

# COVID-19 Simulator

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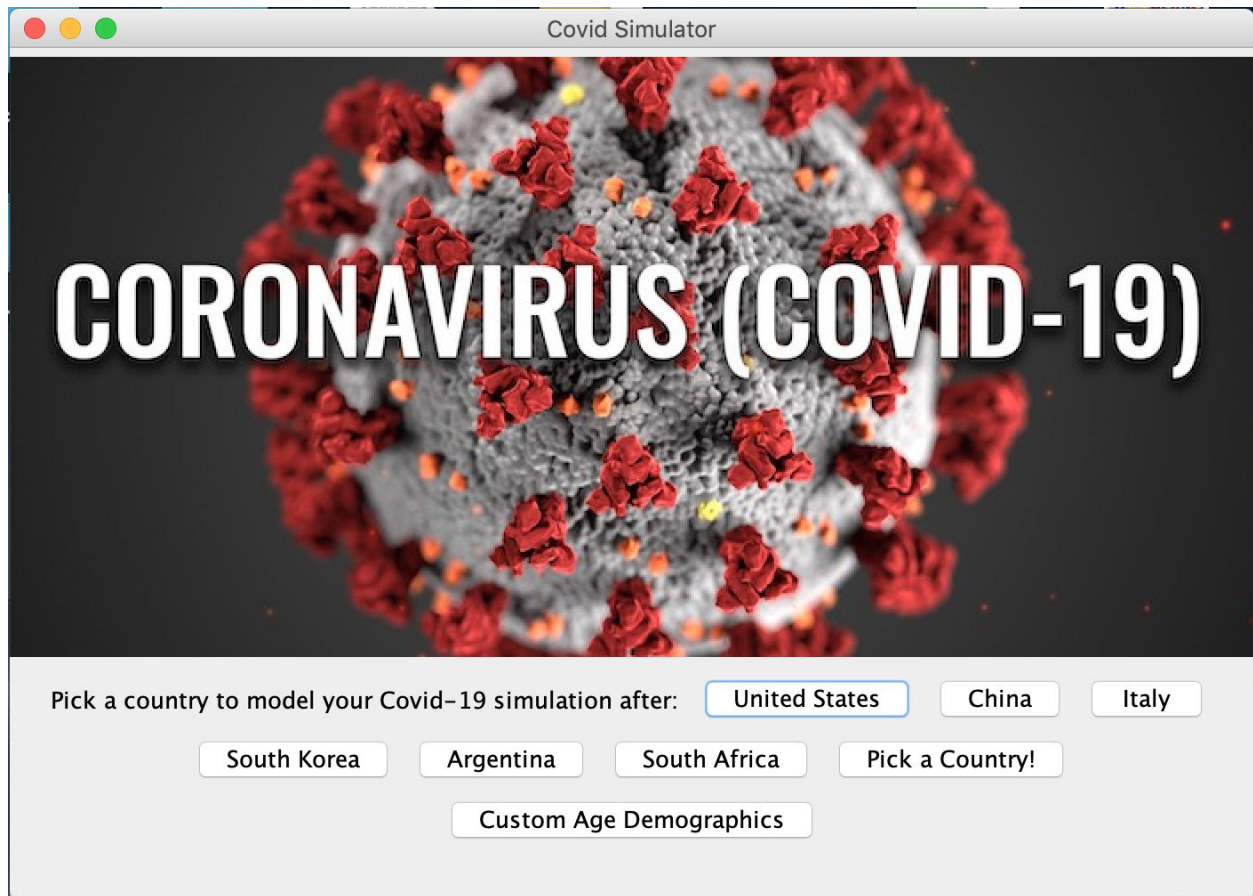
# Simulator User Manual

## How to Run

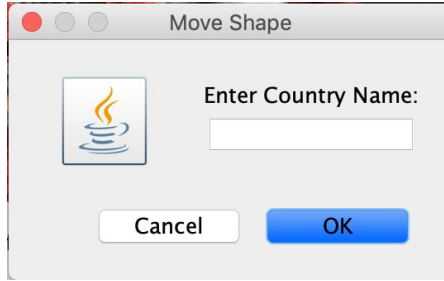
To run the COVID-19 simulator, set up the Java files and image file included in the zip folder in Eclipse. Run the main method in the CovidGUI class to run the program and start the user interface.

## Welcome Screen

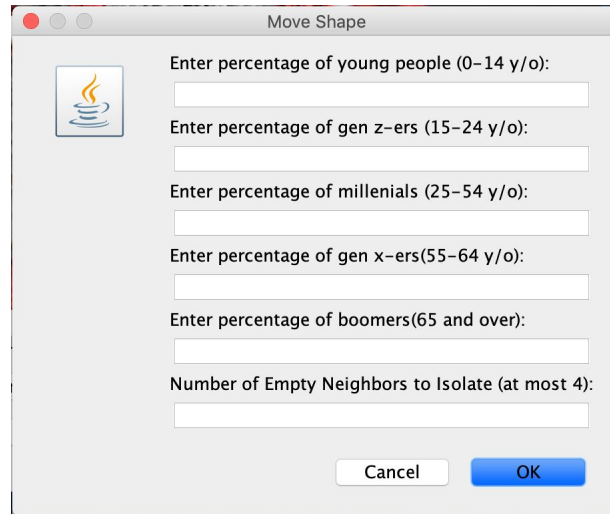
The below image displays the simulator's welcome screen, where you can choose the country you would like to simulate the spread of disease for.



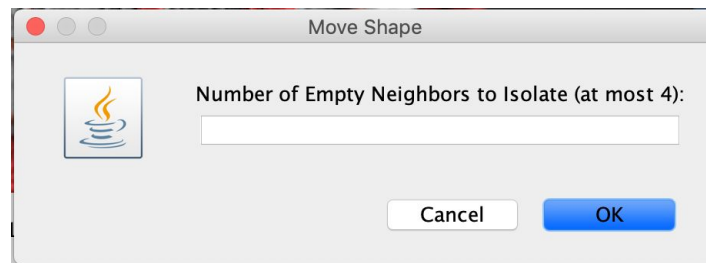
- Choosing any of the specific country buttons will scrape real-time data about infection rates and the distribution of age groups in the country to inform the simulation (more information provided in the Simulator Experimentation section).
- Choosing the “Pick a Country!” button will pop up a text field for you to type in your own country of choice.



- Choosing the “Custom Age Demographics” button will pop up a series of text fields for you to type in your chosen distribution of age groups for an imaginary country.

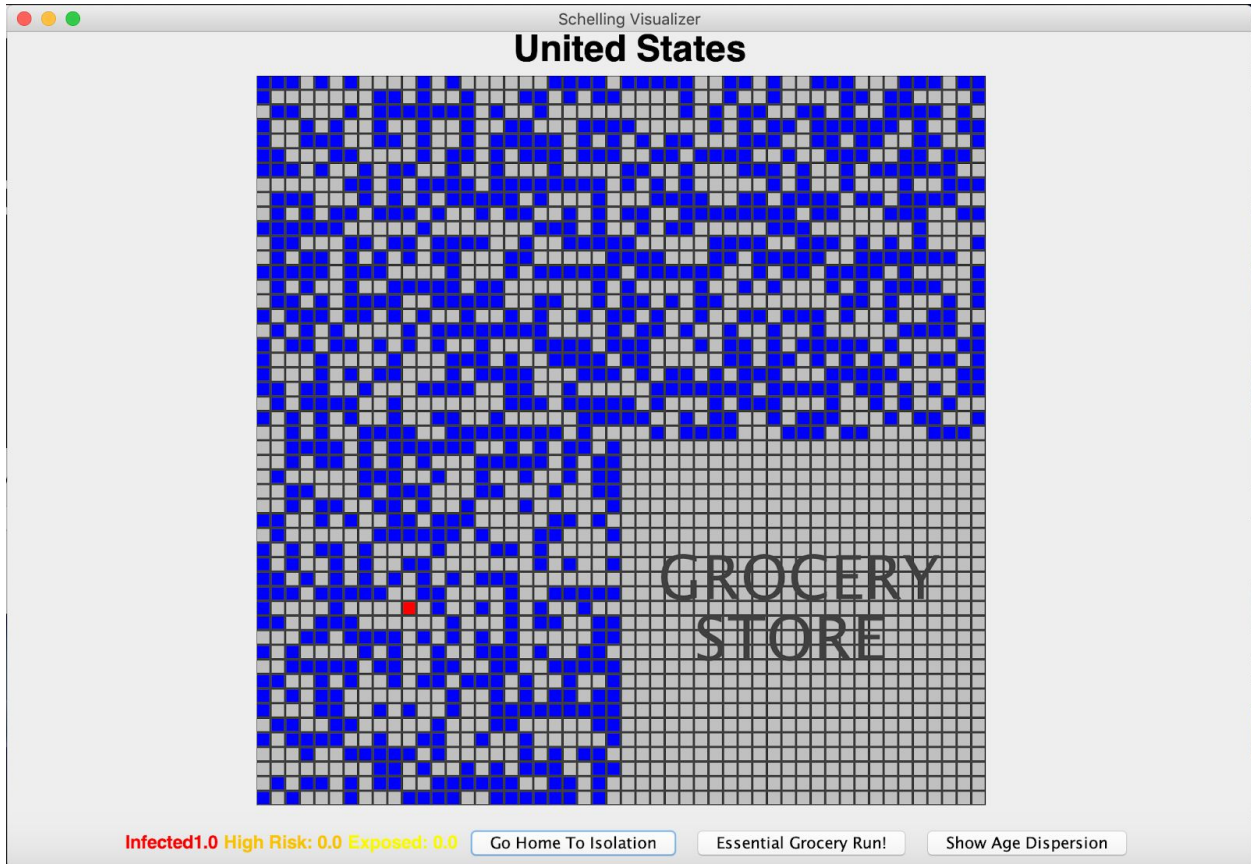


The below image displays the text field that pops up once you have made your country selection, asking you to choose the number of empty spaces you would like to require around each individual in the simulation. A greater number of empty spaces enforces a greater level of isolation.

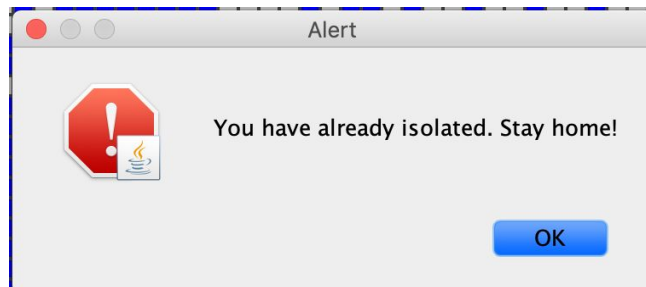


## Simulation Screen

The below image displays the simulator’s simulation screen, where you can toggle between moving the people in the population into isolation and to the grocery store for an occasional essential trip.



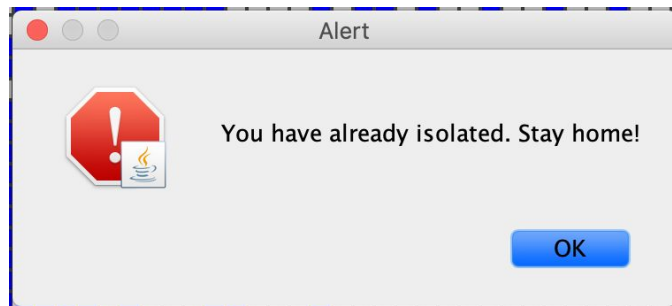
- The grid displays 3 neighborhoods and a grocery store (with each neighborhood or grocery store occupying a quadrant). People on the grid are restricted to moving to their assigned neighborhood or the grocery store in the simulation. The color coding of the default “Infected” view is as follows:
  - Gray for empty space
  - Blue for susceptible/recovered and not exposed/re-exposed ( $\text{infectionRisk} == 0$ )
  - Yellow for susceptible and slightly exposed ( $\text{infectionRisk} > 0$  and  $\text{infectionRisk} < 0.5$ )
  - Orange for susceptible and high risk ( $\text{infectionRisk} \geq 0.5$  and  $\text{infectionRisk} < 1$ )
  - Red for infected ( $\text{infectionRisk} \geq 1$ )
- The “Go Home To Isolation” button sends every person on the grid back to their neighborhood and to a square in their neighborhood with the required number of empty squares around it. Once everyone has moved back to their neighborhoods, their  $\text{infectionRisk}$  values are updated based on the  $\text{infectionRisk}$  values of their neighbors. Clicking this button more than once in a row results in the following pop up message.



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- The “Essential Grocery Run!” button sends a random 10 percent of people to random squares in the grocery store. Once the selected people are in the grocery store, their infectionRisk values are updated based on the infectionRisk values of their neighbors. Clicking this button more than once in a row results in the following pop up message.



- The “Show Age Dispersion”/”Show Infected” button toggles the grid view between viewing the distribution of infected people and viewing the distribution of age groups. The color coding for the “Age Dispersion” view is as follows:
  - Gray for empty space
  - Lightest green for 0-14 year olds
  - Light green for 15-24 year olds
  - Medium green for 25-54 year olds
  - Dark green for 55-64 year olds
  - Darkest green for 65 year olds and up

## Assumptions & Known Issues

- People in the population can get re-infected with the disease repeatedly (so recovered individuals are not distinguished in the simulator)
- A week is considered to be a run to the grocery store + a move to isolation
- We are assuming people of the ages 0-14 increase their viral load/infection risk by 0.1 of their neighbor’s viral load when they come into contact with them. We are assuming people of the ages 15-24 increase their viral load by 0.2 of their neighbor’s viral load when they come into contact with them. We are assuming people of the ages 25-54 increase their viral load by 0.3 of their neighbor’s viral load when they come into contact with them. We are assuming people of the ages 55-64 increase their viral load by 0.4 of their neighbor’s viral load when they come into contact with them. We are assuming people of the ages 65+ increase their viral load by 0.5 of their neighbor’s viral load when they come into contact with them.
- The people positioned on the perimeter of the grid do not have their viral load increased consistently. This is because the updating of each person’s viral load borrows some code from the original Schelling Simulator, which skipped past any individuals with fewer than eight spaces surrounding them (i.e. the people on the perimeter).
- When inputting a country under the “Enter Country Name: “ pop up, you must enter a country name based on the country’s name on the CIA webpage (the input is not case sensitive and there can be leading and trailing white spaces, but the input must match or contain keywords that match the CIA webpage country name) given in the pull down menu on the following page: <https://www.cia.gov/library/publications/the-world-factbook/>
  - Entering a custom country name will take a few minutes (1-5 minutes) to find the data for the specific country. In order to track the progress in searching for a country match, there are print statements to the console that will print the countries that the

programming is looking at and a boolean of the comparison between the input and current country.

- In order to populate infected people on the screen, we used a percentage of people who were infected based on the statistics provided on the following website (<https://www.statista.com/statistics/1043366/novel-coronavirus-2019ncov-cases-world-wide-by-country/>) out of the country's total population (from the country's CIA page above). If the percentage of people infected was low enough that the number of infected people was set to 0 based on the parsed statistics, we populated the country to have a default of 1 infected person to see how the country would respond.
- When running our experiment, we always ran the simulation over 5 weeks (5 trips to grocery store and back).
- When testing whether or not the percentage of high risk individuals (those ages 65+) affected the infection rate, we assumed people were isolating with at least 2 empty squares.
- We assume that users will interact with our simulator correctly based on the provided user manual.

# Simulator Experimentation

## BACKGROUND

In the past several months, millions of people all over the globe have been infected with an extremely virulent and devastating respiratory disease –SARS-CoV-2, causing what is commonly known as COVID-19. This novel Coronavirus is one of the few coronaviruses that can affect humans; others include the common cold, MERS (aka Camel Flu) and SARS. The virus is characterized by its spherical shape and glycoprotein spikes that protrude from the surface appearing as a *crown* under the microscope, hence the name. The microscopic organism enters the human respiratory system and the glycoprotein spikes latch onto the angiotensin-converting enzyme 2 (ACE2) cell surface. This causes the cell to undergo a structural change so that the virus can essentially hack the cell, fusing with the cell membrane, and allowing for replication.

There have been over 1 million cases COVID-19 and as a result 64,283 total deaths as of May 2nd in the US alone. Globally, the disease has reached over 3.5 million people and 245,243 deaths. Countries have issued nation-wide lockdowns, requiring citizens to isolate in order to decrease the spread of the disease as much as possible.

## OUR COVID-19 SIMULATOR

With this global pandemic affecting everyone's daily lives, we wanted to use this opportunity to create a COVID-19 simulator, which would simulate the spread of the disease using real-world data. We used the Schelling Simulator model as our base, and changed several things to reflect the current situation:

Each agent would move until it was surrounded by a sufficient number of empty squares to simulate "isolation". Each agent also has a viral load factor, which would increase with every "interaction" with another agent. These interactions were determined by counting each agent's surrounding neighbors. If the agent comes into contact with an infected agent, their viral load increases by that infected agent's current viral load. Each agent also has an infection propensity number, which would make them more or less prone to the disease (increasing their viral load by a lesser multiple) depending on their age. As in real life, the older the agent is, the more likely they are to become infected.

These numbers for the ages were pulled from the CIA world factbook website using the method of web scraping (via Regex), which we learned from Homework 3. The percentage of infected people was drawn from scraping the Statista database with all the new COVID-19 cases by country and dividing the number of cases by the population scraped from the CIA world factbook. We then inserted this as parameters to each instance of the model depending on which country you chose. We also added an additional option to customize your own "country". You can determine the age distribution of this "custom country" to see how the risk differences can affect the spread of the disease.

In addition to our "isolation" method, we have a "grocery shopping" method. Although people are required to shelter-in-place, people are still permitted essential trips, which includes buying food. The grocery store is one of the few places where people gather and may contract the virus. This is why we see an increase in the viral spread. When they return home to isolation, they may then infect others in their neighborhood. It is important to note that returning home means that the agent has returned back to their designated neighborhood, a variable that is stored in the Person class. The grid is split into four quadrants, with the grocery store occupying one of them, and the other three being neighborhoods. This allows for a more realistic move back to isolation, rather than the agent moving from the grocery store to a random empty square on the grid (as in the original Schelling model).

Lastly, we also have a button that unveils each agent's age group in a gradient, with the youngest age group visualized as the lightest green color, and the oldest age group, visualized as the darkest green color. This allows for the users to see the age of the infected agent.

## QUESTION

What variables in the environment can successfully slow the spread of disease?

## HYPOTHESES

1. **Isolation Level:** If the number of empty squares required around each person in the simulator increases, then the increase in infections over time (either to the grocery store or back to isolation) decreases.
2. **Susceptibility:** If the percentage of Boomers (i.e. high-risk people over the age of 65) in the population (as determined by the `susceptibilityMultiplier`) decreases, then the increase in infections over time (either to the grocery store or back to isolation) decreases.

## METHOD

### Isolation Level

To test our hypothesis about the effect of increasing isolation levels, we ran our simulator using the values of 0, 1, 2, 3, and 4 required empty squares around each individual in the United States, Italy, and South Korea. We ran our simulator for 5 rounds of going to the grocery store and going to isolation (to represent 5 weeks in the environment).

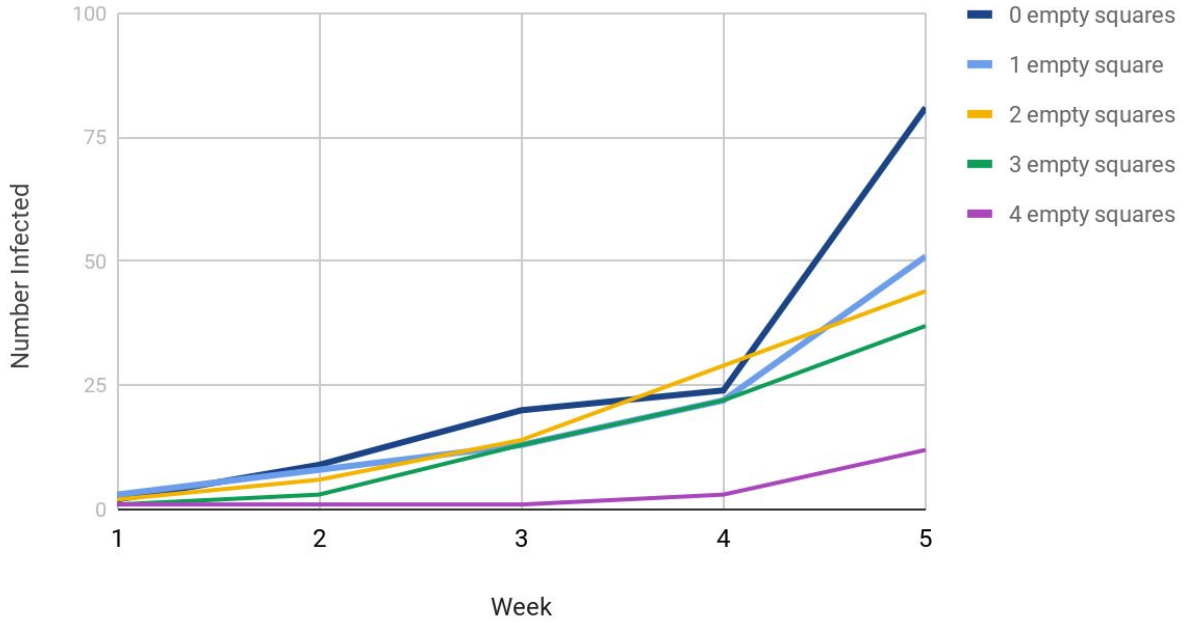
### Susceptibility

To test our hypothesis about the effect of decreasing the percentage of Boomers, we ran our simulator using the values of 20%, 10%, 5%, and 1% of the population being high risk (i.e. with a `susceptibilityMultiplier` value of 0.5). We ran our simulator for 5 rounds of going to the grocery store and going to isolation (to represent 5 weeks in the environment).

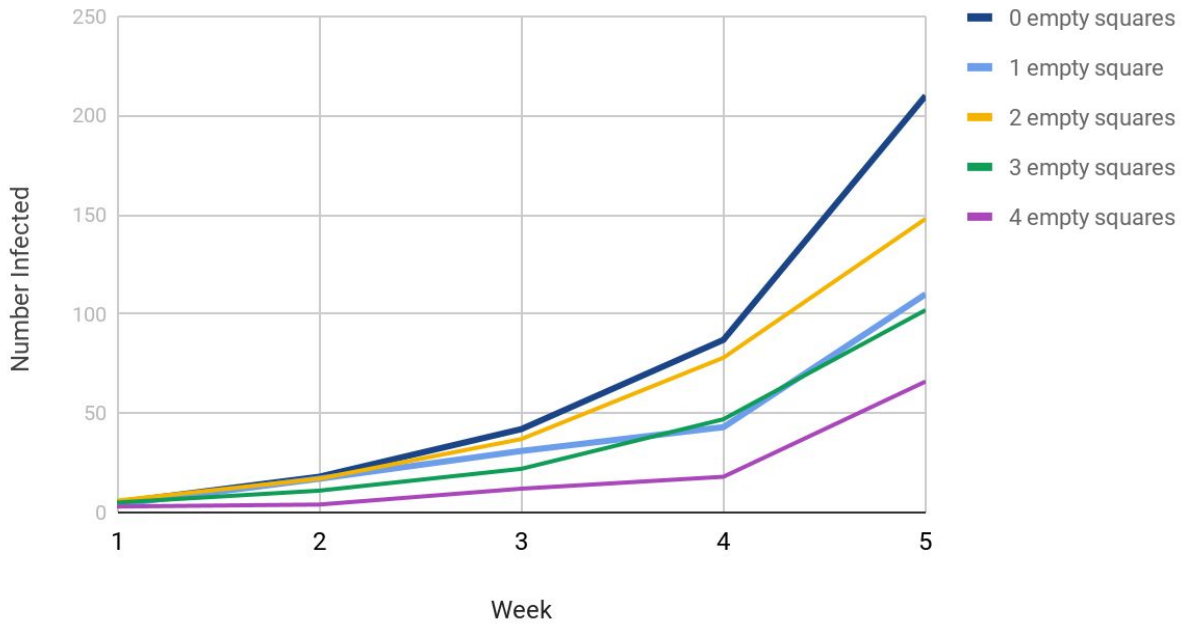
# RESULTS: Summary of Data

## Isolation Level

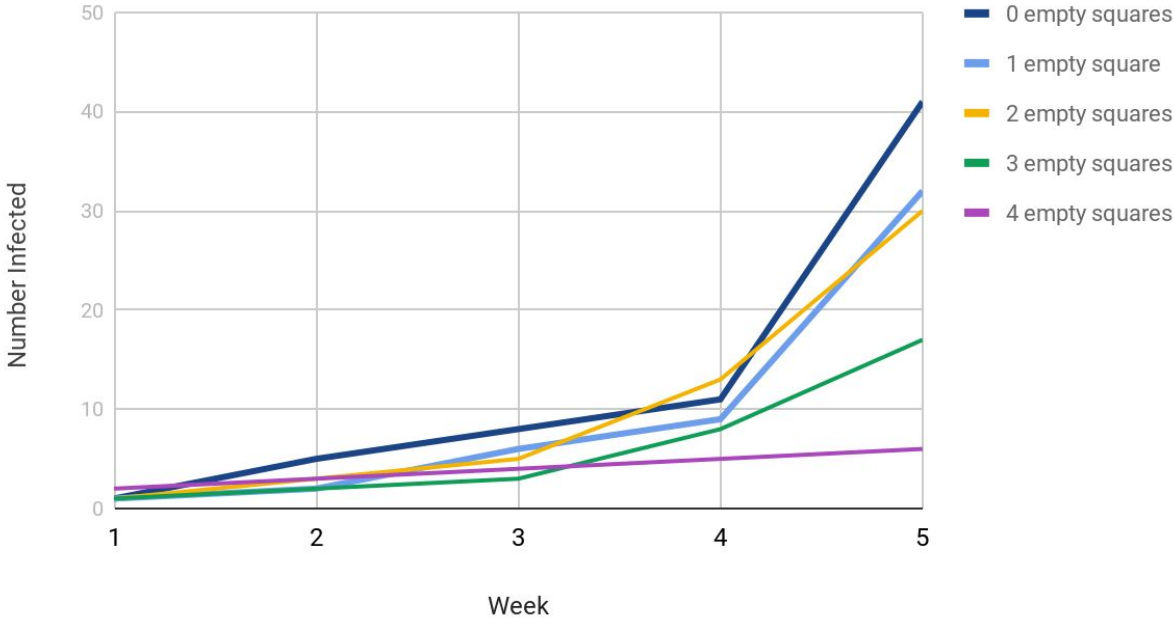
### United States



### Italy

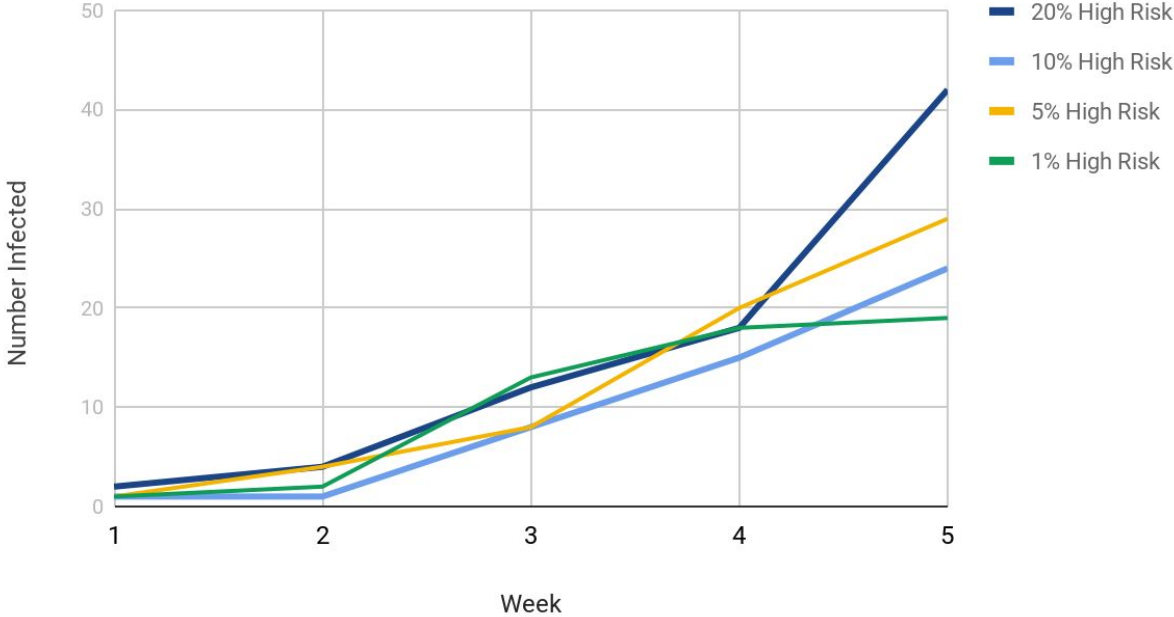


# South Korea



# Susceptibility

## Susceptibility





## Conclusions

### Isolation Level

Based on the summary of the data and the graphical views of the infected populations (see Appendix section), we conclude that our hypothesis is proven. An increase in the number of empty spaces around individuals does almost always correspond to a decrease in the infection rate of a population over time. For both the United States and South Korea, the number of infected people at the end of 5 weeks was greatest for a constraint of 0 empty squares, and decreased for 1, 2, 3, and 4 empty squares (in that order). For Italy, the number of infected people at the end of 5 weeks was greatest for 0 empty squares, and then decreased for 2, 1, 3, and 4 empty squares (in that order). The deviation from the hypothesis here can likely be attributed to the randomness of interactions between neighbors at grocery stores and in neighborhoods, and therefore does not necessarily disprove our claim. So, our overall conclusion is that isolation level is an effective way to slow the spread of COVID-19, regardless of the initial infection rate in a population.

### Susceptibility

We postulated that the higher the percentage of Boomers (aka. ages 65+) in the population would positively correlate with the number of infected individuals. This was due to the notion that the elderly population has a higher risk of contracting COVID-19 and therefore is more likely to be infected. When we ran the simulation, we ran the simulation over the course of “5 weeks” (5 trips to the grocery store and back) with the isolation restraint set to 2 empty squares, simulating modest shelter-in-place regulations. After running the simulation, we have concluded that the percentage of elderly (ages 65+) in a population has some effect on the spread of infection, but is not as predictive as the isolation level, (discussed above). For example, a population with 5% ages 65+ resulted in 17 total infections while a population with 1% ages 65+ resulted in 19 total infections. Although our hypothesis was not 100% correct, this finding is *not* an inaccurate depiction of reality. In real life, the level of isolation is a better deterrent of the spread of infection than the percentage of elderly in the population. For example, Japan is a population with a higher percentage of elderly people than youth—an upside down pyramid; however, their infection rate is less than that of many other countries. This may be due to the fact that in real life, the elderly are less reckless than the younger generation and simply do not leave their home. This reinforces the idea that the most important way to prevent the spread of COVID-19 is to *stay home!*

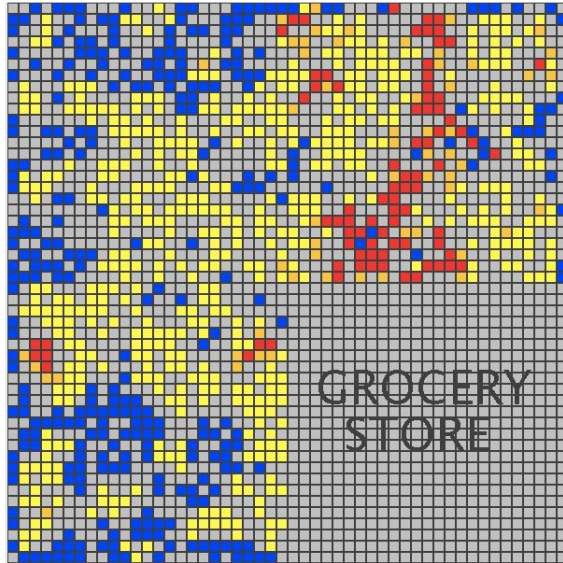
# Appendix

## Graphical Changes in the Simulator

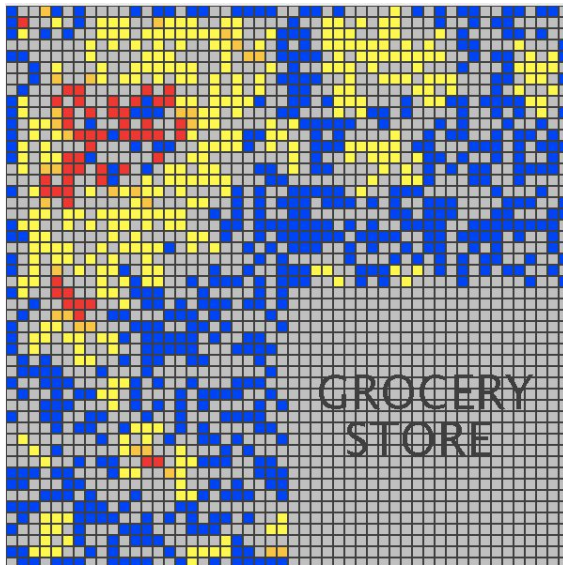
### Isolation Level

*United States*

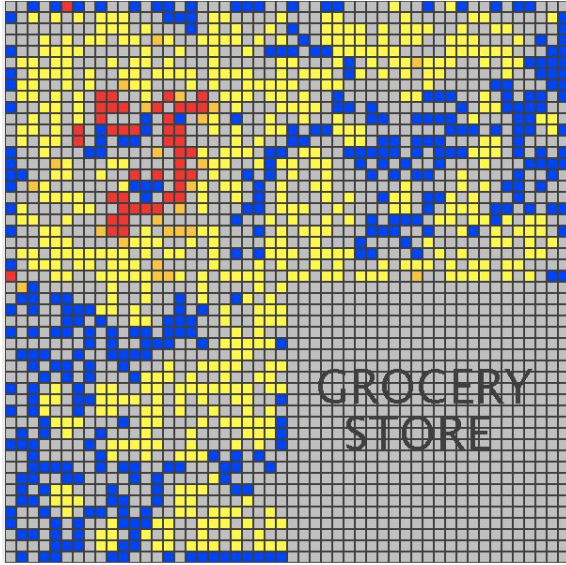
0 empty squares: 81 infected



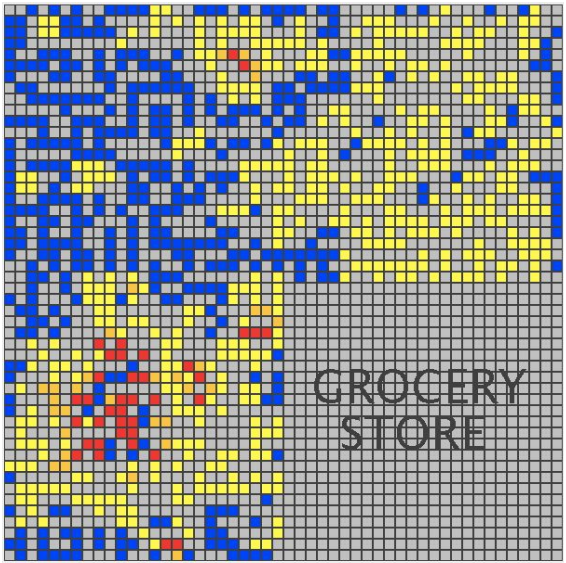
1 empty square: 51 infected



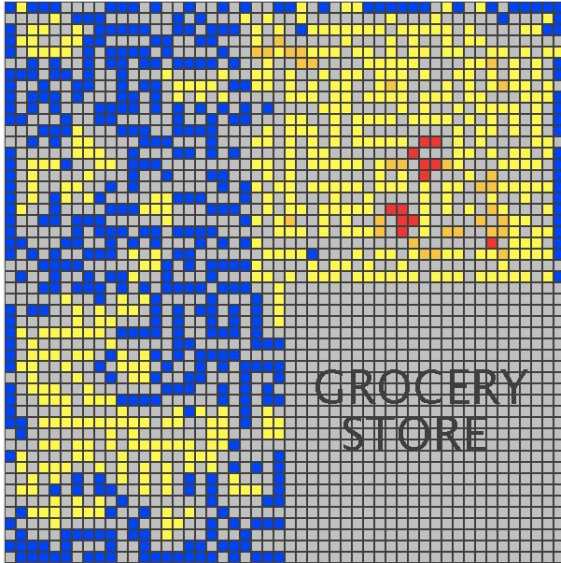
2 empty squares: 44 infected



3 empty squares: 37 infected

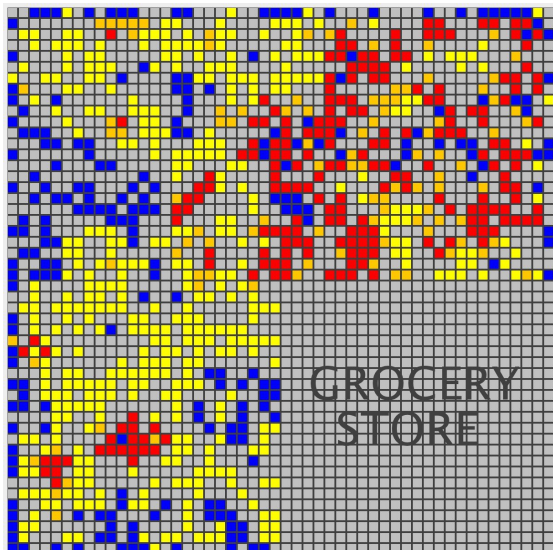


4 empty squares: 12 infected

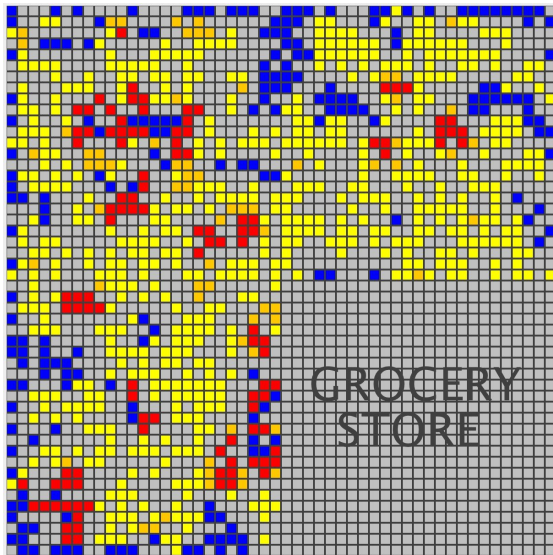


*Italy*

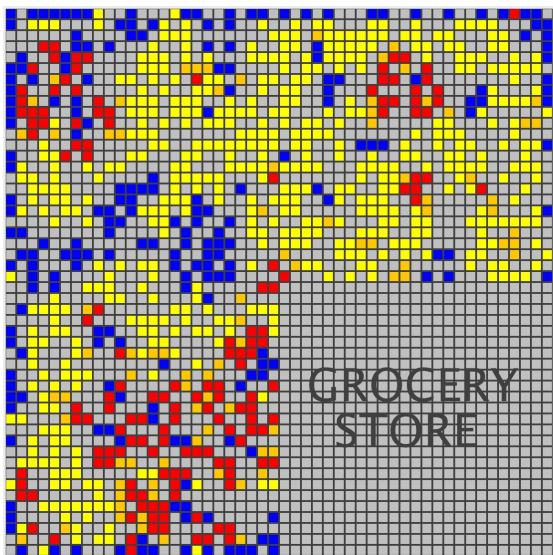
0 empty squares: 210 infected



1 empty square: 110 infected

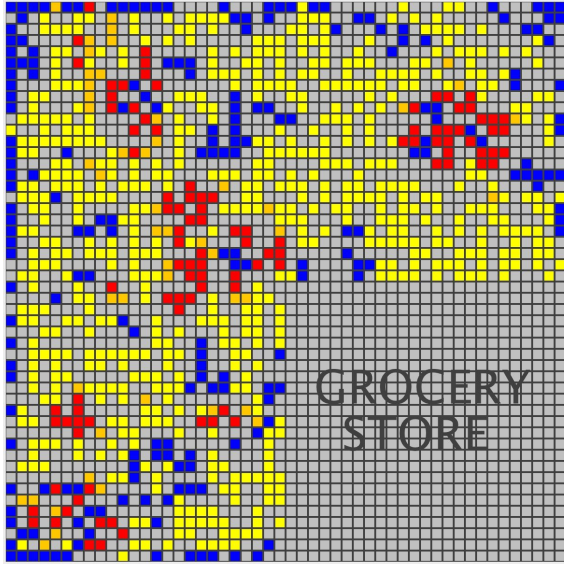


2 empty squares: 148 infected

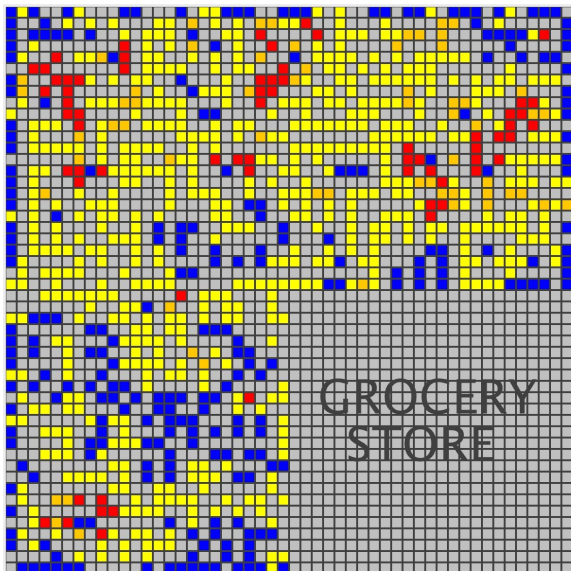




3 empty squares: 102 infected



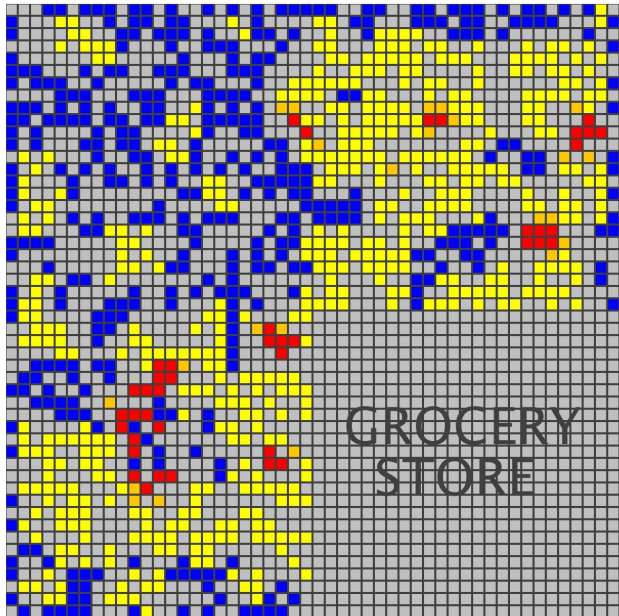
4 empty squares: 66 infected



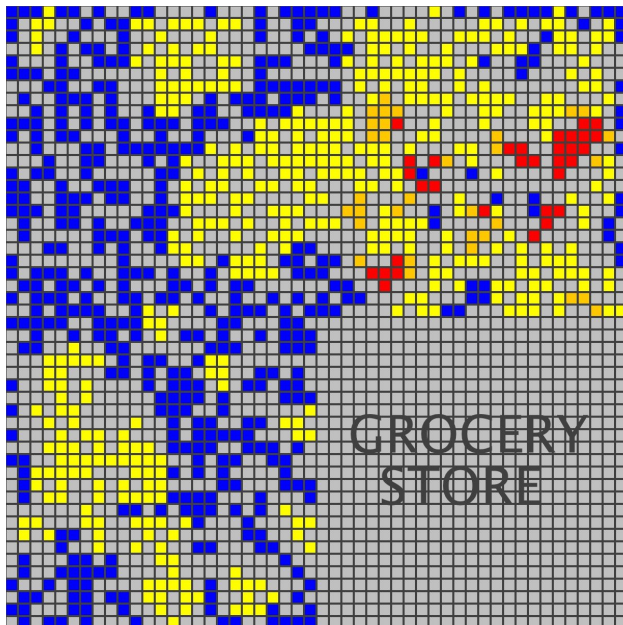


South Korea

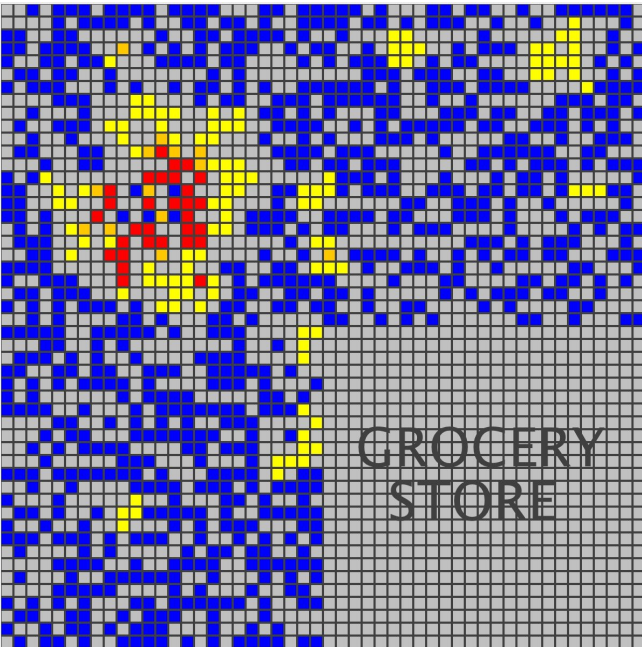
0 empty squares: 41 infected



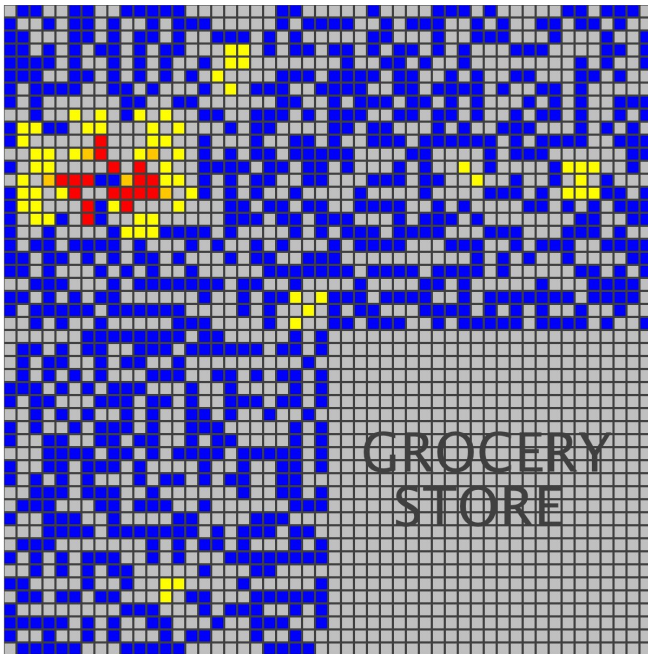
1 empty square: 32 infected



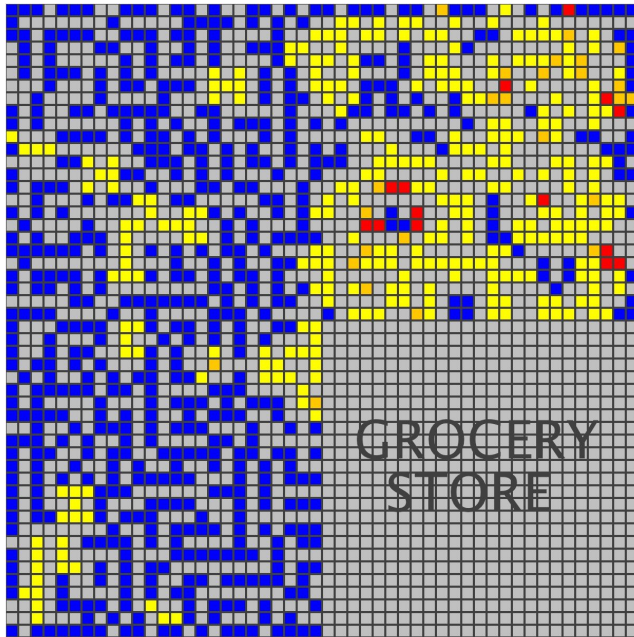
2 empty squares: 30 infected



3 empty squares: 17 infected

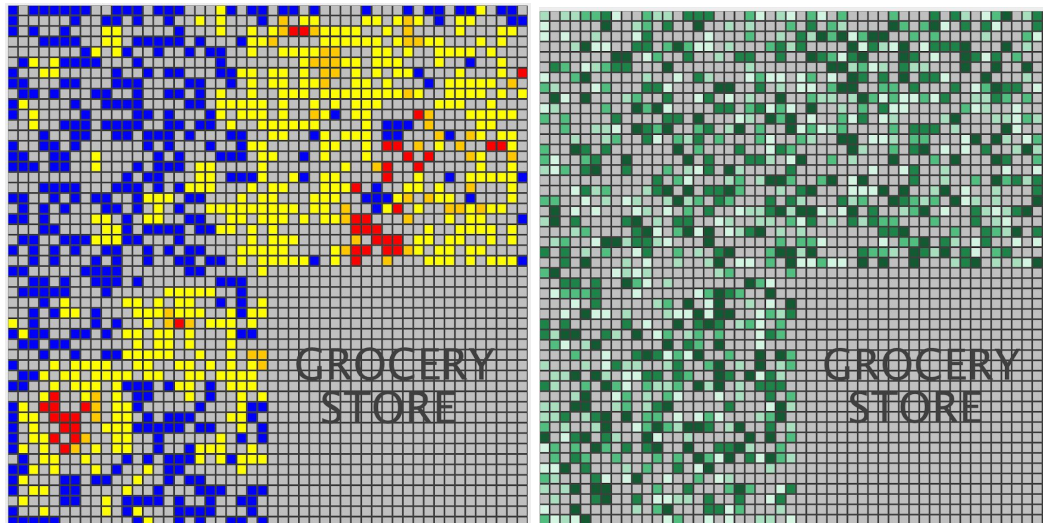


4 empty squares: 15 infected



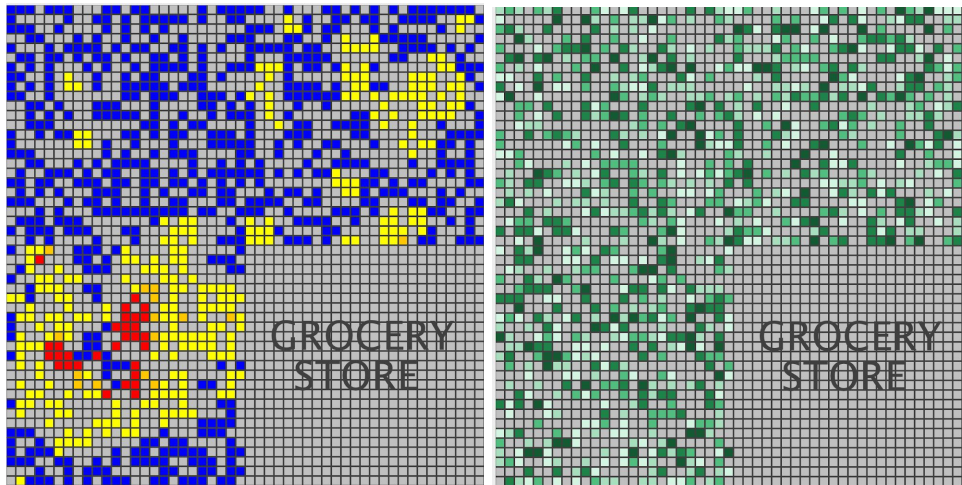
### Susceptibility

20% high risk individuals: 41 Infected; 52 High Risk; 446 Exposed





10% high risk individuals: 30 Infected; 15 High Risk; 268 Exposed



5% high risk individuals: 34 Infected; 19 High Risk; 466 Exposed



1% high risk individuals: 23 Infected; 33 High Risk; 274 Exposed

