Sensitivity of Infrared Sensor Faucet on Different Skin Colours and How it Can Potentially Effect Equity in Public Health

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Abstract

Background

Hand hygiene is essential to human health and day-to-day activities. Maintaining proper hand hygiene can help reduce pathogen growth and transmission of diseases. The automated sensor used for bathroom faucets and soap dispensers can be dated back to the 1950s. These types of fixtures are usually equipped with sensors using a near-infrared beam to detect hands. Its introduction has improved hand hygiene and facilitated good handwashing behaviour. At the same time, disadvantages that come along with advanced technologies should not be neglected, and these disadvantages may lead to inequity in the society.

Methods

Thirty coloured cards for each of the six skin shade types were printed to match the colours on the Fitzpatrick skin type scale. These cards were cut into identical hand shapes which were attached to and to fully covered the researcher's hand. The "hands" were presented in front of the sensor and time required for water to be released from the faucet was recorded.

Results

The results indicated statistically significant differences between the six skin shades and the reaction time for the faucet. The darkest skin type did not dispense water most of the time. The ANOVA test resulted in a p-value of 0.000, indicating that time for water to be released from the faucet was significantly different for different skin tones. As skin tone got darker, more time was required for the sensor to release water. The power of the study was at 100%, indicating that the results of the study were unlikely to be false.

Conclusion

The result of this study suggests that time taken for IR sensors to release water increases as skin shade darkens. As such, it could be suggested that there may be biases between different skin-toned individuals in terms of the IR sensor faucet. As a result, it could make those whose skin shades induce a more prolonged reaction time more likely to avoid hand washing thereby, making them more vulnerable to diseases.

Keywords: "race," "infrared sensor," "technology," "automated," "faucet," "soap dispensers," "detection," "skin colour," "skin shades." "proper handwashing," "racisms," "racial discrimination," "equity," "inequity," "public health".

Introduction:

Technology has advanced to a state that we as humans are not required to do many daily tasks with excessive effort on our own; we have machines that can assist us. From automated doors to facial recognition on cellular phones, machinery has become essential for human activities.

During the COVID-19 pandemic, the public has become more aware of transmission of infectious diseases through contacts. Many technological interventions were introduced to prevent the public from cross-contacting, such as installing doors and elevators with sensors to open them automatically. Although already prevalent in many public washroom facilities before the pandemic, innovative automatic sensor faucets and soap dispensers are being installed to replace manual equipment in public spaces and newer homes as a measure to improve hand hygiene and promote good handwashing behaviour (T&S, n.d.) as well as to conserve water . As ideal as this seems to be, the sensor faucets and soap dispensers embed definite flaws. These types of fixtures are usually equipped with detection sensors using a near-infrared beam to detect the hands. The literature review explains the property of a near-infrared sensor and how it works in faucets and soap dispensers. The review also explores the sensor's ability to detect and operate with different skin pigmentation. The research study conducted consisted of an experimental study which tracked the reaction time of the automated faucet when dispensing water to different skin tones on the campus of BCIT aimed to comment on how the result could affect handwashing behaviour and equities in delivering health interventions.

Literature Review:

Improving hand hygiene:

Hand hygiene is essential to human health and day-to-day activities. Maintaining proper hand hygiene can help reduce pathogen growth and transmission of diseases (Fitriyah et al., 2018). This activity should happen before and after handling food, eating, and using the toilet (Hantrakul et al., 2017). Access to public washrooms is a basic need for society. A washroom may look clean from the outside, but with their humid and warm environment, they can bear disease-causing pathogens such as E. coli, Pseudomonas aeruginosa, Staphylococcus aureus and many others (Suen et al., 2019). Most of these pathogens can survive on the counters for weeks (Suen et al., 2019). Usenet al. conducted studies in 2019 on 55 public washrooms both in "low-class communities and higher-end communities" (Suen et al., 2019) and found out 52 bacterial species on the washroom fixtures, and many were antibiotic-resistant. This finding raised flags for them, and they have suggested interventions such as hands-free motion faucets, hands-free paper towel dispensers for stakeholders to consider for future washroom designs to "minimize the possibility of cross-contamination among users and to decrease the opportunity to re-contaminate hands during and after handwashing" (Suen et al., 2019).

The automated sensor used for bathroom faucets and soap dispensers can be dated back to as early as the 1950s (Hantrakul et al.,

2017). Most automated sensors used for washroom faucets and soap dispensers are described in the literatures as passive infrared sensors (PIR) or just infrared sensors (IR). The working property for the IR is that it would send out a beam within proximity and will be reflected off a human hand, then the beam sends the information to a controller inside indicating that there is a user in front. The controller then releases the valve and out comes the water or soap (Widyaningrum, 2020). These fixtures provide a contact-free environment for the users especially in high disease transmitting settings like hospitals or hotels.

Most reports on this topic emphasize the advantages of automatic faucet and soap dispensers in water conservation and hand hygiene compliance compared to manual equipment. Effectiveness of automated system in increasing hand hygiene behaviour has been demonstrated in a research study done by Samson Wong a former BCIT Environmental Health student (Wong, 2008). In his study, two types of soap dispensers were set up, a manual pump and an automated dispenser. Wong had concluded that the soap amount used in the automated dispenser was double as much as to the manual pump dispenser. As a result, his findings suggested that the automated dispensers may increase the rate of handwashing (Wong, 2008).

Much of the literature has stated that handwashing is the most abundant task that people do every day, and the amount of water used is countless (Fitriyah et al., 2018). The WHO guidelines and other research indicates for standard handwashing procedures that one should obtain enough soap to cover all surfaces of the hand and rinse with warm water for 20 to 30 seconds, but barely 50% of the population can adhere to that standard (Fitriyah et al., 2018; WHO, n.d.). The design of an automated dispenser would help conserve the amount of water while achieving satisfactory results of hand hygiene due to the preprogrammed design rates (Fitriyah et al., 2018; Widyaningrum, 2020). In the study by Fitriyah et al. they decided to produce a programed faucet that could obey the standard handwashing procedure. They designed an automated system that would dispense water and soap simultaneously; thus, users will be able to achieve the prescribed standard handwashing procedures recognized by the WHO. Their study showed promising results that individuals using their faucets all achieved the handwashing standard in comparison with manual faucets (Fitriyah et al., 2018). In another research study done by Hantrukal et al., they proposed, tested and implemented software onto an automated infrared sensor faucet to increase its performance and satisfy user contentment while conserving water. The strategy they used was to set up software via the MQTT protocol (similar to a server) and link to the faucet to set up different delay times for the water to stop when detecting users' movements of retracting their hands (Hantrakul et al., 2017). Their result showed that a delay time of 0.3 seconds is optimal in respect to conserving water and the user also felt that their handwashing procedures were complete. Anything more or less than 0.3 seconds had shown results of wasting water and not meeting consumer satisfaction (Hantrakul et al., 2017). They have suggested that in future works, the faucets should

advance to learn and adapt different user's behaviour each time to delay, thus conserving water. Interestingly, other studies oppose the installation of automated sensor faucets, especially in hospital settings (Merrer et al., 2005). In a study done by Merrer et al., they compared bacteria contaminations between automatic faucets and manual faucets. They also mentioned that non-touching faucets are common in hospital settings for conserving water, to "optimize handwashing technique," and to reduce recontamination between health practitioners (Merrer et al., 2005). The study was conducted in the hematology and ICU wards in two French hospitals, where there is a high likelihood of infectious viruses and bacteria being present. Shockingly, the result showed that in the "92 [water samples collected] from electronic faucets and 135 from manual faucets [e]lectronic faucets were found significantly more frequently to harbour bacterial contamination than manual faucets, regardless of the ward and the hospital" (Merrer et al., 2005). This seems to contradict the other studies above. Merrer et al. also mentioned that electronic faucets are marketed as improving hand hygiene but show no evidence to support it (Merrer et al., 2005). In contrast, another report by Beyea, Suzanne C, indicated that the sensor-operated faucets showed no evidence of nosocomial pathogens while all the manual faucets were detected with pathogens in an Austrian hospital, and sensor faucets are a better solution to prevent transmission of nosocomial pathogens (Beyea, 2003). The report also suggested that clinical staff should monitor water quality when a new faucet is installed to minimize risks (Beyea, 2003). Further studies on bacteria growth on automated faucets may be conducted to present better evidence to the public.

During the COVID-19 pandemic, proper hand hygiene has been massively emphasized and promoted, especially in health care facilities such as hospitals or residential care facilities and public premises. More cost-efficient designs are emerging on the market concerning automated water, sanitizer, soap dispensers and other tools for eliminating contact and spreading the disease. The study done by Wanga et al. illustrated how simple and low-cost technology nowadays can be in terms of designing automated handwashing stations in the shortage of time to combat COVID-19 in countries like Tanzania (Wanga & Pearce, 2020). They described the parts that they used to assemble the equipment and the system's flow in their report. They implemented a solar panel instead of the traditional electric cord, which is also cost-efficient for lower-income countries. Interestingly, they also suggested having further studies to produce a low price while durable system and can also implement to dispense other liquids. It seems like a trend that we are likely moving toward a semi or fully automated world shortly.

Racial discrimination in technology:

These technologies and innovations have significantly increased hand hygiene compliance in many settings, but machinery can also have downsides at the same time. It is not news that technology has had flaws and will continue to because humans design the technology, and humans can make mistakes. However, it should be brought to the public's attention when it comes to a topic as sensitive as racism.

The infrared sensor in automated faucets and soap dispensers is undoubtedly a tremendous technological output for reducing contact and avoiding spreading diseases like COVID-19 and helping prevent recontamination of cleaned hands (Wanga & Pearce, 2020). However, the disadvantages that also come along with advanced technologies should not be neglected. A study conducted by Bourlai et al., recognized that the near-infrared sensor to detect human activity differs from when light is present and when it is absent in security applications, so they conducted experiments at nighttime using the visible and near-infrared image and some other capturing tools (Bourlai et al., 2012). Although there is a slight difference in working mechanism for photo capturing and the sensor faucet infrared sensors, the idea behind them is the same that their recognition in a dark environment is low. Another study regarding skin detection using near-infrared by Kanazawa et al., recognized the different reflecting rates from the human skin with different distances and gave different results when comparing visible and near-infrared image capturing (Kanzawa et al., 2011). They suggested to incorporate other tools such as "a six-band camera that can acquire both three Vis spectrum images and three other NIR spectrum images" (Kanzawa et al., 2011) to work as a combination and help better capture and detect the human skin.

In 2015, a YouTube video drew attention to the public- a dark-skinned man attending a Dragon-con convention "visited a bathroom in the event's host hotel and discovered the soap dispenser, from a British company called Technical Concepts, wouldn't sense his hands. When his friend, a white man named Larry, tried after him, out came the soap" (Plenke, 2015). The owner of the video-the African American man then tried the soap dispensers of the entire bathroom and none of them worked for him. Meanwhile, a research paper was done by Hankerson et al., which also related technology with racial bias. This report was done during the "Black Lives Matter" campaign in the US. In their report, several examples of technological flaws were mentioned. The first example is the automated faucet. With the infrared sensor, darker skin would absorb more and reflect less of the beam sent out by the sensor than lighter skin, and thus, it would not reach the receptor to allow water or soap to be discharged (Hankerson et al., 2016). The authors also mentioned that this issue had been recognized since the 1990s. The faucet could be "adjusted for the range of the beam…but nowhere do these major brands of faucets allow adjustment of the sensor sensitivity for darker-skinned users [and] consumer literature only shows Caucasian people" (Hankerson et al., 2016). Yet, sensor faucets sold in India are adjusted to fit darker skin tones according to the authors. More recently, the authors also described two more examples of technology and racism. The Apple iWatch discriminates against darker-skinned individuals when they try to pay with Apple Pay. The watch appears to think that it lost contact with the user's skin and would not allow them to complete the transaction. Apple then confirmed that darker and red ink tattoos could affect the sensitivity of the iWatch but made no comment on racial implications according to the authors (Hankerson et al., 2016). Another extreme

example presented by the authors was that Google Photos labelled a photo of two dark-skinned individuals as gorillas. The author suggested that this indicated the "under representations of minorities in the Silicon Valley" (Hankerson et al., 2016) and that these situations could have been prevented if they had tested more with racial diversity data before any technology was launched (Hankerson et al., 2016).

Several news articles also commented on that particular video regarding the African American man trying out different soap dispensers, with one article mentioning that for the technology industry, "The less diversity there is in a workplace environment, the more likely major design flaws will be present that only affect people of colour" (Goethe, 2019), similar to the previous report. In addition, a research study conducted by Denise, J revealed that most technology and innovations were originally developed in Northern California, where the "Silicon Valley" resides. She also commented that "the [technology] industry, like the region, carries with it the inequalities of race, class, and gender" (Daniels, 2015). The author suggested that there is a lack of diversity in the tech industry and the internet world. She indicated that the tech world is "colour-blind" and is "choosing to see whiteness." The author further suggested that to move forward, we should "[recognize] the deep roots of racial inequality in existing social structures that shape technoculture" (Daniels, 2015), and work around it.

Racial discrimination and Health Outcomes:

Racism itself is one of the components in the social determinants of health. Minority populations are more susceptible to many diseases compared to other population groups. Racial discrimination or racism is defined in the report by Paradies et al., "as organized systems within societies that cause avoidable and unfair inequalities in power, resources, capacities and opportunities across racial or ethnic groups" (Paradies et al., 2015). Their study consisted of literature reviews and meta-analyses with the majority of articles focused on racism amongst African Americans in the US. Their finding suggested "that racism is significantly related to poorer health, with the relationship being stronger for poor mental health and weaker for poor physical health" (Paradies et al., 2015) in all of the sources that they conducted their literature review. In the article by Viruell-Fuentes et al., they had also commented that "there is growing evidence that perceived discrimination is associated with lower levels of physical and mental health; poor access to quality health care; and certain deleterious health behaviours across several immigrant groups, including Latino, Asian, and Black immigrants" (Viruell-Fuentes et al., 2012). Living in a diverse country such as Canada, which invites around 300,000 new immigrants per year according to statistics, understanding racial differences is crucial in terms of health equity. Referring back to the faucet example, to improve equity, a more impeccable design should be considered to fit with different populations' needs in order to achieve an equitable delivery in different interventions and minimize adverse health outcomes.

Conclusion:

To date, racial bias in technology development has not become transparent, but

there is some evidence showing that it is embedded in many urban designs. Although many designs have increased the convenience for human activities (Wong, 2008), many others such as the false facial recognition example has also shown flaws. Thus, equity in society should be considered when new intervention emerges specially to ensure equitable delivery in health in the areas of public health

The research study focused on the IR sensor faucet at BCIT and whether performance is affected by skin tones. Other published research has also suggested implementing a different type of sensor for this type of washroom equipment, one that works differently from the IR faucet. An example is an ultrasonic sensor, which senses the object within a certain distance rather than needing to reflect the information to the valves and then turn on or off the tab (Widyaningrum, 2020). However, most faucets on the market use the IR sensor because it is relatively inexpensive (Frankiewicz & Cupek, 2013).

In terms of handwashing techniques, if the contact time with soap and water does not satisfy a certain time, it reduces the efficacy of handwashing. Therefore, if the sensor cannot detect people with different skin shades, it could discourage proper handwashing behaviour amongst those with low sensitivity and thus increase the chance of disease transmissions.

Methods and materials:

Materials:

- Human Hand
- Infrared (IR) sensor faucet in BCIT female washroom first floor in building SE6 (Model: SLOAN EAF-150)
- Coloured cards cut out in hand shape in accordance with the Fitzpatrick skin types (Fitzpatrick, T. B. 1975)
- Laptop for data entry and statistical analysis
- Stopwatch app on the phone for tracking time

Standard methods:

An experimental study was used in this research. As no previous studies have been identified on sensor sensitivity of faucets and skin shades, there were no previous methodologies to refer to. The study implemented the Fitzpatrick skin type scale (Fitzpatrick, T. B. 1975), which comprises six different skin types in humans, as the standards for skin shades. Thirty-four coloured cards were printed for each of the six skin shade types at a print shop to match the colours on the Fitzpatrick skin type scale. Thirty-four cards were printed for each skin shades to ensure that there were thirty samples for each skin shade at a minimum, and that there could be extras for the pilot study. These cards were cut into identical hand shapes which were attached to and to fully cover the researcher's hand. The "hands" were presented in front of the sensor and time needed for water to be released from the faucet was timed and recorded.

Figure 1: Samples of hand-shaped Fitzpatrick Scale

Figure 2: the Fitzpatrick Scale

In addition to the materials, a classmate consented to assist with the water dispensing timing on her iPhone using an internal timer app. A BCIT facility member provided the researcher the locations of the different automatic faucets on campus. From this, it was decided that the infrared sensor faucet in the female washroom located on the first floor in building SE6 would be tested. The brand and model of the faucet used for this study is SLOAN EAF-150; this is an infrared sensor faucet that fits into the criteria of this study.

Figure 3: SLOAN EAF-150 Faucet

For each six skin type experiments, 30 time measurements were taken. Hence there were a total of 180 data points. The order of presenting the “hands” against the faucet was: thirty samples of skin type 1 followed by thirty samples of skin type 2, followed by, thirty samples of skin type 3, followed by thirty samples of skin type 4, followed by thirty samples of skin type 5 and finally, thirty samples of skin type 6.

During the experiment, the classmate controlled the timer and counted in seconds to assess how long it took for the water faucet to react and dispense water with each different type of skin shade. The results were recorded as raw data on a notepad after every time the timer stopped for each of the tests of the six different skin shades. This information was then transferred onto an Excel sheet after the experiment. To ensure the consistency of the result, the point where the researcher stood remained constant, as demonstrated in Figure 6:by always standing two tiles away from the sink. For each skin shade, the timer started when the "hand" reached out from the edge towards the faucet. Every time, as a reference tool, the hand's middle finger would reach out to a position to be just touching the edge of the sink below the faucet and at an angle of 40-45^{o}C tilt against the faucet, and when water first began to dispense, the timer stopped.

<u>The Fizpatrick scale:</u>

The Fitzpatrick scale was developed in 1975 by Thomas B. Fitzpatrick, a dermatologist who studyed skin cancer. He subdivided the human skin tones into six different types to categorize the susceptibility to sunburns. They are:

"

- Type 1 – typically has a light, ivory skin but when exposed to the sun always burns and peels but never tans.

- Type 2 – has a light, fair complexion and burns quickly when exposed to the sun and rarely tans.
- Type 3 – usually has a beige tint to the skin and may burn when exposed to the sun, but is capable of tanning.
- Type 4 – this is a person with an olive skin or light brown tone and will not freckle when exposed to the sun. This person rarely gets a sun burn and tans regularly.
- Type 5 – is a dark brown or black skin tone, rarely gets a sun burn and always tans under sun exposure.
- Type 6 – is black and is the darkest skin tone. This person never burns when exposed to the sun."

  (The Fitzpatrick Scale., 2020)

Even though the primary purpose of this scale is to predict skin tolerance to the sun, it is clinically recognized worldwide (Verywell Health, 2020). It is also used in many other skin treatment settings, such as facial treatment and laser treatment. It is used to see how a patient will react to these treatments (Verywell Health, 2020). Therefore, the Fitzpatrick scale is a reliable and valid tool for this research design.

Ethical Consideration:

In terms of ethical consideration, there are "ethical issues that are raised when people are involved as participants in research" (Kirschenmann, 2021). There are three core principles to be considered in a research study: Respect for Persons, Concern for Welfare, and Justice, set out in the Tri-Council Policy Statement (TCPS2) are being adhered to by researchers (Government of Canada, 2018). Referring back to the alternative methods, the researcher had considered that dividing people into different skin colours can be a sensitive issue and thus can discourage people from participating in the research. Furthermore, it would not be respectful to assign skin type colours to individuals because the researcher does not possess any clinical credentials and could misclassify the skin colours of the individuals. As a result, it would be both unethical and possibly threaten the conclusion of the study. Therefore, performing the test on the researcher's hand solely referencing the Fitzpatrick scale would eliminate ethical concerns and ensure the study's validity and reliability.

Inclusion and exclusion criteria:

Since this study did not involve humans as the participants except for the researcher's hand, the inclusion criteria are just the researcher herself and her classmate and the timer.

Statistical Analysis:

Description of data:

The data collected in this study was numerical, in seconds for testing the reaction time of the IR sensor faucet to dispense water under different skin types.

Descriptive statistics:

Data as time in seconds was recorded onto an Excel sheet. A summary table consisting of the count, sum, and mean of each column of data was calculated and presented using Excel's internal data analysis function. It was

noted that for skin type 6, there were only five instances where water dispensed.

Figure 4: ANOVA summary table for data recorded by Excel

Inferential statistics:

The statistical test used to analyze this numerical data was the One-way ANOVA. An ANOVA test is used when testing three or more means to see the differences between them (Heacock, 2021). One-way ANOVA was chosen for this study because only one independent variable was tested in the study (ANOVA Test, 2021).

This study was a non-parametric test because the data was not normally distributed in the population. (IBM, (n.d.).) In addition, the data also exhibited unequal variances. Therefore, the Kruskal-Wallis test was used for analysis. (Heacock, 2021). When analyzing the result, the raw data was exported from the Excel sheet to NCSS for inferential analysis.

Ho and H_A	Test used	Result	Conclusion
Ho: There is no difference in the water dispensing time from the infrared faucet between each of the six different skin types from the Fitzpatrick scale. Ha: There is a difference in the water dispensing time from the infrared faucet between each of the six different skin types from the Fitzpatrick scale.	One-way ANOVA: Kruskal-Wallis test	P=0.000 Power=1 or 100%	Reject Ho and conclude that there is a statistically significant difference between the six types of skin shades and the reaction time of the IR sensor faucet. As skin shade darkened, the reaction time for the faucet to dispense water increased. Type 6 only had 5 valid responses that activated the faucets, but they are still considered meaningful for the study. It was also noticed that type 1 was different from type 3, 4, 5, 6. Type 2 was different from type 5, 6. Type 3 was different from type 1 and 6. Type 4 was

			different from type 1 and 6. Type 5 was different from type 1, 2, 6. Type 6 was different from type 1, 2, 3, 4, 5.

Table 1: Null and alternate hypothesis

Discussion:

The objective of this study was to determine whether technology may introduce racial differences, particularly with the IR sensor faucet. The results indicated statistically significant differences between the six skin shades and the reaction time for the faucet. Both the descriptive and inferential statistical analysis, agreed with the report done by Hankerson et al. (2016), the darkest skin type did not dispense water most of the time. The results also further corroborated the YouTube video from an African American individual was not only buzzworthy but also had particular merit to it (Plenke, 2015). The ANOVA resulted in a p-value of 0.000, which indicated that a null hypothesis being true is unlikely, and alpha errors are also insignificant. The power of the study was at 100%, indicating that the results of the study were unlikely to be false. In relation to public health, individuals with darker skin shades may be more susceptible to diseases. Referring to the result of the study, they may not have enough contact time and may not be able to wash their hands using these IR faucets properly.

Unfortunately, no similar studies were available to compare with this one. However, it was noticed that many published reports and articles also mentioned potential discrimination on different skin tones on smart electronic devices. Examples include sensitivities of iWatch when using to pay from Apple which was affected by dark skin tones, and Google Photo labelling dark-skinned individuals as gorillas (Hankerson et al., 2016). Several recent news articles also illustrated the frustrations in technology regarding racial differences. A news article dated November 2021 summarized a study done by a doctor from the University of Michigan. He found out that the pulse oximeter devices used clinically to detect blood oxygen levels have a “"significant discrepancy" in the device's accuracy when used on patients with a darker skin tone” (BBC News, 2021). The oximeter works similarly to an IR faucet in how the device beams out a light onto the user and bounce back for detection. For the oximeter, a light beam through the blood “and skin pigmentation may affect how light is absorbed” (BBC News, 2021). Therefore, the readings on the oximeter may not be accurately presented. These limitations were crucial during the COVID-19 pandemic as they could prevent the patient from receiving the appropriate care (BBC News, 2021). This also aligns with the question set out for this research.

This experiment sets out a preliminary study and precedent for further investigations into whether the different opportunities or

inequities between races are truly present in modern technologies. This should also alert corresponding agencies to conceptualize solutions.

Limitations:

This study aimed to determine if there is bias in the IR faucet regarding different human skin shades in terms of water dispensing reactions. Ideally, recruiting people of varying skin colour would have been the best study target. However, due to the budget and time constraint and ethical considerations, to include actual humans was deemed unfeasible. The study was done by using color card and in order of the different skin shades-30 samples of skin type 1 followed by 30 samples of skin type 2 …etc, and this may have limited randomization. Given the time and money constraint, only one brand of IR sensor faucet was chosen. This may not have been representative for other brands as different brands may have different sensitivities. Therefore, if more time and money were allowed, the study should compare the different faucet brands.

Another factor that could have affected the result of the study is the selection of a classmate who knew the purpose of this study to assist with timekeeping. This may have introduced information bias. However, the classmate's professionalism was ensured during the pilot study to minimize bias. Lastly, there are no studies with similar methods to date and therefore there are no results to compare with and no guidelines to follow.

Knowledge Translation:

This study suggested that there is racial bias in the IR sensor faucet. The central theme of this study can be further utilized to investigate other advanced technologies to examine if there are similar types of bias in other forms of technologies, whether used in everyday life or even in other professional fields. The findings of this study should help advocate for equal opportunities when experiencing different technologies. Another recent example of a similar inequity presented in a news article described darker skin bias in smartphone cameras (Dunne, 2022). This news article illustrated the frustrations in the photographic industry to accurately capture and represent colour and darker skinned individuals in photos for decades. This was because “A "norm of whiteness" existed among those who created the film,” as commented per the researcher in this new article (Dunne, 2022). This gave the public the idea that the development of these technologies may be under the control of non-coloured individuals.

There is a need to increase awareness and improve guidelines in the industry for advanced technology inventions. These should be implemented to help avoid further complications. Such practices should include government agencies funding and encouraging further research to include different ethnic individuals in the professional groups on future technology developments to help eliminate embedded racial bias in the industry. Other practices may consist of choosing alternative equipment to be used that may not result in inequalities and inequities—for instance, using a movement detecting device as a trigger for dispensing water rather than

something debatable such as the IR sensor. And of course, education to allow the populations to know that these inequities may exist is also important and should be put forward.

Future Research:

The following are recommended research ideas to further fill in the knowledge gaps:

- The same method as this study but to enhance validity and reliability: (i) Compare various brands of IR faucet, (ii) Ensure to randomly allocate the skin shades cards between each test, and (iii) select a person who is not a classmate, nor aware of the study's hypothesis to help with timekeeping, thereby minimizing bias
- Use the same method but with real multiracial people as targets of study
- Also, use the same methodology but have an engineer install a timer within the faucet system to allow more accurate time capturing during the study.

Conclusion:

Advanced technologies have improved and are integrated into humans' daily lives. However, more news articles are emerging that comment on the different opportunities between different skin shade individuals when experiencing the same piece of technology. This issue is often overlooked when creating and developing the technology, resulting in unequal opportunities. This research study was conducted with the idea of the effect of IR sensor faucet reaction time to hand hygiene. The result of this study has suggested that there are biases between different skin-toned individuals in terms of the IR sensor faucet. The presence of varying reaction times between different skin shades with the faucet may reduce proper hand hygiene practices. As a result, it could make those whose skin shades induce a more prolonged reaction time more likely to avoid hand washing, and thereby, more vulnerable to diseases. These biases may be unintentional; however, organizations should still be alerted to the possibility that there may be bias in certain new technologies and to be cognisant of being more inclusive thereby ensuring more equity in society.

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Competing Interest:

The authors declare that they have no competing interests while conducting this study.

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