Thesis Portfolio

Design of a Fan-Powered Face Mask with Advanced Filtration Capability
(Technical Report)

Obesity as the Catalyst for Change: How a Societal Trend Can Impact Car Restraint Design
(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

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Engineers constantly design and iterate products to protect the broad range of users that will interact with them. With the worldwide COVID-19 pandemic impacting every aspect of the college experience, my technical project team wanted to create a device that would help the world get back to normal as quickly as possible. Current mask technology fails to provide an ideal and comfortable user experience while also stopping the spread of COVID-19, and my team sought to fix this issue by creating a powered mask that filters inhalation and exhalation air. For my STS research, I decided to draw on my experience from working at the UVA Center for Applied Biomechanics, a world-class injury biomechanics research laboratory. During my time at the lab, I met Carolyn Roberts, a researcher who was investigating how sex impacts injury prevalence, injury outcome, and injury mechanism. Her research focused on how females are not properly protected in motor vehicle crashes, but I was curious if this trend extended to other demographics, more specifically obese individuals. My final STS paper investigates how the increased prevalence of obesity has influenced injury biomechanics research, and what steps need to be taken to fill the knowledge gaps that currently exist in the field.

The technical portion of this thesis investigates proper mask filtration technology and how it can help contain the spread of COVID-19. Current mask technology either filters inhalation and exhalation air or is comfortable to wear for extended periods of time. Designs that properly filter air, like an N95 respirator, are uncomfortable to wear; while comfortable designs, such as a Powered Air Purifying Respirator (PAPR) fail to filter air properly to prevent COVID-19 from spreading (Mayo Clinic Staff, 2020; CDC, 2020). The final technical deliverable, a powered mask that filters inhalation and exhalation air, addressed the issues with both designs to provide a comfortable breathing experience while protecting the user and individuals in their environment. The effectiveness of the final design was assessed using three metrics:

Computational Fluid Dynamics (CFD) analysis via SolidWorks, qualitative breathing assessments, and mock fit testing as seen in the healthcare workplace, and was found to be effective in each evaluation.

The STS portion of this thesis investigates how current car restraint designs fail to protect obese drivers, and how the research field is adjusting to this problem. Despite the National Highway Traffic Safety Association (NHTSA) reporting a decrease in roadway fatalities for the second year in a row, the numbers behind how cars protect all passengers does not tell the whole story (NHTSA, 2019). Modern research shows that factors such as age, gender, and body mass index introduce an added variability in motor vehicle crashes that results in a higher risk of severe injury and fatality (Carter, 2014). New societal norms, such as an increase in the prevalence of obesity (CDC, 2019), seem to be shifting car design to focus more on protecting less represented anthropometries, or body types, in an effort to equally protect all drivers on the road, but to what extent is this change occurring in this field? The final STS deliverable, a research paper, examines the injury biomechanics field through various methods and frameworks to determine how societal norms, specifically obesity, are impacting the development of vehicles.

Both projects helped to highlight a crucial aspect of engineering: the proper implementation of design iteration. In the case of the technical project, the final deliverable was the culmination of many design iterations, each one more focused and streamlined than the last. Throughout the process, design requirements had to be modified to achieve the given deadline. In the case of the STS research, injury biomechanics researchers assumed the 50^{th} percentile male was a good benchmark for human body kinematics in motor vehicle crashes as a result of limitations in research technology and limited funding. Making initial assumptions led early car

restraint development to not properly utilize design iteration and resulted in the technology not equally protecting every driver on the road. In design iteration, certain ideal aspects of a technology may need to be discarded as a result of technological capability, time restraints, or resource acquisition challenges. The problem of picking which aspects to carry into the final product will result in a technology not satisfying every design parameter set out at the start of the process. It is the responsibility of engineers to carefully assess which parameters must be discarded throughout the design process through the lens of societal impact as well as the technology's effectiveness in solving the problem at hand. Both lenses of analysis are crucial in technological design because any gaps could cause a technology to negatively impact society once it is adopted by consumers. Often times the people using the technology are forgotten in the face of scientific test data and success metrics. Engineers must look beyond the numbers, ask the hard questions, and constantly strive to understand how the complex systems they create interact with the world around them.

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