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The Importance of Vaccines and Quarantines in Viral Outbreaks

Background:
Over the past three years, COVID-19 has heavily impacted populations across the world in almost every way possible, however, it isn't the first widespread disease to occur. Other past widespread diseases include the likes of different Plagues, the Spanish Flu (H1N1), and influenza. For each of those pandemics/epidemics, quarantine rules were placed and vaccines were created to strengthen people's immunity systems against the respective disease, usually in doses of two with a waiting period in between them. Quarantines were created to reduce risk and, therefore, number of infections by controlling infected people's whereabouts, similarly with vaccines by enhancing susceptible people's immune systems. However, not all people are not considerate enough to quarantine despite being infected and not all people want to get vaccinated (are antivax).

Question:
How effective exactly are vaccines and quarantines in reducing the number of infections and controlling outbreaks? And how important is it that everyone both quarantines and gets vaccinated? These prevention methods will be examined individually as well as together by observing the number of days it takes for the outbreak to be over or when the max number of ticks/days in the simulations have been reached.

Experimental Design:
The following are settings that are consistent throughout all scenario type below:
- 4000 humans in the population
- max simulation length of 1460 days (4 years)
- an infection probability of 5% from infected people towards susceptible neighbours
- an infection period of 7 days
- a recovery threshold of 49% for infected people to recover and become immune
- an immunity period of 28 days (4 weeks)

Four main types of scenarios are considered, with types 2 and 3 both having three different scenarios. Each scenario will be run five times due to stochasticity of certain aspects. For each simulation ran, the number of days until the outbreak ends (or until the max number of days has been reached) will be recorded along with its graphical representation of the population and plots of the number of infected people overtime are made. The number of first and second doses administered overtime are also plotted but only for vaccine and quarantine + vaccine scenarios.

1. **Baseline (no prevention methods):**
   The Baseline's does not have any additional settings aside from the consistent ones listed above.

2. **Quarantine:**
   General Quarantine Settings:
   All Quarantine scenarios have a quarantine delay of 14 days for the population to realise they have to start quarantining. There is no scenario where consideration is 0% as it would be no different than the Baseline.

   A. **Consideration 80%:**
   Has a consideration probability of 80% for each individual.

   B. **Consideration 95%:**
   Has a consideration probability of 95% for each individual.

   C. **Consideration 100%**
   Has a consideration probability of 97% for each individual.

3. **Vaccine:**
   General Vaccine Settings:
   All Vaccine scenarios have a vaccine delay of 168 days (6 months) - for vaccines to be created and made available to the population, a vaccination probability of 1% - for the chance of an individual being able to get a vaccination (limited supply), a vaccination delay of 168 days (6 months) for getting the second dose - due to vaccination intervals as well as limited supply, and first and second dose reduction multipliers of 8% and 2% respectively - to reduce the risk of infection. There is a scenario where antivax probability is 0% as even without any antivax people the vaccines have an effect on the spread of infection.

   A. **Antivax 0%:**
   Has an antivax probability of 0% for each individual.

   B. **Antivax 1%:**
   Has an antivax probability of 1% for each individual.

   C. **Antivax 5%:**
   Has an antivax probability of 5% for each individual.

4. **Quarantine + Vaccine:**
   There is only one Quarantine + Vaccine scenario which is used as a final comparison to the Baseline. It has the same **general settings** from Quarantine and Vaccine scenario types as listed above. Additionally, it will be using a consideration probability of 95% and an antivax probability of 1% to represent the most realistic (at least I think) scenario.

Results:

1. **Baseline:**

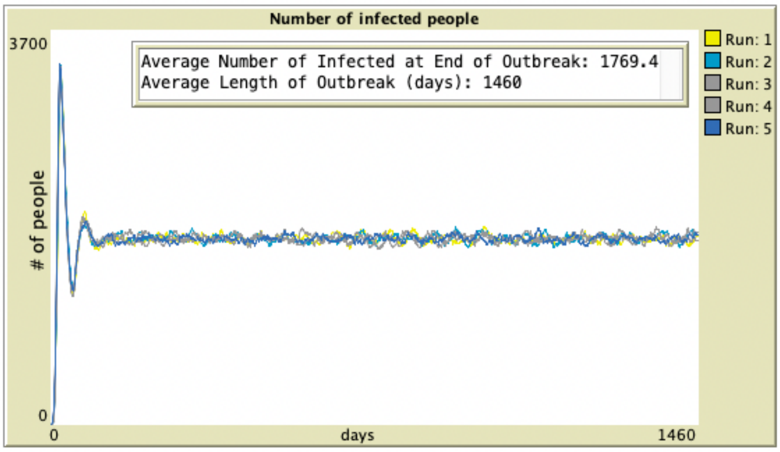

Fig 1: Plot of infected people in five simulations with Scenario 1.

2. A. **Quarantine, Consideration 80%:**

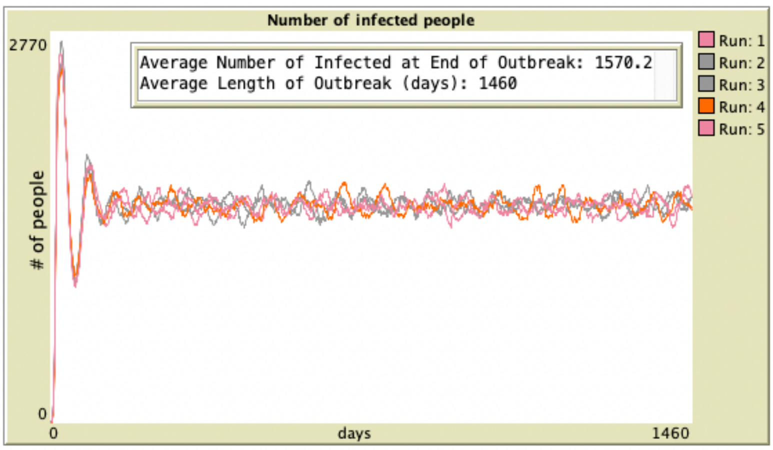

Fig 2: Plot of infected people in five simulations with Scenario 2.A.

B. **Quarantine, Consideration 95%:**

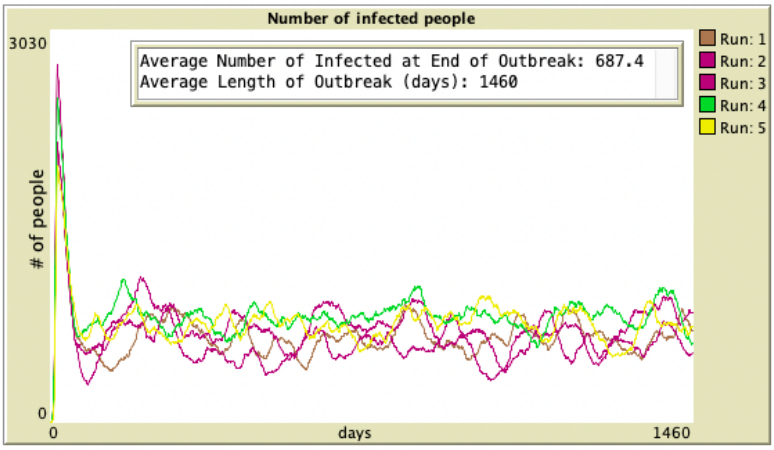

Fig 3: Plot of infected people in five simulations with Scenario 2.B.

C. **Quarantine, Consideration 97%:**

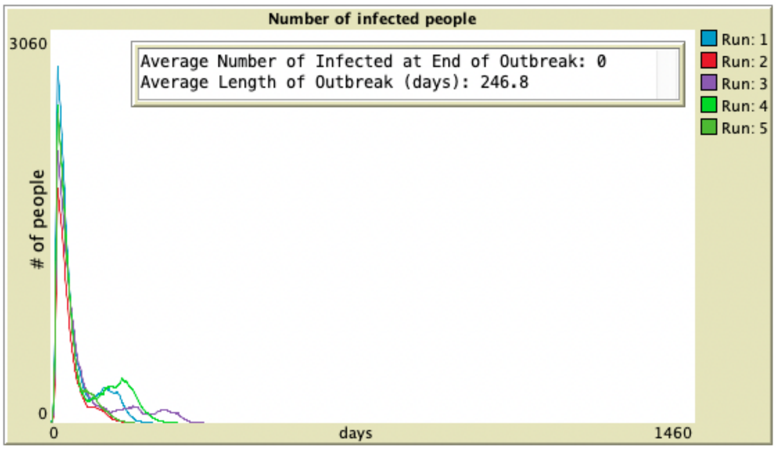

Fig 4: Plot of infected people in five simulations with Scenario 2.C.

3. A. **Vaccine, Antivax 0%:**

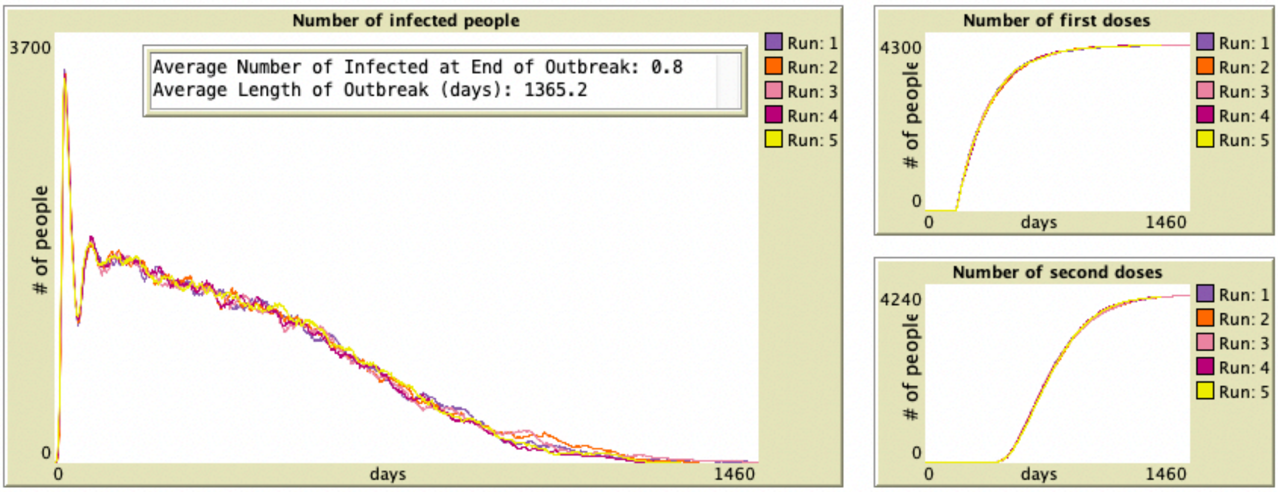

Fig 5: Plot of infected people and first and second doses in five simulations with Scenario 3.A.

B. **Vaccine, Antivax 1%:**

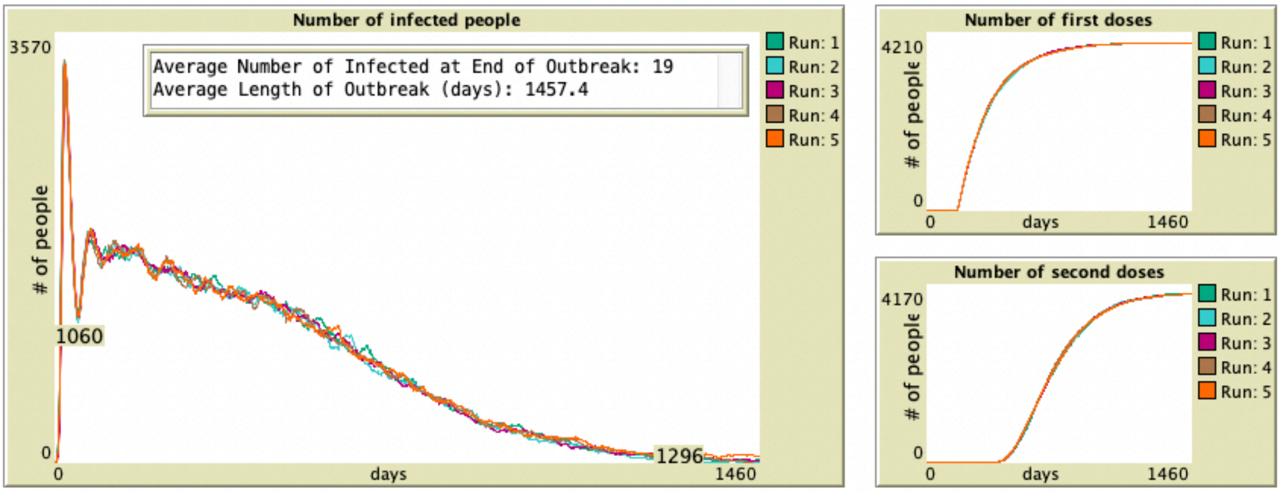

Fig 6: Plot of infected people and first and second doses in five simulations with Scenario 3.B.

C. **Vaccine, Antivax 5%:**

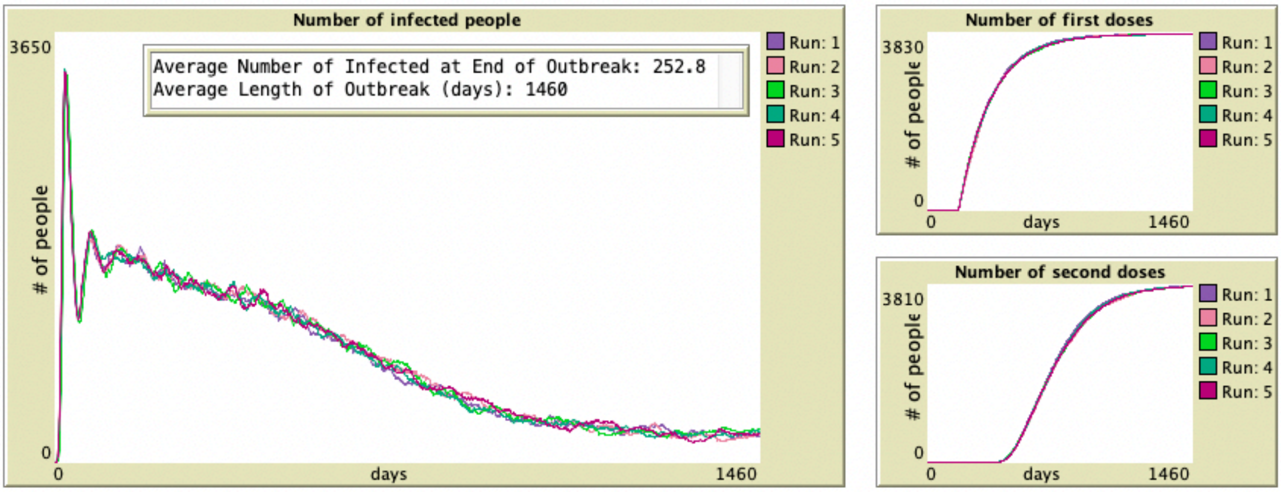

Fig 7: Plot of infected people and first and second doses in five simulations with Scenario 3.C.

4. Quarantine + Vaccine:

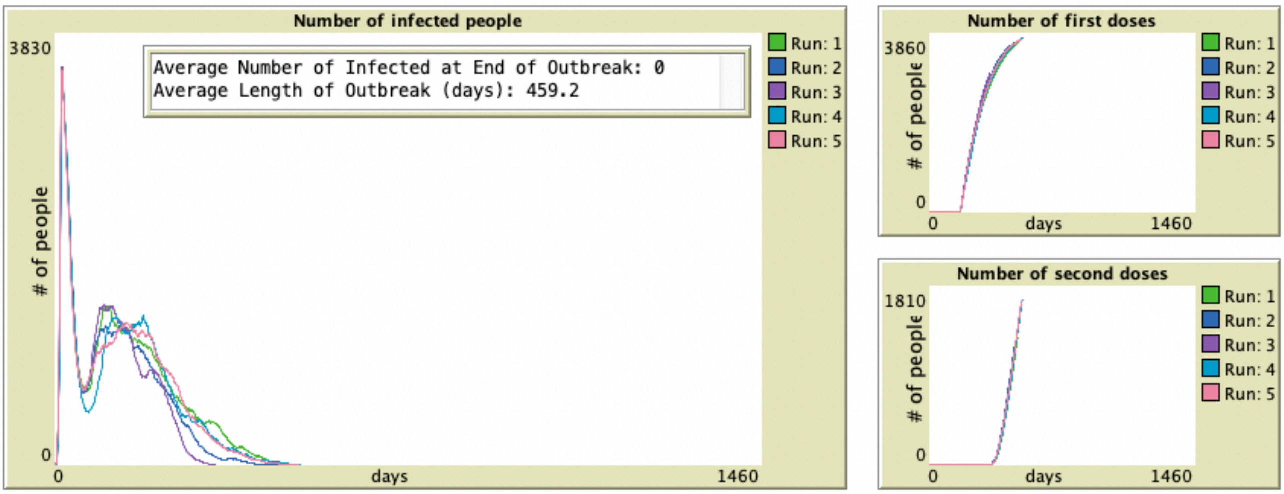

Fig 8: Plot of infected people and first and second doses in five simulations with Scenario 4.

Discussion:

As shown from the figure results above, the Baseline has the worst average number of infected people at the end of simulations with 1769.4 humans.

All Quarantine type scenarios outperform the Baseline with average number of infected people, where the higher consideration percentage the lower the average infected number. We can also see that with just a ‘small’ consideration increase of 2% it can lead to significantly early outbreak ends when comparing scenario 2.C. with 2.B. None of the simulations from 2.A. and 2.B. end early where as 2.C. has a much lower average outbreak length. This shows that if every individual who follows quarantine rules correctly counts and can make an impact on the outbreak length.

All Vaccine type scenarios also outperform the Baseline in significantly lower average numbers of infected people. The similar gradient declines over time between all three scenarios are due to the increase in first and second dose administrations, with the gradient being more steeper when second doses start being given out than when first doses do, but both being equally important in the process. Almost all the simulations in 3.A. were able to cure all its infected people which if given more time it would have surely been able to. Comparing scenarios 3.B. and 3.C., we can see that even with a 4% increase in antivax probability it does not heavily impact the gradient decreases from the vaccine doses, that if given enough time 3.C. would still be able to cure all its infected just with a longer time period. This shows that the effect from vaccines are too strong to be cancelled out by the effect from number of antivax people.

Comparing the Quarantine and Vaccine scenarios, overall vaccines are shown to have a stronger impact than quarantining on average number of infected. However, when a high percentage of people are considerate to quarantine (97-100%) the effect of quarantining begins to outweigh the effect of vaccines, but this is unlikely as there would usually be less considerate people and even those who are unaware that they are infected.

In the Quarantine + Vaccine scenario with “realistic” settings, we can see the effects of having quarantine rules and vaccine doses working together in reducing both the average number of infected and average outbreak length. Each simulation’s outbreak ended early with 0 infected people. This final scenario has an average outbreak length of less than a third of that of the Baseline, further showing how important it is to have both quarantines and vaccines when facing a viral outbreak.

It can be said that both prevention methods work in unison and this result is probably why they have been widely used in pandemics and epidemics. However, it is difficult to achieve a high percentage of consideration and a 0% antivax percentage within a population, especially in much larger populations which without a doubt would need more than these two methods to successfully overcome an outbreak such as COVID-19.