Thesis Project Portfolio

Design of a Skin-Tone Inclusive Technique for the Non-Invasive, Transcutaneous Measurement of Bilirubin

(Technical Report)

Healthcare Providers, Federal Agencies, and the Media Change in Trust Due to Bias Found in Pulse Oximeters

(STS Research Paper)

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Contents of Portfolio

Executive Summary

The medical community commonly utilizes optical imaging, an established clinical technology, in various medical devices to measure blood oxygen saturation, heart rate, and jaundice progression. These measurements are essential in guiding treatment plans and obtaining insurance approval. However, these optical devices are susceptible to interference from other pigments in the skin, such as melanin, which governs skin tone and is a strong light absorber, making it difficult for these devices to measure accurately. For example, the oximeters used to measure blood oxygen saturation levels report higher levels in people with darker skin tones, which can lead to undiagnosed hypoxia and potential deprivation of required supplemental oxygen, resulting in worse disease outcomes. The COVID-19 outbreak in 2019 brought this issue to the forefront of public awareness as multiple articles highlighted this bias in pulse oximeters. Also, jaundice disease and treatment progression are often measured through the skin. However, bilirubin, the pigment responsible for jaundice, has an absorbance spectrum that overlaps with melanin, leading to the overestimation of bilirubin concentration by measurement devices. As a result, dark-skinned newborns may receive unnecessary phototherapy and more skin pricks, causing emotional distress, infections, and even bone disease.

Jaundice is common in newborns due to high levels of bilirubin, a pigment from broken-down blood cells that accumulate in the skin because of poorly functioning livers. Phototherapy, which uses light to break down bilirubin, is used to treat severe hyperbilirubinemia. However, noninvasive bilirubin monitors tend to overestimate bilirubin concentration in neonates with high melanin content, resulting in unnecessary phototherapy, which can disrupt the newborn's thermal environment. We investigated a novel solution that uses the properties of phototherapy, which converts bilirubin to other optically detectable molecules. We hypothesized that with concentrated phototherapy in a small area, we will be able to measure the conversion of bilirubin over time and measure bilirubin independently of skin tone. We found the optimal wavelength of light to efficiently convert bilirubin was 470nm and purchased a LED light array at this wavelength. Next, we created a computational model that models the conversion of bilirubin, which indicated that the greatest change in absorbance would be at 460nm, our measurement wavelength. Experimentally, we found the greatest change in absorbance across physiological concentrations of melanin was ~450 nm, which validated our computational model. Overall, the percent error was 9.44%+/-10.3%. However, this was mostly due to the low melanin/low bilirubin solution, which photo bleached much quicker than expected and seems to be an outlier in this group. Excluding that solution the percent error goes down to 4.5% +/-2.9%. Our novel technique shows promise for skin tone-independent measurement of bilirubin.

Pulse oximeters are widely used in clinical and non-clinical settings to measure blood oxygenation levels of critically ill, perioperative, and chronically ill patients because they are quick, cheap, and easy to use. They provide healthcare providers with vital information about their patient’s respiratory function. Recent research found that blood oximeters report

significantly higher blood oxygen saturation levels in the dark-skinned population, resulting in a 3.2-fold increased likelihood of undiagnosed hypoxia. This could potentially lead to dark-skinned patients not receiving needed supplemental oxygen, which may lead to worse disease outcomes. This motivates my research question: How did healthcare providers, federal agencies, and the media respond to the new knowledge about biases of the pulse oximeter during and after the COVID-19 pandemic? I focused on three social groups: healthcare providers, federal agencies, and the media. Public statements and documents released by those groups were coded and analyzed to answer my research question. Medical organizations urged federal agencies to increase the diversity of clinical trial groups and called on manufacturers to create new technologies to reduce bias. In turn, many federal agencies responded by acknowledging the bias and noting the importance of monitoring patient respiratory function. Many also agreed more research should be done in the future. The media played a vital role in informing the public about the bias and the need to address it, which catalyzed FDA action. Addressing bias in pulse oximeters is crucial to ensuring equitable healthcare for all, and this research may be useful to understand how social groups interact with new research.

This work addresses both a technical and social situation, but each is connected. The technical research shows that our novel technique may be able to reduce racial bias in healthcare, but it is a slow and laborious process with many problems. Future groups building on our groundwork may be able to create a working prototype. This research shows that social change can come from technical research. On the other hand, the societal research indicates that there are many groups of people that encourage continued research which may lead to more funding for similar technical research projects. This research could be continued through interviews and or surveys of patients, medical professionals, and politicians to hear first-person statements and help focus the sociotechnical research. I am hopeful that bias in medical care will be continued to be reduced through research of novel techniques and interactions of social groups.