SPA DRP: Infectious Disease Modeling

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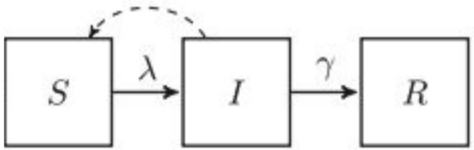
Introduction/Motivation

- COVID is on everyone’s mind right now
- Vaccines are promising!
- But, new variants of concern could possibly be more resistant to the vaccine, or have higher transmissibility.
  - What would happen in this case?
  - Would we need to continue mask wearing, raise the vaccination rate, and/or reduce contacts?

Research Question

"How does the india variant, mask compliance,and contact rate affect our vaccination threshold for COVID-19?"

- Note: Vaccine threshold= minimum vaccination level to lower COVID spread



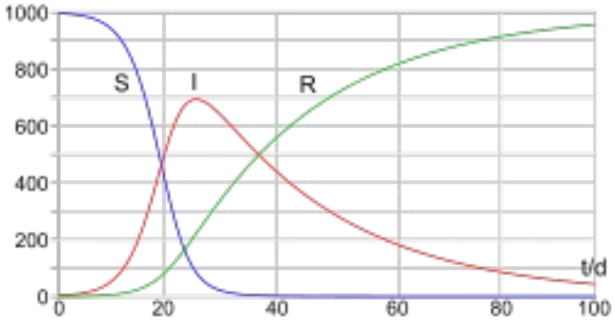
What is an SIR model?

- Compartmental model to see mathematical modelling of infectious disease
  - S=Susceptible
  - I=Infected
  - R=Recovered
- People move from box to box depending on parameters of model
  - Modeled by differential equations

$$\frac{dS}{dt} = -\beta IS \ , \quad \frac{dI}{dt} = \beta IS - \gamma I \ , \quad \frac{dV}{dt} = \gamma I$$

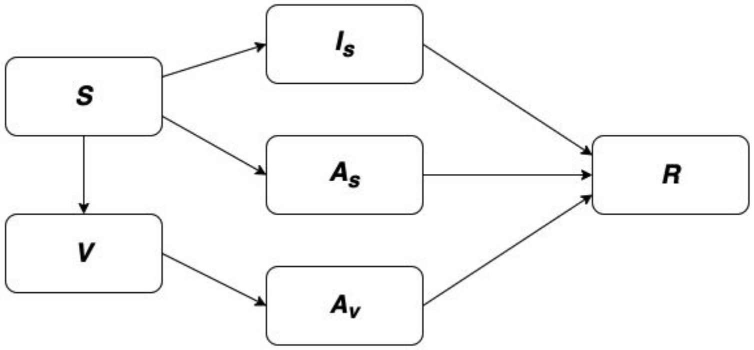
- Equations plotted on graph to see infectious

  disease spread



Our Model

- Added boxes to simple SIR model
- COVID vaccines now available, and vaccinated individuals who get infected have virtually no symptoms
- Non-vaccinated asymptomatic individuals have higher contacts than those with symptoms, and thus a different equation to model group
    - S= susceptible
    - I= Infected and unvaccinated
    - As=Asymptomatic and unvaccinated
    - Av=Asymptomatic and vaccinated
    - R=Recovered
    - V=Vaccinated



Our Model

Parameters holding fixed:

- Assuming vaccination rate is stable
- Probability of symptoms is same for every unvaccinated individual
- People stay recovered once infected
- No one entering or leaving population
- 4 variants being measured

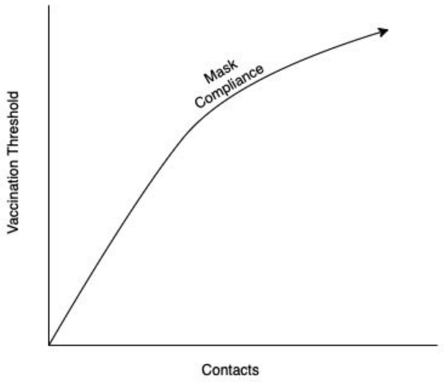
This model is a HUGE simplification of real life and not at all accurate representation, but this will allow us to look at the effect of a few variables:

- Contact rate
- Mask Compliance
- Transmissibility of India Variant

Simulation Approach

With previous parameters held fixed, we simulated different scenarios for India variant transmissibility in US

- With mask compliance (proportion out of 0-1), contact rate (1-10 people per day), and vaccination level (0-100%), simulate infection spread over 200 days
- Small number of people start off infected with each of 4 variants
- Model will plot necessary conditions for infection to not grow



4 scenarios

India Variant is just like normal COVID (Control)

- Sets baseline to compare other plots
- Expect masks, low contact rate, and high vaccinations to lower infection as general rule

India Variant is more contagious

- High contact rate should be more detrimental
- Higher vaccine threshold necessary to maintain spread
- Vaccines very important in this scenario

Vaccine works less against India Variant

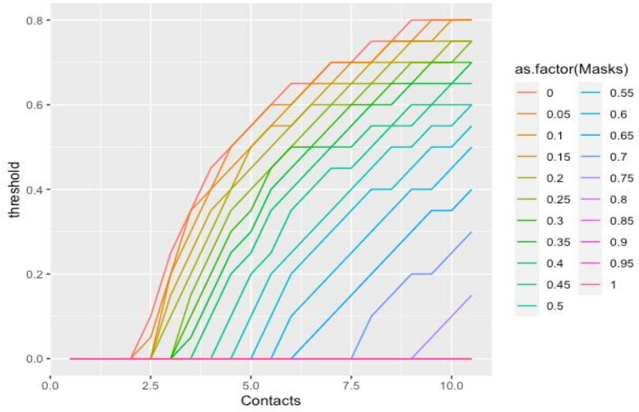
- High contact rate still more detrimental
- Vaccine threshold should be higher for fixed mask and contact rate since vaccines doesn’t work as well

More contagious and vaccine works less against India Variant

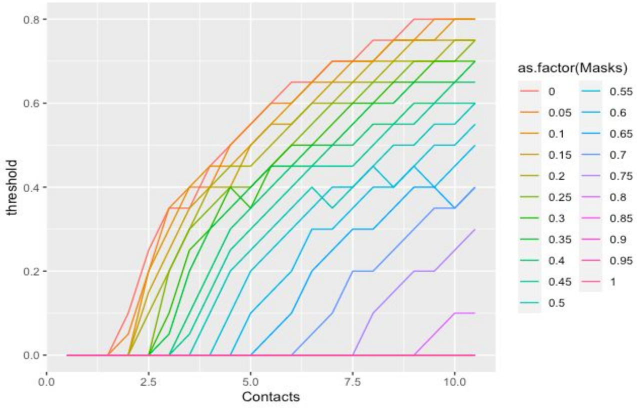
- Combo of both scenarios!
- Plot should have highest vaccine threshold of all

4 scenario plots

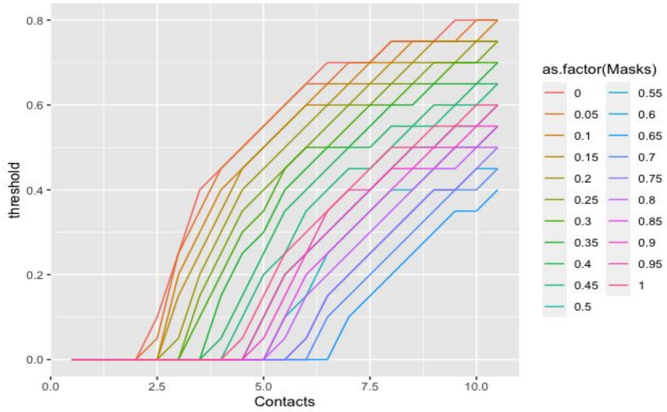
India Variant Control



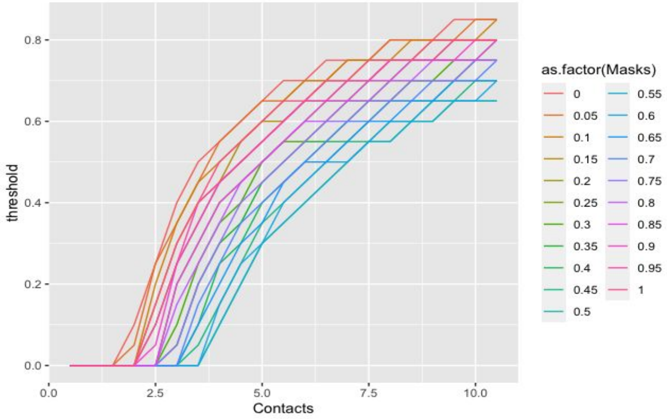
India Variant More Contagious



India Variant Lower Vaccine Efficacy



India Variant Contagious and Lower V.Efficacy



Conclusion

- Still bugs in code, but trend mostly follows hypothesized scenarios
- Lower vaccine efficacy is more closely associated with a need for higher vaccine threshold and mask compliance/contact rate to control spread
- Vaccines are still highly effective even if efficacy is reduced
    - Fixed vaccine threshold still required higher mask compliance and lower contacts
- If variants become more contagious or resistant to current vaccine, mask wearing and reducing contacts can help control spread.

Appendix

$$\frac{dS}{dt} = -vS - \sum_{i=1}^{4} \beta_{iI} I_i S - \sum_{i=1}^{4} \beta_{iA} A_{Vi} V$$

$$\frac{dI_i}{dt} = p_{iS}(\beta_{iI} I_i S + \beta_{iA} A_{iS} S) + \ p_{iV}(1 - \alpha_i)(\beta_{iI} I_i V + \beta_{iA} A_s V) - \gamma I_i$$

$$\frac{dAs_i}{dt} = (1 - \alpha_i)(\beta_{iI} I_i S + \beta_{iA} A_s V) - \gamma A_{si}$$

$$\frac{dV}{dt} = vS - \sum_{i=1}^{4} (1 - \alpha_i) \beta_{iA} A_{vi} V$$