Design of a Fan-Powered Face Mask with Advanced Filtration Capability

(Technical Paper)

What We Can Learn from Hurricane Katrina: Applying Lessons Learned to the Response and Recovery of the United States After COVID-19

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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.

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Addressing Issues with Current Masks and Adoption Factors

In the 10 months since COVID-19 began infecting people in Wuhan, China, the illness has spread worldwide and ravaged individual and economic health, alike. According to the New York Times, there have been over 1.1 million reported deaths worldwide, as of October 20, 2020 (Times 2020). In addition to loss of life, economies around the world have suffered greatly. From the beginning of April to the end of June, the United States gross domestic product declined 31% which "was more than three times larger than the previous record-holder" (U.S. economy plunges 2020). With a pandemic raging across the world, it is very important that we do whatever is within our power to slow viral spread.

More than just individual humans, companies and governments are investing heavily in ways to combat COVID-19. According to the U.S. Department of State, the U.S. has allocated $20.5 billion towards "international response, including commitments for the development of vaccines and therapeutics, preparedness efforts, and foreign assistance" (UPDATE 2020). This investment is one of many large expenditures made from public and private sources in the hopes of reducing the severity of COVID-19. Due to abundant investment, new technologies and techniques are constantly being developed to minimize the spread of the virus, but one of the simplest and cheapest strategies, the facemask, has been a controversial topic and, in some areas, lacks the necessary adherence to be effective (Eikenberry 2020). Even when the compliance rates are high, face masks are not perfect. They all have drawbacks, whether comfort or efficacy concerns there is no perfect mask.

Due to the imperfect nature of current masks, the technical topic for this prospectus will be centered around the creation of a superior, novel mask which has electric fans to assist with filtration, breathing, and comfort. The STS topic of this prospectus is to analyze the factors

which affect adoption of masks. This process of understanding the factors which drive adoption of facemasks will help investigate ways in which the public adoption rate could be increased.

Building an Electric Assist Fan Powered N95 Mask

The worldwide death toll of over one million is one of many reasons to create solutions which offer better protection and comfort than has been seen in the past (COVID-19 MAP, 2020). Current mask technology has two main designs: non-powered, or passive, systems and fan powered systems. When properly designed, non-powered systems consist of filter material that covers the nose and mouth to prevent aerosols that contain viruses from entering and exiting the body from inhalation and exhalation. Properly filtering both inhalation and exhalation is crucial to protect both the wearer, if others are infected, and others, if the user is infected. This technology, such as an N95 mask, shown in Figure 1, is effective but uncomfortable to breathe in for long periods of time (Mayo Clinic Staff, 2020). In contrast, fan powered designs force air through a filtration system and provide constant airflow across the face. This design, such as a powered air purifying respirator (PAPR) can be worn for extended periods. The PAPR is not without its flaws though; as can be seen in Figure 1, the respirator is large and bulky. Most importantly, the PAPR fails to filter exhalation air, meaning that those nearby are at risk if the person wearing the PAPR is contagious (CDC, 2020). Ideally, combining the capability to filter inhalation and exhalation air in non-powered systems with the ease of breathing in fan powered systems would create the best user experience and the highest possible level of safety.

Figure 1: The left image depicts a Honeywell PAPR. The PAPR consists of the full hood, fanny pack blower, and tubing (Serban 2020). The right image shows a passive N-95 filter in use (Letzter 2020).

The final technical deliverable will be a powered mask system that filters inhalation and exhalation. Research on current standards associated with powered systems will help inform design requirements and initial prototype designs (Ann, 2020). Current mask designs, such as a half-face respirator or continuous positive airway pressure (CPAP) mask, will be repurposed to ensure that the final product's fit on the face meets current Occupational Safety and Health Administration (OSHA) standards (Respirator Fit Testing, 2020). This mask design will be combined with a 3D printed housing that will contain a fan, filter material, and potentially a battery unit. As this specific type of mask has not been produced and made widely available to the general public yet, the development of the technical deliverable will present many challenges.

The final deliverable will be assessed with three metrics: computational fluid dynamics (CFD) analysis in SolidWorks, tests of breathability through in person trails, and performance in an OSHA mock fit test. CFD will be used to assess the overall airflow throughout the system and help to determine if a proper amount of air is being supplied for the user. As CFD cannot supplement real world application, an actual test will assess the ease of breathing through a qualitative comparison between the final deliverable and an N95 mask. Finally, a mock fit test

will be performed to determine if the final system properly filters inhalation and exhalation air. This fit test will consist of spraying a bitter, Bitrex, solution within an enclosed environment. If the user cannot smell the solution, then the mask functions properly and effectively filters air. (Respirator Fit Testing, 2020). The development of this mask will drastically improve the safety and comfort of the general public. This mask could allow people to return to the office and reinvigorate public places because a contagious person would not be able to emit aerosolized particles. On the other hand, people who are not immune would not have to worry if their coworkers or fellow shoppers, for example, were contagious because they would only be breathing in filtered air.

Understanding the Driving Forces Behind Mask Adoption to Increase Mask Wearing in Public

Over the past 6 months or so, masks have been disputed as an effective strategy to mitigate the spread of COVID-19 (Xiao, 2020). Despite the disagreement over whether or not to wear masks, a failure to do so could have catastrophic consequences. There are a few reasons that have led to public reluctance to adopt masks. Two major factors which have slowed mask adoption are misguided guidelines and questionable evidence of effectiveness. The STS part of this project hopes to investigate the factors that affect mask adoption, so mask adoption could be increased going forward.

The first main factor influencing mask compliance are the guidelines set in place for the public. Guidelines have told people not to wear masks because they need to be reserved for healthcare workers or that masks are ineffective. For example, “the US Surgeon General advised against buying masks for use by healthy people” (Feng et al. 2020). The Surgeon General recommends that these masks be reserved “for professional use in health-care settings” because

supplies are limited and the general public is not a great enough risk to warrant medical mask use (Feng et al. 2020). The World Health Organization (WHO) corroborates the findings of the Surgeon General, recommending that medical masks only be worn by medical and healthcare workers who are in direct contact with people who may be infected. Staff who are not directly patient facing need not wear masks however (World Health Organization, April 2020). The WHO has since changed its stance, but to a large extent the damage had already been done (World Health Organization, June 2020). Public guidelines have been a major influence for people to disregard masks as a method for mitigating the spread of COVID-19.

Another reason people seem unwilling to comply with mask policies is a perceived lack of effectiveness by the public. For example, Greenhalgh claims that a major reason that "various authors have justified not wearing masks… is limited evidence that they are effective" (Greenhalgh et al., pg 1). People seem to think there is no point in wearing a mask because there lacks evidence showing how effective cloth facemasks really are. As Greenhalgh states, however, that argument is dangerous and "can be challenged on the grounds that absence of evidence is not evidence of absence" (Greenhalgh et al., pg 1). The authors that Greenhalgh writes of must realize that just because there have not been extensive studies showing that facemasks are effective, that is not sufficient evidence to prove they are not. In general, it is extremely important that the public and the policy makers realize that it would be prudent to err on the side of caution because when something is not definitively proven, that does not mean it is untrue.

Despite the various reasons that people do not wear masks, it is quite important going forwards that they do. The long incubation period leads to pre-symptomatic spread which is a major transmitter of COVID-19. First of all, people could be contagious up to 2.5 days before

they are symptomatic (Ferretti et al., 2020, pg. 1). This means that if only symptomatic people wore masks, then there is a two-day window where an infected person can transmit the virus without showing a single symptom, as seen in Figure 2. The 2.5 day lag does not take into account people who are completely asymptomatic.

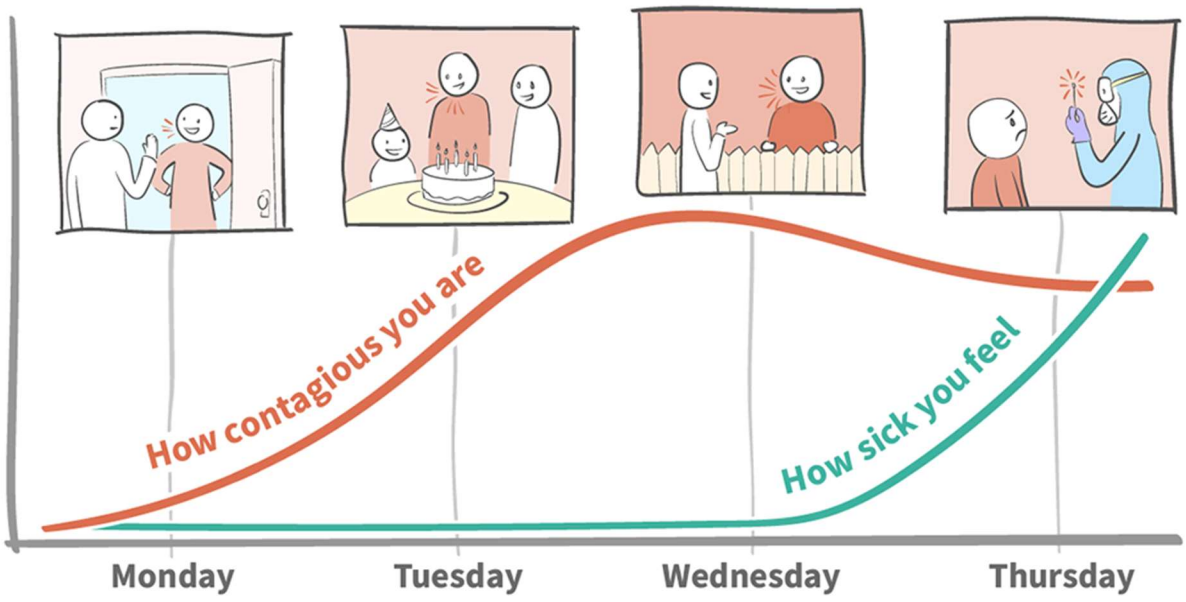

Figure 2: Timeline which displays the average 2.5 day lag of symptoms behind levels of contagion (Schive 2020).

Due to the lag of symptoms behind contagion, Ganyani et al. estimates that pre-symptomatic transmission could contribute to over 50% of viral spread (Ganyani et al., 2020, pg. 1). The extremely high transmission rate by people who do not yet show symptoms is one major reason that high mask compliance rates are so crucial to mitigating transmission. Simple mask adoption can save lives. As Eikenberry states in a study "immediate near universal (80%) adoption of moderately (50%) effective masks could prevent on the order of 17–45% of projected deaths over two months in New York" (Eikenberry et al., 2020, pg. 1).

Project Outcomes

The technical deliverable of this project will be a mask which uses electric fan assist to filter air before it is inhaled and after it is exhaled. The mask will allow contagious and non-immune people to mingle with impunity. The STS portion of the project will deliver knowledge of factors which lead to people not adopting masks in the hopes that we can influence higher adoption and compliance rates with masks in the public. With an improved understanding, stakeholders, such as business and governments, will be better able to influence the public to adopt masks. Individuals, governments, and companies all have agendas and priorities when it comes to COVID-19 and Actor Network Theory is an important tool to view the relationships and interactions between the myriad actors. More research into the psychology and cultural norms of mask wearing is needed to fully understand the interpersonal aspects of mask adoption.

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