Demonstrating a School Simulator:
Modeling COVID-19 Transmission and Evaluating School Plans

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Research Class of Dr. Zaslavsky, Summer 2020

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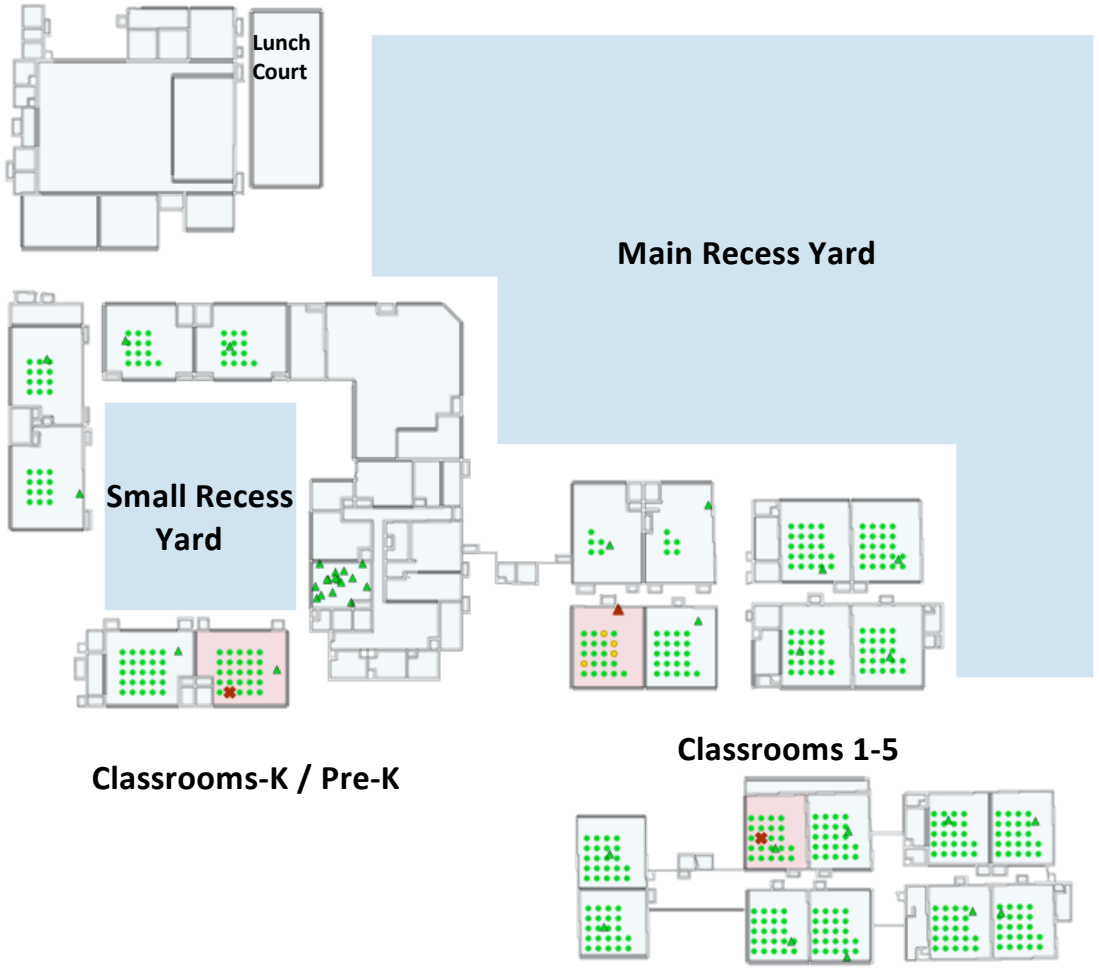
The Goal

- **Help schools match their policies with their resources, their unique spaces and children**
- **Give schools an opportunity to test their plans**

We use actual school designs, room capacities, and daily schedules to model potential COVID-19 transmission from asymptomatic students:

- Who will be affected, where and when?
- Which activities are conduits of transmission?
- Which combination of measures will work best for this specific school?

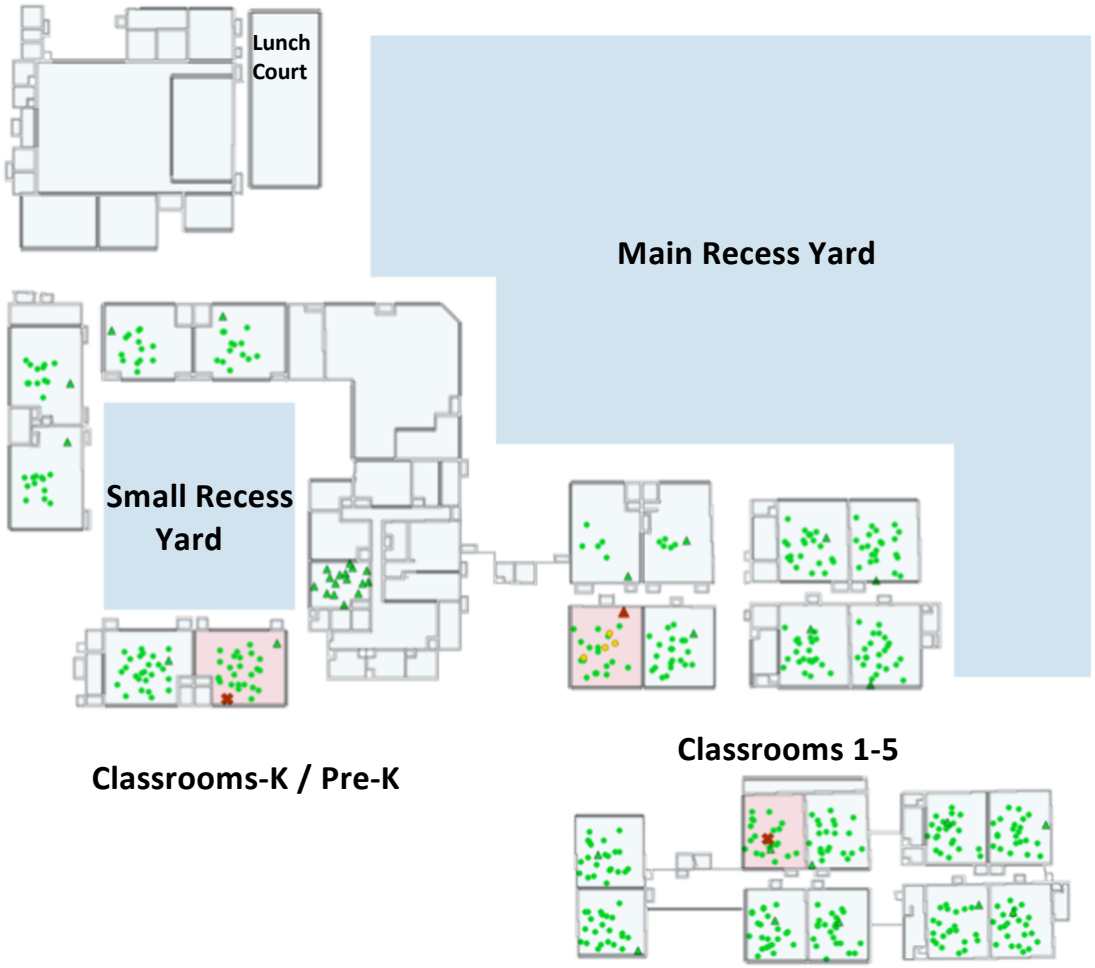
- Work in Progress!



Activities Modeled

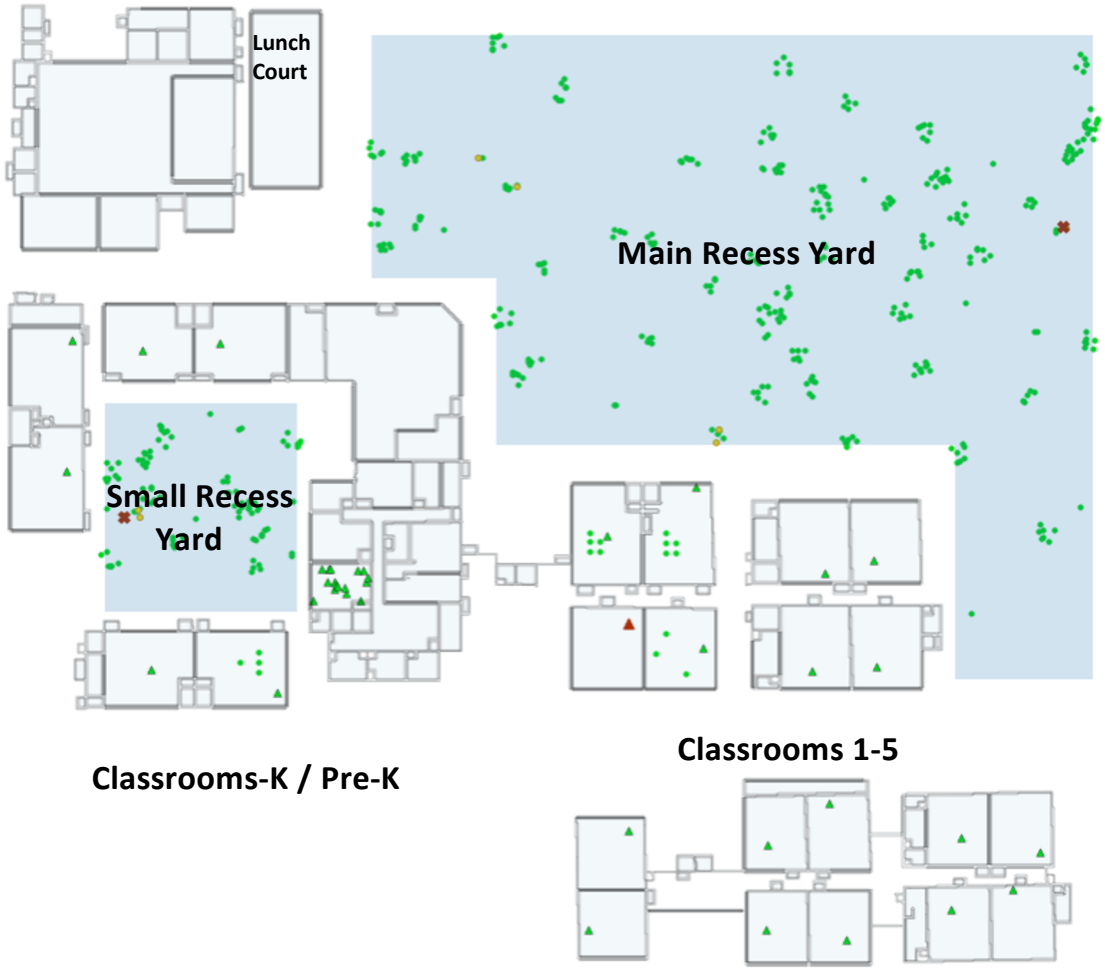
Learning at individual desks during class time

3 class periods, with recess and lunch in between



Activities Modeled

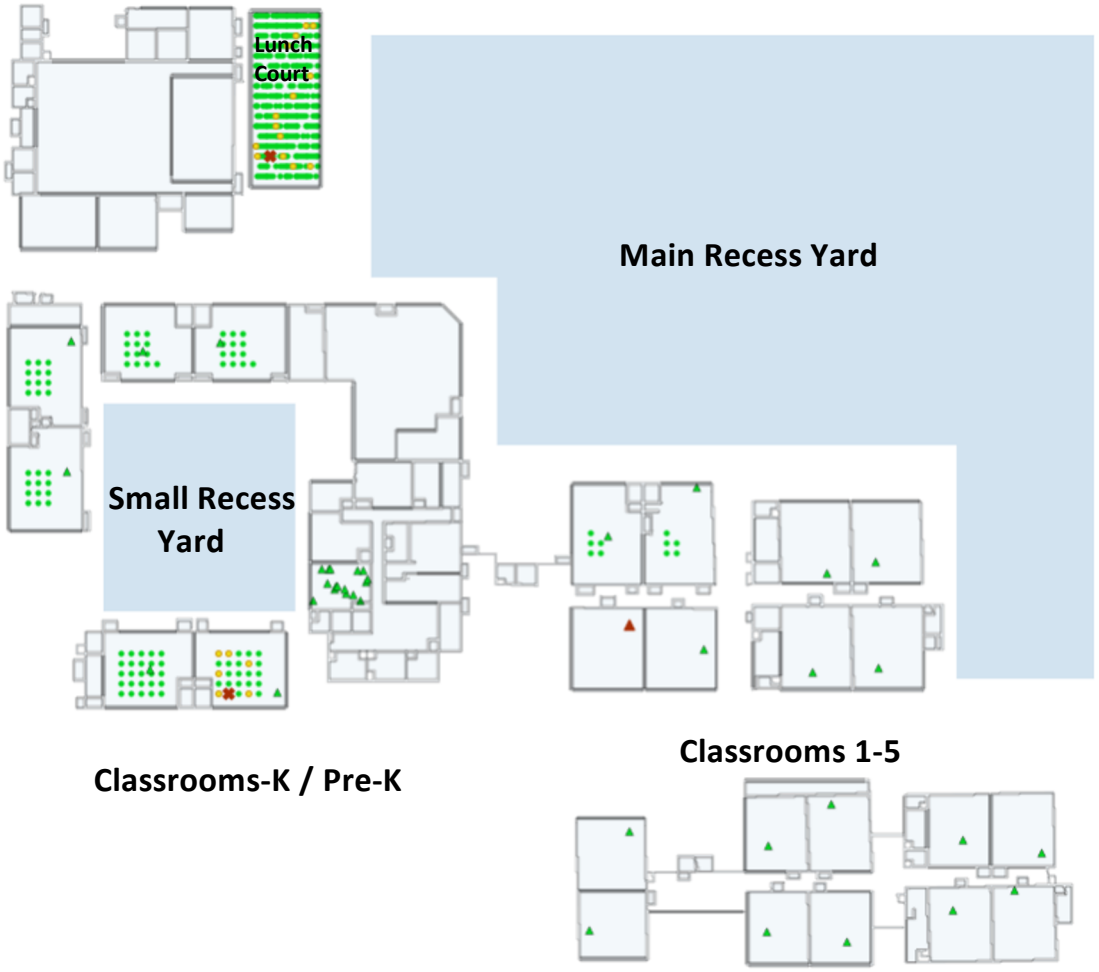
Group activities during class time



Activities Modeled

Recess

grades 1-5: in main recess yard
K/Pre-K: in small recess yard



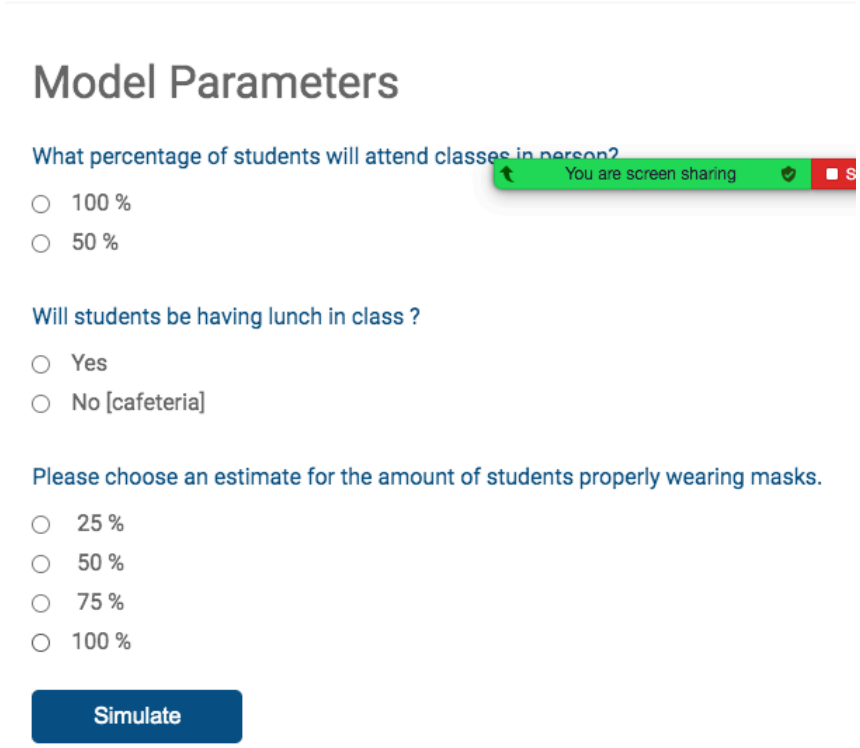
Activities Modeled

Lunch

grades 1-5: in lunch court
K/Pre-K: in classrooms

Let’s Simulate!

Run model here!



What to expect

- **Short-term:**
  - A web-based version to let schools explore a limited set of scenarios, for one school layout
  - Limited because it takes 60-90 mins to run a single scenario (for now)
- **Longer-term:**
  - Additional school layouts and schedules, and parameters you can enter via a dashboard
  - A public service for San Diego schools
- **We want to work with you, to make it real and useful to actual schools**

Many thanks to San Diego Unified, San Diego Office of Education, and San Diego Health and Human Services Agency!

What we could model

1. Different class sizes
2. Mask wearing, for all or some grades
3. Lunch: in cafeteria or in class; inside or outside
4. Plexiglas dividers
5. Use of shared spaces (library, multi-purpose room, gym, etc.)
6. Shortening class times and more frequent ventilation
7. Recess: with or without masks; by stable cohorts or not
8. Staggered attendance, and start/end times
9. Hand washing, sanitizing
10. Transportation to/from school

Get in touch!

Click here!

We want to hear about your scenarios

Suggestions

At the moment our model simulates changes in transmission by varying:

1. **Class sizes**
2. **Location of lunch.**
3. **Mask compliance.**

What are some parameters or risk-minimizing strategies that you would like us to simulate in the future?

Effects from HVAC, School buses, Common Areas, Testing teachers etc.

If you want to get in touch for further discussion of your school's plans, please enter your email address below!

Email Address

Submit

Additional Materials

Model Description

Selected References with Annotations

Model Details

Schedule

- Students are placed in appropriate classrooms (Pre-K / 1-5)

- They follow a simple time-table everyday as follows

Time	Activity
08:00 AM – 09:30 AM	Class-1
09:30 AM – 10:00 AM	Recess Break - 1
10:00 AM – 12:00 PM	Class-2
12:00 PM – 12:45 PM	Lunch in Cafeteria
12:45 PM – 1:30 PM	Post-lunch Recess
1:30 – 3:30 PM	Class-3

Classes, Recess and Lunch

- Students are placed 6-feet apart and have assigned individual seats.
- Group activities take place – Students can interact with teacher / neighbor.
- Contact is defined as coming within 3 ft of one another for a duration of 10 minutes or more.
- K/Pre-K have lunch in-class. 1-5 have lunch in lunch court.
- Recess for 1-5 in main yard. Students are assumed to play with random members from their own class.
- Recess for K/Pre-K in separate smaller yard.
- **Students stop coming to school once symptoms are detected.**

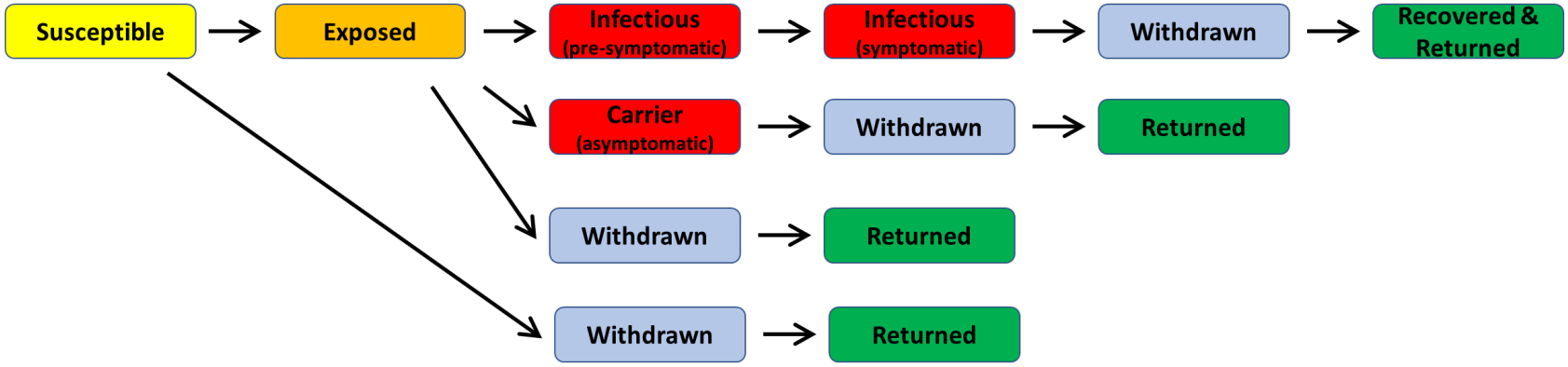
Effects Modeled

- **Droplet Transmission[1, 2, 3]:** *T*akes places primarily due to contact, defined as prolonged exposure >= 10 minutes with an individual closer than 3 ft. Agents are infectious 1 to 2 days before symptom onset.
- **Human Behavior[2]:** Tendency to play with a set of friends during recess, Teachers moving around the class, Group–based activities, Eating lunch with specific set of friends in cafeteria. Moving around to select food in cafeteria.

[1] https://www.umc.edu/CoronaVirus/FAQs.html#risk
[2] https://medical.mit.edu/faqs/COVID-19
[3] Stutt, R. O., Retkute, R., Bradley, M., Gilligan, C. A., & Colvin, J. (2020). A modelling framework to assess the likely effectiveness of facemasks in combination with 'lock-down'in managing the COVID-19 pandemic. *Proceedings of the Royal Society A*, *476*(2238), 20200376.

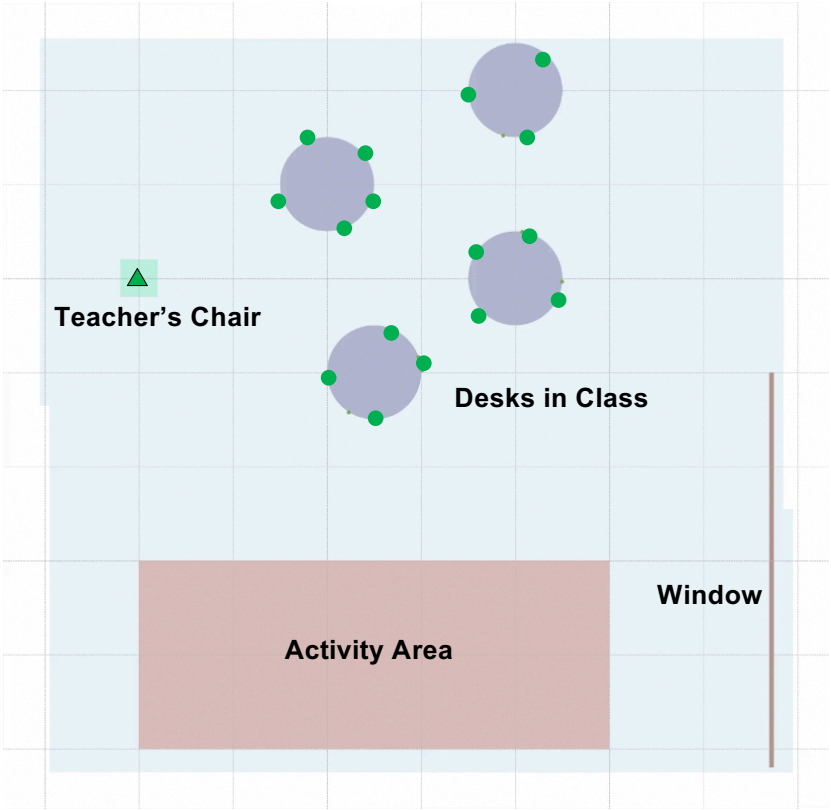
Agents in the model

- Students



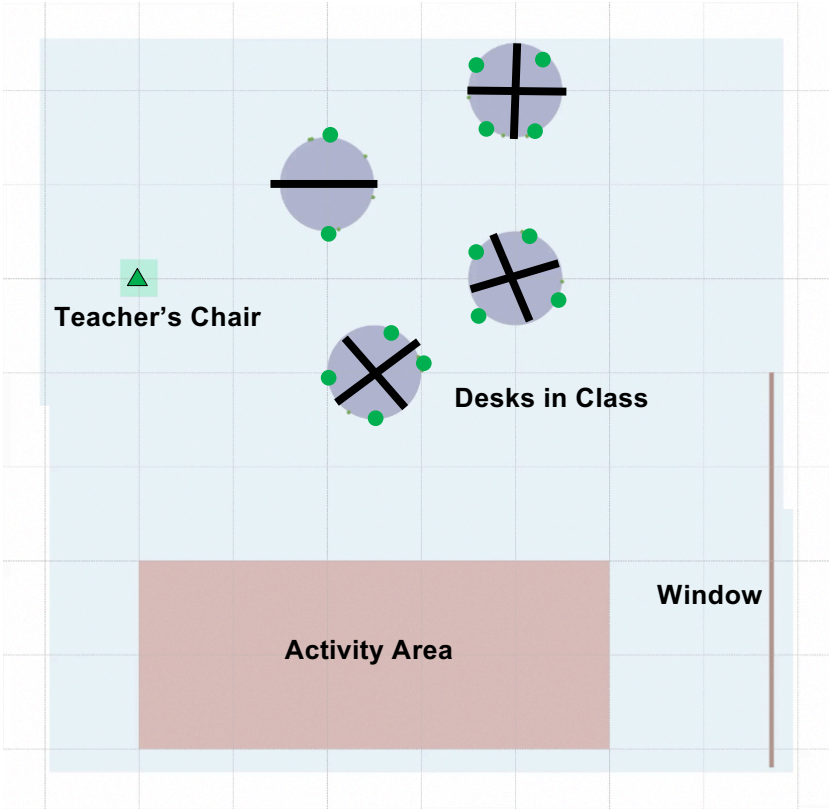
- Teachers
- Spaces (classrooms, etc.): viral load = F (physical dimensions, use (resulting in different viral accumulation), ventilation,…)

Examples of what we could model

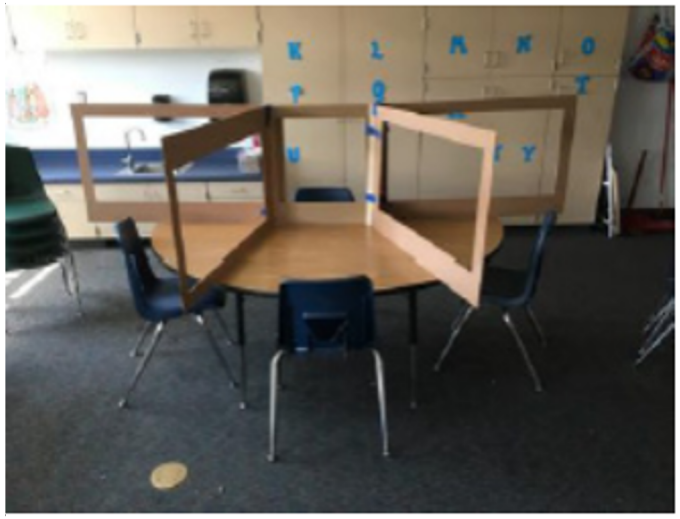


Varying desk layouts inside classes

Examples of what we could model



Barriers in desks



Annotated References

What we know about Covid-19 in schools: Brief Summary

- Schools are **not a high risk** for transmission between pupils or between staff and pupils. Children are mostly affected by transmission within households.
- Elementary school students are mostly **asymptomatic or paucisymptomatic**. Symptomatic children have longer viral shedding.
- Expected **increase in symptomatic illness** among elementary school teachers **is low** (4.1%)
- Children 5-11 y/o are **less protected by mask wearing**, and compliance is poor
- A combination of NPI strategies is needed
- Most papers cite **insufficient data and model limitations**

Are schools high-risk?

[1] Heavey Laura , Casey Geraldine , Kelly Ciara , Kelly David , McDarby Geraldine . No evidence of secondary transmission of COVID-19 from children attending school in Ireland, 2020. Euro Surveill. 2020;25(21):pii=2000903.
https://doi.org/10.2807/1560-7917.ES.2020.25.21.2000903

- “schools are not a high risk setting for transmission of COVID-19 between pupils or between staff and pupils.” (based on limited cases; Ireland; 3/20; similar results in Iceland, Italy, NSW Australia)
- More extensive studies precluded by closures/lockdowns

Age as factor of infection susceptibility

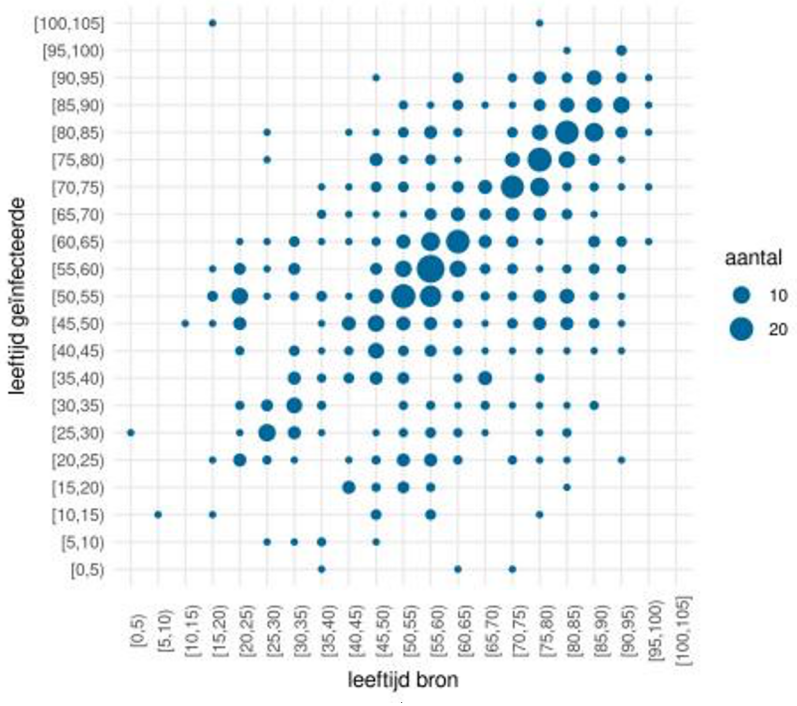
[2] Nicholas, G.D., Petra, K., Yang, L., Kiesha, P., Mark, J., Rosalind, M. and CMMID COVID-19 working group, Age-dependent Effects in the Transmission and Control of COVID-19 Epidemics. *Nature medicine*. https://doi.org/10.1038/s41591-020-0962-9

- "We find that those aged under 20 years are roughly half as susceptible to infection as those over 20 years of age, and that 79% of infections are asymptomatic or paucisymptomatic (that is, subclinical) in 10- to 19-year-olds, compared with 31% in those over 70 years of age (data from China, Italy, Japan, Singapore, Canada, S. Korea)

Spread of virus within and between age groups, from data on contact tracing

(Results shared by Howard Taras, study in the Netherlands)

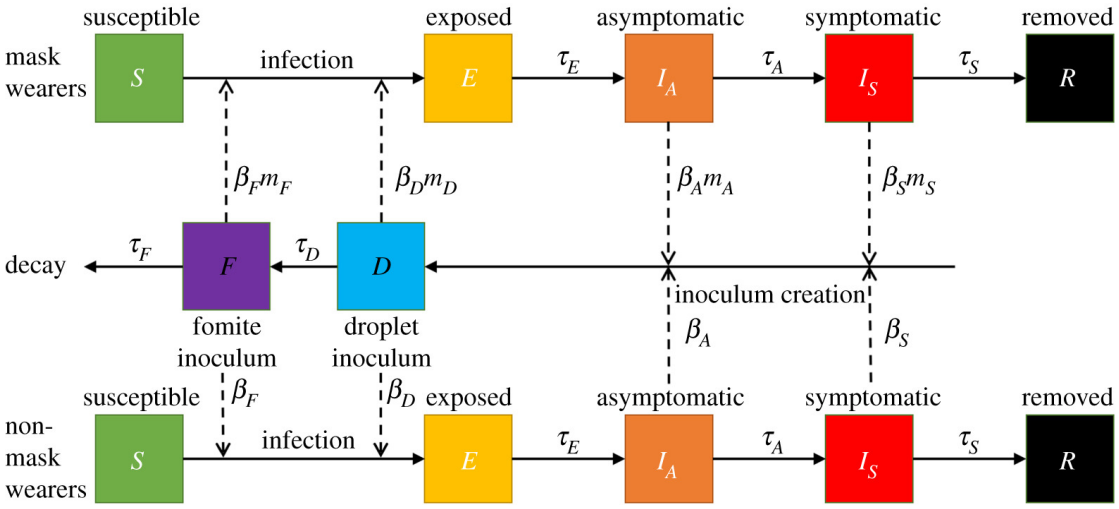
- The virus primarily spreads between people of the same age, less frequently between age groups. Minimal spread in the age group 0-18.



NPI Strategies to be used by schools

[3] Stutt, R.O., Retkute, R., Bradley, M., Gilligan, C.A. and Colvin, J., 2020. A modelling framework to assess the likely effectiveness of facemasks in combination with 'lock-down' in managing the COVID-19 pandemic. *Proceedings of the Royal Society A*, *476*(2238), p.20200376.

- "A combination of facemask wearing and lock-down periods implemented together is indicated to provide a better solution to the COVID-19 pandemic than either in isolation"
- Based on an ABM:



How will the teachers be affected?

[4] Head, J.R., Andrejko, K., Cheng, Q., Collender, P.A., Phillips, S., Boser, A., Heaney, A.K., Hoover, C.M., Wu, S.L., Northrup, G.R. and Click, K., 2020. The effect of school closures and reopening strategies on COVID-19 infection dynamics in the San Francisco Bay Area: a cross-sectional survey and modeling analysis. *medRxiv*. https://www.medrxiv.org/content/10.1101/2020.08.06.20169797v1

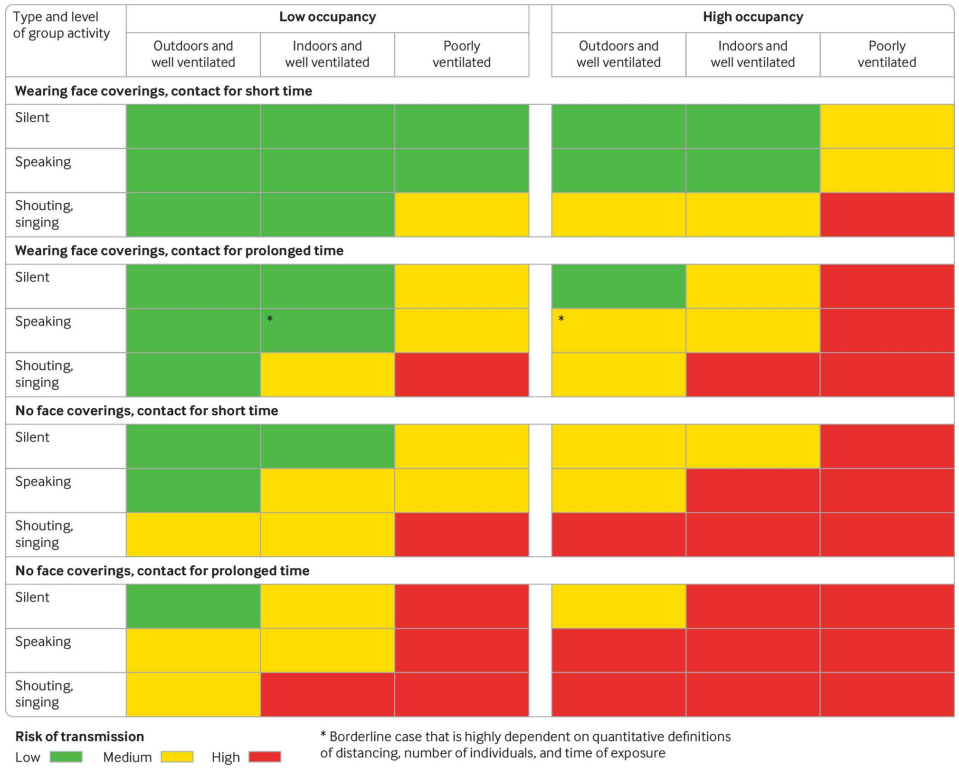
- ”Under assumptions of moderate community transmission, we estimate that fall 2020 school reopenings will increase symptomatic illness among high school teachers (an additional 40.7% expected to experience symptomatic infection, 95% CI: 1.9, 61.1), middle school teachers (37.2%, 95% CI: 4.6, 58.1), and elementary school teachers (4.1%, 95% CI: -1.7, 12.0). ”
- “A hybrid-learning approach with halved class sizes of 10 students may be needed in high schools, while maintaining small cohorts of 20 students may be needed for elementary schools.”

Shall 6ft distancing be enforced?

[5] Jones Nicholas R, Qureshi Zeshan U, Temple Robert J, Larwood Jessica P J, Greenhalgh Trisha, Bourouiba Lydia et al. Two metres or one: what is the evidence for physical distancing in covid-19? *BMJ* 2020; 370 :m3223
https://www.bmj.com/content/370/bmj.m3223

- Effective distance is activity-dependent; also depends on ventilation, PPEs, occupancy.

Risk of SARS-CoV-2 transmission from asymptomatic people in different settings and for different occupation times, venting, and crowding levels



How do we model viral shedding?

[6] Lu Y, Li Y, Deng W, et al. Symptomatic Infection is Associated with Prolonged Duration of Viral Shedding in Mild Coronavirus Disease 2019: A Retrospective Study of 110 Children in Wuhan. Pediatr Infect Dis J. 2020;39(7):e95-e9. Epub 2020/05/08.

- Symptomatic children have a longer duration of viral shedding than asymptomatic children
- "The median age was 6 years old. The median period of viral shedding of COVID-19 was 15 days (interquartile range [IQR], 11–20 days) as measured from illness onset to discharge. This period was shorter in asymptomatic patients (26.4%) compared with symptomatic patients (73.6%) (11 days vs. 17 days)."

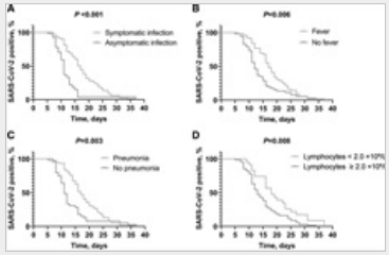


FIGURE 1.: Factors associated with prolonged duration of viral shedding in children with COVID-19. Figure shows symptomatic infection (A), fever (B), pneumonia (C) and lymphocytes <2.0 × 10^9/L (D) were associated with prolonged duration of viral shedding in Children with COVID-19. Data were analyzed by the Kaplan-Meier method and negative conversion of SARS-CoV-2 was selected as the event endpoint. COVID-19, coronavirus disease 2019; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

Use of masks by children:

[7] WHO: Advice on the use of masks for children in the community in the context of COVID-19, 8/21/2020
https://apps.who.int/iris/bitstream/handle/10665/333919/WHO-2019-nCoV-IPC_Masks-Children-2020.1-eng.pdf

- 1-7% of COVID-19 cases are reported to be among children
- Most reported cases among children have resulted from transmission within households (but insufficient school data)
- Documented transmission among children and staff within educational settings is limited:
  - 15. Macartney K, Quinn HE, Pillsbury AJ, Koirala A, Deng L, Winkler N, et al. Transmission of SARS-CoV-2 in Australian educational settings: a prospective cohort study. Lancet Child Adolesc Health. 2020. Epub 2020/08/08.
  - 16. Fontanet A, Grant R, Tondeur L, et al. SARS-CoV-2 infection in primary schools in northern France: A retrospective cohort study in an area of high transmission. medRxiv. 2020. (https://www.medrxiv.org/content/10.1101/2020.06.25.20140178v2).
  - 17. Fontanet A, Tondeur L, Madec Y et al. Cluster of COVID-19 in northern France: A retrospective closed cohort study. medRxiv. 2020. (https://www.medrxiv.org/content/10.1101/2020.04.18.20071134v1)
  - 18. Stein-Zamir C, Abramson N, Shoob H, et al. A large COVID-19 outbreak in a high school 10 days after schools' reopening, Israel, May 2020. Euro Surveill. 2020;25(29). Epub 2020/07/29.
  - 19. Torres JP, Pinera C, De La Maza V, et al. SARS-CoV-2 antibody prevalence in blood in a large school community subject to a Covid-19 outbreak: a cross-sectional study. Clin Infect Dis. 2020. Epub 2020/07/11.
  - 20. Heavey L, Casey G, Kelly C, Kelly D, McDarby G. No evidence of secondary transmission of COVID-19 from children attending school in Ireland, 2020. Euro Surveill. 2020;25(21). Epub 2020/06/04.

Use of masks by children:

[8] Chen X, Ran L, Liu Q, Hu Q, Du X, Tan X. Hand Hygiene, Mask-Wearing Behaviors and Its Associated Factors during the COVID-19 Epidemic: A Cross-Sectional Study among Primary School Students in Wuhan, China. Int J Environ Res Public Health. 2020;17(8). Epub 2020/04/26

- Use of masks more effective among children 9-12 yo than among 6-9 yo
- Children 5-11 yo are significantly less protected by mask wearing (possibly inferior fit of the mask)
- Overall compliance with mask wearing among children is poor
- 51.6% mask wearing compliance among primary school kids (in Wuhan! How likely is it in the US?)

Sources of ABM Model Parameters

[3] Stutt, R.O., Retkute, R., Bradley, M., Gilligan, C.A. and Colvin, J., 2020. A modelling framework to assess the likely effectiveness of facemasks in combination with 'lock-down' in managing the COVID-19 pandemic. *Proceedings of the Royal Society A*, *476*(2238), p.20200376.
https://royalsocietypublishing.org/doi/pdf/10.1098/rspa.2020.0376

Table 1. Model parameters and default values for the modified SIR compartment model with free-living inoculum. Note that our inferences, choices of parameters and population sizes do not relate to healthcare environments, as would be found in hospitals, where inoculum levels may be extremely high and personnel already wear appropriate PPE.

parameter	description	default value	source
N	population size	60 million	approximate mainland GB population size
R_0	basic reproductive rate	4	[30]
β_A	inoculum release rate of asymptomatic infectious individuals	2.71 unit inoculum per day per capita	relative to β_S [39]
β_S	inoculum release rate of symptomatic infectious individuals	1 unit inoculum per day per capita	arbitrarily defined, without loss of generality
β_D	infection rate due to droplet inoculum	4.46×10^{-5} per unit inoculum per day	fitted subject to default values of R_0, μ and N
β_F	infection rate due to fomite inoculum	2.58×10^{-9} per unit inoculum per day	fitted subject to default values of R_0, μ and N
m_A	reduction in inoculum release rate of asymptomatic individuals for mask wearers	0.5	arbitrarily set in the absence of detailed data on individual-based transmission; consistent with lower ranges quoted by Furuhashi [47]; van der Sande *et al.* [25]
m_S	reduction in inoculum release rate of symptomatic individuals of mask wearers	0.5	arbitrarily set in the absence of detailed data on individual-based transmission; consistent with lower ranges quoted by Furuhashi [47]; van der Sande *et al.* [25]
m_D	reduction in inoculum infection rate due to droplet inoculum for mask wearers	0.5	arbitrarily set in the absence of detailed data on individual-based transmission
m_F	reduction in inoculum infection rate due to fomite inoculum for mask wearers	1.0	arbitrarily set in the absence of detailed data on individual-based transmission
q	reduction of transmission rates from lock-down of the population	0.5	[30] showing R_e dropped from ~4 before to ~1 after lock-down
τ_E	average duration between infection and onset of asymptomatic infectiousness	3.8 d	[39]
τ_A	average duration between onset of asymptomatic infectiousness and first symptoms	1.2 d	[39]
τ_S	average duration between first symptoms and end of infectiousness	3.2 d	[39]
τ_D	average lifespan of droplet inoculum before deposition	10 s	[44–46]
τ_F	average lifespan of fomite inoculum before loss of viability	48 h	[43]
μ	assumed proportion of infections due to droplet inoculum in the absence of masks or other forms of control	0.5	arbitrarily set in the absence of detailed data on individual-based transmission

Sources of ABM Model Parameters

[4] Head, J.R., Andrejko, K., Cheng, Q., Collender, P.A., Phillips, S., Boser, A., Heaney, A.K., Hoover, C.M., Wu, S.L., Northrup, G.R. and Click, K., 2020. The effect of school closures and reopening strategies on COVID-19 infection dynamics in the San Francisco Bay Area: a cross-sectional survey and modeling analysis. *medRxiv*.
https://www.medrxiv.org/content/10.1101/2020.08.06.20169797v1

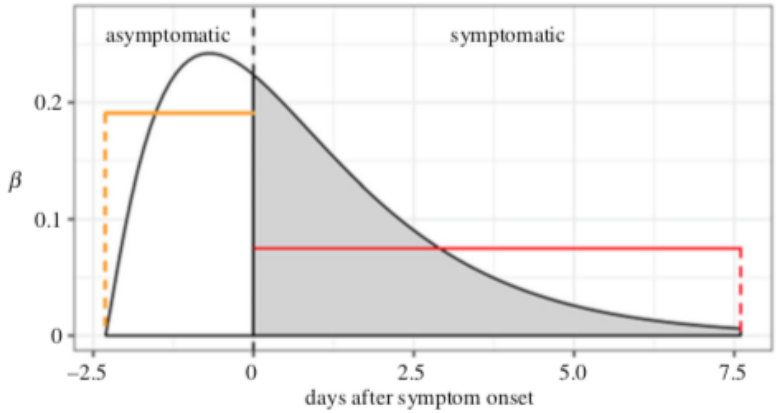
Table 1. Parameters of the susceptible-exposed-infected-recovered model

Parameter	Ages (i)	Values	References
Basic reproduction number, R_0	all	2.5	Kucharski, et al[55] Wu, et al[56]
Average incubation period, d_L (95% CI)	all	5.4 (2.4, 8.3)	Guan, et al[42] Li, et al[43] Lauer, et al[44]
Average duration of infection, non-hospitalized individuals, d_I (95% CI)	all	13.1 (8.3, 16.9)	Huang, et al[45]
Average time from infection to hospitalization, d_H (95% CI)	all	10.3 (6.5, 13.3)	Wang, et al[46]
Average duration of hospitalization, individuals who recover, d_R, or die, d_M (95% CI)	all	14.4 (11.3, 16.6)	Lewnard, et al[47]
Probability case is clinical, Pr(clinical|age)	$i < 20$ $i \geq 20$	0.21 0.69	Davies, et al[13]
Probability infection is acquired from subclinical transmission, α	all	0.50	Davies, et al[13] Prem, et al[41]
Probability of hospitalization among clinical cases, Pr(hospital|age)	$i < 10$ $10 \leq i < 20$ $20 \leq i < 30$ $30 \leq i < 40$ $40 \leq i < 50$ $50 \leq i < 60$ $60 \leq i < 70$ $70 \leq i < 80$ $i \geq 80$	0.00001 0.000408 0.0104 0.0343 0.0425 0.0816 0.118 0.166 0.184	Verity, et al[57]
Probability of death among hospitalized patients, Pr (death|age, hospital)	$i < 20$ $20 \leq i < 30$ $30 \leq i < 40$ $40 \leq i < 50$ $50 \leq i < 60$ $60 \leq i < 70$ $70 \leq i < 80$ $i \geq 80$	0.02 0.031 0.0475 0.0785 0.1215 0.186 0.301 0.4515	Lewnard et al[47]
Ratio of susceptibility among adults to susceptibility among children, $\beta_{i<20}/\ \beta_{i\geq 20}$	all	0.50 or 1	Various; (see Supporting Information)

Sources of ABM Model Parameters

[3] Stutt, R.O., Retkute, R., Bradley, M., Gilligan, C.A. and Colvin, J., 2020. A modelling framework to assess the likely effectiveness of facemasks in combination with 'lock-down' in managing the COVID-19 pandemic. *Proceedings of the Royal Society A*, *476*(2238), p.20200376.
https://royalsocietypublishing.org/doi/pdf/10.1098/rspa.2020.0376

- People are most infectious in the 1-2-day time period before the onset of symptoms. They follow a relatively quick decrease of infectiousness post this period.

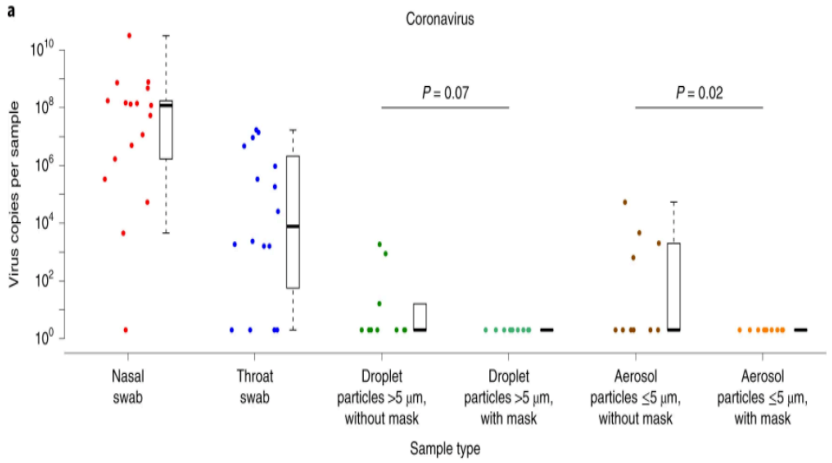


Sources of ABM Model Parameters

[9] Leung, N.H.L., Chu, D.K.W., Shiu, E.Y.C. *et al.* Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nat Med* **26,** 676–680 (2020). https://doi.org/10.1038/s41591-020-0843-2

1. Masks *significantly* reduce the number of virus containing aerosol particles in exhaled breath from infected individuals

2. Masks reduce the number of virus containing aerosol droplets by orders of magnitude in exhaled breath from infected individuals



Sources of ABM Model Parameters

[10] Aerosol Transmission Estimator

https://docs.google.com/spreadsheets/d/16K1OQkLD4BjgBdO8ePj6ytf-RpPMlJ6aXFg3PrIQBbQ/edit#gid=519189277

- Parameters describing:
  - Quanta emission rates, for different activity types (for children, reduced proportionally to body mass)
    - Quanta is “infectious dose of the aerosol pathogen, whose inhalation leads to infection”
  - Inhalation (breathing rates) – from EPA Exposure Factors Handbook, age-dependent
  - Mask efficiencies in reducing inhalation
  - Building ventilation rates
  - Decay rates of the virus infectivity in aerosols
  - Deposition of virus-containing aerosol to surfaces
  - Virus removal rates for different filters

Sources of ABM Model Parameters

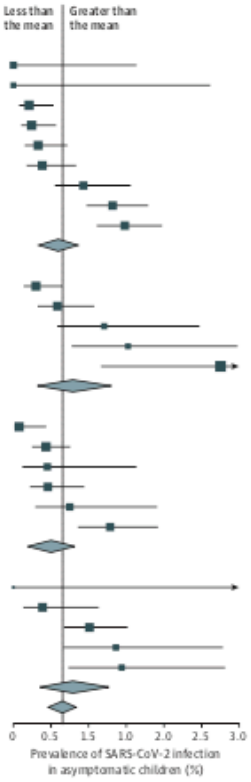
[11] Sola AM, David AP, Rosbe KW, Baba A, Ramirez-Avila L, Chan DK. Prevalence of SARS-CoV-2 Infection in Children Without Symptoms of Coronavirus Disease 2019. *JAMA Pediatr.* Published online August 25, 2020. doi:10.1001/jamapediatrics.2020.4095.
(Sent by Isabel Corcos)

https://jamanetwork.com/journals/jamapediatrics/fullarticle/2769878?utm_campaign=articlePDF&utm_medium=articlePDFlink&utm_source=articlePDF&utm_content=jamapediatrics.2020.4095

Asymptomatic infection prevalence rate amongst children in the west coast is roughly 0.59%.

Figure 1. Prevalence of Asymptomatic Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Infection in Children

Region/ CSA	No./ total No.	Testing indication	Testing site	Calculation period	Prevalence, % (95% CI)	Weight, %
West						
1	0/231	Preop	NP	June 1-June 30	0.00 (0.00-1.64)	2.68
2	0/143	Preop OHNS	NP	June 1-June 23	0.00 (0.00-2.62)	1.39
3	4/1919	Preop	NP	May 29-June 30	0.21 (0.08-0.53)	5.98
4	5/2058	Preop/clinic	MT	NA	0.24 (0.10-0.57)	5.94
5	6/1821	Preop	NP	NA	0.33 (0.15-0.72)	5.69
6	6/1562	Preop/clinic	NP	June 5-June 22	0.38 (0.18-0.84)	5.45
7	14/1506	Preop	NP	May 29-July 8	0.93 (0.55-1.55)	4.40
8	40/3032	Preop	NP	May 29-July 9	1.32 (0.97-1.79)	4.86
9	45/3039	Preop	NP	NA	1.48 (1.11-1.98)	4.73
West (all) I^2 = 85.5% (P < .001)	120/15311				0.59 (0.28-0.90)	
Midwest						
10	6/2000	Preop	NP	May 29-July 8	0.30 (0.14-0.65)	5.81
11	10/1704	Preop	NP	NA	0.59 (0.32-1.08)	5.12
12	7/580	Preop	NP	NA	1.21 (0.59-2.47)	2.50
13	8/525	All ASX	NP	NA	1.52 (0.77-2.98)	2.02
14	9/408	Preop OHNS	NP	NA	2.21 (1.16-4.14)	1.27
Midwest (all) I^2 = 72.4% (P = .006)	40/5217				0.87 (0.37-1.37)	
South						
15	1/1293	All asx	NP	June 4-July 7	0.08 (0.01-0.44)	6.19
16	12/2767	Preop	NP	NA	0.43 (0.25-0.76)	5.78
17	2/443	All ASX	NP	NA	0.45 (0.12-1.63)	3.63
18	7/1528	Preop	NP	NA	0.46 (0.22-0.94)	5.26
19	4/534	Preop	NP	NA	0.75 (0.29-1.91)	3.12
20	23/1789	All ASX	NP	NA	1.29 (0.86-1.92)	4.18
South (all) I^2 = 80.4% (P < .001)	49/8354				0.52 (0.20-0.84)	
Northeast						
21	0/42	Preop	NP/MT	NA	0.00 (0.00-8.38)	0.16
22	3/774	Preop	MT	June 1-June 23	0.39 (0.13-1.13)	4.68
23	23/2273	All ASX	OP	June 1-June 23	1.01 (0.68-1.51)	4.83
24	7/514	Preop	NP	NA	1.36 (0.66-2.78)	2.14
25	8/556	Preop	NP	May 29-June 29	1.44 (0.73-2.81)	2.18
Northeast (all) I^2 = 45.5% (P = .12)	41/4159				0.90 (0.45-1.35)	
Overall I^2 = 79.4% (P < .001)	250/33041				0.65 (0.47-0.83)	



Similar approach (ABM for schools)

[12] Brian Gill, Ravi Goyal, Jacob Hartog, John Hotchkiss, and Danielle DeLisle, REL Mid-Atlantic Considerations for Reopening Pennsylvania Schools. June 2020
(shared by Natasha Martin)

Forecasting time to the fifth infection, in 5 scenarios:

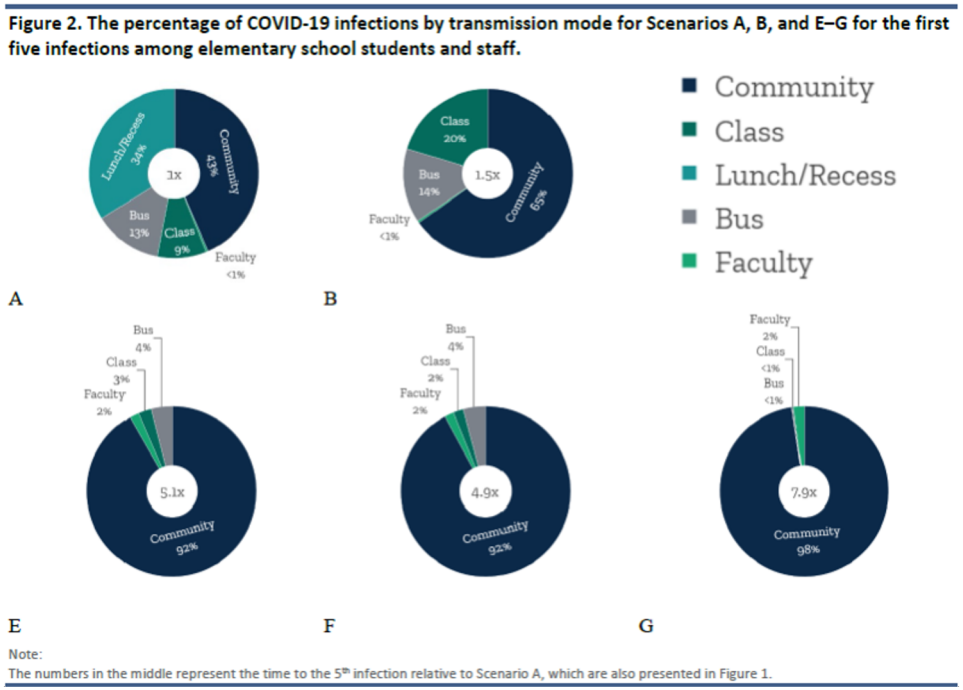
A: **baseline** without precautions

B: **daily** attendance with precautions

E: **two day a week** rotation of two groups of students with precautions

F: weekly, **four-day rotations** of two groups of students with precautions

G: daily rotations of five groups of students, each attending **once a week** with precautions

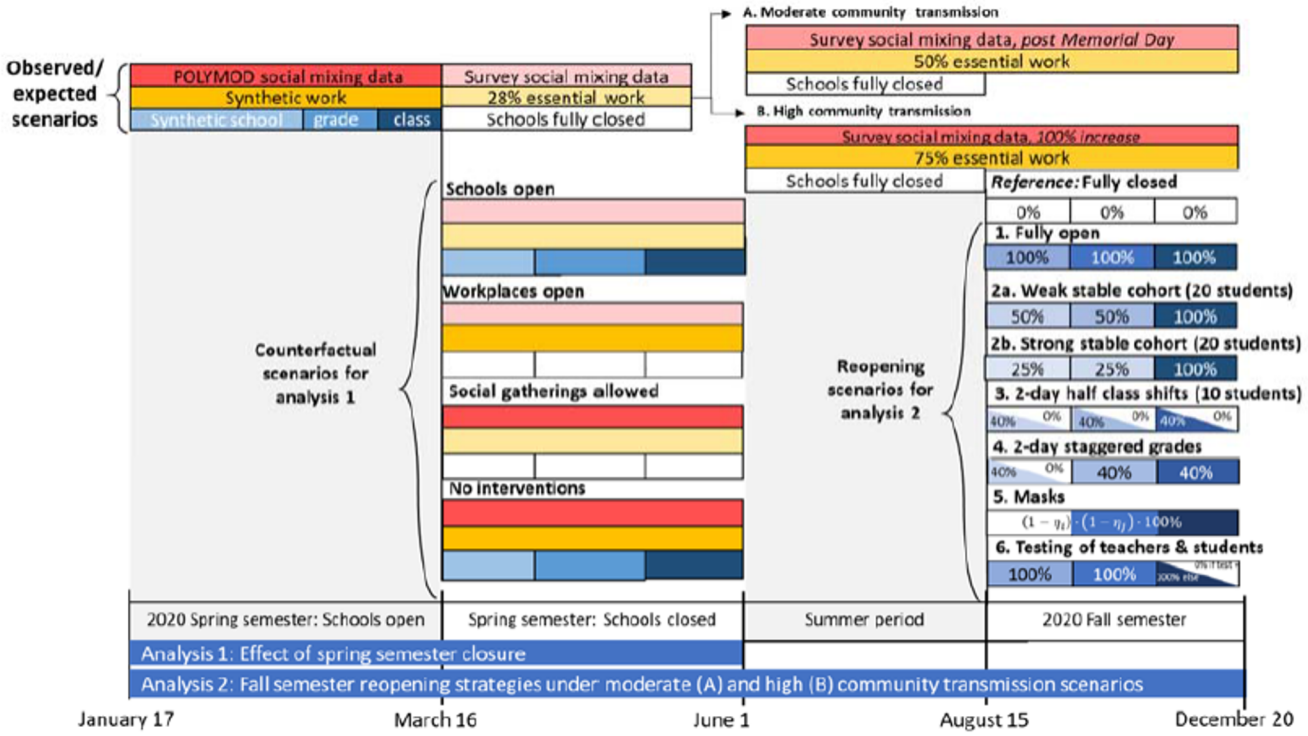


Elementary school

Simulation Scenarios

[4] Head, J.R., Andrejko, K., Cheng, Q., Collender, P.A., Phillips, S., Boser, A., Heaney, A.K., Hoover, C.M., Wu, S.L., Northrup, G.R. and Click, K., 2020. The effect of school closures and reopening strategies on COVID-19 infection dynamics in the San Francisco Bay Area: a cross-sectional survey and modeling analysis. *medRxiv*. https://www.medrxiv.org/content/10.1101/2020.08.06.20169797v1

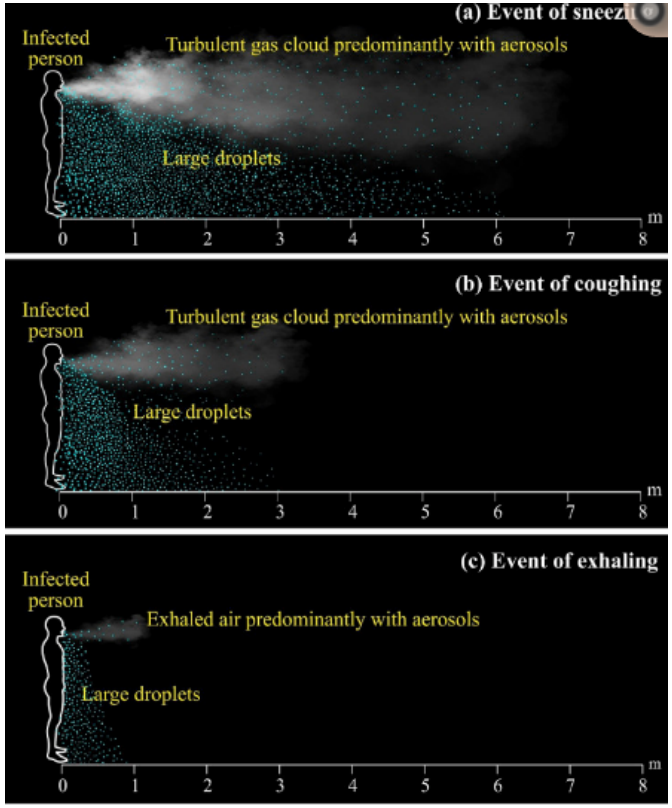
- Interventions simulated in the SEIR (*susceptible-exposed-infected-recovered*) model. Testing reopening strategies under a high and moderate community transmission scenarios



Droplet vs Aerosols - why 6 feet?

[13] Jayaweera, Mahesh, et al. "Transmission of COVID-19 Virus by Droplets and Aerosols: A Critical Review on the Unresolved Dichotomy." *Environmental Research*, Elsevier Inc., Sept. 2020 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7293495/#bib5

- Distance traveled by droplets/aerosols is dependent on multiple factors
- While both droplets and vapor do exist at further distances, the vast majority are expelled to within 2 meters of the infected individual



NYT Interactive Visualization of droplet distance

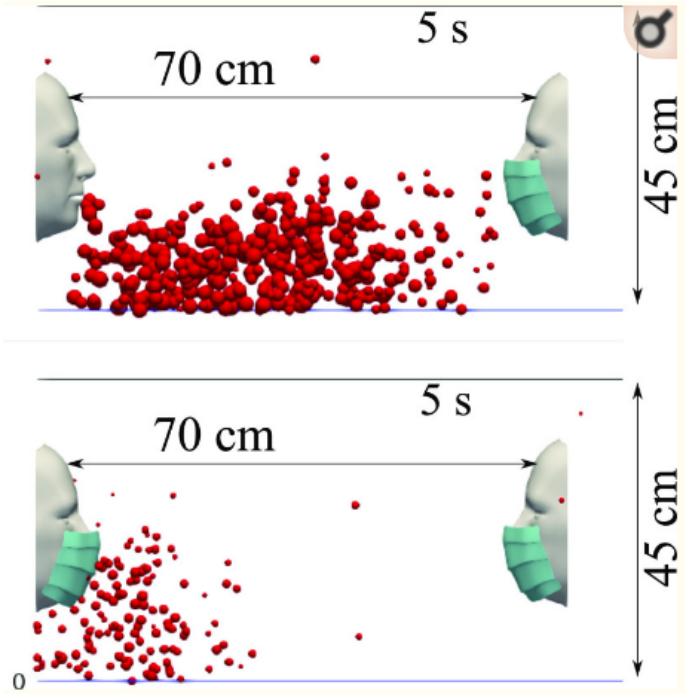
[14] Parshina-kottas, Yuliya, et al. “This 3-D Simulation Shows Why Social Distancing Is So Important.” *The New York Times*, The New York Times, 14 Apr. 2020, www.nytimes.com/interactive/2020/04/14/science/coronavirus-transmission-cough-6-feet-ar-ul.html.

- Interesting of some of the reasoning behind the 1-2 meter recommended distance (and our 6 meter assumption)

On Droplets and Face Masks

[15] Dbouk, Talib, and Dimitris Drikakis. "On Respiratory Droplets and Face Masks." *Physics of Fluids (Woodbury, N.Y. : 1994)*, AIP Publishing LLC, 1 June 2020
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7301882/

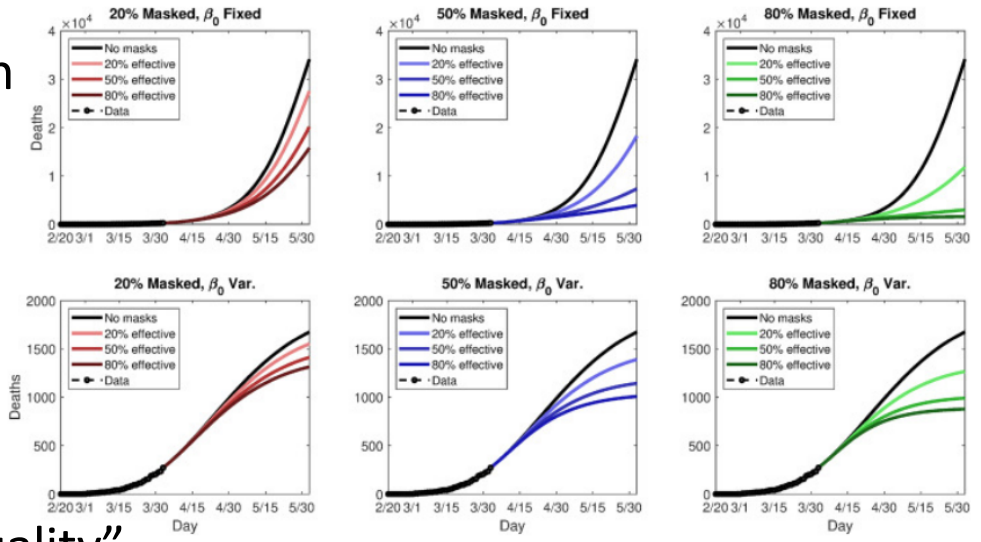
- Droplet distance is greatly reduced via mask use
- However, use of a mask does not provide complete protection from airborne droplets



Do masks historically influence COVID death rates

[16] Eikenberry, Steffen E., et al. "To Mask or Not to Mask: Modeling the Potential for Face Mask Use by the General Public to Curtail the COVID-19 Pandemic." *Infectious Disease Modelling*, Elsevier, 21 Apr. 2020, www.sciencedirect.com/science/article/pii/S2468042720300117.

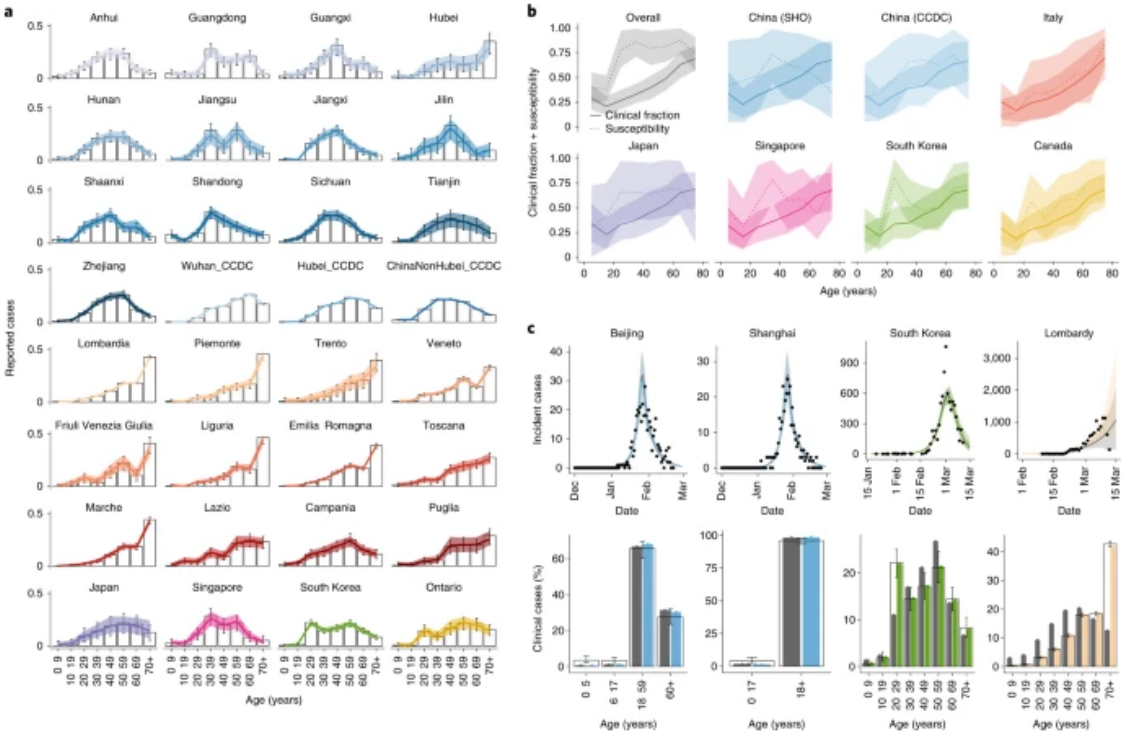
- Use of masks has a marked effect on the transmission rate of a population
- "our findings suggest that mask use should be as nearly universal as possible and implemented without delay, even if most masks are home-made and of relatively low quality"



Age-Dependent effects on COVID Transmission

[17] Davies, Nicholas G., et al. “Age-Dependent Effects in the Transmission and Control of COVID-19 Epidemics.” *Nature News*, Nature Publishing Group, 16 June 2020, www.nature.com/articles/s41591-020-0962-9.

Fig. 2: Estimating the age-specific symptomatic rate from age-specific case counts for six countries.



Bad use of ventilation might be a factor:

[18] Airborne route and bad use of ventilation systems as non-negligible factors in SARS-CoV-2 transmission

Correia, G., et al. "Airborne Route and Bad Use of Ventilation Systems as Non-Negligible Factors in SARS-CoV-2 Transmission." *Medical Hypotheses*, Churchill Livingstone, 25 Apr. 2020, www.sciencedirect.com/science/article/pii/S030698772030801X.

- Three ways:
  - Air circulation in confined places w/ infected
  - Recirculating air in vent systems
  - Inadequate exhaust systems for HVAC
- HVAC must be sure to abide by the above to provide adequate filtering of the air in any given room

UVC Lamps and radiation:

[19] Center for Devices and Radiological Health. "UV Lights and Lamps: Ultraviolet-C Radiation, Disinfection, and Corona." *U.S. Food and Drug Administration*, FDA, www.fda.gov/medical-devices/coronavirus-covid-19-and-medical-devices/uv-lights-and-lamps-ultraviolet-c-radiation-disinfection-and-coronavirus. https://www.fda.gov/medical-devices/coronavirus-covid-19-and-medical-devices/uv-lights-and-lamps-ultraviolet-c-radiation-disinfection-and-coronavirus

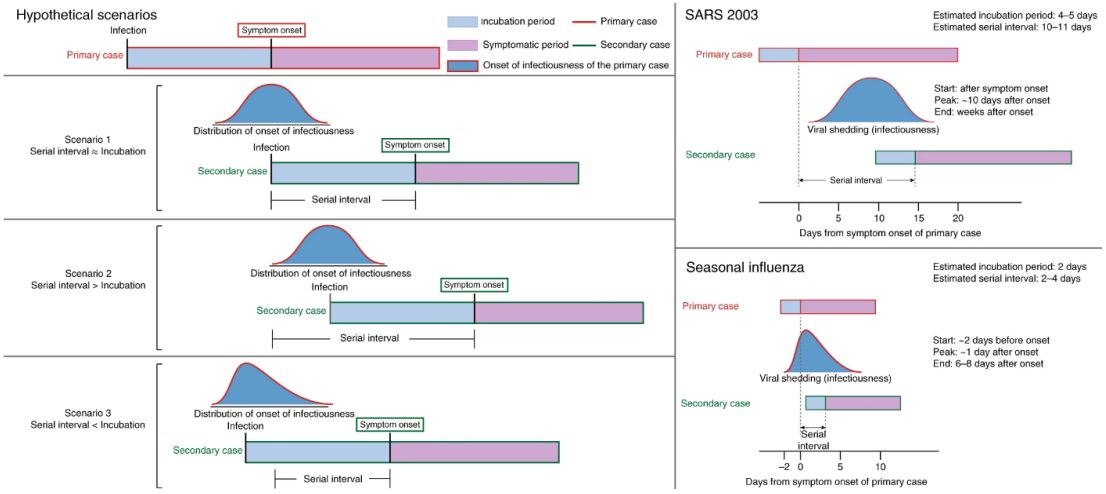
- Useful in air filtration systems to disinfect incoming air

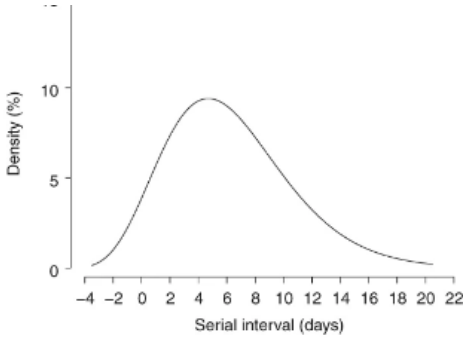
- Harmful to both virus's and humans through direct exposure to UVC radiation

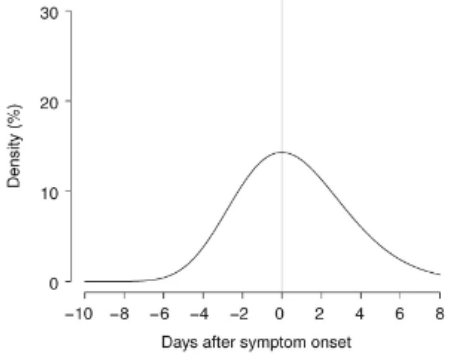
Sources of ABM Model Parameters

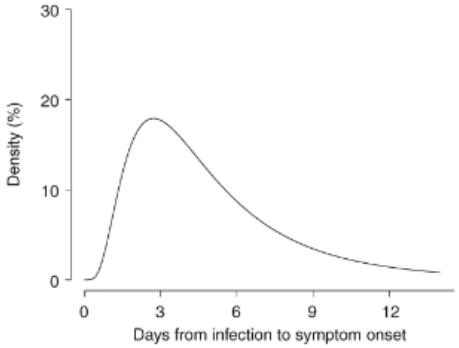
[20] He, Xi, et al. "Temporal Dynamics in Viral Shedding and Transmissibility of COVID-19." *Nature News*, Nature Publishing Group, 15 Apr. 2020, www.nature.com/articles/s41591-020-0869-5. https://www.nature.com/articles/s41591-020-1016-z

- People become infectious between 5.9 and 17 days (mean 12.3 days) before symptom onset
- Infectiousness profile peaks at symptom onset (~ 0 days)









Airborne Risk of COVID

[21] Buonanno, Giorgio, et al. "Quantitative Assessment of the Risk of Airborne Transmission of SARS-CoV-2 Infection: Prospective and Retrospective Applications." *MedRxiv*, Cold Spring Harbor Laboratory Press, 1 Jan. 2020, www.medrxiv.org/content/10.1101/2020.06.01.20118984v1.full.pdf html. https://www.medrxiv.org/content/10.1101/2020.06.01.20118984v1.full.pdf+html

- Applicable for Activity types
- Applicable for behavior
- Emission rate by activity
- Further info on paper itself

Type of indoor environment	Hospital room	Gym	Public indoor environments (e.g. restaurant, bank)	Conference room or auditorium
Emitting subject	Patient (Resting, oral breathing)	Exercising person (heavy exercise, oral breathing)	Speaking person (light exercise, voiced counting)	Singer or conference loud speaker (light exercise, unmodulated vocalization)
Exposed subject	A-1. Medical staff (light exercise) A-2. Patient (resting)	Exercising person (heavy exercise)	Speaking person (light exercise)	Spectator (sedentary activity)
Volume (m^3)	100	300	300	800
Ventilation, AER (h^{-1})	• Natural ventilation 0.5 h^{-1}, • Mechanical ventilation 3 h^{-1}, • Mechanical ventilation 10 h^{-1}			
Deposition rate, k (h^{-1})			0.24	
Inactivation rate, λ (h^{-1})			0.63	

Most Useful Recent Modeling Papers

- [22] McCarthy, J.E., Dumas, B.A., McCarthy, M.T. and Dewitt, B.D., 2020. A deterministic linear infection model to inform Risk-Cost-Benefit Analysis of activities during the SARS-CoV-2 pandemic. *medRxiv*. https://www.medrxiv.org/content/10.1101/2020.08.23.20180349v1.full.pdf

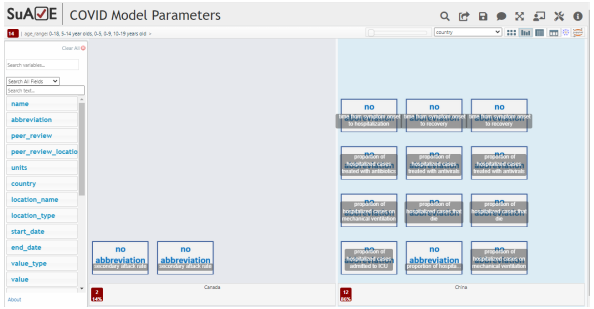
  estimates of relative risk for diverse activities (eg for a sequence of sub-activities during air travel)

- [23] McCarthy, J.E., McCarthy, M.T. and Dumas, B.A., 2020. Long range versus short range aerial transmission of SARS-CoV-2. *arXiv preprint arXiv:2008.03558*. https://arxiv.org/pdf/2008.03558.pdf

  "compare the relative viral loads that somebody would receive from exposure to an infectious person standing close to them and the amount they would receive via aerosols in an indoor environment where they remain for a long time"

Key Modeling Resources

- **Models of Infectious Disease Agent Study** (MIDAS): datasets, parameter estimates
  - *Out of 845 listed model parameters, only 14 are specific to ages 0-18* (https://tinyurl.com/midaschildrenparams)



- **California COVID Assessment Tool** https://calcat.covid19.ca.gov/cacovidmodels/
- **Long-Term Intervention Strategies for COVID-19** https://covid-measures.stanford.edu/

https://midasnetwork.us/covid-19/