Improved Performance of N95 Isolation Masks: Enhancing Communication, Fit, and Comfort

Team Members: Nicole Cavett[1], Athenia Jones[1], Julian Kopelove[1], Kailey Mihavetz[1], Priscilla Seah[1]
Advisors: Dr. William Bentley[1], Dr. Jeffrey Hasday[2]
1. The Fischell Department of Bioengineering, University of Maryland, College Park, 2. University of Maryland School of Medicine

THE FISCHELL DEPARTMENT of BIOENGINEERING

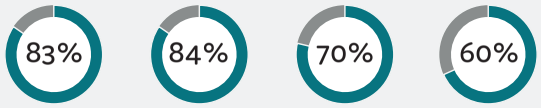
A. JAMES CLARK SCHOOL OF ENGINEERING

Motivations

N95 respirators are important components to personal protective equipment (PPE) as they are designed to reduce the wearer's risk of inhaling hazardous airborne particles.[1]

Studies show that healthcare workers (HCWs) are poorly compliant with respiratory protection guidelines, especially when a N95 respirator is recommended.[1] It has been reported that users have difficulty breathing, difficulty communicating effectively with patients, and discomfort from humidity and temperature

Desired N95 Respirator Characterisitcs



Agree that there is a **need to create a new N95** for healthcare workers.

Prefer a N95 that is **"socially acceptable"** (ie. it doesn't frigthen patients).

Prefer an N95 that **does not require fit testing.**

Prefer a **disposable** respirator instead of a reusable respirator.

Figure 1 . Desired features in a respirator as report by healthcare workers.[1]

Design Concepts

To improve compliance and to reduce the risk of disease transmission, we have developed a prototype with features that improve the fit and comfort of the mask.

Our prototype achieves the following design objectives through the incorporation of novel features:

① Improve the fit of the N95 to ensure effective filtration
② Improve ease of communication
③ Improve heat and humidity regulation

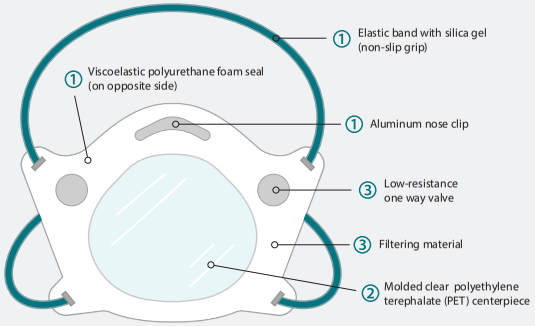


Figure 2. 2D prototype design concept. Numbers in figure correspond to the design objective.

Methods

Temperature and Humidity Testing:

- *Exercise Performed*: Brisk walk for 10 mins. while wearing control (3M 1860) and repeated for prototype
- *Measurement:* Temperature and humidity measurements using a wireless hygrometer (iButton Hygrochron Temperature/Humidity Sensor, Maxim Integrated)

Qualitative Comfort and Communication Testing:

- *Exercise Performed*: User performs 25 jumping-jacks, then blind tested (either with control or prototype).
- *Measurement:* Survery using a 5-point likert scale of 1 to 5 (where 1 = least comfortable/ effective, 3 = neutral, 10 = most comfortable, most effective).

Participants were asked the following survey questions:

① How comfortable is the face seal?
② How comfortable is the temperature of the mask?
③ How strong is the smell of the perfume? (1 = cannot smell, 5 = very strong smell)
④ When the tester is wearing the mask, how well can you read the tester's lips?

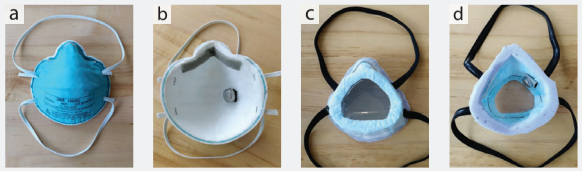


Figure 3. Setup of wireless hygrometer (iButton) in control N95 mask (a) and (b) and in the prototype (c) and (d). Fig. 3 (a) and (c) depict the front of the mask.

Results

Initial testing shows perceived temperature of the prototype is higher due to humidity. Comfort of the seal decreases over time due to high contact pressure. In addition, the ransparent window starts off clear but gradually fogs over time. For additional data and biological replicates see hand out provided.

Hygrometer data shows that he prototype significantly reduced temperature within the mask from 33.18(˚C) to 31.18(˚C) and significantly increased humidity within the mask from 82.31% to 86.12%.

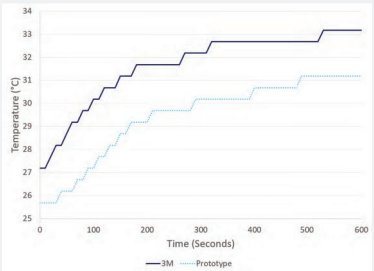


Figure 4. Temperature readings for respirator dead space. Unpaired, two sample t-test used to analyze results between both.

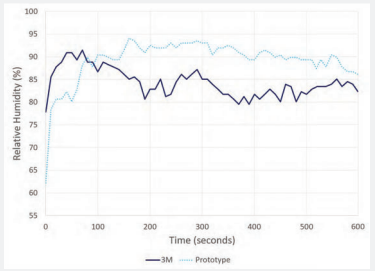


Figure 5. Relative humidity readings for respirator dead space. Unpaired, two sample t-test used to analyze results between both.

Qualitatively, the memory foam seal made the prototype more comfortable around the edges, while also securing a better seal. The percieved temperature was noticeable by the users in both designs. Fogging of the prototype occured after 4 minutes of active use.

Novel Filter Media

Three effective layers:

① Surgical Mask: 99% 0.5 micron particles
② Cellulose fibers: 10% 0.5 micron particles
③ Surgical Mask: 99% 0.5 micron particles

Assumed fully aligned pore diameters for the most conservative estimate, the additive layers of the prototype should theoretically filter 99.991% of 0.5 micron particles (vs. 95.000% of 0.3 micron particles in typical N95 mask).[2]

Conclusions

While maintaining filtration efficiency, our prototype incorporates novel features to improve communication, fit, and comfort from a typical N95 mask.

Table 1. Comparison of features between a typical N95 mask (3M 1860) and our prototype.

Design Concept	Typical N95	Prototype
Communication	Completely opaque	Clear PET centerpiece
Comfort	No exhalation valves	2 one-way exhalation valves
	Charged filter media	Charged filter media
	Thin nose foam pad	Viscoelastic polyurethane seal (periphery of mask)

Ethical Implications

- Improved comfort will increase compliance, leading to greater personal protection and decreased pathogen transmission.
- Improved communication will help mitigate patient intimidation and anxiety, enabling suffering individuals to seek medical attention.
- Our prototype is universally designed so that the increased visibility of the user's mouth will be assistive to patients who are elderly or who have audio impairments (for lip reading).

Future Works

Future iterations of the prototype:

① Will incorporate dessicant to decrease humidity
② Will improve fit of the mask to greater variety head forms
③ Increase the distance of the prototype to the face to increase

References

1. Baig, A. S., Knapp, C., Eagan, A. E., & Radonovich, L. J. (2010). Health care workers views about respirator use and features that should be included in the next generation of respirators. American Journal of Infection Control, 38(1), 18-25. doi:10.1016/j.ajic.2009.09.005

2. Souzandeh, H., Scudiero, L., Wang, Y., & Zhong, W. (2017). A Disposable Multi-Functional Air Filter: Paper Towel/Protein Nanofibers with Gradient Porous Structures for Capturing Pollutants of Broad Species and Sizes. ACS Sustainable Chemistry & Engineering,5(7), 6209-6217. doi:10.1021/acssuschemeng.7b01160