Non-Pharmaceutical Herd Immunity using Homemade Masks

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Introduction

- The model was developed in response to the Coronavirus disease 2019 global pandemic in the United States
- It is an abstract agent-based SEIR model developed using NetLogo to explore the use of homemade masks of various quality in a representative United States population
- The goal was to determine if a non-pharmaceutical "herd immunity" can be achieved using homemade masks

Terms

- Asymptomatic (Exposed & Infectious) – Show no symptoms
- Egress – Protection from the wearer
- Herd Immunity – A population being sufficiently resistant that a disease cannot sustain itself because it runs out of hosts
- Ingress – Protects the wearer
- SEIR - Compartmental epidemiology model
- Symptomatic (Infectious) – Shows symptoms

Agenda

- Background & Data Sources
- Model & Methodology
- Results
- Conclusion

Background & Data Sources

- In the US, the Centers for Disease Control and Prevention (CDC) reversed an early recommendation against the wearing of masks by the public to one in favor of wearing masks
- Professional masks remain difficult to find
- The CDC homemade mask instructions only list "cotton fabric" as a material[1]

[1] *How to make masks*, **CDC**, 2020, https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-to-make-cloth-face-covering.html

Masks

- Three categories of masks:
  - N95 respirators (European FFP2)
    - Generally 95% effective
  - Surgical/medical
    - 15% to 95% effective
  - Homemade
    - Should not be used for health care workers
      - MacIntyre et al., 2015
    - Last resort protection
      - Davies, et al., 2013
    - Should be high quality and layered
      - Konda, et al., 2020

Homemade mask research 2013

Filtration Efficiency and Pressure Drop Across Materials Tested with Aerosols of *Bacillus atrophaeus* and Bacteriophage MS2 (30 L/min)[a]

Material	*B atrophaeus*		Bacteriophage MS2		Pressure Drop Across Fabric	
	Mean % Filtration Efficiency	SD	Mean % Filtration Efficiency	SD	Mean	SD
100% cotton T-shirt	69.42 (70.66)	10.53 (6.83)	50.85	16.81	4.29 (5.13)	0.07 (0.57)
Scarf	62.30	4.44	48.87	19.77	4.36	0.19
Tea towel	83.24 (96.71)	7.81 (8.73)	72.46	22.60	7.23 (12.10)	0.96 (0.17)
Pillowcase	61.28 (62.38)	4.91 (8.73)	57.13	10.55	3.88 (5.50)	0.03 (0.26)
Antimicrobial Pillowcase	65.62	7.64	68.90	7.44	6.11	0.35
Surgical mask	96.35	0.68	89.52	2.65	5.23	0.15
Vacuum cleaner bag	94.35	0.74	85.95	1.55	10.18	0.32
Cotton mix	74.60	11.17	70.24	0.08	6.18	0.48
Linen	60.00	11.18	61.67	2.41	4.50	0.19
Silk	58.00	2.75	54.32	29.49	4.57	0.31

[a] Numbers in parentheses refer to the results from 2 layers of fabric.

Used in model.

Testing the Efficacy of Homemade Masks: Would They Protect in an Influenza Pandemic? **Davies, Anna, et al.** 4, 2013, Disaster Medicine and Public Health Preparedness, Vol. 7, pp. 413-418.

Homemade mask research 2020

Used in model.

Table 1. Filtration Efficiencies of Various Test Specimens at a Flow Rate of 1.2 CFM and the Corresponding Differential Pressure (ΔP) across the Specimen[a]

	flow rate: 1.2 CFM		
	filter efficiency (%)		pressure differential
sample/fabric	<300 nm average ± error	>300 nm average ± error	ΔP (Pa)
N95 (no gap)	85 ± 15	99.9 ± 0.1	2.2
N95 (with gap)	34 ± 15	12 ± 3	2.2
surgical mask (no gap)	76 ± 22	99.6 ± 0.1	2.5
surgical mask (with gap)	50 ± 7	44 ± 3	2.5
cotton quilt	96 ± 2	96.1 ± 0.3	2.7
quilter's cotton (80 TPI), 1 layer	9 ± 13	14 ± 1	2.2
quilter's cotton (80 TPI), 2 layers	38 ± 11	49 ± 3	2.5
flannel	57 ± 8	44 ± 2	2.2
cotton (600 TPI), 1 layer	79 ± 23	98.4 ± 0.2	2.5
cotton (600 TPI), 2 layers	82 ± 19	99.5 ± 0.1	2.5
chiffon, 1 layer	67 ± 16	73 ± 2	2.7
chiffon, 2 layers	83 ± 9	90 ± 1	3.0
natural silk, 1 layer	54 ± 8	56 ± 2	2.5
natural silk, 2 layers	65 ± 10	65 ± 2	2.7
natural silk, 4 layers	86 ± 5	88 ± 1	2.7
hybrid 1: cotton/chiffon	97 ± 2	99.2 ± 0.2	3.0
hybrid 2: cotton/silk (no gap)	94 ± 2	98.5 ± 0.2	3.0
hybrid 2: cotton/silk (gap)	37 ± 7	32 ± 3	3.0
hybrid 3: cotton/flannel	95 ± 2	96 ± 1	3.0

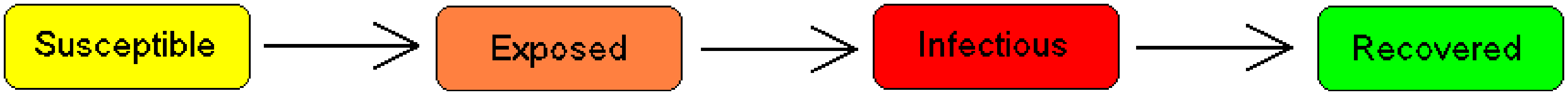
[a]The filtration efficiencies are the weighted averages for each size range—less than 300 nm and more than 300 nm.

Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks. **Konda, Abhiteja, et al.** 5, 2020, ACS Nano, Vol. 14, pp. 6339–6347.

Model & Methodology

- SEIR
- Model GUI
- Initial parameters
- Execution flowchart

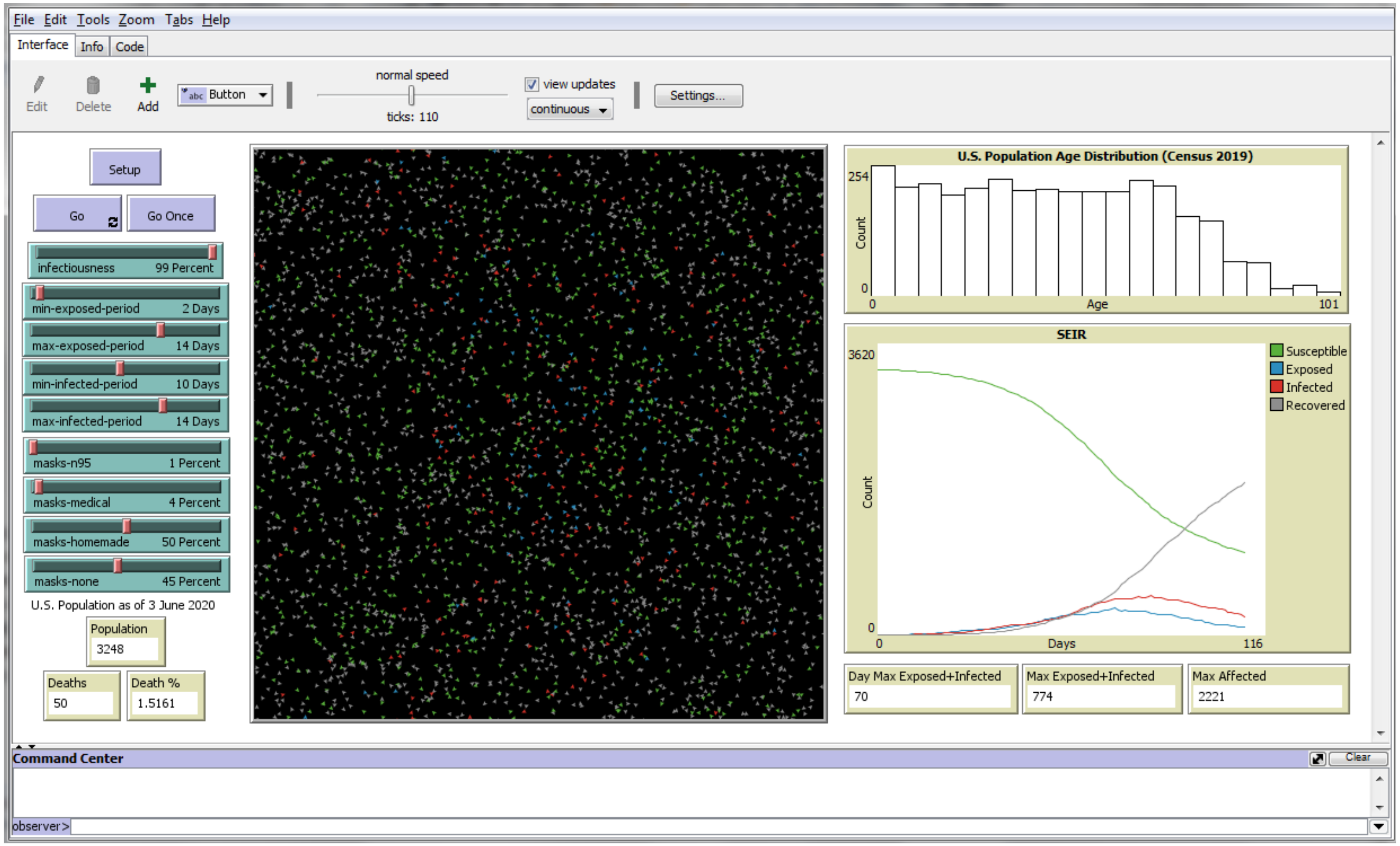
SEIR



- Compartmental epidemiology model
  - Can be deterministic or stochastic
  - Model presented today is stochastic
- People/Agents move from one state (compartment) to the next

Source: Wikipedia, https://en.wikipedia.org/wiki/Compartmental_models_in_epidemiology

Model GUI (NetLogo)

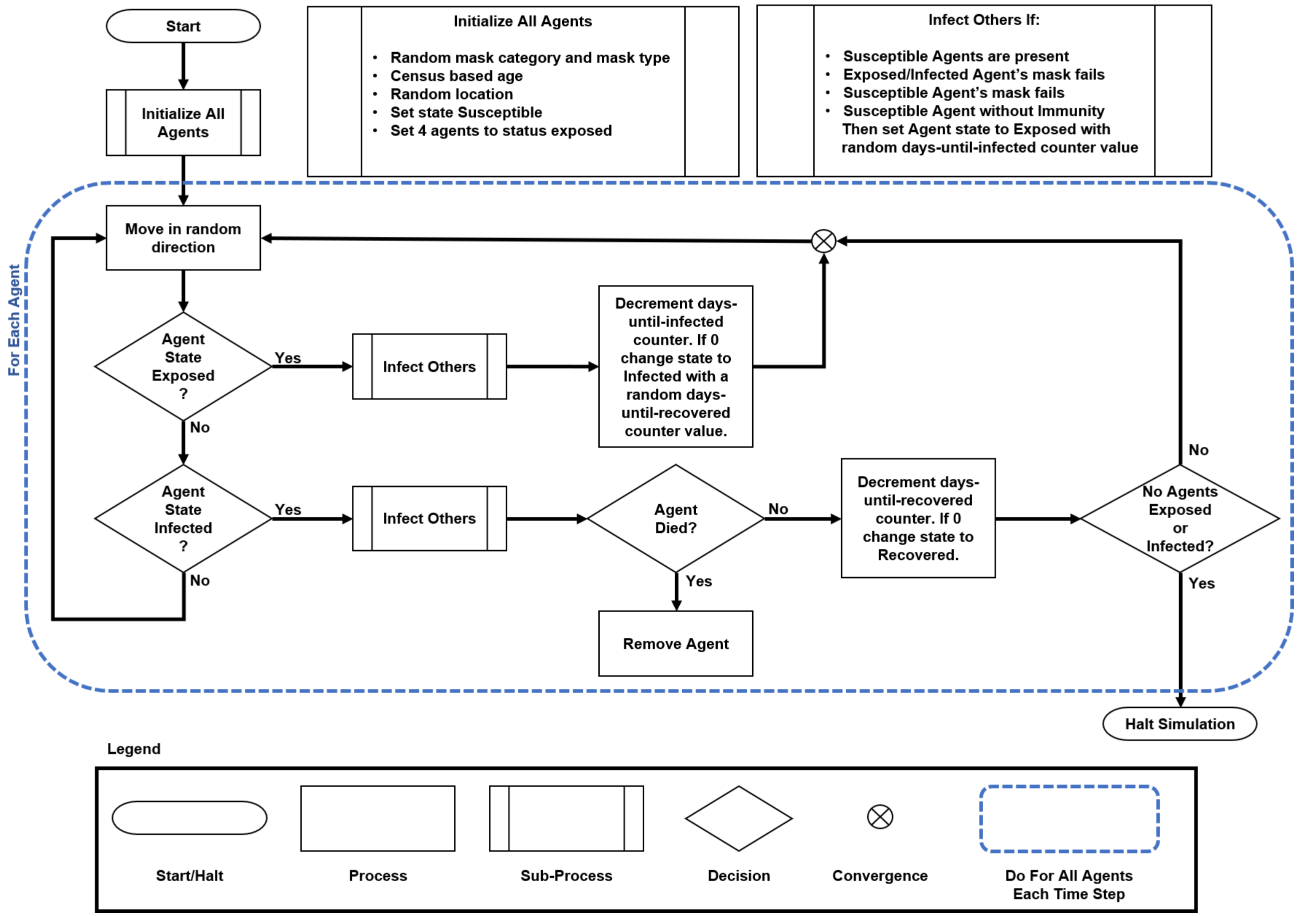


Initial parameters

Parameter	Value	Set By
infectiousness	99%	User interface
min-exposed-period	2 Days	User interface
max-exposed-period	14 Days	User interface
min-infected-period	10 Days	User interface
max-infected-period	14 Days	User interface
population*	329,736,376	In Code

* 3 June 2020. Each agent represents 100,000 people.

Model execution flowchart



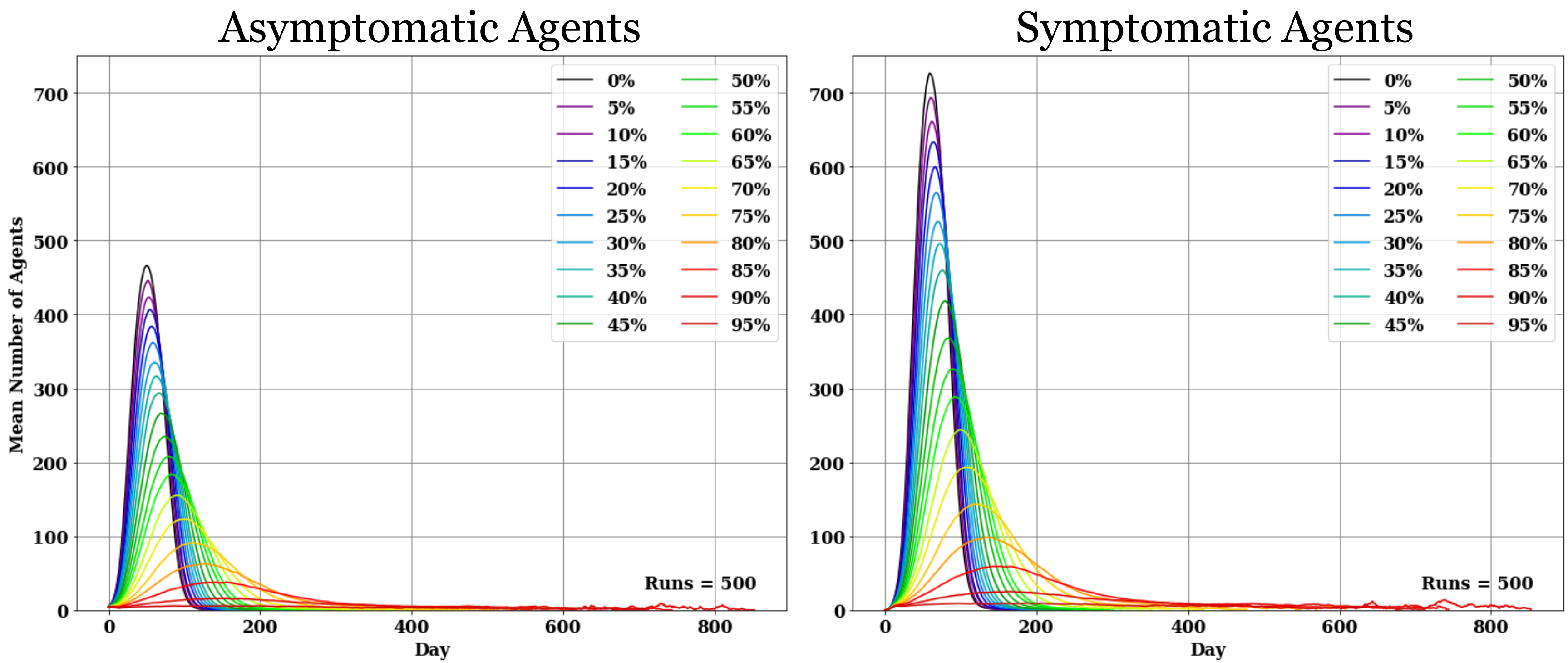
Data collection and analysis

- NetLogo's BehaviorSpace tool is used to vary homemade mask usage from 0% to 95% while fixing N95 at 1% and Surgical/Medical at 4%
- Model is run 500 times for each of the twenty homemade mask scenarios
- Mean and standard error values for all results were calculated and data graphics were created with a program developed for this purpose

Results

- Collective use of homemade masks in the simulation demonstrated a positive difference in high adoption scenarios
- As homemade mask adoption increases, the total number of asymptomatic agents and symptomatic agents on each day decreases and the peak day moves further away from the beginning of the pandemic
- This has a similar effect to social distancing in "flattening the curve"

Homemade masks flatten the curve

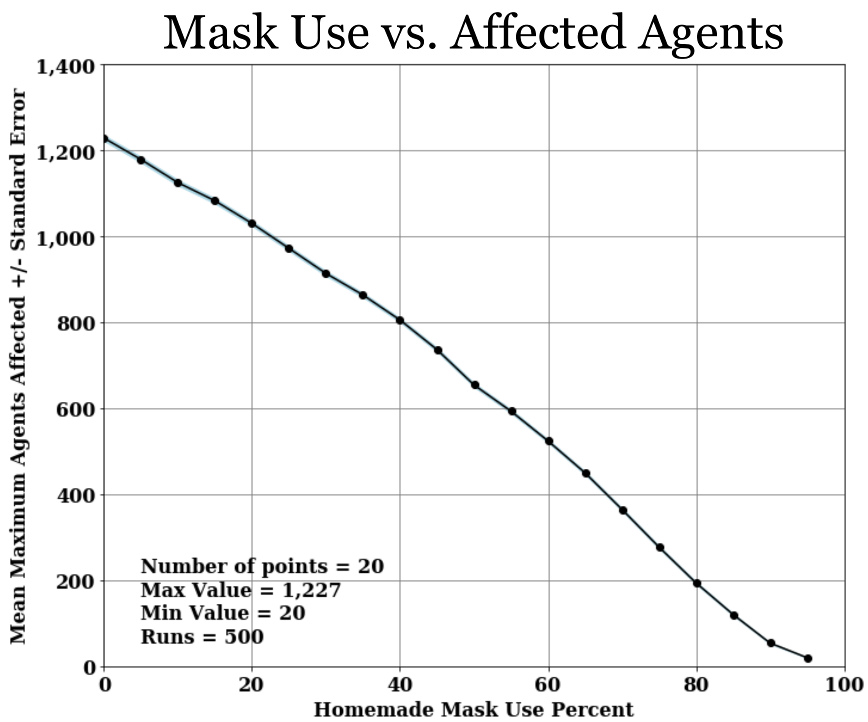


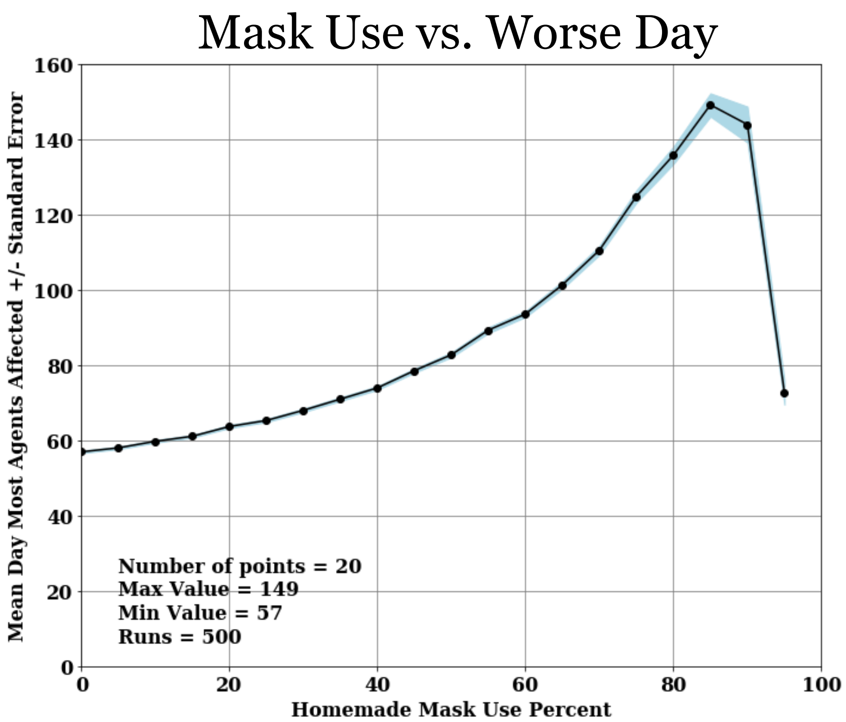
The left figure shows the mean number of agents exposed (asymptomatic) each day while the right figure shows the same for agents infectious (symptomatic) each day.

Results (continued)

- Examining the maximum number of agents affected on the worse day (combining asymptomatic and symptomatic states) demonstrates a monotonically decreasing number of agents as homemade mask adoption increases
- The number of days into the pandemic that the worse day occurs increases as part of the effect of flattening the curve until adoption reaches 85%, then decreases during the remaining two adoption percentages

Worse day tipping point



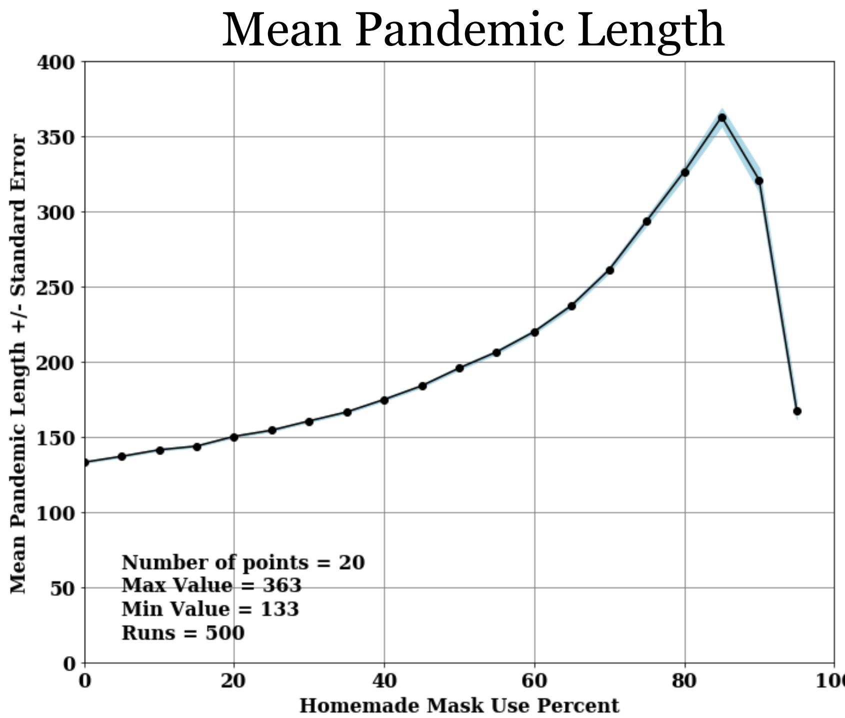


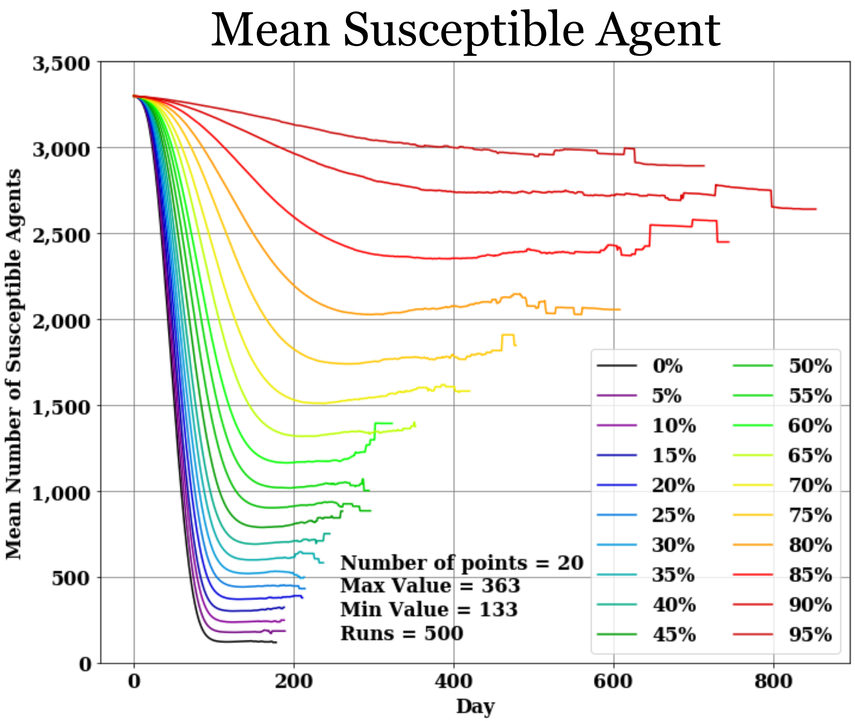
The mean maximum agents affected on the worse day is shown in the left figure. The right figure shows the mean day on which the mean maximum number of agents were affected. Standard error for the y-axis is shown in light blue.

Results (continued)

- Pandemic length increasing monotonically as mask adoption increases until adoption reaches 85%, then decreases after that
- Tracking the maximum length (the end of each plot) and daily mean number of susceptible agents for all mask adoption scenarios demonstrates the maximum pandemic lengths decease at high homemade mask adoptions

Pandemic length & mask usage





The left figure shows the mean number of days the pandemic lasted for each home-made mask adoption percentage with standard error for the y-axis in light blue. The right figure shows the number of susceptible agents each day for each homemade mask adoption percent-age with the end point showing the maximum length of all runs.

Conclusion

- As demonstrated by this abstract simulation, high adoption levels (>85%) of mixed efficacy masks have potential to create a non-pharmaceutical "herd immunity" that will:
  - Flatten the curve
  - Decrease pandemic length
  - Have a low economic impact

Conclusion (continued)

- In another recent study in response to COVID-19 a deterministic compartmental SEIR model of homemade mask use concluded an 80% adoption of moderately effective homemade masks could significantly reduce death rates in two studied US states

To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. ***Eikenberry, Steffen E, et al. 2020, Infectious Disease Modelling, Vol. 5, pp. 293-308.***

More Information

- ODD[1] and NetLogo[2] Model on CoMES
  - https://tinyurl.com/y2dvu8df
- Dale Brearcliffe
  - http://tangledinfo.com/
  - dbrearcl@gmu.edu

[1] *The ODD Protocol for Describing Agent-Based and Other Simulation Models: A Second Update to Improve Clarity, Replication, and Structural Realism*. **Grimm et al.**, 2020, JASSS.
2 **Wilensky, Uri**. NetLogo. Evanston : Center for Connected Learning and Computer-Based Modeling, Northwestern University, 1999.