Head-to-Ground Helmet Testing Device

A Virtue Ethics Approach to Exoskeleton Research and Development

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
Max Wooten

October 15, 2024

Technical Team Members
Tristan Witz
Lauren Gagermeier
Dawson Chitwood
Binh Nguyen
William Moeller
Sam Suppes
Aidan Connor

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

Richard Kent, Mechanical and Aerospace Engineering

Introduction

The ways in which humans design technologies in order to study the human form have led to dramatic advancements in the fields of biomechanics and biomedical engineering. One such innovation, the exoskeleton, is on the precipice of triggering a significant shift in the market for assistive devices. Exoskeletons possess incredible potential for rehabilitation efforts for those affected by spinal cord injuries (SCIs), neuromuscular diseases, or other trauma-based injuries. Disabled veterans are also a major target demographic for exoskeletons, raising concerns regarding the ethics behind their deployment in a military setting. That being said, as a result of the capital-intensive nature of production, the complexity of the devices, and the relative youth of the industry, the technology remains unpredictable and has had trouble establishing itself in a commercial setting. Along with the technical challenges of developing exoskeletons, there are significant moral and ethical obligations of manufacturers that must be accounted for. This paper will ultimately be answering the question: how do the virtue ethics of exoskeleton developers affect innovation and go-to-market strategy?

The field of biomechanics struggles with the complexity of modeling human movement, resulting in an expensive and highly dynamic research environment. As consumer products are developed with the motion of the human body as the source for biomechanical data, standardization and repeatability of experiments can prove challenging. In the case of exoskeletons, the human body proves challenging to model as a result of the complexities of potential injuries and serviceable demographics. Another major technological challenge in biomechanics is achieving accurate simulations of real-world events to aid in the design of protective devices. The societal implications of this research are plentiful as best exemplified by the development and implementation of seatbelts, airbags, and crumple zones in motor vehicles

(Palmås, 2023). However, protective equipment in sports is another challenge for engineers as a result of the irregularity and unpredictability of the dynamics of the human body when competing in athletics. The technical project will contribute to this field of research by designing a head-to-ground collision testing device for football helmets. With the emergence of widespread media awareness of the dangers of concussions and their long term implications, this research is especially in demand for the future of the sport of football. It will answer the question: how can engineers at helmet manufacturers better design their products to protect athletes from concussions resulting from collisions with the ground? Successful implementation will provide designers with more force, velocity, and angular acceleration data that will allow them to create more robust and holistic products that are better cemented in empirical data.

Technical Project

The technical project seeks to answer the question of how a new head-to-ground testing device can help prevent concussions resulting from collisions with the ground for athletes playing football. Many of the existing testing devices employed to simulate concussive impacts with helmets simply test linear contact with different positions of the helmet using pendulums or hydraulic rams (Dymek et al., 2022). However, according to Dr. Richard Kent, a large number of concussions are caused by collisions between the helmet and the ground. Kent argues that "Helmeted impacts to the ground involve fundamentally different mechanics than helmet-to-helmet impacts. They involve a compliant body (earth) of effectively infinite mass and different interface contact properties and can involve substantial rotational velocity of the helmet prior to impact." and that "no current or proposed helmet assessment methodology specifically considers these factors and the biomechanics of helmet-to-ground impacts have not been well

described." (*The Biomechanics of Concussive Helmet-to-Ground Impacts in the National Football League - PubMed*, n.d., pg. 1) Kent's extensive research with the National Football League has laid the groundwork for our technical project to support this lapse in design consideration and testing. (Kent et al., 2020)

Due to limitations regarding funding, feasibility, and sizing considerations, a scale model of a production quality, full-size, test device that can be implemented at NFL helmet manufacturers will be designed. The central design considerations for this simulation apparatus will be the successful acquisition of empirically significant and reasonable data, repeatability, and a variety of adjustability utilizing degrees of freedom. The device will operate using a curved-track and bearing drop tower system. Gravity will accelerate a dummy to achieve vertical and horizontal speeds proportional to those a full-sized device would generate when simulating the impact of an NFL athlete colliding with the ground. The dummy's torso will be launched from the curved track with maximum horizontal velocity at a position in which the pelvis will land first (adjustable angle between the torso and the ground), thus creating a whipping effect of the dummy's head, inciting intense angular acceleration of the helmet towards the ground.

The model will consist of three degrees of freedom that will allow for a broader range of experimental data acquisition. Adjustable initial conditions will be: the height of the drop tower before the curved portion of the track, the height at which the dummy will launch horizontally above the ground, and the angle at which the dummy will be launched relative to the ground.

STS Project

The sociotechnical portion of this paper that I will focus on will be analyzing the ethical considerations of exoskeleton developers and how they affect design and market strategy. To accomplish this, I will apply the framework of virtue ethics to specific cases of corporate

character and ethical leadership. Virtue ethics has its origins in ancient philosophical traditions, primarily in the works of the Greek philosophers Plato and Aristotle. Its basic methodology is grounded in the societal mindset of choosing to help those in need for the purpose of being charitable or benevolent. (Hursthouse & Pettigrove, 2023). Shannon Valor, author of *Technology and the Virtues: A Philosophical Guide to a Future Worth Wanting,* argues that this framework of analysis is "ideally suited for managing complex, novel, and unpredictable moral landscapes, just the kind of landscape that today's emerging technologies present." (Vallor, 2016, pg. 1). Virtues are the intrinsic traits and ideologies that influence righteous decisions, not to be confused with simple beliefs. Virtues are the foundation of one's moral decision making and are not dynamic; they are systemic and constructed over a lifetime. Contemporary philosopher Gregory Trianosky says that "Aristotle may be read as saying 'do as the virtuous person does', or the person of practical wisdom, would do." (Trianosky, 1990, pg. 3) Virtue ethics, however, experienced a decline in popularity during the 19th and 20th centuries and Valor argues that it wasn't until G.E.M. Anscombe's 1958 essay, *Modern Moral Philosophy,* was published that the ideology made a revival in the West. (Vallor, 2016) Anscombe argues strongly against the popular moral theories of utilitarianism and deontology and emphasizes the importance of virtue in relation to combating injustice. (Anscombe, 1958) Anscombe's essay provides a great foundation for my analysis of her ideas and their application to the exoskeleton industry.

Ethical design and the consequences of technological innovation are especially prevalent in today's society, demanding careful consideration to ensure responsible and successful outcomes. All stakeholders in the equation: investors, engineers, corporate executives, marketing teams, users themselves, regulatory bodies, retailers, and many others all bear the responsibility of ethical and responsible practices in order to ensure that technologies execute their intentions

with morality (Clegg et al., 2007). For the purpose of this paper, I will be analyzing the extent to which virtue ethics, the system that actions are the result of intrinsic beliefs of kind-heartedness and goodwill, influence businesses as holistic entities in their operations. As this relates to exoskeleton manufacturers, I will challenge the ethics of certain sources of funding, potentially misleading marketing campaigns, and executive decision making. Some of this murkiness can be attributed to American innovation often intersecting with military interests, particularly when new technologies demonstrate potential for combat applications. This pattern is evident in the development of exoskeletons, which have roots deeply embedded in military concepts and popular culture (Jia-Yong et al., 2020). This is not inherently unethical as it relates to this paper, however it raises some questions regarding the true intentions of corporations who develop medical, rehabilitation, and industrial exoskeletons.

Research Question, Methodology, and Timeline

The question that this paper intends to answer is: how do the virtue ethics of exoskeleton developers affect innovation and go-to-market strategy? This is a particularly important question because it will contextualize the industry and provide better insight into the trajectory of exoskeleton innovation. In order to answer this question, I will be applying the research methodology of case study research. The case study method is an appropriate methodology because it will allow me to explore the complexities and stakeholders of exoskeleton corporations in depth in their natural context. (Crowe et al., 2011) To support this research, the sources I will use are: prior literature regarding exoskeletons and ethics, relevant philosophy, first hand accounts from interviews with stakeholders, and financial reports (if applicable for a publicly traded company). All procured information will be analyzed through the virtue ethics

framework as I answer the central research question of this paper. This will all culminate with a final conclusion about the sociotechnical aspects of the exoskeleton industry that I chose to highlight.

My research timeline will consist of an aggressive approach to acquire the necessary information I will need to complete my research paper. I plan to choose a specific company to examine by the New Year, obtain a strong foundation in the principles of virtue ethics through the thorough analysis of my key texts by the start of the spring semester, and ultimately complete my research and case study by the beginning of February.

Key Texts

There are three main texts that will provide the foundation for my research across virtue ethics, the case study methodology, and exoskeleton technology. First, Shannon Vallor's essay, *Technology and the Virtues: A Philosophical Guide to a Future Worth Wanting*, argues that the framework of virtue ethics is particularly attuned to manage and analyze complex and unpredictable modern moral dilemmas. However, Vallor postulates that a purely Western approach to ethics would be inadequate for the analysis of modern technologies and that a truly global approach is required to bridge the gaps between cultures and political environments. This is important to my research because it outlines the historical importance of my chosen framework as well as how it has evolved over time. Secondly, Sarah Crowe illustrates how the case study methodology of research is a particularly effective strategy for analyzing a specific complex issue in its natural setting in her article, *The Case Study Approach*. Crowe argues that case studies are best suited for investigating business practices, however emphasizes that sufficient prior research is required in order for them to be successful. This article is significant

to my research paper because it provides a foundation for how to functionally conduct a case study and the requirements for proper implementation. Lastly, Jathan Sadowski's essay, *Exoskeletons in a Disabilities Context: the Need for Social and Ethical Research,* examines the potential of exoskeletons as a device engineered to enhance the lives of people with disabilities. Sadowski argues that the impending breakthroughs for exoskeletons specialized in rehabilitation can no longer be overlooked. This essay is important to my research because it contextualizes exoskeletons as a technology for assisting individuals with disabilities, while also offering a point of contrast with their use in military applications.

Conclusion

This paper will ultimately answer the question of how virtue ethics influence the operations of exoskeleton companies. I will use the case study methodology to investigate a single firm and acquire information central to answering the research question. Exoskeletons are a sophisticated technology that has yet to fully realize its potential, particularly in commercial applications. As these devices grow in popularity and complexity, business ethics will grow in importance as unforeseen consequences may develop. The technical aspect of this paper will explore another aspect of biomechanics: injury-simulating test devices. The sociotechnical portion of this paper will complement the technical analysis of the helmet-to-ground concussion simulation device in that my research will consider the ethical components of the design process and overall business functionality.

References:

Anscombe, G. E. M. (1958). Modern Moral Philosophy. *Philosophy*, *33*(124), 1–19. https://doi.org/10.1017/S0031819100037943

Clegg, S., Kornberger, M., & Rhodes, C. (2007). Business Ethics as Practice. *British Journal of Management*, *18*(2), 107–122. https://doi.org/10.1111/j.1467-8551.2006.00493.x

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., & Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology*, *11*, 100. https://doi.org/10.1186/1471-2288-11-100

Dymek, M., Ptak, M., & Fernandes, F. A. O. (2022). Design and Virtual Testing of American Football Helmets–A Review. *Archives of Computational Methods in Engineering*, *29*(2), 1277–1289. https://doi.org/10.1007/s11831-021-09621-7

Hursthouse, R., & Pettigrove, G. (2023). Virtue Ethics. In E. N. Zalta & U. Nodelman (Eds.), *The Stanford Encyclopedia of Philosophy* (Fall 2023). Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/fall2023/entries/ethics-virtue/

Jia-Yong, Z., Ye, L. I. U., Xin-Min, M. O., Chong-Wei, H. A. N., Xiao-Jing, M., Qiang, L. I., Yue-Jin, W., & Ang, Z. (2020). A preliminary study of the military applications and future of individual exoskeletons. *Journal of Physics: Conference Series*, *1507*(10), 102044. https://doi.org/10.1088/1742-6596/1507/10/102044

Kent, R., Forman, J., Bailey, A., Cormier, J., Park, G., Crandall, J., Arbogast, K. B., & Myers, B. (2020). Surface Contact Features, Impact Obliquity, and Preimpact Rotational Motion in Concussive Helmet-to-Ground Impacts: Assessment via a New Impact Test Device. *Annals of Biomedical Engineering*, *48*(11), 2639–2651. https://doi.org/10.1007/s10439-020-02621-x

Palmås, K. (2023). Design in Marketization: The Invention of Car Safety in Automobile Markets. *She Ji: The Journal of Design, Economics, and Innovation*, *9*(1), 5–20. https://doi.org/10.1016/j.sheji.2023.04.001

The biomechanics of concussive helmet-to-ground impacts in the National Football league—PubMed. (n.d.). Retrieved September 17, 2024, from https://pubmed.ncbi.nlm.nih.gov/31837745/

Trianosky, G. (1990). What Is Virtue Ethics All about? *American Philosophical Quarterly*, *27*(4), 335–344.

Vallor, S. (2016). Virtue Ethics, Technology, and Human Flourishing. In S. Vallor (Ed.), *Technology and the Virtues: A Philosophical Guide to a Future Worth Wanting* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780190498511.003.0002