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ARTICLE

To Mask or not to Mask? Why is that Even a Question?

By: Nathaniel James Martin | Edited by: Sara Pietropaolo | Layout by: Ahmed Nadeem

Age: 13 | Winnipeg, MB

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During the COVID-19 pandemic, wearing masks has been controversial. Many scientific studies have examined mask use in various places and concluded that masks help stop the spread of the COVID-19 virus (Budzyn et al., 2021; Donovan et al., 2022; Gettings et al., 2021; Jehn et al., 2021; Hendrix et al., 2020; Leffler et al., 2020; Payne et al., 2020). Yet many news articles have headlines indicating mask use is not effective, and sometimes even dangerous (Zweig, 2021; Margery Smelkinson, 2022). The science in news articles is not reviewed by other scientists, like in scientific journals, so writers can misunderstand the conclusions of studies and take them to mean something they do not. For instance, while the reporter is correct that the CDC study did not find evidence supporting students wearing masks in schools, the CDC study was not designed to test the effectiveness of students wearing masks, so it should not have been used to encourage students not to wear masks in school (Zweig, 2021). The virus causing the COVID-19 pandemic has caused many deaths and hospitalizations (Margery Smelkinson, 2022; University of Oxford, 2022a) and there are many long-term consequences in people who were exposed to the virus (University of Oxford, 2022b; Lopez-Leon et al., 2021). In my opinion, we should try to avoid the virus using safe and effective means, and this project aims to see if masks could be one of those ways.

In this project I examined why masks are important and which types of masks work the best at stopping air and soil from getting through them while they are worn. I conducted 6 experiments to investigate mask effectiveness. In two experiments, I blew air through different masks on a 3D printed head to see how far away people can stand from one other and not be exposed to a breath by measuring how far the air reached. In the next two experiments, I blew dirt through the masks to see which masks best prevent the spread of particles. My fifth experiment measured how far I could see fog from my breath outside and my sixth experiment measured the time it took for my glasses to fog in different masks. My long-term goal is to combine the best properties of the masks to design a better mask.

Question: Do masks help migrate/decrease the spread of particles, and should they be used? Overall, my hypothesis is that masks will significantly reduce the distance over which air and soil (mimicking viruses) coming from the mouth can be detected. For Experiments 1, 3, 4, and 5, I predict that the N95 masks will be the best at stopping the air and dust from moving very far because they create more space for air to be in the mask, they form a seal against the wearer's face so that particles cannot escape around the edges, and most importantly they prevent 95% of airborne particles from moving away from the person wearing the mask. For Experiment 2 my prediction is that wearing two masks will be better than wearing one mask. For Experiment 6 my prediction is that my glasses will fog the slowest with N95 masks. My N95 masks have a tight seal and hopefully will not let any air through the top, making my glasses fog slower.

MATERIALS AND METHODS

Designing the experiments: I put a mask on the 3D printed head to blow air and detect how far away it can be measured. To control as much as possible, I made a 3D printed head for the shape to be correct. I chose the typical sized head of someone 152 cm tall. To control distance, I designed a ruler that could be 3D printed and consistently attached to the head, so the distance was consistent for each experiment. The head was designed so that a turkey baster could slide through. When the ball of the turkey baster was pressed, air would come from the head's mouth.

I constructed a LEGO bridge and placed it over the ruler with a piece of toilet paper hanging from the bridge. I used one bridge and moved the bridge to different distances and blew air at each distance to see if I could detect it. I measured the distance the toilet paper wiggled when I was doing absolutely nothing to make it wiggle and that distance seemed to be consistent. I called this distance the "background wiggle." When I used the turkey baster, I measured the approximate distance the toilet paper wiggled and if it was bigger than the "background wiggle" I would count it as "detected air movement". For the experiments with soil, I measured the farthest distance where soiled landed.

MATERIALS:

- 3D printed head
- 17 masks
- Turkey baster
- LEGO
- Toilet paper
- Meter stick
- 3D printed ruler
- 3D printed head
- Plastic ruler
- Computer screen
- Measuring spoon
- Soil
- Sieves
- Brush
- Phone (camera and timer)
- Excel

Table 1. Experiment Descriptions

Experiment 1	I used a mask on the head to find which mask works best to stop air getting through.
Experiment 2	I used two masks on the head instead of one. The goal of this is to find if double masking helps stop air from getting through masks.
Experiment 3	I used larger soil to teach me about how soil passes through masks. The goal is to find which masks help stop particles from passing through.
Experiment 4	I used smaller soil closer to the size of viruses in droplets to find which masks help stop smaller particles from passing through.
Experiment 5	I saw how far fog went away from my face outside with different masks. This was to try to get a more accurate/different approach to finding which masks stop air better.
Experiment 6	I tested how long it took for my glasses to fog outside using different masks. This was to determine which mask is the best to wear outside for people with glasses, like me.

Controls: Same measuring device, same squeeze of the turkey baster, same threshold, same soil. Variable: Mask (Experiment 1, 3, 4,5, and 6). Masks (Experiment 2) The different masks and the 3D printed head are shown in Figure 1.

Experiment 1: Using 10 different masks on the head, I blew air through each mask with a turkey baster to determine at what distance a person can stand and not be exposed to the air when a mask is worn. Using the Lego-toilet paper measuring device. I found the farthest distance at which air could be detected, to the nearest centimeter. Each mask was tested 3 times.

Experiment 2: I used 9 different combinations of double masks with the N95, the surgical mask recommended in schools, and the cloth mask that let through air only on one trial. I repeated the procedure from the first experiment.

Experiment 3: I put soil between 75 µm and 1 mm in the mouth and the blew the turkey baster to send the soil through the mask. I measured the position of the soil that landed on the paper farthest from the head.

Experiment 4: This was the same as Experiment 3 but with soil smaller than 45 µm, measuring forward and side distance because in Experiment 3, the soil also went sideways.

Experiment 5: I froze the film of the camera filming me when I could see the fog the farthest from my mouth and measured the distance on the screen from the middle of my mouth to the edge of the fog. I took that number and measured that length on the meter stick in the picture to get the actual distance. I did 3 trials for each mask and each direction.

Experiment 6: I sat outside on a humid day wearing a mask and timed how long it took for my glasses to fog. I used the mask from China, then the N95 mask. I started a timer as soon as I went outside, sat on the porch, and then stopped the timer when my glasses fogged. Between each trial I dried my glasses. I did 3 trials for each mask.

RESULTS

I calculated and plotted the average and standard deviation of the three measurements from the trials for each mask.

EXPERIMENT 1

The cotton mask barely shortened the distance from the face that air movement could be detected. The other fabric masks varied in their results. The surgical masks performed about as well as the poorer fabric masks. The N95 masks did not allow air to be detected at all, just like the very large mask from China. See Figure 2.

EXPERIMENT 2

Any time an N95 mask was used either on the bottom or top, or both, no air movement was detected. When the surgical mask and fabric mask were used together in either order, no air movement was detected. Double surgical masks allowed air to be detected close to the head. The double fabric mask allowed the air to be detected the furthest away from the head. See Figure 3.

EXPERIMENT 3

In cases where the mask did not fit properly, soil came out the

Figure 1. The materials for my experiment. Figure 1a): Experiments 1, 2, 3, and 4: The masks I tested in my project next to the 3D printed head used for testing and the 3D printed ruler used for measuring. The turkey baster is inside the head. Figure 1b) The masks I tested for Experiment 5. I used these new masks because the previous ones were covered in soil.

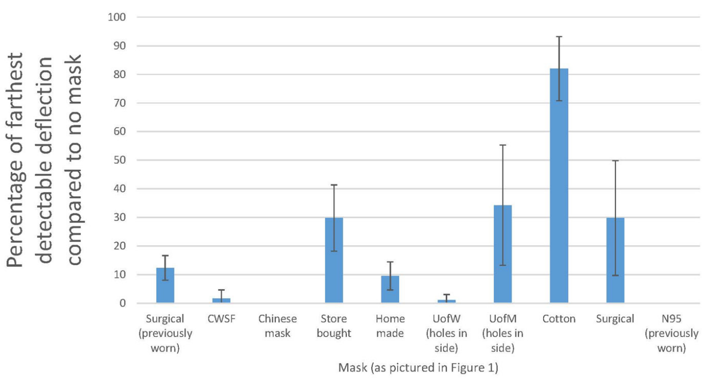

Figure 2: Experiment 1: This graph shows the shows the percentage of the average farthest detected air distance from a mask compared to no mask. The bars represent the average of 3 different measurements. The error bars represent the standard deviation of the 3 measurements. They give an estimation of the spread in the measurements. Two masks did not allow detectable air to pass through them. The cotton mask barely performed better than no mask.

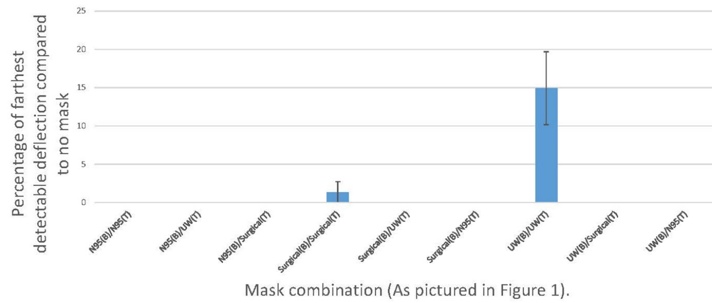

Figure 3: Experiment 2. The results from double masking. B indicates mask on the bottom, closest to the head. T indicates mask on the top, farthest from the head. Only two combinations of double masks allowed air to be detected.

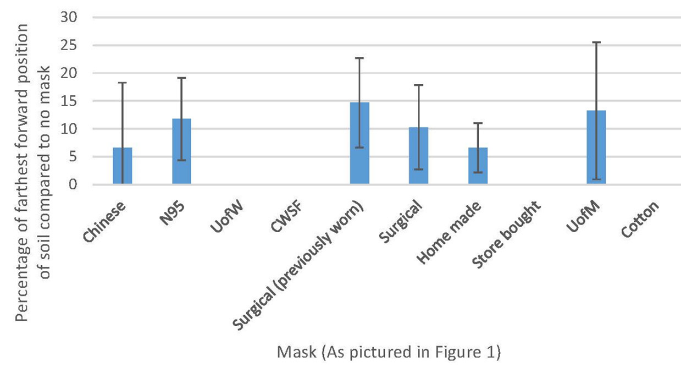

Figure 4: Experiment 3: The percentage distance of farthest forward position of bigger soil compared with no mask. Plotted is the comparison of forward distances the soil moved, not the sideways, backwards, upwards, or downwards movement. Four masks had no measurable forward movement of soil.

sides or top or bottom. It moved far, but not necessarily straight. Measurements of the distance the soil moved were only made in the forward direction and are shown in Figure 4. The fabric masks were the only masks where the soil went forward, sometimes only after the fit was adjusted. The store-bought mask caught the soil in a pocket, so no soil was detected. The N95 and surgical masks let soil through places that were not sealed.

EXPERIMENT 4

While the surgical masks prevented the soil from being in the front of the head, beside and behind the head there was a lot of soil because the soil came out the sides. The soil from the N95 mask came out the top and landed on the mask except for one piece that landed in front of the head. Once again, the store-bought mask caught the soil in a pocket, so no soil was detected. In only one trial, the homemade mask only let a small amount of soil straight through a small distance. The data are summarized in Figure 5.

EXPERIMENT 5

Experiment 5: The fog was visible from all masks and moved in different directions depending on the mask. Sometimes the fog moved in front of my mouth, sometimes beside my mouth, sometimes behind my head. The Chinese mask performed the best with the farthest point of the fog visible being closest to my mouth.

EXPERIMENT 6

Figure 7 shows the time in seconds it took until my glasses fogged for three trials for each mask. My glasses fogged faster and faster for each of the six trials.

DISCUSSION

For all experiments, the standard deviation gives an idea of the spread in my measurements which could be caused from me not controlling everything well. For example, I tried to push the turkey baster as hard each time, but I could have differed.

Experiment 1: The cotton mask barely shortened the dis-

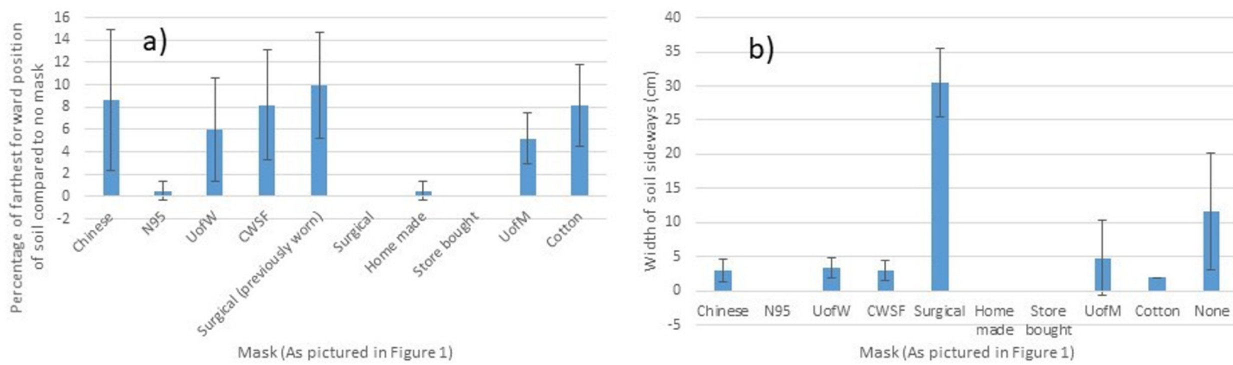

Figure 5: Experiment 4: Figure 5a: The percentage distance of farthest forward position of smaller soil compared with no mask. Plotted is the comparison of forward distances the soil moved, not the sideways, backwards, upwards, or downwards movement. Figure 5b: describes the width of the soil that landed from one side of the head to the other. Most masks allowed the soil to pass through, some in one direction, some in more than one direction.

tance from the face that air movement could be detected. The other fabric masks varied in their results. To me, it seemed fit was important once enough layers were part of the mask. The surgical masks, which did not fit well, performed about as well as the fabric masks that did not fit well. The N95 masks did not allow air to be detected at all, just like the very large mask from China. Future experiments should find the best fit mask of each type for comparisons so that the comparisons can be made based more on material rather than fit. Another future experiment could test several sizes of the same mask to test the importance of fit for each material.

Experiment 2: Any time an N95 mask was used either on the bottom or top, or both, no air movement was detected. When the surgical mask and fabric mask were used together in either order, no air movement was detected. I think this might be because the tight fabric mask helped the surgical mask fit better. Double surgical masks allowed air to be detected close to the head and I believe that is because the pair of masks still did not fit well. The double fabric mask allowed the air to be detected the furthest away from the head. I believe this is because the combination was so tight and the ear loops so thick that the pair did not fit the head well. I believe I was able to detect air movement farther from the head for this experiment because the background noise was smaller.

Experiment 3: This Figure might be misleading. In cases where the mask did not fit properly, soil came out the sides or top or bottom. It moved far, but not necessarily straight so the graph shows a small distance because it only shows the forward distance. The fabric masks were the only masks where the soil went forward, sometimes only after the fit was adjusted. The N95 and surgical masks let soil through places that were not sealed. Masks did better if they fit well. The store-bought mask collected the soil like a pocket and did not allow any soil to pass through.

Experiment 4: Once again soil would come out wherever there was not a tight seal. In most cases, the soil also came out straight from the mask in a cloud. While the surgical masks prevented the soil from being in the front of the head, beside and behind the head there was a lot of soil because the soil came out the sides. The soil from the N95 mask came out the top and landed on the mask except for one piece that landed in front of the head. Once again, the store-bought mask caught the soil in a pocket, so no soil was detected. In only one trial, the home-made mask only let a small amount of soil straight through a small distance.

Experiment 5: The fog moved in different directions depending on the mask. The Chinese mask performed the best with the farthest point of the fog visible being closest to my mouth.

Experiment 6: My third experiment did not work as planned. I sat outside on a humid day wearing a mask and timed how long it took for my glasses to fog. I used the mask from China first. Between each trial I dried my glasses well. After the first mask, I put on an N95 mask and repeated the experiment. For the third trial of the second mask, my glasses fogged as soon as I opened the door. My glasses fogged faster and faster for each of the six trials. I have plans to redesign this experiment to have better controls. For instance, I should allow my glasses to return to the same starting temperature before each trial.

DESIGN FLAWS AND LIMITATION

The overall design of the project took several months of careful planning. Dental floss was the original detection device on the LEGO bridges, but it was too thin to detect every blow and static electricity would cause it to stick to the side of the LEGO bridge when it did detect the blow. The toilet paper, the detection device used, had to fit through the opening in the Lego bridge to detect the air properly. Only one bridge was used and moved because when I placed several LEGO bridges with toilet paper along the ruler, I noticed the toilet paper farther from the head would move less when there were bridges and toilet paper in front of it than when it was the only bridge over the ruler.

The major issue with the toilet paper was that it moved too much when air was not blowing from the turkey baster. I thought of some possible reasons;

1. My breathing moved the toilet paper, so I wore a mask and the toilet paper still moved, but not as much as before.

2. Vibrations from people moving on the moved the toilet paper. I tried moving to different surfaces and found the least shaky one, but the toilet paper still moved. I asked my parents to leave the house so it would be still, but the toilet paper still moved.

3. I thought the air through our vents moved the toilet paper, so I turned off the furnace and the toilet paper still moved. I put the LEGO bridge inside an upside-down cardboard box to block air and vibrations, but the toilet paper still moved. I could not squeeze the turkey baster and read the ruler inside the box.

4. When I pushed the squeeze the turkey baster it seemed to make vibrations because the turkey baster was attached head and the ruler which is touching the LEGO bridge. So, I made the LEGO bridge wider so if the apparatus wiggled, the toilet paper would not wiggle.

With all these new designs in place, the toilet paper wiggled less, but still wiggled even without air from the turkey baster. While I think I could have missed some detection of air using the "background wiggle" method, this method gave a clear "yes", whereas before I did not have that. So, this became my method.

For the soil, I chose distance because if I tried to measure the weight, the scale would not pick up anything. Distance helped me get precise measurement and I had already found and solved many of the troubles with it in the previous experiments. In the future, I would use a more sensitive scale.

CONCLUSIONS

In conclusion, masks help migrate/decrease the spread of particles and should be used. I discovered that my hypothesis was mostly correct. I predicted that N95 masks would work the best. N95 masks were one of the masks that performed the best. I was able to detect only some soil and unable to detect air passing through N95 masks. Other masks also stopped air and soil from passing through if they fit well or formed a pocket. Double masking only helped when the fit was improved. My results indicate that well-fitting masks made of the right material can help to stop the spread of air that could contain the virus that causes the COVID-19 pandemic.

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ABOUT THE AUTHOR - NATHANIEL JAMES MARTIN

Nathaniel Martin is a 13-year old grade 9 student in the Advanced program at Grant Park High School. He plays the clarinet and has been part of the Manitoba Junior Honour Band in 2021 and 2022. He enjoys curling and baseball. In 2022, Nathaniel won his club Hit Draw Tap championship and his baseball team was the runner up in the Manitoba 15UA championships. His favorite subject in school is geography. He has completed all swim levels and will be starting life guarding lessons soon.