

Thesis Project Portfolio

Redesigning the Incentive Spirometer

(Technical Report)

Ethics in Medical Devices

(STS Research Paper)

An Undergraduate Thesis

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Paul Daniel Miranda

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Sociotechnical Synthesis

The technical report focuses on the capstone the team had worked on since the beginning of the fall semester of 2021. The capstone project highlights the incentive spirometer, a medical device designed for postoperative care after pulmonary complications. Coupled with the COVID-19 pandemic giving rise to pulmonary complications among patients, the urgency to use the incentive spirometer has never been more prevalent. Though as impactful as incentive spirometers are, the patient often neglects them due to the tediousness of their use. Our advisor Dr. Masahiro Morikawa, MD, MPH, the clinical director of UVA Family Medicine, took notice of the lack of patient adherence to this device and the need for improvement. The team attempts to solve the clinical problem of low patient adherence by gamifying the incentive spirometer. The term gamifying means to add a game-like element to encourage engagement.

To further break down an incentive spirometer it is split into 5 main parts: tubing, a mouthpiece, a gas flow indicator, a piston, and the outer casing. The device works by the patient blowing into the mouthpiece causing the piston to rise to wherever the gas flow indicator was set. Being that the process of using the device is mundane leading to the low patient adherence the team decided to add a gamified element to the device to make it more entertaining. Going off of the previous groundwork made by former UVA students they surveyed patients at the UVA hospital to determine what game-like element would be most popular. This resulted in a Ferris wheel design that picks up balls and drops them into a basket being the most appealing according to the patients surveyed.

Progress for the gamified incentive spirometer started off as brainstorming ideas and solutions to how prototype the device. Sketches were made to determine what

constraints/specifications the design entails. To prototype the parts the team, settle on additive manufacturing to make the gas flow indicator and the gears that will turn the Ferris wheel using a 3D printer at the UVA's Fabrication Lab. Other prototyping methods include laser cutting for the shovels that pick up the balls and vacuuming forming to mold the outer shell. The team selected PLA and PETG as the materials used to make the incentive spirometer for their durability and nontoxic aspects.

The original plan once a functioning prototype is fully assembled the team plans to survey patients to compare the device's performance and engagement levels against a conventional spirometer. The survey will be based on a scale from 1-10 on the following parameters: ease of use, engagement, frequency of use, visual appeal, and functionality. Although there were unexpected roadblocks that hindered the team's progress to get to this point. These include limitation of equipment use because the Fabrication Lab is primarily for UVA's School of Architecture use so equipment availability is not always there. Additional limitations include COVID restrictions that were as emergence of new variants rose and the nature prototyping is time consuming having to reiterate new designs. Despite all the draw backs the team decided to realign the goals and test the parts that are done for their functionality to prove the proof of concept.

Being that the capstone is improving upon and designing a medical device tie into the Research Paper of the importance of incorporating into medical devices. The paper first delves into the very definition of ethics and medical devices and why is it important for ethics to be used in medical devices. Background is then given about early medical devices, which is the origin of the stethoscope and how the engineering design process was incorporated into the

creation of it. The engineering design process is then explored into how having a patient centered mentality in the process can greatly benefit the design.

Next the paper focuses on specific medical device/ethical concerns or problems that are found within the examples. The first one discussed is the incentive spirometer and how its background is rooted into eugenics with its influence in the past and how it overcome that to be a useful medical device to this day. The next example talks about the incorporation of artificial intelligence in health and how patient privacy factors into its use. Another example explores into how medical device companies essentially bribe doctors to pushing their product. This can result in patient having to pay more for things that don't significantly improve their health. The last example is of medication cabinets and how it's easy to override them, which can result into patients' death. The paper then concludes into how this research paper can be used in further research in a clinical/hospital/lab setting. Restating the need of integration of ethics in medical devices.