The Effectiveness of Face Masks of Preventing COVID-19 Infections

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Abstract

Now (as of September 22nd 2021) , COVID-19 is still an ongoing international pandemic. So, we wanted to find the most effective way for us to prevent the spread of coronavirus. First, we focused on masks. We researched what kind of masks are the best to prevent viruses before they enter our bodies. Then we conducted an experiment which used the simulation-making software, artisoc. Using artisoc, we examined the percentage of the virus which the mask prevented from being released outside the body.

１. Purpose

How effective masks are at preventing COVID-19 infections? There are many people in the world infected with at any time. We would like to prevent infections.

The percentage of COVID-19 related deaths in Japan is 1.6% as of 2021. On the other hand, the percentage of deaths in the world is 2.2%. Why is the former is lower than the latter?

We thought that it is because Japanese people always wear masks. Therefore, we sought to find out effectiveness of masks first, and we wanted to know the reason why the COVID-19 became a pandemic, and whether masks are effective at preventing people from being infected.

We simulated the percentage of viruses that mask can block using two types of masks.

２. Method

(1) The Purpose of The Experiment

To examine the effectiveness of face masks, we used a simulation software called artisoc. Using artisoc, we can simulate a lot of phenomena which happen in society by using digital models of people and things. By using a simulation, we examined the percentage of the viruses which stuck to the filter.

(2) About The Types of Masks

In this experiment, we used two types of masks called “gauze masks” and “non-woven masks”

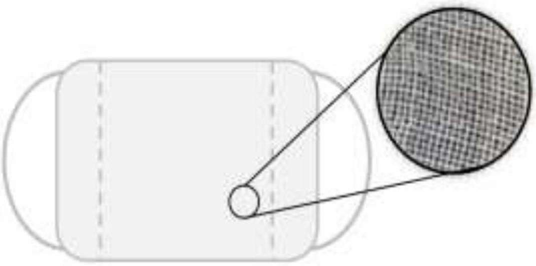


Chart 1　the structure of gauze masks

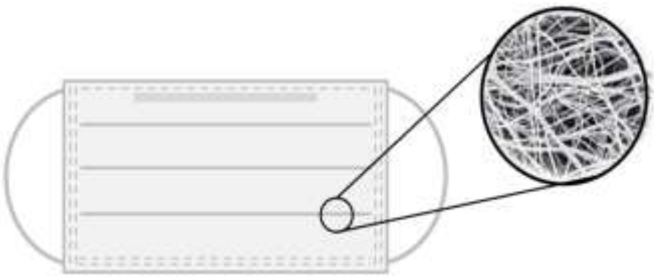


Chart 2　the structure of non-woven masks

Gauze mask is a cloth mask in which the mesh fibers are evenly spaced out. On the other hand, the mesh fibers of non-woven masks make a very tight woven pattern by overlapping the fibers randomly.

To experiment the simulation, we used “artisoc”, the simulating software, which is explained by “人工社会の可能性 01 人工社会構築指南 artisoc によるマルチエージェント・シミュレーション入門” written by Yamakage Susumu. Using this software, we made models of mask fibers and viruses and programmed the movement of virus particles. We examined the percentage of viruses released from our bodies and prevented by the masks.

The following shows how we programmed the simulation.

In artisoc, we first generated a square space whose size was 200x200 (We defined the radius of virus particles as 0.050). Then, we lined the models of mask’s fiber on the center of the space (Chart 3). In the case of gauze masks, we lined them up in a column with equal intervals. We defined the radius of the fiber as 1.0. In case of non-woven masks, we placed them at random in the range of 200x5.6. We defined the radius of the fiber as from 0.02 to 0.05 at random.

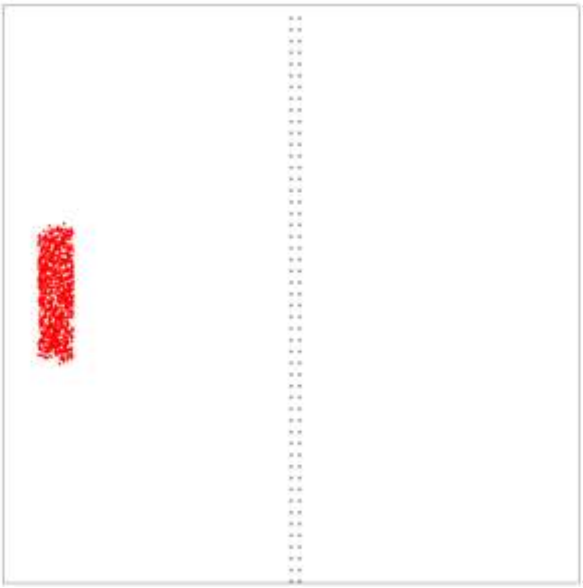


Chart 3 the lineup of each models in the space

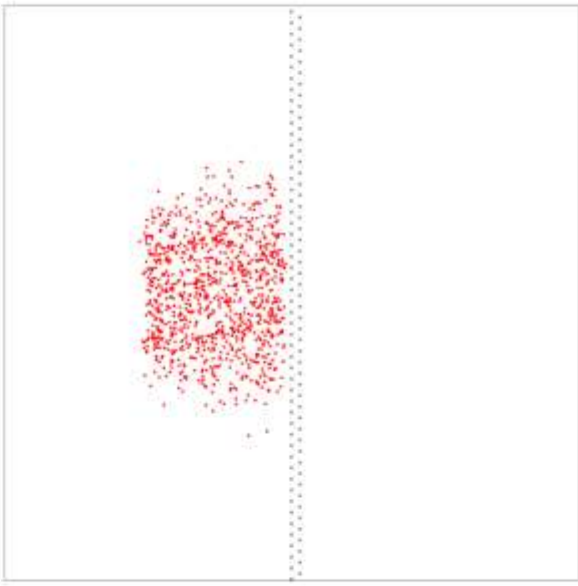
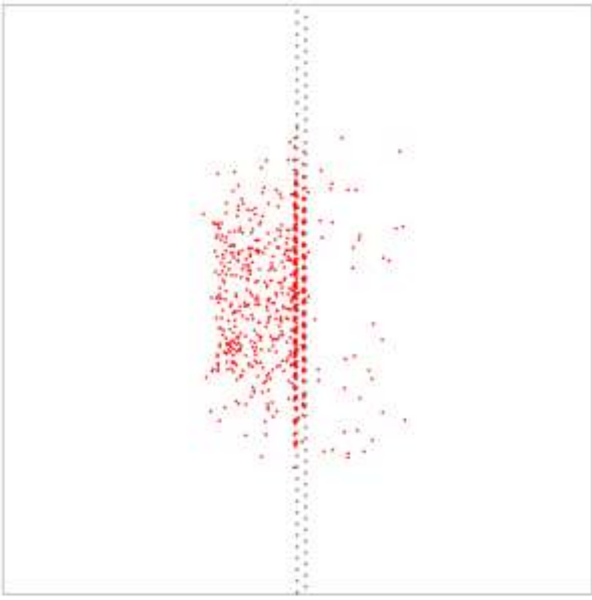


Chart 4 the appearance right before the viruses met the fibers

The dotted line in this figure is the model of masks (gauze masks), and the red dot is the model of viruses. We regarded the shape of fibers and viruses as circular ones. We determined the size of fibers and viruses, referring to the real size of them.

Second, we released viruses from the left side of the space. The viruses were made to move radially (as Chart 3 and Chart 4 shows). We made the direction vary at the range of ±1° once in a step. The velocity of viruses was randomly defined as from 0.16 per a step to 0.32 per a step.

After viruses moved (Chart 4), a program examined the distance from the virus to the fiber. If its distance was shorter than the sum of the radius of the virus and the filter, the program made the virus stop (Chart 5). When all the viruses are stopped or through the mask (Chart 6), we calculated the percentage of the viruses which stuck to the filter. We conducted this simulation for 20 times for each mask type.



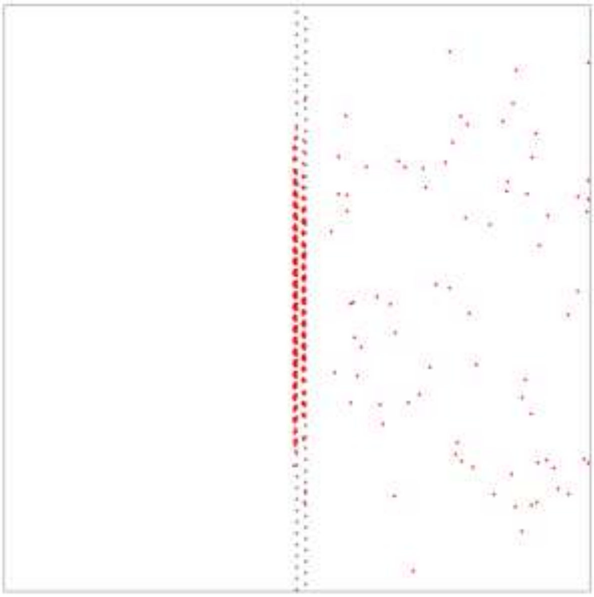
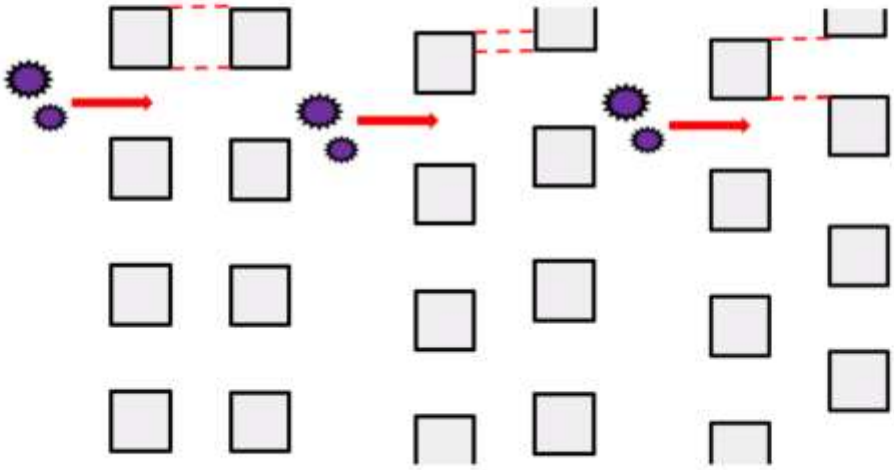


Chart 5　the appearance when the viruses met the fibers

Chart 6　the appearance when the simulation is completed

3. Result

We calculated the virus prevention rate for each mask. The prevention rate shows the percent of viruses which are released from our bodies and prevented by the fibers. The masks included one gauze mask with a one-layer structure, three gauze mask with a two-layer structure, and one non-woven mask. There are many types of 2-layer gauze mask that differ depending on the structure of the meshing, so we chose three for our test samples (Chart 7).



① the largest gap　② small gap　③ the smallest gap

Chart 7　the difference in the gap among 2-layer gauze masks

A gauze mask with 2 layers ① is a 2-layer gauze mask in which the meshing layers are completely overlapped.

A gauze mask with 2 layers ② is a 2-layer gauze mask in which the meshing layers are almost overlapped, but not completely.

A gauze mask with 2 layers ③ is a 2-layer gauze mask in which the meshing layers are interwoven.

② has the smallest gap, and ① has the largest gap.

The following graph (Chart 8) shows the virus prevention rate for each mask structure. This shows the box plots, which represent the average, the maximum, the minimum, and other values of virus prevention rate.

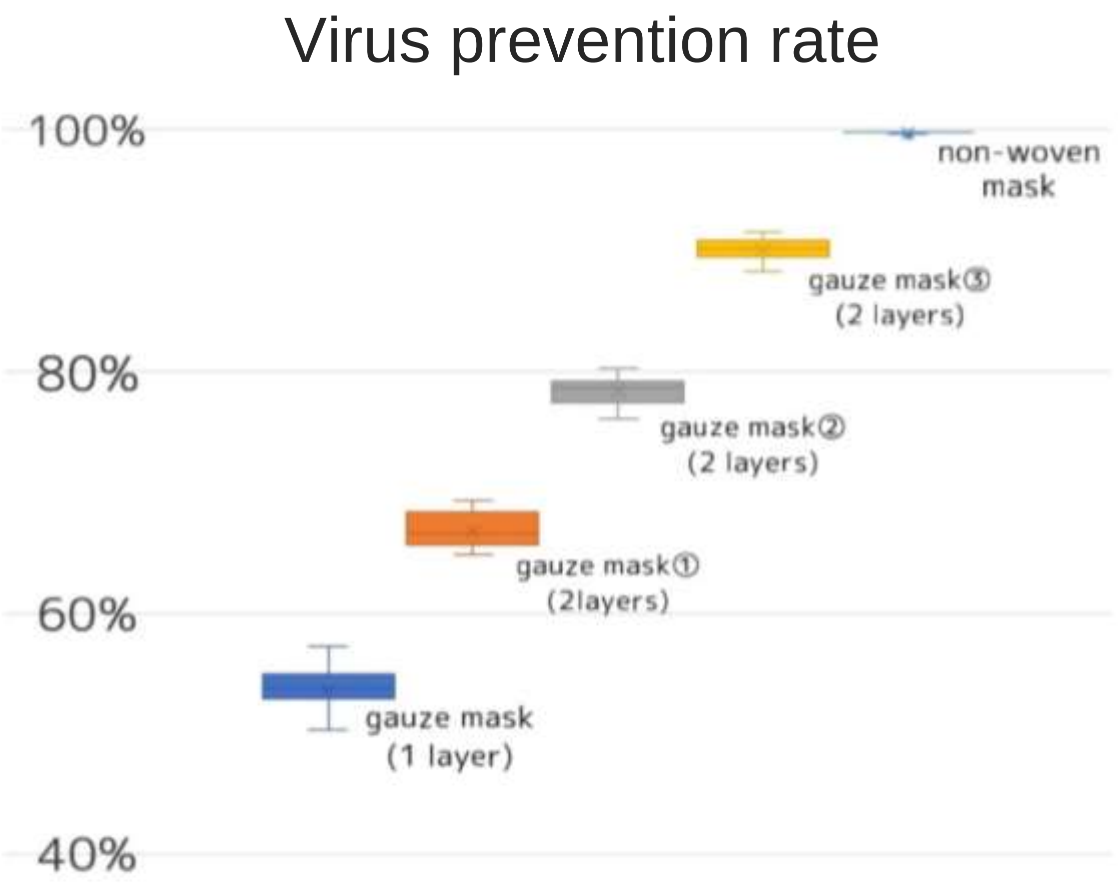


Chart 8 the virus prevention rate of each kind of mask

The number of viruses used in the simulation is 1000, so the value of the virus prevention rate is (the number of prevented viruses/1000)x100.

The measured values of the virus prevention rate are as follows.

1-layer gauze mask

The average: 54.0% The minimum: 50.4% The maximum: 57.2%

2-layer gauze mask① (the largest gap)

The average: 66.8% The minimum: 64.8% The maximum: 69.3%

2-layer gauze mask② (small gap)
The average: 78.4%　The minimum: 76.1%　The maximum: 80.3%

2-layer gauze mask③ (the smallest gap)
The average: 90.1%　The minimum: 88.3%　The maximum: 91.5%

Non-woven mask
The average: 99.7%　The minimum: 99.5%　The maximum: 99.8%

From the graph, we can see that the more layers a mask has, the higher the virus prevention rate becomes, and that the smaller the gap between the two layers becomes, the higher the virus prevention rate becomes. Also, we can see that compared to the gauze masks, which has a regular mesh, the irregularly made non-woven mask has a higher virus prevention rate, as the prevention rate was close to 100%.

４. Consideration

About the gauze mask, we found that it makes the virus prevention rate higher to make the gap between 2 layers as small as possible. And then we found that by using non-woven masks whose fibers are thinner, mesh is smaller, and has more fibers than gauze masks, we can prevent most viruses. Also, the more layers a non-woven mask has, the higher the possibility we can completely prevent all the viruses. For these reasons, we considered that non-woven masks are more suitable to prevent the viruses than gauze masks.

５. Conclusion

From the experiment, we had three main findings:

1. the prevention rate is quite different depending on each mask.
2. a gauze mask can prevent more virus particles than a non-woven mask.
3. we can expect masks to reduce the infection rate.

６. Future Experiment

We have three prospects for our experiment.

1. We were able to find out the prevention rate of each mask in our experiment. In the future, we want to observe and analyze how coronavirus particles spread in real life.
2. Using python, a program language, we tried to examine the differential between the theoretical number of sensitive, infected, and recovered people according to SIR model, which shows the change of the pandemic's situation and the actual number of those people in America (Chart 9). However, the actual value is much smaller than the theoretical value. In addition, the number of infected people is not correct, so we will use the number of dead people because it is reliable data in the future experiment.

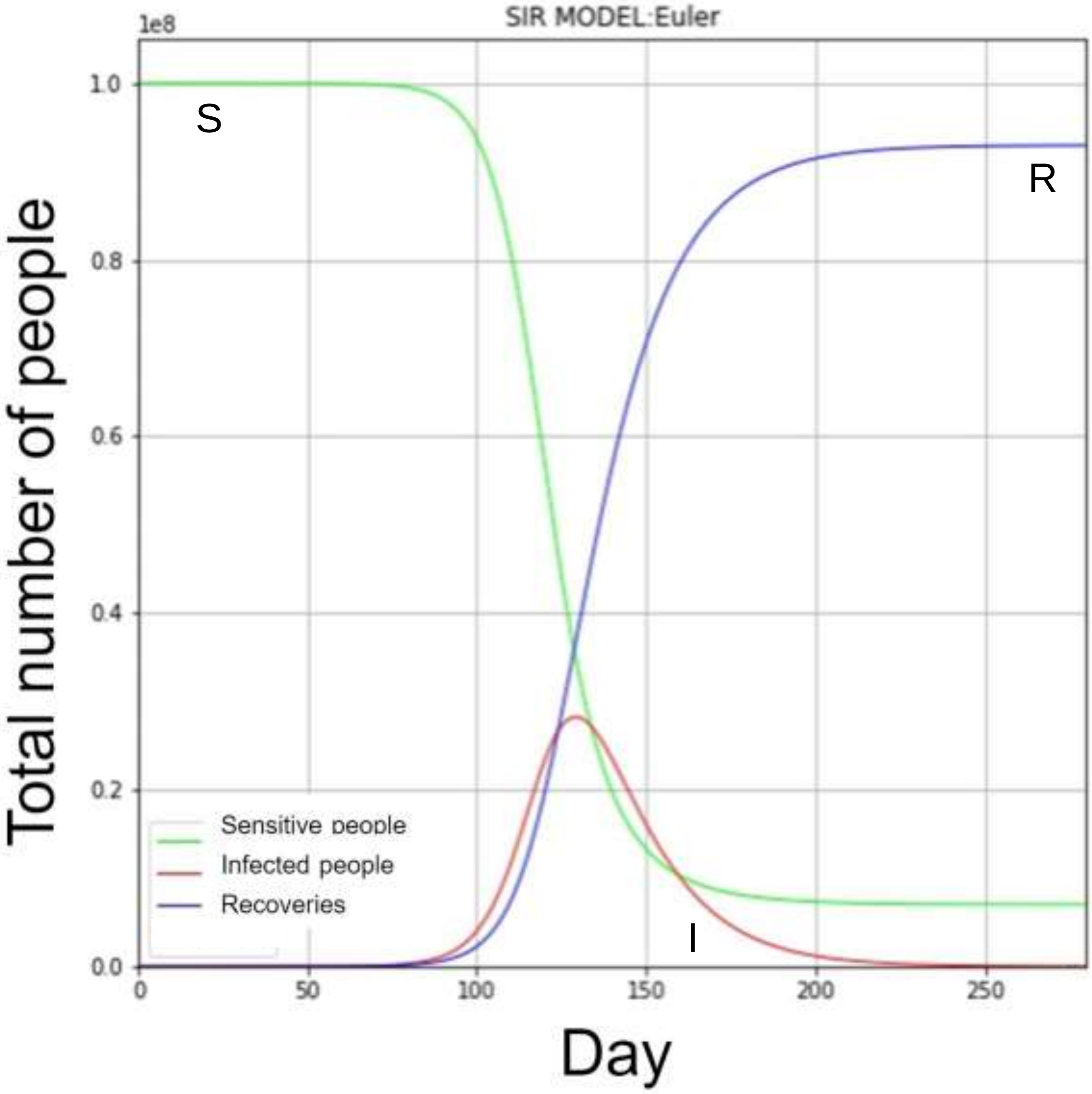


Chart 9　the graph which shows the differential between the theoretical number of sensitive, infected, and recovered people according to SIR model

3. We researched the total number of infected and dead people, and put it on the graph (Chart 10). As a result, we were able to find that the death rate is quite different depending on each prefecture. In the future, we will consider the reason why the difference of the death rate occurred, and figure out what order to give vaccines to each prefecture.

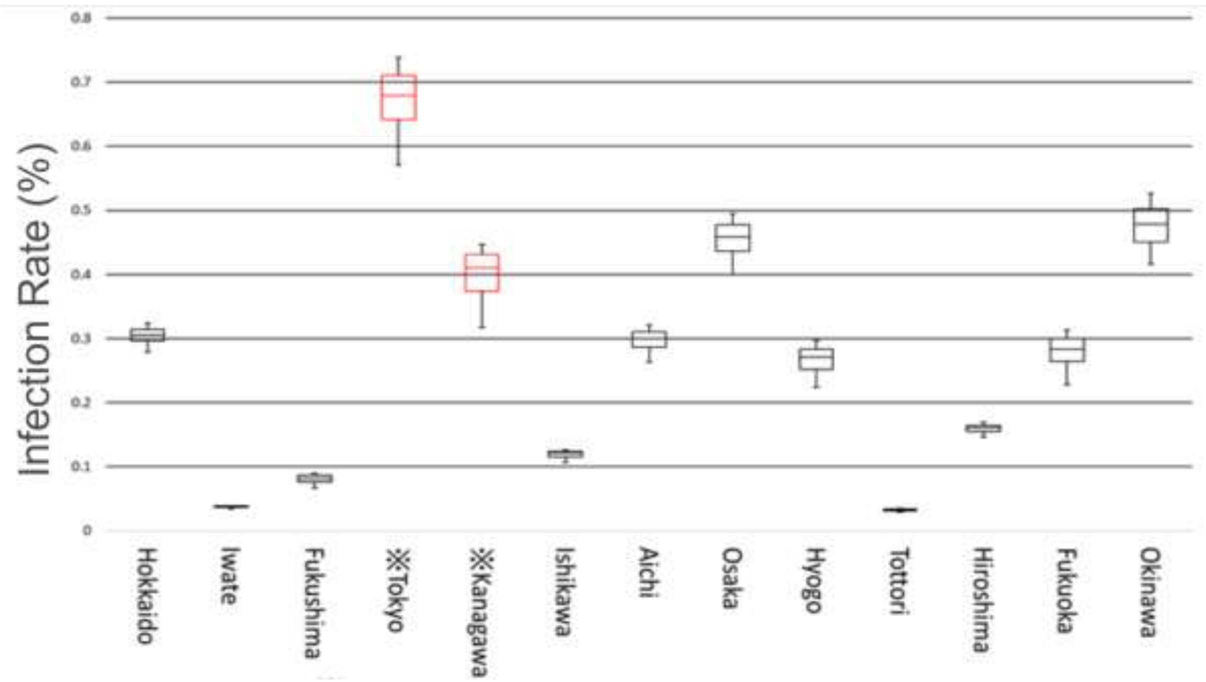


Chart 10　the infection rate for each prefecture

(Areas marked with"※" were at risk for emergency declarations as of March 5th 2021)

7.Reference

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8.Key words

Coronavirus　simulation　gauze mask　non-woven mask　artisoc