMG readings.

A full prototype will be completed by the end of the fall semester to undergo an iterative process in the spring. Improvements will be made to the exoskeleton based on patient response.

STS Project

In its basic form, technology replicates or amplifies the bodily and mental abilities of the human organism (Bray, 2000). Today, we can see this fully in practice with wearable technology. Exoskeletons offer an alternative treatment for patients' rehabilitation needs, and for some, it will be an extension of themselves. It is common to look around and see people wearing smartwatches, headphones, and other smart devices. Currently, the public has limited access to advanced exoskeletons that mainly serve industrial purposes. These exoskeletons are not affordable and do not enhance human ability but rather provide support to the user's frame. Advanced exoskeletons could potentially become commonplace among the general population, but addressing influential factors is necessary. The proposed STS paper will delve into these factors and analyze their influence on the societal acceptance of exoskeletons.

There are dozens of rehabilitation methods for limited mobility or paralysis of the upper limb, such as simple arm exercises, electric nerve stimulation, and deep brain stimulation. (Hatem et al., 2016). The emergence of exoskeletons as a treatment results in an altered perception of the patient and the future of exoskeletons outside of this field. The movement of exoskeletons from being used solely for rehabilitation to everyday use breaches the divide between industry use and personal use. The notions about people with disabilities and their use of exoskeletons influence societal perceptions and biases. Additionally, examining the association between exoskeletons and ableism is necessary.

In order to gain a comprehensive understanding of the current acceptance of exoskeletons, thorough research into their limitations is crucial. By identifying and exploring the various factors that may limit the use and effectiveness of exoskeletons, we gain valuable insight into how these devices are accepted and embraced within various contexts. Using this information, strategies and solutions are developed to overcome these limitations and promote a more widespread acceptance of exoskeletons. Notably, the concerns about the advancement of wearable technology and its ethical use will be a large part of the discussion. Other research objectives will examine the influence of economic, political, and media representation.

Two analytical frameworks will be employed to understand societal acceptance of exoskeletons. These frameworks are Actor Network Theory (ANT) and the Social Construction of Technology (SCoT). ANT is an approach that breaks down the analysis into actors and networks. Actors refer to both human and nonhuman entities that impact social processes, while networks are the complex relationships and interactions between these actors (Cresswell, 2010). In this study, ANT will be used to identify various actors such as current wearable technology, patients, medical professionals, identity factors, technology companies, and other stakeholders and analyze their relationships with one another. SCoT is a theory that delves into social concepts of technology; it is how human actions and experiences shape technology. SCoT has several central concepts: relevant social group, interpretive flexibility, closure, stabilization, technological frame, and inclusion (Bijker, 2001). These core concepts will examine the factors associated with exoskeleton acceptance. The factors associated with this topic include identity factors, rehabilitation technology, wearable technology, commercialization, and user perspective.

In addition to these frameworks, other methods will examine the public policy associated with wearable technology, feedback from patients currently using exoskeletons for rehabilitation purposes, and available works under disability STS.

Key Texts

In the the book *Connected Health: Improving Care, Safety, and Efficient with Wearable and IoT Solution* by Richard Krohn, David Metcalf, and Patricia Salber, the authors focus on examining wearable devices in the Connect Health market. They dive into various issues, covering the use of wearable devices in medical provider spaces and the consumer realm. This book will help understand where to build foundations for exoskeleton use and where it may be less necessary.

In the article *Challenges and solutions for application and wider adoption of wearable robots* by Babič et al., the authors delve into the evolving field of wearable robots, highlighting the advancements in science and technology. They address various challenges that have hindered the widespread integration of wearable robots into everyday life. The authors categorize these challenges into several key areas, including "mechanical layout, actuation, sensing, body interface, control, human-robot interaction and coadaptation, and benchmarking." They aim to provide potential solutions and insights to facilitate a greater adoption of wearable robots. As the proposed STS topic explores the limitations of exoskeleton acceptance, this article will play an essential role in understanding the challenges of applying wearable robots to a greater audience.

The book *Year of the Tiger: An Activist's Life by Alice Wong* will be an insightful addition to the STS and technical project. In this book, the author shares a collection of original essays, graphics, interviews, and more to share her story on disability activism. Wong, a person with disabilities, is an active proponent in fighting for the dismantling of systemic ableism. The technical project and STS project revolve around using exoskeletons for rehabilitation and the use of people with disabilities. It is essential to acknowledge what the user wants and to give them a say in their treatment, especially if the users are people with disabilities, as they are an underrepresented group.

In the article *Exoskeletons in a disabilities context: the need for social and ethical research,* Jathan Sadowski delves into the technical, social, and ethical aspects of exoskeletons in the context of disabilities. He highlights the importance of conducting social scientific and ethical analyses of exoskeleton technology, which has the potential to impact the lives of individuals with disabilities significantly. In his words, the paper aims to "shine light on the dearth of social scientific and ethical analyses of this subject…" Sadowski's insights and arguments provide a thought-provoking and informative perspective, providing an excellent foundation for a more in-depth discussion. It fills gaps in knowledge that are crucial to understanding the implications of exoskeleton technology in the realm of disabilities.

References

Babič, J., Laffranchi, M., Tessari, F., Verstraten, T., Novak, D., Šarabon, N., . . . Veneman, J. (2021). Challenges and solutions for application and wider adoption of wearable robots. *Wearable Technologies, 2*, E14. doi:10.1017/wtc.2021.13

Bengler, K., Harbauer, C., & Fleischer, M. (2023). Exoskeletons: A challenge for development. *Wearable Technologies, 4*, E1. doi:10.1017/wtc.2022.28

Bijker, W. (2001). Technology, Social Construction of. *International Encyclopedia of the Social & Behavioral Sciences*, 15522-15527. https://doi.org/10.1016/B0-08-043076-7/03169-7

Brey, P. (2000). 'Technology as Extension of Human Faculties.' *Metaphysics, Epistemology, and Technology. Research in Philosophy and Technology, vol 19.* Ed. C. Mitecham, London: Elsevier/JAI Press.

Bunker, J. P. (2001, December). The Role of Medical Care in Contributing to Health Improvements Within Societies. *International Journal of Epidemiology*, *30*(6), 1260-1263. https://doi.org/10.1093/ije/30.6.1260

Cresswell, K.M., Worth, A. & Sheikh, A. (2010). Actor-Network Theory and its role in understanding the implementation of information technology developments in healthcare. *BMC Med Inform Decis Mak* 10, 67. https://doi.org/10.1186/1472-6947-10-67

Dias, D., & Paulo Silva Cunha, J. (2018). Wearable Health Devices-Vital Sign Monitoring, Systems and Technologies. *Sensors (Basel, Switzerland)*, *18*(8), 2414. https://doi.org/10.3390/s18082414

Hatem, S. M., Saussez, G., Della Faille, M., Prist, V., Zhang, X., Dispa, D., & Bleyenheuft, Y. (2016). Rehabilitation of Motor Function after Stroke: A Multiple Systematic Review

Focused on Techniques to Stimulate Upper Extremity Recovery. *Frontiers in Human Neuroscience*, *10*, 133735. https://doi.org/10.3389/fnhum.2016.00442

Krohn, R., Metcalf, D., & Salber, P. (2017). Connected Health: Improving Care, Safety, and Efficiency with Wearables and IoT Solution (1st ed.). Productivity Press. https://doi.org/10.4324/9781315184494

Sadowski, J (2014). Exoskeletons in a disabilities context: the need for social and ethical research, *Journal of Responsible Innovation*, 1:2, 214-219, DOI: 10.1080/23299460.2014.918727

Wong, A. (2022). *Year of the Tiger: An Activist's Life*. Knopf Doubleday Publishing Group.