COVID-19 Screening: Can Testing More People Flatten the Curve?

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***Abstract*—The world is experiencing a deadly pandemic. Many people are dying from the COVID-19 disease, and the world economy is struggling to respond. The hospitals are full of sick COVID-19 patients. The health officials are on the front-lines. In several states, lockdowns are still in place. Most people who suffer COVID-19 are either asymptomatic or have mild symptoms, but there are not enough tests available for everyone to get tested. In this paper, we tried to explore what if we increase the percentage of people being tested and then quarantine them while the economy is still open? We were interested in the question of whether this will flatten the curve? We modeled this scenario by using an Agent-Based Model (ABM) with SIRQ dynamics for studying epidemic spread. We ran several experiments where we increased the threshold to test more people to see whether the curve flattens. The results show that as we increase the percentage of people tested and quarantined, the curve flattens, and the virus eliminates from the population.**

I. Introduction

The entire world has been under attack by an invisible virus, SARS-COV-2. Many people around the world are suffering from the disease COVID-19, which is produced by SARS-COV-2. This paper looks to extend our paper, *COVID-19 Spread and Evolution*, which we wrote for a project in UNM's Complex Adaptive Systems class taught by Dr. Melanie Moses. That paper began by introducing complex adaptive system ideas and how they relate to viruses and epidemic spread. It then explored **neutral networks** and **epidemic spread** in greater detail.

The **neutral network** of a virus gives it a robust property, which allows it to evolve and adapt. Viruses are in an arms race with their host. Both are usually against each other. The host's immune system desperately searches for a way to eliminate the virus from the system. The virus uses it's high mutation rate ability to respond and adapt.

The other idea explored in that paper was **epidemic spread**. We used Cellular Automata(CA) as a toy model, which allowed us to explore the epidemic spread behavior. We used the dynamics of an SIR model to explore the spread. We were able to explore the behavior of an outbreak in an enclosed space. This model seemed to resemble a situation more inclined to the dynamics of an outbreak on a cruise ship or other similarly enclosed areas. While this model is useful, there are some limitations. These limitations led us to this current paper.

While we explored epidemic spread using our toy CA SIR model, we had many questions, and we wanted to answer some of them. Mainly, we were very curious about asymptomatic people, and how this could play a role in the epidemic spread. Could this be a reason why this virus spreads so rapidly? Was it silently infecting different parts of the world before the symptoms of COVID-19 were discovered? We decided to take these questions and focus them on one single question, which we explore in detail. **How much benefit is there as we increase the percentage of people tested and quarantined?**

To answer this question, we felt that it was critical to use an Agent Base Model (ABM). An ABM breathes life into the people represented by our model. Instead of static cells that never move in a CA model, an ABM models the dynamics of movement throughout a city. It also allowed us to model, not just the movement of people, but locations that can act as hubs. An example of this would be a store like Walmart, which brings many people together in one place.

The rest of this paper will focus on our question. Section 2 will talk about the current data that currently exists about the population of asymptomatic people, and how contagious this population is. Section 3 of this paper goes into extensive details about our model and the results it produced. Section 3 will discuss the results of our simulation experiment and talk about any interesting points discovered.

II. Current SARS-COV-2 data

To begin this paper, we need a foundation of some current data that exists about COVID-19. This data is currently changing all the time, and much information found online often has not been peer-reviewed yet. It is critical to understand that some of the data used in this research paper may evolve as this epidemic matures, and more data is collected. We will keep this section relatively short as we collect enough information to build our model. We will begin this section by understanding the current recommended screening process in the USA.

Many countries have different approaches to how to handle this epidemic. This paper will focus on the CDC recommendations. These are the recommendation used by most places in the USA. The guidelines are different for the public compared to facilities like hospitals. The guidelines for the general public mainly focus on wearing masks, social distancing, and consistent cleaning. The CDC states that ”a significant portion of individuals with coronavirus lack symptoms (“asymptomatic”) and that even those who eventually develop symptoms (“pre-symptomatic”) can transmit the virus to others before showing symptoms” [1] [2] [3] [4] [5] [6] [7] [8].They feel the use of cloth face coverings are particularly useful to prevent asymptomatic spread [1].

The CDC also has advice for people that get sick and what they should do to help prevent the spread. This advice would apply to symptomatic people because the asymptomatic people would not know that they are infected. The CDC recommends that people keep in contact with medical care staff, stay home except for medical care, avoid people, monitor symptoms, continue to cover the face, and clean often. [9]

The recommendations change for businesses and hospitals. There are many recommendations for a hospital. These include how to triage patients effectively and how to interact safely with infected patients. The most relevant recommendation for this paper is the screening process for all individuals. The CDC recommends reducing the number of entrances into the building. When a patient arrives, they should get a fever check and questioned to see if they are showing any symptoms. The facility should offer face masks or cloth coverings or at least ask everyone to wear their own if they can not provide them. All patients showing symptoms should have priority in triage [10].

Who is getting tested for COVID-19? Unfortunately, testing everyone is not feasible because there does not exist enough tests [12]. The CDC has recommendations on how to prioritize who can get tested. On their website, they recommend the following [11]:

High Priority

- Hospitalized patients **with** symptoms
- Healthcare facility workers, workers in congregate living settings, and first responders **with** symptoms
- Residents in long-term care facilities or other congregate living settings, including prisons and shelters, **with** symptoms

Priority

- Persons **with** symptoms of potential COVID-19 infection, including: fever, cough, shortness of breath, chills, muscle pain, new loss of taste or smell, vomiting or diarrhea, and/or sore throat.
- Persons **without** symptoms who are prioritized by health departments or clinicians, for any reason, including but not limited to: public health monitoring, sentinel surveillance, or screening of other asymptomatic individuals according to state and local plans.

These recommendations are focused around people that are showing symptoms. The population of asymptomatic infected individuals does not have specific recommendations. This lack of guidance for asymptomatics makes sense, as it is hard to know who is a member of the asymptomatic population. What is this population? How many people are asymptomatic carriers of the disease? Daniel P. Oran and Eric J. Topol state in their article that 40% of individuals that tested positive for SARS-COV-2 showed no symptoms of COVID-19. They quickly mention that this is not a representative of the entire population and that more data is desperately needed to identify this number. They felt that 40% is still a significant proportion and could be a significant factor in the rapid spread of the disease [13] [17]. To understand how these numbers could differ from study to study, Stanford analyzed the Diamond Princess for an asymptomatic population. They found that the proportion was roughly 17.9% of asymptomatic individuals [14]. Another article found that as many as 50% of people with COVID-19 are not aware they have the virus [18]. We must keep this lack of data in mind as this information may rapidly change as we start to understand more about this epidemic.

It seems right that a significant amount of the infected population is asymptomatic or presymptomatic. Could this be why SARS-COV-2 has spread so much more rapidly than SARS-COV-1, which is remarkably similar? Our current response to SARS-COV-2 looked at how we reacted to the original SARS for guidance. The original SARS virus was contained within eight months. SARS-COV-2 is far from being contained and has infiltrated many more countries and people compared to the original SARS. What is different? It could be this asymptomatic or presymptomatic population. While they may not contain as much of the viral load as an extremely sick and highly symptomatic person, The asymptomatic individual still seems to transmit the disease. It may be the *Achilles' Heel of Current Strategies to Control COVID-19* [15]. We still do not know how much of a factor this plays in the transmission of COVID-19. There is evidence they play a role. The exact details of this role need further investigation. Even if they are not as contagious as a highly symptomatic individual, they can move through society undetected, and they probably interact with more people than a sick individual [16]. This additional interaction increases the chance the virus can spread.

This brief exploration of the current data that exists emphasizes how much we have yet to discover. We may not know how many people are asymptomatic for some time. There is a significant proportion of asymptomatic people. The number will most likely increase as we start providing antibody tests to individuals. Could the high asymptomatic population be SARS-COV-2's superpower in helping it spread throughout the world? What would happen if we had the technology to quickly create and mass produce tests associated with a viral outbreak, even if the virus contains a property like a high asymptomatic population that still transmits the virus? This idea is what we will explore in the remainder of this paper. Would it be worth it to invest in science that can quickly create and mass produce these types of tests? **How much benefit is there as we increase the percentage of people tested and quarantined?**

III. Methods & Results

A. Model overview and notable assumptions

As discussed above, we use ABM with SIRQ dynamics to model our experiment where an agent can be in a Susceptible (S), Infected (I), Recovered (R), or Quarantined (Q) state. The ABM gives us the ability to help answer our proposed question. While there are many ABM libraries out there such as NetLogo, Mason, etc. we decided to build our model in Java and JavaFX from scratch. We believe that modeling an ABM does not only require the best usage of the tools out there, but it also requires that the programmers can use those tools. Since both of us have advanced expertise and experience building ABM in Java, we decided to proceed to build our model in Java.

For any given model, whether it be ABM or any other real-world model, making assumptions are critical. Without making assumptions, one would find it difficult to answer their proposed question or reach their end goal. Our model is no different from other real-world models out there. Realistically, it is challenging to capture everything as the world is complex, and there are many variables associated with any model. Therefore one has to make assumptions, and we did the same to help answer our question: **How much benefit is there as we increase the percentage of people tested and quarantined?**

After going over how making assumptions are fundamental in any model, let us introduce the assumptions we have made to help answer our question. As we know, there are not many tests available for every American out there that wants to return to work [12]. One critical assumption we have made in our model is that our experiment explores a world where there are infinite tests available. Hence, if an agent gets infected from another agent, they can get tested and quarantined based on their contagion level. If we look at CDC's recommendations on quarantining and when one can leave home, they mention that people should wait at least ten days since their first symptoms appeared. They should wait until their symptoms have improved, and they have had no fever for at least 72 hours (without using fever reduction medicines) [9]. While it is hard to capture these specific guidelines in our model, we assume that quarantining people over a uniformly distributed time and keeping them quarantined until they no longer infected captures the CDC's guidelines. We assume a quarantined person is protected from the world and will not spread the disease.

After going over critical assumptions related to infinite test availability and quarantining time for an infected person, there are some other notable assumptions that are worth mentioning. We assume there is a correlation between how sick someone is to how contagious they are. The more a person shows symptoms, the more contagious they are. We also assume that there are more asymptomatic people compared to symptomatic people. We also assume that the epidemic spreads while a person is inside their home community or when a person leaves a building such as grocery stores or restaurants.

To help satisfy these assumptions, we added several parameters to our model so that we could use them and tune them in our simulation to help answer our question. Some of these important tun-able parameters are:

- **at_quarantine**, which determines how many seconds a person stays in quarantine in a uniformly distributed manner.
- **at_community**, which determines how many seconds a person stays at their home community in a uniformly distributed manner.
- **at_destination**, which determines how many seconds a person stays at a building in a uniformly distributed manner.
- **countdown_till_epidemic_spread**, which determines when to start the epidemic spread.
- **symptom_scale_threshold**, which determines what percent of people to test and quarantine.

In our model, every person gets a symptom scale, which symbolizes how contagious they are. The lower the symptom scale for a person is, the higher the chance of that person being asymptomatic. The higher the symptom scale is, the higher the chance of that person being symptomatic. For example, if a person has a symptom scale value of 1.0, there is a 100% chance that whoever comes in contact with this person will get infected. In contrast, the person who has a symptom scale value of 0.001 is asymptomatic, and whoever comes in contact with this person will have a 0.01% chance of getting infected. When we look at the real-world data that is out there thus far, we know most people have mild symptoms [20]. We also know that around 50% of people who have Covid-19 are asymptomatic [18]. Based on this, we picked a Beta Distribution at alpha = 2 and beta = 3.5 as a distribution for a person's symptom scale. While the symptom scale value is between 0 and 1, using this specific beta distribution, the values between 0.1 to 0.3 have a higher weight. It will generate more people with a symptom scale value in this range. Figure 1 below shows this scenario, which we depicted in our model. It represents that most people are asymptomatic, or they have mild symptoms with the exceptions of some being extremely sick, which lies in 0.8 to 1.0 range.

Getting back to the tunable parameters that we introduced earlier. All of them help tune our simulation and search for the answer to the proposed question, but the **symptom_scale_threshold** is the most critical tunable parameter in our model. This parameter lets us directly answer our proposed question: **How much benefit is there as we increase the percentage of people tested and quarantined?**. We now know that each person gets a symptom scale based on our beta distribution, what this **symptom_scale_threshold** does is it lets us test those people who are above a threshold. The lower this threshold is, the more people get tested and vice versa. Tuning this parameter lets us explore if there is any benefit as we increase the threshold and test and quarantine more people. Can we flatten the curve if we lower the threshold and test more people? To answer these questions, we ran several

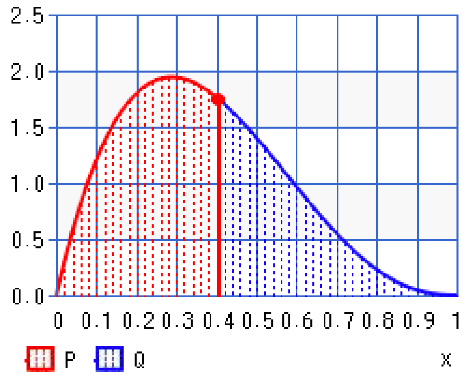

Fig. 1. The figure represents beta distribution at alpha = 2 and beta = 3.5 [19].

experiments and tuned our parameters until we found the ones which helped answer our question. In the next section, we will go over the experiments we ran and what results we got that helped answer our question.

B. Experiments and Simulation Results

After going over the specifics of our toy model and the associated assumptions that we have made, we now focus on running the experiments and showing the results produced by our simulation. Before going into the details of the experiment, it is essential to know the details of the simulation. Figure 2 shows the structure of our simulation. The outskirts represent communities in which people live, and the center represents buildings to which people visit. The dots represent people in our simulation. We also added the capability to viewing graphs so we could measure the curve in real-time.

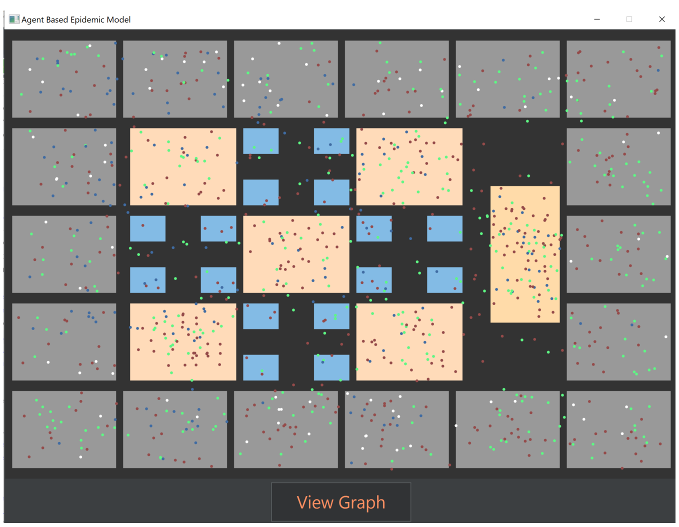

Fig. 2. This figure represents shows template of our simulation. It showcases communities (gray), buildings (light-orange, light-blue), Susceptible people (green), Infected people (red), Recovered people (blue), and Quarantined people (white).

After going over the specifics of our simulation, let us go over the details of the experiment we ran. We ran our simulation multiple times, and each time, we changed **symptom_scale_threshold** parameter ranging from 0.0 to 1.0 to see how the curve changes based on the threshold. We first picked 1.0 as our threshold value. We then started reducing this threshold value by 0.1 to see how the curve behaves as more people are tested. The figure 3 shows the curve representing the disease spread with no interventions. Since we only test those people who are at symptom scale 1.0, we see the number of infected people increases sharply, and almost all the population gets infected, and nobody gets quarantined.

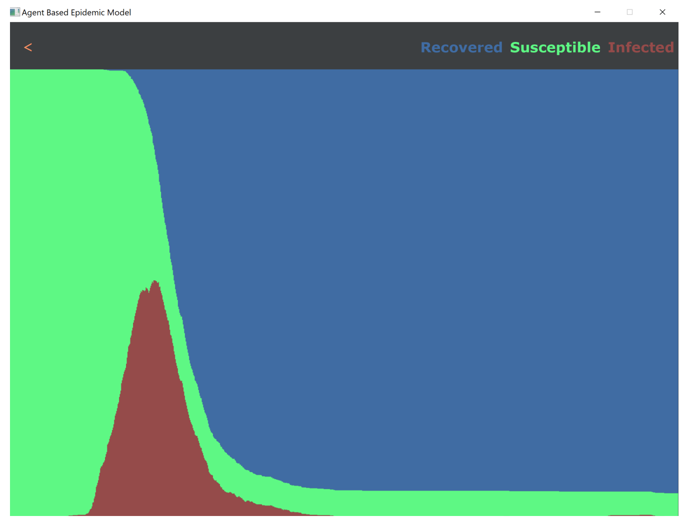

Fig. 3. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 1.0.

After looking at the curve at threshold = 1.0, we wanted to reduce the threshold and test to see what happens when we make the threshold = 0.9, threshold = 0.8 and so forth? We saw that the curve started to flatten a little as we tested more people and quarantined them (see Appendix A for seeing graphs at threshold value 0.9, 0.8, 0.7, and 0.6). While the curve started to flatten a little, we started seeing interesting results when we hit the threshold $<= 0.5$. Figure 4 shows the curve when we set the threshold value to 0.5.

Looking at the curve at threshold = 0.5, we can see the curve changes drastically in figure 4. The curve is flattened and spread out over more time as compared to figure 3. We can also see fewer people are getting infected as we can notice there are more people still susceptible to the disease once it dies out.

Further reducing the threshold to < 0.5, we see more interesting results, especially when we look at 0.3 and 0.2 (See Appendix B for seeing graph at threshold = 0.4). Figure 5 shows the curve at threshold = 0.3 and figure 6 shows the curve at threshold = 0.2. If we look at these two figures, we see the curve dramatically flattens, and the number of people infected reduces. Due to the threshold being at 0.3 and 0.2, respectively, we can see that more testing is in place. As more

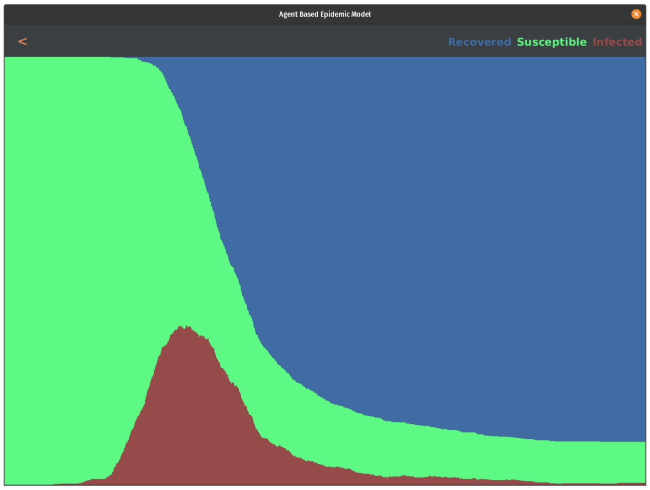

Fig. 4. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.5.

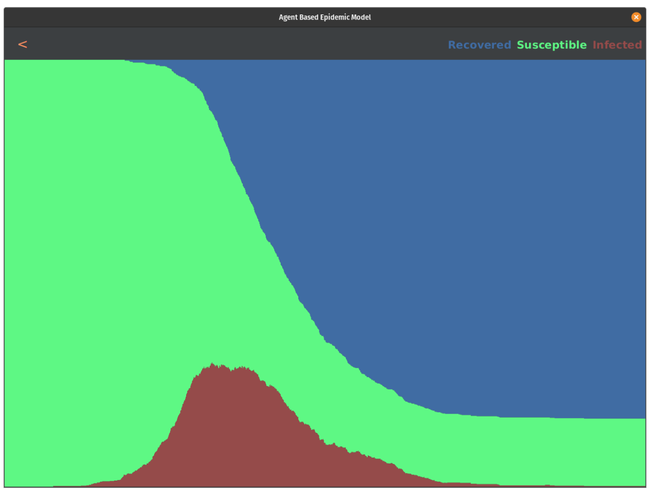

Fig. 5. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.3.

people get tested, more people go to quarantine; hence, we see many people in the population who never get infected at all and remain susceptible throughout the epidemic spread in our simulation.

Reducing our threshold value to 0.2 gave us promising results, but we thought, what if we lower this threshold even more? Would we be able to eliminate the virus? Would we see even more flattening of the curve? The figures 7 and 8 show us what happens to the curve when we lower the threshold to 0.1 and 0.0, respectively. Looking at the figures 7 and 8, we can see that if we test most of the population if not all, and quarantine them, then the results show us that we could eliminate the virus.

With the help of an ABM with SIRQ dynamics, we explored the space of epidemic spread and whether testing more people and quarantining can be beneficial? To focus on our question,

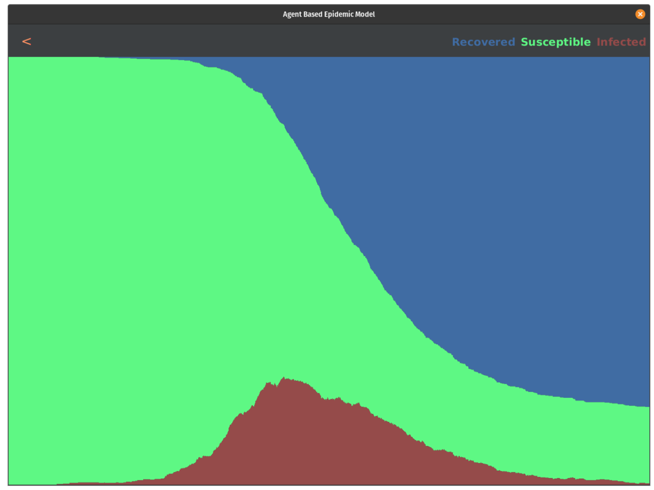

Fig. 6. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.2.

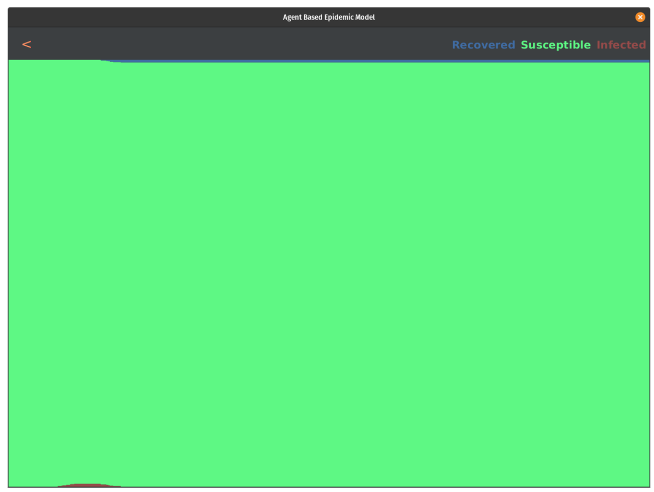

Fig. 7. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.1.

we made notable assumptions in our model and focused on tuning **symptom_scale_threshold** parameter as we get closer to answering our question. The results produced by our experiments show us that we can flatten the curve if we can test more. We also saw that proper testing and quarantining procedures could affect the curve and possibly eliminate the virus from the population. Our model shows promising results if there are more tests available. However, it does not depict the absolute real-world scenario because there is still much data coming in. It also raises a few questions. What does the actual Covid-19 distribution resemble? Is it following beta distribution with $\alpha = 2$ and $\beta = 3.5$ or any other distribution? We may not know what the actual distribution looks like until this pandemic ends, but based on our research and data that's out there so far, our model showed good results and answered our proposed question.

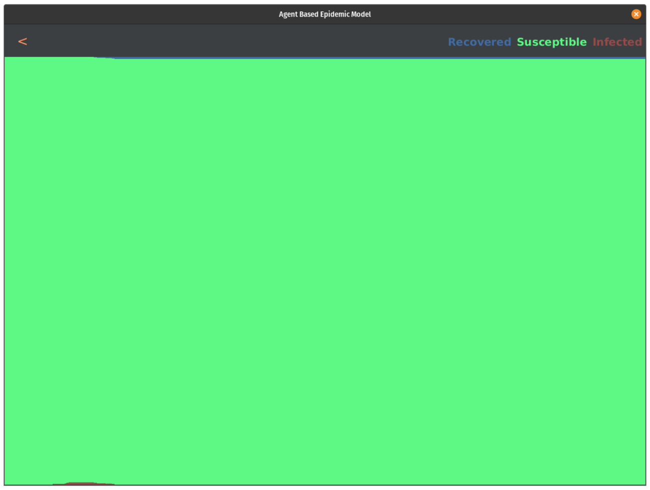

Fig. 8. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.0.

IV. Discussion & Conclusions

In this paper, we briefly talked about why we decided to focus on the effects of testing and quarantining ranges of individuals. We found that silent spreaders like asymptomatic, presymptomatic, or individuals with mild symptoms could be a key reason why SARS-COV-2 has spread so dramatically compared to SARS-COV-1. This data led us to focus the content of this paper on exploring the question: **How much benefit is there as we increase the percentage of people tested and quarantined?**. We set the simulation up to focus on this question.

The results of our experiment are positive. What can we learn from it? We can significantly affect the spread of an epidemic with more tests. We could flatten the curve dramatically. If we had enough tests, we could even eliminate the spread. An added benefit is that we would not even need to close businesses. The impact on the economy would be very minimal compared to what we are currently experiencing. The outcome of these results relies on the specific Beta distributions used to distribute the symptomScale among the population. What would the impact be if we include social distancing in this model? Could we possibly eliminate the virus with a **SYMPTOM_SCALE_THRESHOLD** set much higher than 0.1? Another challenge is how to determine who gets tested. In our simulation, we have the benefit of programmatically dividing up the population based on their symptomScale. How can we divide up the real-world population? Age may be an effective threshold in real life. It may be related to this symptomScale that we have designed, but it would need more research.

We believe that there is more research that could to do in regards to determining a critical threshold value in how many people need to be tested to eliminate an epidemic spread early on. We believe that there could be valuable information in rerunning our experiment with social distancing included in the model. Most importantly, we feel there may be some critical property in the probability distribution used for the symptom scale that can help us determine a critical threshold that needs to be used to gain the maximum benefit. We feel there is a lot to be discovered if we keep exploring these questions and more.

There are many more questions that we will need to answer as a society to gives us the weapon to fight back in a war such as the one against COVID-19. As this world becomes more populated, the risk of an epidemic such as COVID-19 may become more likely. The information from this simulation tells a critical point. We need to invest in this industry. We need an infrastructure that can quickly adapt to a novel virus and build massive amounts of tests for the current population. Producing tests could be the difference between an epidemic and a world that was not even aware that an epidemic was possible.

V. Possible future additions to our model

While we completely focused on quarantining different fractions of the infected populations, and how this affected the outcome of the simulation. There are more questions that could be explored with our model. Some slight coding may need to be done but the following are some examples of questions that could be explored:

1) **How does social distancing affect the outcome of epidemic spread?** We could implement this by adding the following behavior:
   - People spend more time at their communities.
   - People change their walking behavior at these communities to keep as much distance as possible from each other.
   - people spend less time at stores
2) **How does age play a factor in the spread of SARS-COV-2?** We could easily implement this by adding the following behavior to the sim.
   - Using real world census data we can build a random population that reflects the age of the general population.
   - We can then change our symptom scale variable to reflect this data.
   - We can explore quarantine scenarios where the threshold of whom gets tested and quarantined is an age. (this would be a more realistic process that could be implemented in the real world)
3) **Is there a relationship between the probability distribution of of extremely symptomatic, mild symptomatic, and asymptomatic. How does this distribution tell us how many people we should test and quarantine?** We currently made the alpha and beta variabled used in the beta distribution as command line argumants for our simulation. There could be alot of value studying how these different distributions effect how easily it is to contain an epidemic outbreak. If we reversed the variable values and evaluated this same experiment with a majority of individuals as highly contagious and symptomatic. what would the results be?

References

[1] "Recommendation Regarding the Use of Cloth Face Coverings," Centers for Disease Control and Prevention, 03-Apr-2020. [Online]. Available: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover.htmlstudies. [Accessed: 10-May-2020].

[2] Rothe C, Schunk M, Sothmann P, et al. Transmission of 2019-nCoV Infection from an Asymptomatic Contact in Germany. The New England journal of medicine. 2020;382(10):970-971.

[3] Zou L, Ruan F, Huang M, et al. SARS-CoV-2 Viral Load in Upper Respiratory Specimens of Infected Patients. The New England journal of medicine. 2020;382(12):1177-1179.

[4] Pan X, Chen D, Xia Y, et al. Asymptomatic cases in a family cluster with SARS-CoV-2 infection. The Lancet Infectious diseases. 2020.

[5] Bai Y, Yao L, Wei T, et al. Presumed Asymptomatic Carrier Transmission of COVID-19. Jama. 2020.

[6] Kimball A HK, Arons M, et al. Asymptomatic and Presymptomatic SARS-CoV-2 Infections in Residents of a Long-Term Care Skilled Nursing Facility — King County, Washington, March 2020. MMWR Morbidity and mortality weekly report. 2020; ePub: 27 March 2020.

[7] Wei WE LZ, Chiew CJ, Yong SE, Toh MP, Lee VJ. Presymptomatic Transmission of SARS-CoV-2 — Singapore, January 23–March 16, 2020. MMWR Morbidity and mortality weekly report. 2020;ePub: 1 April 2020.

[8] Li R, Pei S, Chen B, et al. Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV2). Science (New York, NY). 2020.

[9] "What to Do If You Are Sick," Centers for Disease Control and Prevention, 08-May-2020. [Online]. Available: https://www.cdc.gov/coronavirus/2019-ncov/if-you-are-sick/steps-when-sick.html. [Accessed: 10-May-2020].

[10] "Infection Control: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)," Centers for Disease Control and Prevention, 12-Apr-2020. [Online]. Available: https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html. [Accessed: 10-May-2020].

[11] "Interim Guidance: Healthcare Professionals 2019-nCoV," Centers for Disease Control and Prevention, 05-May-2020. [Online]. Available: https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-criteria.html. [Accessed: 10-May-2020].

[12] J. McDonald, "How Many COVID-19 Tests Are 'Needed' to Reopen?," FactCheck.org, 09-May-2020. [Online]. Available: https://www.factcheck.org/2020/05/how-many-covid-19-tests-are-needed-to-reopen/. [Accessed: 10-May-2020].

[13] "Getting a handle on asymptomatic SARS-CoV-2 infection," Scripps Research. [Online]. Available: https://www.scripps.edu/science-and-medicine/translational-institute/about/news/sarc-cov-2-infection/index.html. [Accessed: 10-May-2020].

[14] K. Mizumoto, K. Kagaya, A. Zarebski, and G. Chowell, "Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020," Eurosurveillance, vol. 25, no. 10, Dec. 2020.

[15] M. Gandhi, D. S. Yokoe, and D. V. Havlir, "Asymptomatic Transmission, the Achilles' Heel of Current Strategies to Control Covid-19," New England Journal of Medicine, 2020.

[16] P. Huang, "What We Know About The Silent Spreaders Of COVID-19," NPR, 13-Apr-2020. [Online]. Available: https://www.npr.org/sections/goatsandsoda/2020/04/13/831883560/can-a-coronavirus-patient-who-isnt-showing-symptoms-infect-others. [Accessed: 10-May-2020].

[17] "COVID-19: What proportion are asymptomatic?," CEBM, 15-Apr-2020. [Online]. Available: https://www.cebm.net/covid-19/covid-19-what-proportion-are-asymptomatic/. [Accessed: 10-May-2020].

[18] R. Plater, "50 Percent of People with COVID-19 Aren't Aware They Have Virus," Healthline, 24-Apr-2020. [Online]. Available: https://www.healthline.com/health-news/50-percent-of-people-with-covid19-not-aware-have-virus. [Accessed: 11-May-2020].

[19] "Beta distribution Calculator," High accuracy calculation for life or science. [Online]. Available: https://keisan.casio.com/exec/system/1180573225. [Accessed: 11-May-2020].

[20] Healthline. 2020. What It's Like To Have A 'Mild' Case Of COVID-19. [online] Available at: ¡https://www.healthline.com/health-news/what-its-like-to-survive-covid-19¿ [Accessed 12 May 2020].

Contributions

Siri wrote the introduction, current SARS-COV-2 data section, discussion and conclusions section, and possible future additions to our model section. Anas wrote methods results section, abstract, and the appendices. Both authors collaborated to implement the model and simulation presented in this paper.

Appendix A
The figures showing the graph at threshold values > 0.5

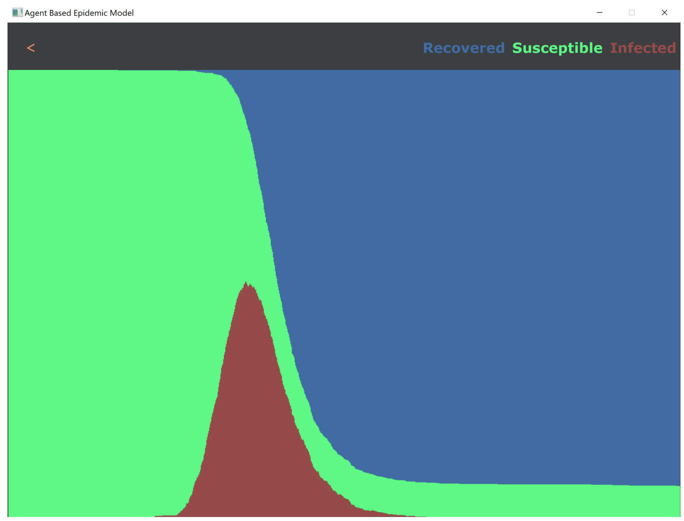

Fig. 9. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.9.

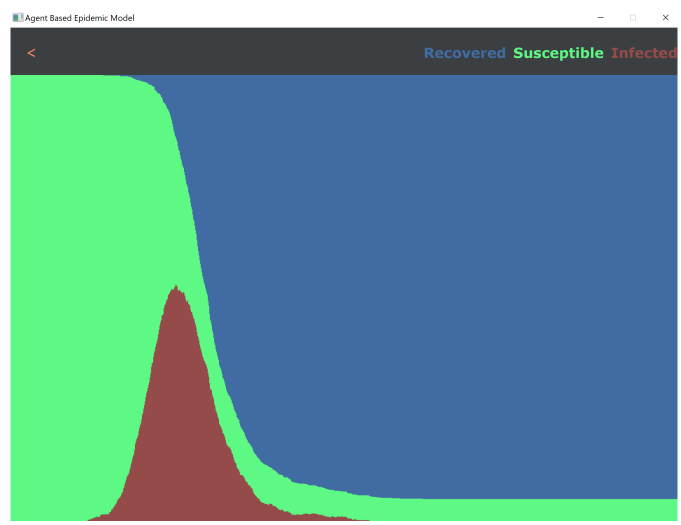

Fig. 10. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.8.

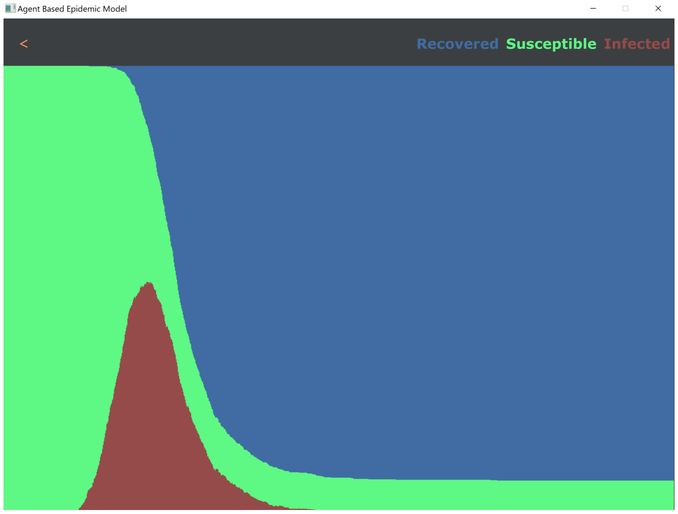

Fig. 11. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.7.

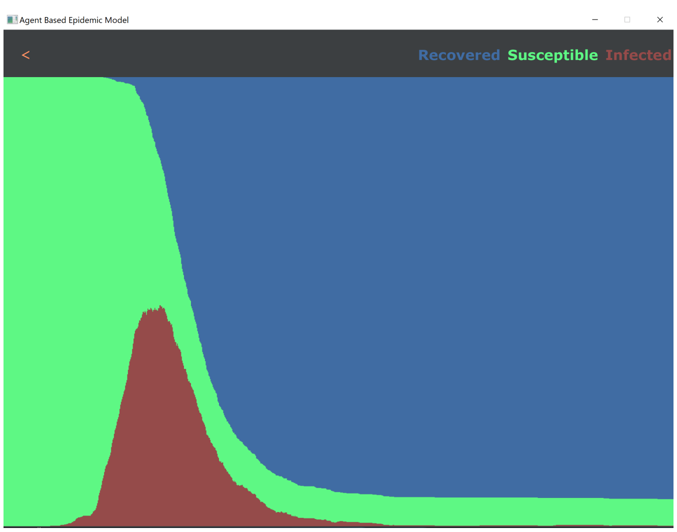

Fig. 12. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.6.

Appendix B
The figure showing the graph at threshold values $= 0.4$

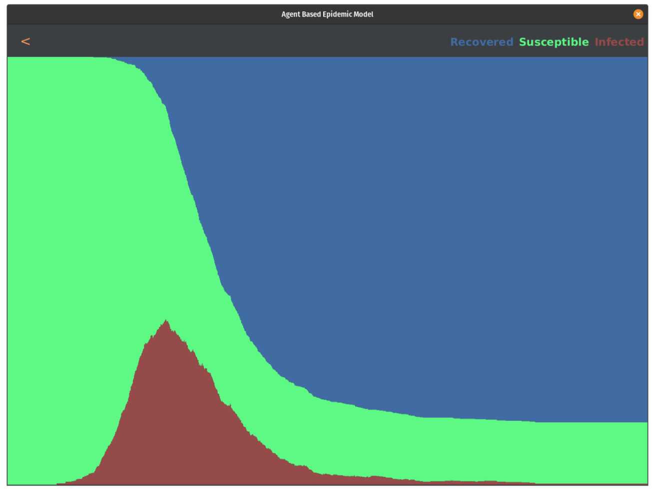

Fig. 13. The figure represents the curve showing number of susceptible, infected, and recovered people when the symptom_scale_threshold value is 0.4.