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The Effect of Masks and Travel with the Simulation of COVID-19 Pandemic

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Abstract: COVID-19 is a new type of infectious respiratory disease that has affected our lives enormously. Many restrictions have been enforced hoping to slow down the spread of the pandemic. Social distancing campaigns have been encouraged, masks have become mandatory and travel has been banned. Understanding the virus is vital in order to find a solution to end the suffering. In this project, we make our own attempt to simulate the spread of COVID-19 in hopes of understanding the spread of the pandemic. As a result, the project build a user-interactive design for the simulation of outbreaks. The project are able to set various parameters that we believe are still less understood. By tweaking these parameters in a well rounded simulation, we can test ideas and gain a visual understanding of what affects the spread. Solutions for flattening the curve were found, and distinguishing the policies that work from those that do not was available. In the project, travel was not restricted to their own region. The project focused more on international travel. The balls would be contained in their own region but at any given time, be able to travel to other contained regions. The effect of travel did not have much impact on the curve once the virus was spread to all regions. Travel restrictions seemed to have the most impact in the initial containment of the virus.

Keywords: COVID-19, Pandemic, Simulation, Masks, Travel

1. Introduction

1.1. COVID-19

COVID-19 is a new type of infectious respiratory disease that occurs by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The virus is transmitted when his/her mucosae of mouth or nose or eyes are exposed to respiratory droplets from an infected person.

The reasons why it has been a big issue in the world are that the death rate is high, the infection occurs quickly, and the incubation period is a maximum of two weeks. The most severe problem is that currently there is no treatment. Also, if a mutation occurs, treatment will be even harder.

Not only COVID-19 has affected human health, but it also has already affected our lives too. Currently, there are many difficulties in our lives due to many restrictions, and there have been many changes since the outbreak. Social distancing campaigns are encouraged in the world to stop spreading the virus. People are practicing social distancing by working from home and using video conferencing, etc. If it keeps spreading, the economic activities will be reduced, and the economic depression may occur as well, resulting in bringing economic damage, so the country and the world are trying to end spreading the virus.

1.2. Simulation

Many attempts have been made to understand the COVID-19 virus and pandemics in general. Since the society we live in grows more and more complex, finding accurate methods of knowing and preventing the spread of the disease becomes difficult. Simulations are a good way of modeling complex environments and observing how things might pull through. A simulation in Washington Post [10] models the infectious process in an elegant showcase of bouncing balls. The model is very intuitive and is largely accurate to the random nature of human activity. Other simulations try to incorporate more complex scenarios and factors such as social distancing, hospital capacities, reinfection and social structures [10, 11].

In this project we make our own attempt to simulate the spread of COVID-19 focusing more on some aspects that have yet to be covered: The effect of masks and travel.

We will first discuss the implementation of the simulation which we did using Javascript. Then we will simulate the effect of masks and how it helps to flatten the curve. We will then analyze how traveling between societies is relevant to the spread of the virus and whether it should be restricted in this time where COVID-19 is already prevalent.

2. Simulation

2.1. Bouncing Balls

We based our simulation model on the Washington Post model [10] using bouncing balls. Each ball is randomly placed in the grid with a starting velocity vector of equal speeds and also random directions. As the balls traverse through the grid they may either bump into each other or a wall. In either case, we obtain the reflected vector of the ball using the equation (1), where r is the reflected velocity vector, d is the original velocity vector and n is the normal vector which is perpendicular to the collision surface.

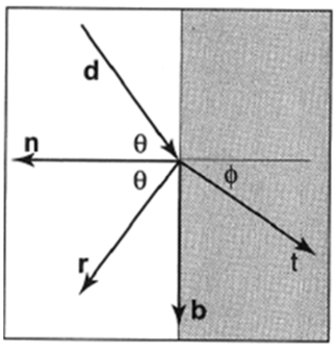

Figure 1. *Obtaining the reflected velocity vector.*

2.2. Status by Color and Masks

The result is shown in figure 2. We colored the balls to represent their current status. Blue balls are susceptible, meaning they have not been infected and are able to be infected in the future, red balls are infected, black balls are dead, and purple balls are recovered balls who are no longer infected and cannot be infected again. Each ball has a probability to be spawned with a mask which is shown in white. When an infected ball collides with a susceptible ball, the infect function is called and the susceptible ball's status may be changed to infected based on the infection rate, R (in this case set to 0.5) and the inward, outward protection constant. This will be further explained in section 3.

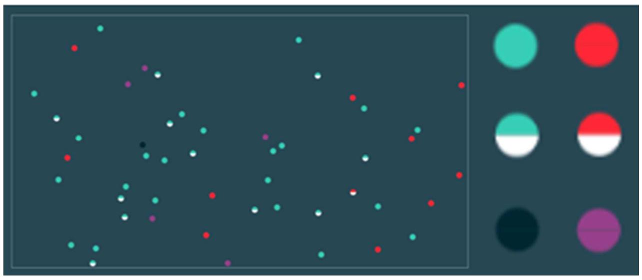

Figure 2. *Simulation of bouncing balls with status colors.*

2.3. Multiple Regions

We also added a selectable map structure. The simulation can be run in either a scenario of one region, 2 regions, 4 regions, 6 regions and 8 regions. The balls are able to travel between regions based on the travel probability constant. At any given point in time, a ball has a probability to travel to any region other than the current one it is in. When this happens, the ball is no longer colliding with other balls until it reaches its destination which is a split second in order to less affect the infection curve.

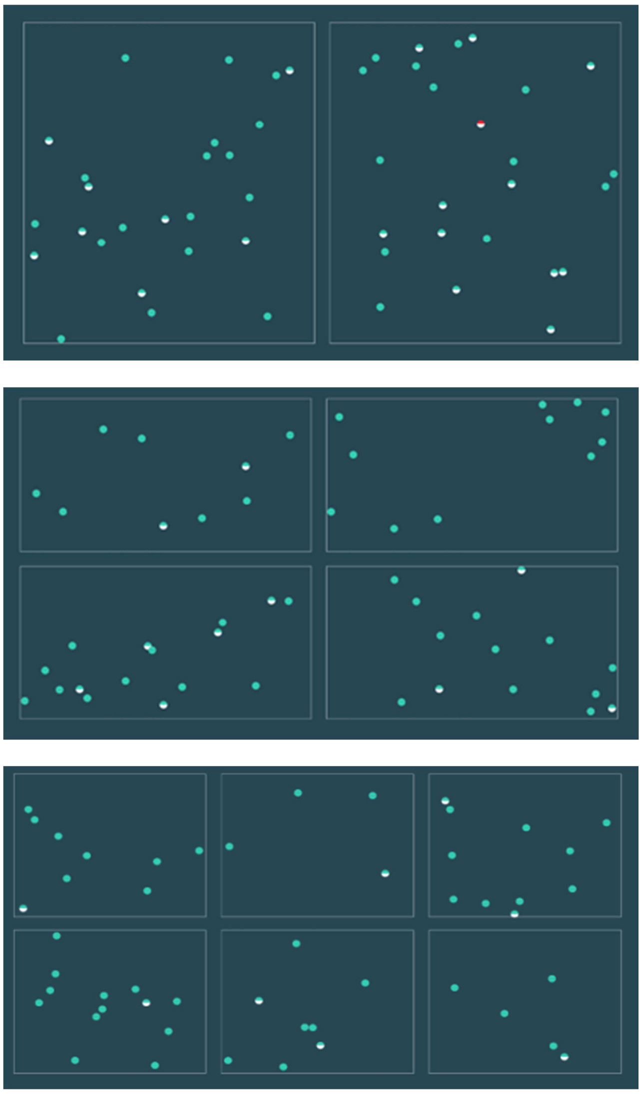

Figure 3. *Various layout options for the simulation.*

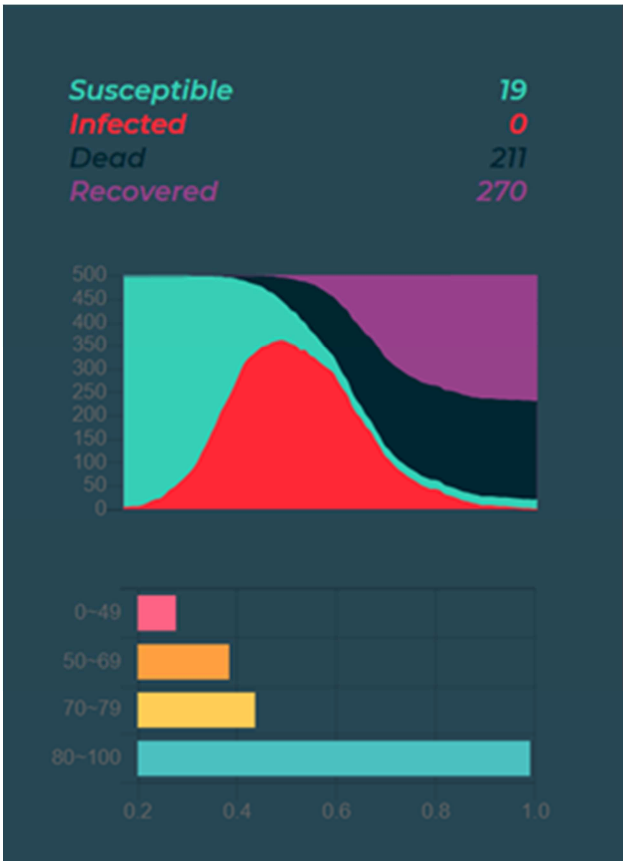

Figure 4. User interactive statistics are shown on the right of the simulation.

2.4. Data Analysis and Statistics

Data is collected and statistics is visualized in real time on the right of the simulation (Figure 4). Users are able to monitor the change of the curve either in a global view or a region specific view. When a user clicks on a region the statistics are updated to show only data related to the selected region.

3. Effect of Masks

3.1. Background Information

The masks can be the best intervention against COVID-19. They are a physical barrier to respiratory droplets that can reach through the nose and mouth, and to the removal of droplets from infected individuals. Their role may be especially important in COVID-19, where infected individuals may be spreading an asymptomatic or pre-symptomatic virus. Today we have access to various kinds of masks including cloth masks, surgical masks, N95 and KF94 masks. The surgical mask filters large particles out of the air and protects others by reducing the exposure of the mask wearer to saliva and respiratory secretions. The N95 and KF94 masks provide more protection than the surgical mask because it can filter out large and small particles as the wearer inhales. [3]

How viruses that cause airborne diseases move droplets from person to person is complicated but can be generally divided into two large categories based on size.

In research from Huang (2020) droplets below a diameter of 10um (micrometer) are carried by winds and can travel across rooms. On the other hand, droplets larger than 10um (micrometer) may evaporate or fall to the surface within 2m and reach distances as far as 6m away, depending on size, air humidity and temperature. [5]

Various studies have shown that masks help prevent coronavirus infections. N95 masks indeed filtered out 99% of particles and the surgical masks lowered the number of aerosol droplets behind the mask by four times as much as the outside of the mask. [5]

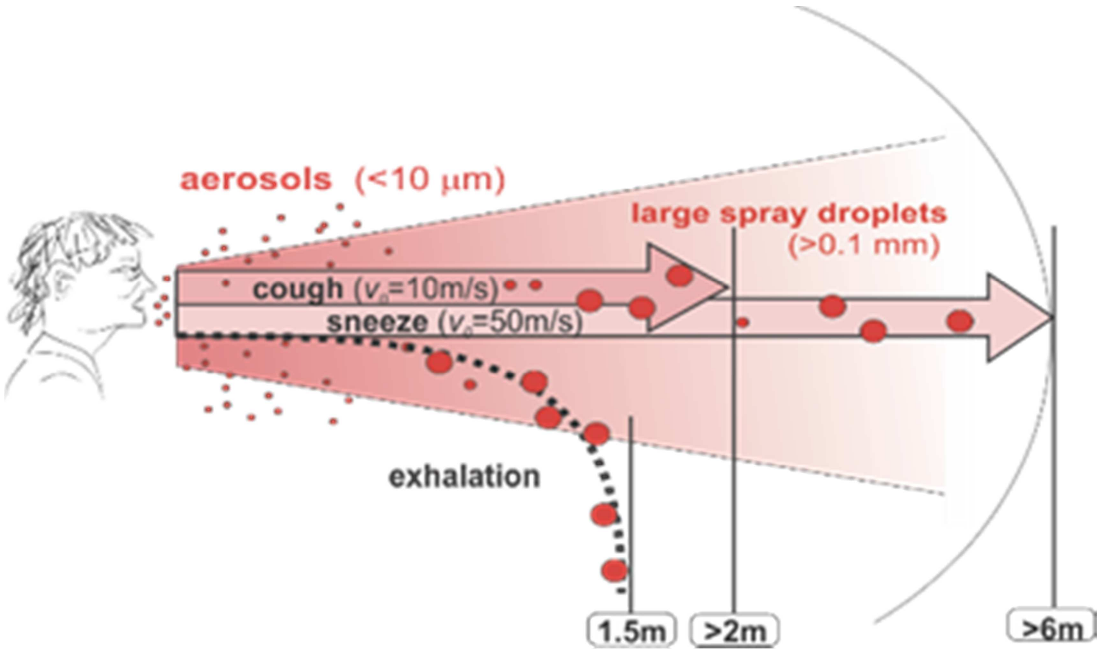

Figure 5. Example of how droplet spread when exhaled.

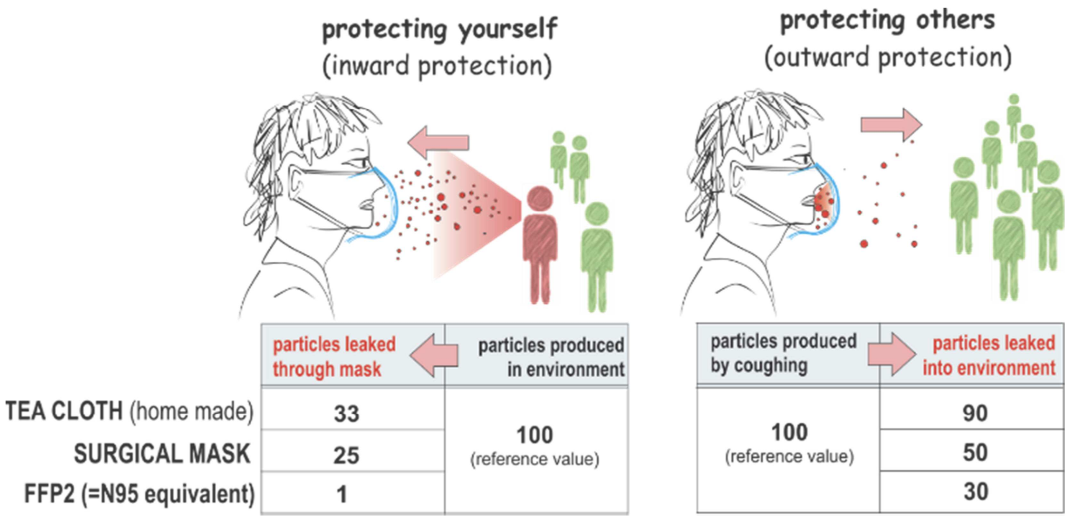

Figure 6. *Example of filtering effect of aerosols by various masks.*

3.2. Simulation and Analysis

We ran simulations based on various masks: cloth, surgical, and N95 masks. We based the data of particles leaked on figure 6.

If no one wears a mask, the number of confirmed cases will rise sharply and the death toll will rise, as shown in left of figure 7. The cloth mask can be better than not wearing masks, but the result shows a cloth mask is not effective to protect the population, as shown in the right of figure 7.

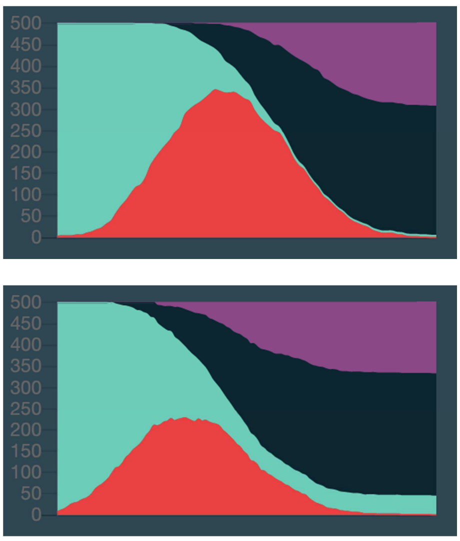

Figure 7. *When the ratio of mask wearer is 0.0 (left).*

Susceptible: 44 / Infected: 456 / Dead: 288 / Recovered: 168
When the ratio of cloth mask wearer is 0.5 (right)
Susceptible: 44 / Infected: 456 / Dead: 288 / Recovered: 168

If the entire population wears cloth masks it will flatten the curve even further. However, if the entire population wears surgical masks, the results would be completely different. Still, a small number of people will be infected but it can slow and prevent the spread of the virus, as shown in figure 8.

Various studies have shown N95 masks offer more protection than a surgical mask. The curve of the graph is more flatten when 50 percent of the population wears N95 masks, as shown in the left of figure 9. If the entire population wears N95 masks, the result will be better than the entire population wearing surgical masks, as shown in the right of figure 9.

However the result of N95 is not as significant compared to the surgical masks. This is why when in a shortage of masks it is sufficient to wear the surgical masks and leave room for the people who are in direct contact with COVID-19 infectants to wear the N95 masks.

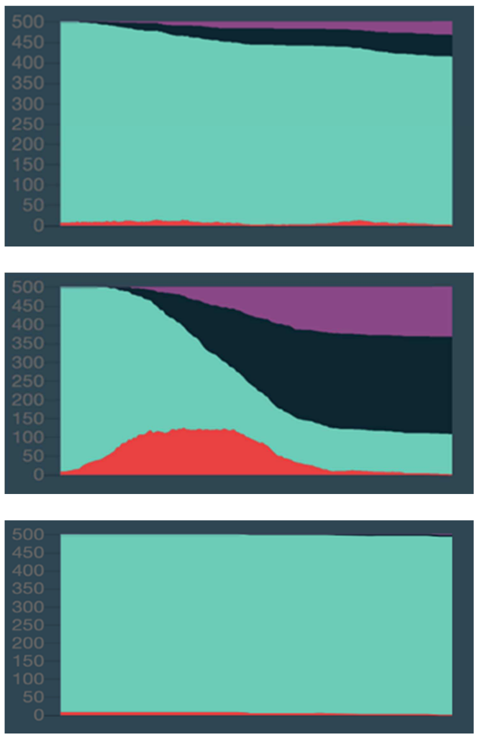

Figure 8. *When the ratio of cloth mask wearer is 1.0 (left).*

Susceptible: 107 / Infected: 393 / Dead: 260 / Recovered: 133
When the ratio of surgical mask wearer is 1.0 (right)
Susceptible: 483 / Infected: 17 / Dead: 8 / Recovered: 9

Figure 9. *When the ratio of N95 mask wearer is 0.5 (left).*

Susceptible: 247 / Infected: 253 / Dead: 157 / Recovered: 96
When the ratio of N95 mask wearer is 1.0 (right)
Susceptible: 493 / Infected: 7 / Dead: 5 / Recovered: 2

4. Effect of Travel

If the virus was immediately contained to one region of the world, then the travel restrictions would have been effective, and the cases of COVID-19 would most likely have been reduced drastically, as shown in Figure 9.

Although the probability as seen in figure 10 fluctuates between simulation to simulation, once the virus was spread to all the regions, the overall infection rate did not differ significantly.

On the regional scale the travel restrictions did have some impact in the initial rate of spreading. In the regions where the initially less infected people, the fewer infections occurred, as can be seen in figure 11.

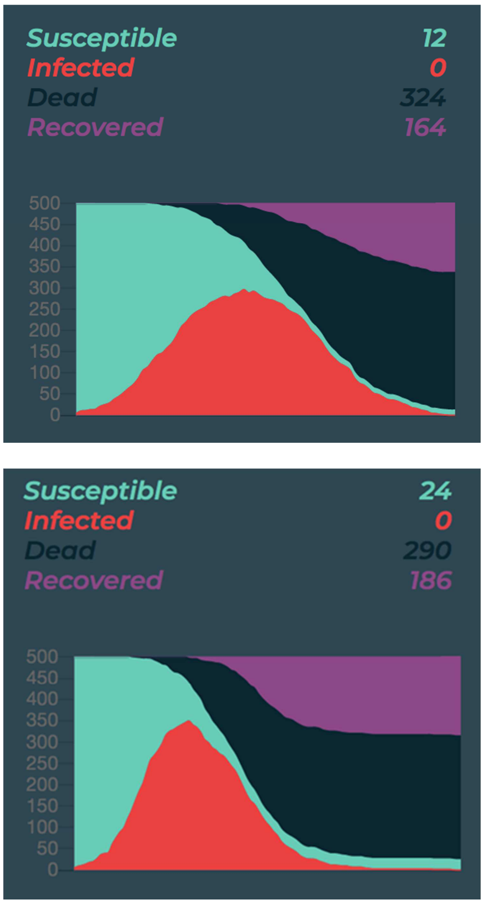

Figure 10. *When the traveling probability was set to 0.002 (Up) and when it was 0.0000, thus completely restricted (Down).*

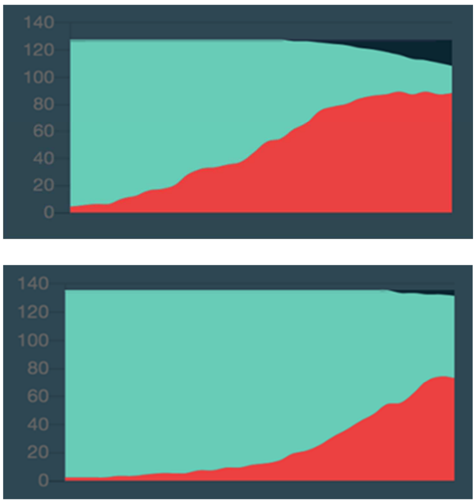

Figure 11. *(Up) the region that had twice as many infected people (Down) the region that had fewer infected patients.*

5. Other Factors

5.1. Age

We ran simulations based on age groups. In the future we would like to give different age distributions to different groups. We based the fatality rate of age groups on surveys made by statista [8]. Table 1 shows the assumed fatality rate that each age group has. This number represents the probability of each entity's status to be changed to 'dead' each time step. The simulation is run by these assumptions.

Table 1. *Fatality Rate Assumptions by Age Group.*

Age Group	Fatality Rate
~ 49	0.1%
50 ~ 69	1%
70 ~79	6%
80 ~	20%

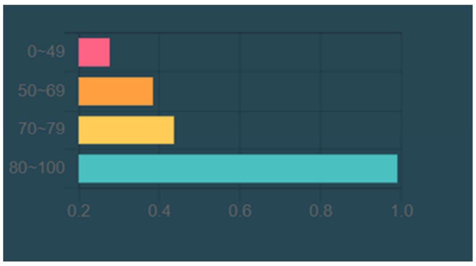

Figure 12. *Simulation Results by Age Groups.*

5.2. Climate

Many tend to believe that the climate affects the spread of COVID-19, thinking that the colder weather aggravates the rate of infection. Although this is not an entirely false statement, weather is not the only factor that determines the rate of the spread of the virus. Weather, to a certain extent, influences the surrounding environment and the conditions in which the virus must survive in order to transmit; however, the spread of the virus depends almost entirely on the human behavior that accompanies the weather change [1]. "In terms of relative importance, weather is one of the last parameters." [1].

Several researches that have been recently conducted have provided that SARS-CoV-2 does in fact favor dry, cold conditions, away from the direct exposure to the sunlight. [2] Artificial ultraviolet light was detected inactivating the SARS-CoV-2 virus in the lab, in temperature around 40°C [2]. But the difference made is negligible, and supervised experiments, as conducted in the study, fails to "scale up the society" entirely [1].

On the other hand, researches are showing more evidence that the human behavior in a certain weather affects the transmission rate. Although the climate may be cold and dry in the winter, for instance, people prefer warm indoor conditions with poorly ventilated air. Such conditions are quite favorable to the spread of COVID, sustaining the infection rate [2].

Further, COVID -19 pandemic has a downfall on its side in terms of conducting research. The connection between the transmission rate and the weather for much of the prior diseases, for instance, were studied through research conducted in a specific location, multiple times each year, for many years. However, being a relatively new disease, first discovered by the end of 2019, it lacks the benefit of time for extensive research [4].

5.3. Reinfection

A few cases of reinfection are emerging around the world, and researchers state that the antibodies against COVID-19 lingers for at least 6 months. [6]

Although such cases are rare, they are on the rise; these cases suggest that the immunity and the antibodies against SARS-CoV-2 are relatively quick to wane. [7]

5.4. Vaccine

Ever since the outbreak of the COVID-19 in the world, there has been a lot of buzz around the vaccines. Several scientists contested that developing a vaccine is not a matter of months or 1-2 years. It takes 10-12 years to research and come up with an effective formula.

During mid-2020, countries were stating that it might 2-3 years to develop a COVID-19 vaccine. However, before the end of the year, several companies developed vaccines and even started its trial phases on humans. While some of the volunteers reported that they saw little to no side effects of the vaccine in their body, others contested that they contacted the virus even after they were given the vaccine.

The first COVID-19 vaccine was launched in Russia, the Sputnik V vaccine which is claimed 92% effective. The Pfizer-BioNtech vaccine launched its results in November. Today, over 44,000 people have received the first dose of vaccine in six countries. With an effective rate of 95%, the Pfizer-BioNtech vaccine will soon be licensed. The other vaccine that is being talked-about is the Oxford University-Astra Zeneca vaccine which was approved at the end of the year. It has been tested on over 20,000 volunteers and will soon be given to around 100 million people in the UK in two doses.

The vaccine distribution is taking place in order of priority. The first ones to receive vaccines are the COVID-19 warriors and health care workers. After that, it will be the elderly and children. With the new COVID-19 strain, people are now skeptical about the vaccines. However, scientists have stated that the vaccines will still be effective even on the new mutation of the virus.

6. Conclusion

In this project we created a simulation based on the bouncing balls model [9]. We incorporated various factors that were not simulated deeply in other projects. Previous projects had the travel factor but mostly focused on interregional travel. i.e. Traveling within their respective region. Also masks were not taken into account in most simulations. We focused mainly on the effect of masks and travelling between regions. We compared between scenarios where no one was wearing masks and where the entire population was wearing masks. We also did experiments in between values such as societies where half of the population wore masks. Wearing masks seemed to reduce the rate of infection significantly. Surgical masks are recommended since they have a noticeable difference in the curve than cloth masks and are almost the same as N95 masks. In our project, travel was not restricted to their own region. We focused more on international travel. The balls would be contained in their own region but at any given time, be able to travel to other contained regions. The effect of travel did not have much impact on the curve once the virus was spread to all regions. Travel restrictions seemed to have the most impact in the initial containment of the virus.

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