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COVID-19 in Austin, Texas: Epidemiological Assessment of Grocery Shopping

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Overview

There are an estimated 24,000 grocery store workers in the Austin-Round Rock metropolitan area (MSA) representing 2% of the labor force [1].

The Austin *Stay Home - Work Safe* order that was issued on March 24, 2020 and extended on April 13, 2020 restricts non-essential work, but permits work in grocery stores and public grocery shopping [2,3]. Daily interactions between grocery workers and the general population may undermine efforts to reduce person-to-person contact, and exacerbate the individual and city-wide risks associated with COVID-19 transmission.

In response to a request from the city of Austin, we projected the epidemiological impacts of grocery work under different assumptions regarding the effectiveness of precautionary measures taken by workers and shoppers in grocery stores. To do so, we modified the Austin-Round Rock module of our *US COVID-19 Pandemic Model* to explicitly include a population subgroup representing grocery workers and contacts that occur between members of the general public and grocery workers in stores. As a base case scenario, we assumed that grocery workers would maintain typical workforce contact rates, estimated as twice the average workplace contacts for 18-49 year olds in the general population.

The projections suggest that the epidemiological risks to the community and population of grocery workers depend on three key factors:

- *Efficacy of Stay Home-Work Safe*: In-person grocery shopping is projected to be most detrimental under scenarios where the social distancing order is *highly* effective. If the order is highly effective, then the additional COVID-19 transmission can undermine the strong mitigation achieved. If the Stay Home-Work Safe order is only moderately effective, the additional transmission occurring in grocery stores may be marginal.

- *Precautionary measures taken by shoppers*: Precautionary measures taken by the general public when shopping to limit contacts with grocery workers and other shoppers can substantially reduce COVID-19 transmission.

- *Precautionary measures taken by grocery workers*: Precautionary measures taken by grocery workers can reduce COVID-19 transmission to an even greater extent than measures taken by shoppers.

Our analysis suggests that grocery shopping can considerably increase the community-wide risk of COVID-19 and that both shoppers and workers can and should do their part to protect themselves and others from transmission in stores. Furthermore, the risk of COVID-19 hospitalizations within the population of grocery workers is expected to be much higher than that in the non-working 18-49 year old population.

Preventing COVID-19 transmission is difficult because the virus spreads quickly and sometimes *silently* by people who do not know they are infected. Data from around the world indicate that infected people often become contagious before they develop symptoms. Thus, people who look and feel perfectly healthy could potentially spread the virus to others while shopping or working in grocery stores.

Since the virus can spread through the air [4], physical distancing and face coverings can reduce the risk of transmission [5,6]. However, there is no perfect precaution that, on its own, can completely protect an individual from getting infected or infecting others while shopping. Multiple measures are recommended to reduce the risk as much as possible. For example, we recommend that grocery stores and the general public consider the following measures, many of which are already required by official orders or adopted voluntarily by grocery chains.

- General precautions for workers and shoppers
    - Maintaining physical distance from all others at all times
    - Wearing face coverings and gloves when in public spaces

    - Abstaining from shopping or working if one is exhibiting symptoms of COVID-19 or was recently exposed to the virus
    - Abstaining from shopping or working if a household member is exhibiting symptoms of COVID-19
    - Frequent hand-washing with soap or cleansing with hand sanitizer
- Additional precautions for shoppers
    - Reduce the frequency of shopping errands and limit group sizes during those errands
    - Use pick-up and delivery services rather than visiting stores in person
    - Abstain from visiting stores and other high density public places if one is in a known high-risk category [7]
    - Clean items purchased at grocery stores before consumption
- Precautions for store management
    - Provide workers with compensated time off for the duration of the infectious period of COVID-19 if they or a household member is exhibiting symptoms of COVID-19
    - Provide workers with compensated time off during high-risk periods if they are in a known high-risk category [7]
    - Make hand-sanitizer available at entrances, exits, and throughout the store
    - Regularly clean shopping carts and high-touch areas
    - Use physical barriers to ensure safe distance between people at checkout counters
    - Provide extra space and floor markings to ensure sufficient distances between shoppers waiting in check-out lines
    - Limit the number of people in a store at one time, with actively managed single entrances and exits
    - Expand pick-up and delivery services to reduce the number of people visiting stores in person

    - Provide ample guidance for shoppers and workers regarding COVID-19 precautions via extensive signage and public announcements in multiple languages

Scenarios

We updated the Austin-Round Rock module of our *US COVID-19 Pandemic Model* to simulate COVID-19 epidemics under various reductions in contacts at grocery stores during the *Stay Home-Work Safe* order. The simulations ran from February 15 through mid-August, 2020. They assume the following initial conditions and key parameters:

- Starting condition: February 15, 2020 with 1 infected adult
- Epidemic doubling time: 2.8 days
- Reproduction number: 2.6
- Average incubation period: 6.9 days [8]
- Proportion of cases asymptomatic: 17.9% [9]
- Social distancing reductions in transmission:
    - Schools closed starting on March 14, 2020
    - *Stay Home-Work Safe* starting on March 25, 2020, reducing transmission by either 75% or 90%

All other model parameters, including age-specific hospitalization and fatality rates are provided in the Appendix.

We estimate the impact of grocery store shopping on COVID-19 hospitalization rates through August, under various levels of precautionary measures taken by grocery workers and grocery shoppers:

- Grocery worker precautions: Reduce probability of becoming infected while at work by co-workers or shoppers by 0%, 50% 75%, or 90%.
- Grocery shopper precautions: Reduce probability of becoming infected by grocery workers while shopping by 0%, 50% 75%, or 90%.

Results

Grocery workers are at high risk for COVID-19 infection and transmission through frequent daily contact with large numbers of shoppers and co-workers. If they come to work infected, they can amplify transmission not only within the community of grocery workers but throughout the community catchment for their store and beyond. We project the epidemiological impacts of grocery work under scenarios in which the March 24, 2020 Stay Home-Work Safe order reduced transmission by either 90% or 75%. As of April 15, 2020, COVID-19 hospitalization data from the Austin-Round Rock MSA suggest that social distancing has reduced transmission by 93% with (95% CI: 85%-100%).

Highly effective Stay Home-Work Safe (90%)

If the Stay Home-Work Safe measure reduces transmission by 90% across the Austin-Round Rock MSA, then our model suggests that the ongoing epidemic can be mitigated to the point that hospitalizations decline in the weeks ahead. This baseline scenario can be seen in Figures 1-3 in panels where both grocery shoppers and workers reduce their risk by 90%.

To examine the impact of *grocery shoppers* reducing their risks, consider the three red lines in Figure 1. The red lines assume that grocery workers take precautions that reduce their risk of infection at work by 50%. Even if shoppers take extreme precautions that reduce their infection risk while shopping by 90%, hospitalizations are still projected to increase through the summer (rightmost graph).

To examine the impact of *workers* reducing their risks, compare the red, blue and green lines in the left panel of Figure 1. These lines assume that shoppers take precautions that reduce their risk of infection while shopping by 50%. If grocery workers reduce risk by 75% (green), then we expect that hospitalizations will slow considerably; if workers reduce risk by 90% (blue), then we expect hospitalizations to dissipate.

Taken together, the risk of transmission at grocery stores is considerable but can be mitigated by transmission-reducing measures such as physical distancing, frequent hand washing, wearing gloves and cloth face coverings, and remaining home from work or shopping if a person or some household member is symptomatic. *The impact of such preventative measures is greater when taken by grocery workers than shoppers, but both are critical to mitigating the risk of COVID-19 transmission.*

Our projections for cumulative hospitalizations through August 17, 2020 corroborate this observation for both the greater Austin community (Figure 2), and also the individual grocery workers (Figure 3). Precautions taken by grocery store workers can substantially mitigate risks, regardless of the level of precautions taken by shoppers. In contrast, if grocery workers are taking extremely effective precautions, then additional measures taken by shoppers will have a relatively small effect. The risk of COVID-19 hospitalizations is consistently higher in the population of grocery workers than in the general 18-49 year old population (Table 1). For example, even if workers take steps to reduce their risk of infection by 75%, their risk of hospitalization will be three- to four-fold higher than their non-working counterparts under a highly effective *Stay Home-Work Safe* order.

These analyses assume that the *Stay Home-Work Safe* order enacted in Austin on March 24, 2020 has reduced transmission by 90%. If we assume instead that the order has only been 75% effective, we still find that precautions among grocery workers and shoppers can reduce COVID-19 transmission, but to a lesser degree, and a similar trend that measures taken by workers have a greater impact than those taken by shoppers.

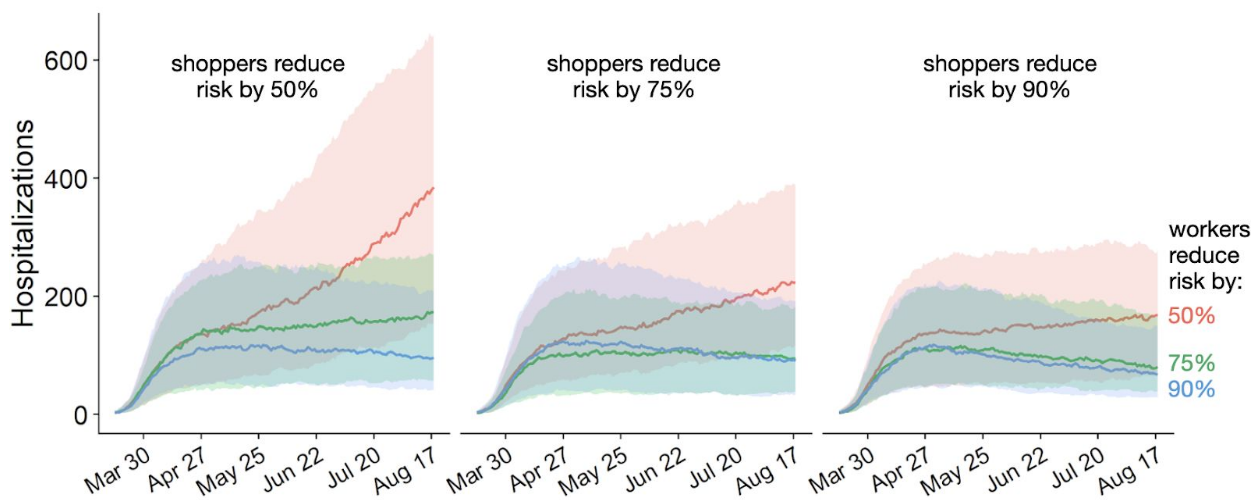

Figure 1. The projected impact of transmission-reducing measures taken by grocery workers and shoppers on the numbers of daily COVID-19 hospitalizations in the Austin-Round Rock MSA, assuming that the March 24th *Stay Home-Work Safe* order has reduced community transmission by 90%. Each panel represents different levels of *precautionary measures* among shoppers, while each line represents different levels of precaution among grocery workers. The impact of such measures is greater when taken by grocery workers than shoppers, but both are needed to mitigate the risks.

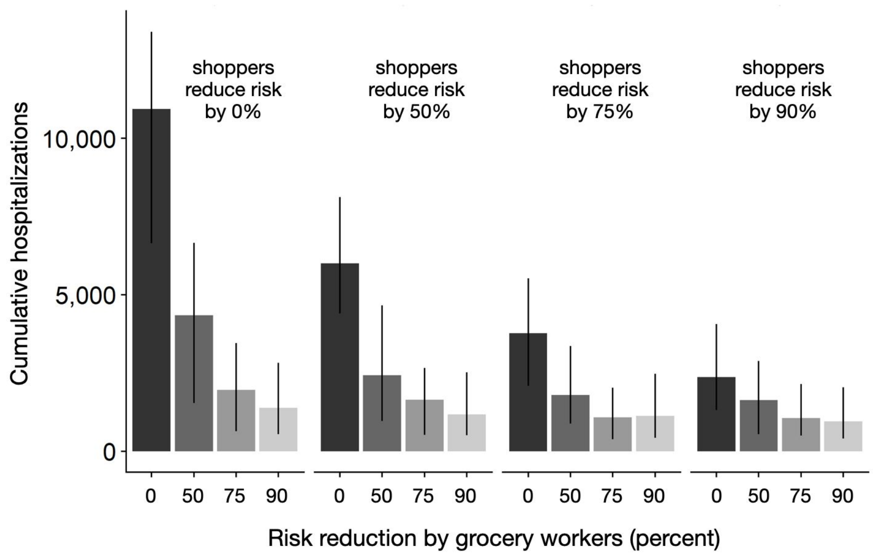

Figure 2. The projected impact of transmission-reducing measures taken by grocery workers and shoppers on the cumulative COVID-19 hospitalizations through August 17, 2020 in the Austin-Round Rock MSA, assuming that the March 24th *Stay Home-Work Safe* order has reduced community transmission by 90%. Each panel represents different levels of *precautionary measures* among shoppers, while the gray shading represents different levels of precaution among grocery workers, from none to a 90% reduction in workplace transmission. The impact of such measures is greater when taken by grocery workers than shoppers, but both are needed to mitigate the risks.

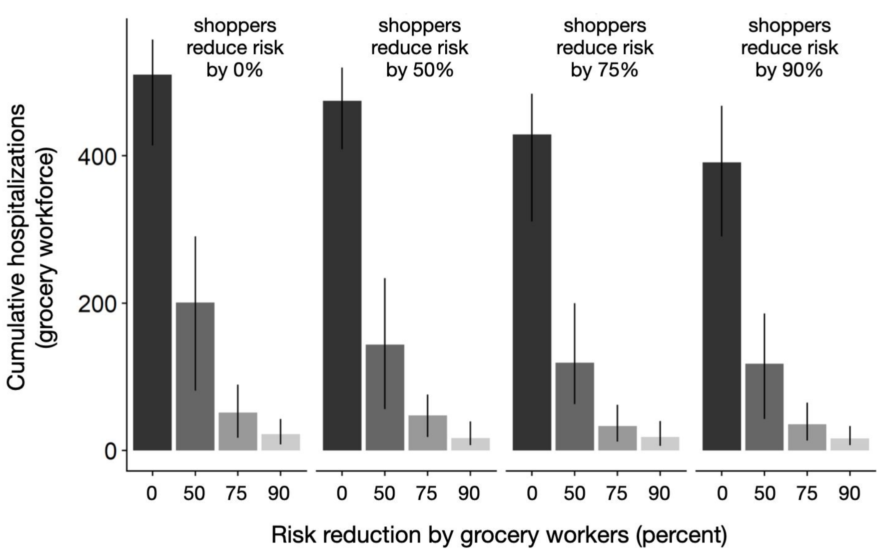

Figure 3. The projected impact of transmission-reducing measures taken by grocery workers and shoppers on the cumulative COVID-19 hospitalizations in the population of grocery workers through August 17, 2020 in the Austin-Round Rock MSA, assuming that the March 24th *Stay Home-Work Safe* order has reduced community transmission by 90%. Each panel represents different levels of *precautionary measures* among shoppers, while the gray shading represents different levels of precaution among grocery workers, from none to a 90% reduction in workplace transmission. The impact of such measures is greater when taken by grocery workers than shoppers, but both are needed to mitigate the risks.

Table 1. Relative risk of COVID-19 hospitalizations in grocery workers versus the general population of 18-49 year olds. We estimated the overall COVID-19 hospitalization rates (per 1,000) through mid-August for grocery workers and other 18-49 year olds. The numbers in the table are the ratio of these two quantities, with hospitalizations per 1,000 in grocery workers in parentheses. Values above one indicate higher risk for grocery workers compared with the general population.

Stay Home-Work Safe Efficacy	Precautionary measures by workers	Precautionary measures by shoppers			
		0%	**50%**	**75%**	**90%**
90%	**0%**	5.38 (21)	9.29 (20)	13.62 (18)	20.13 (16)
	50%	5.19 (8)	6.56 (6)	8.17 (5)	8.00 (5)
	75%	3.00 (2)	3.33 (2)	3.50 (1)	3.75 (2)
	90%	1.80 (1)	1.75 (1)	1.75 (1)	1.75 (1)
75%	**0%**	1.39 (24)	1.63 (24)	1.76 (24)	2.00 (23)
	50%	1.50 (22)	1.67 (20)	1.65 (21)	1.70 (20)
	75%	1.33 (17)	1.34 (16)	1.38 (16)	1.41 (15)
	90%	1.02 (14)	1.07 (12)	1.05 (11)	1.04 (12)

Moderately effective Stay Home-Work Safe (75%)

If the Stay Home-Work Safe measure reduces transmission by only 75% across the Austin-Round Rock MSA, then our model suggests that the ongoing epidemic will continue to spread and ultimately surpass our healthcare capacity. In this scenario, the additional risk posed by grocery shopping is still large but less pronounced relative to the significant projected burden of COVID-19 throughout the spring and summer of 2020.

To examine the impact of *shoppers* reducing their risks, consider the three red lines in Figure 4. The red lines assume that grocery workers take precautions that reduce their risk of infection at work by 50%. Even if shoppers take extreme precautions that reduce their risks while shopping by 90%, hospitalizations are still projected to increase through the summer (rightmost graph).

To examine the impact of *workers* reducing their risks, compare the red, blue and green lines in the middle panel of Figure 4. These lines assume that shoppers take precautions that reduce their risk of infection and transmission while shopping by 75%. If grocery workers reduce risk by 75% (green), then we expect that hospitalizations will slow marginally; if workers reduce risk by 90% (blue), then we expect another small slowdown in hospitalizations.

The impact of grocery worker and shopper behavior is minimal but more apparent when looking at projections for cumulative hospitalizations through August 17, 2020 for both the whole community (Figure 5) and the grocery workforce (Figure 6). We find similar trends as with the 90% social distancing projections above, but with mitigated effects: hospitalizations are impacted more by precautionary measures taken by grocery workers than precautionary measures taken by the shoppers.

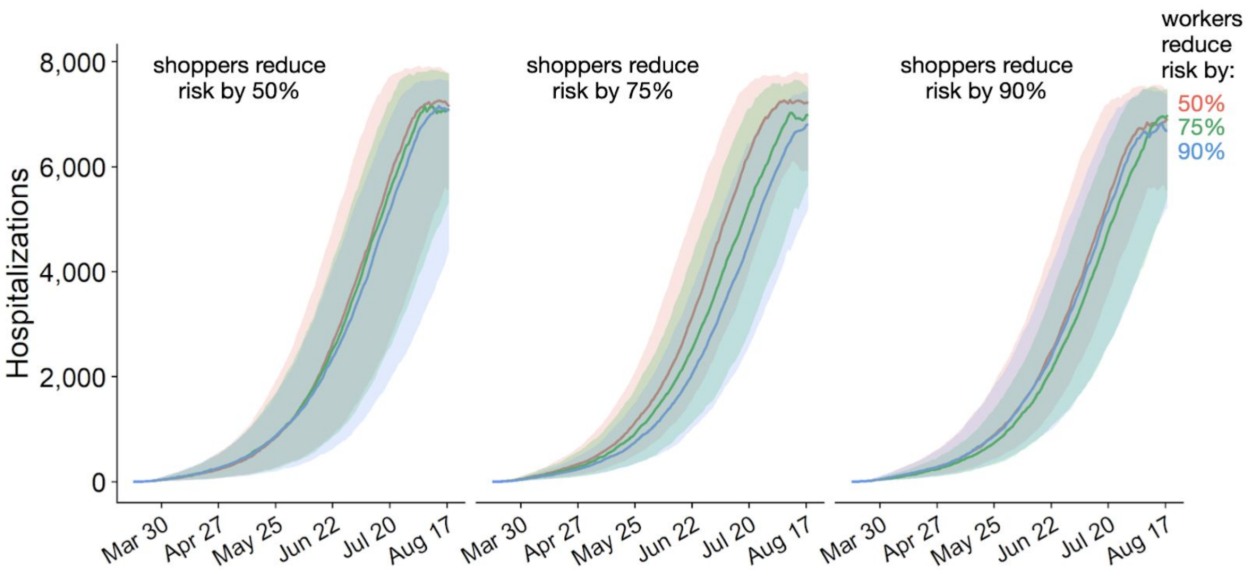

Figure 4. The projected impact of transmission-reducing measures taken by grocery workers and shoppers on the numbers of daily COVID-19 hospitalizations in the Austin-Round Rock MSA, assuming that the March 24th *Stay Home-Work Safe* order has reduced community transmission by 75%. Each panel represents different levels of *precautionary measures* among shoppers, while each line represents different levels of precaution among grocery workers. Although less apparent than under the more effective social distancing scenario (Figure 1), the impact of such measures still exists and is slightly greater when taken by grocery workers than shoppers.

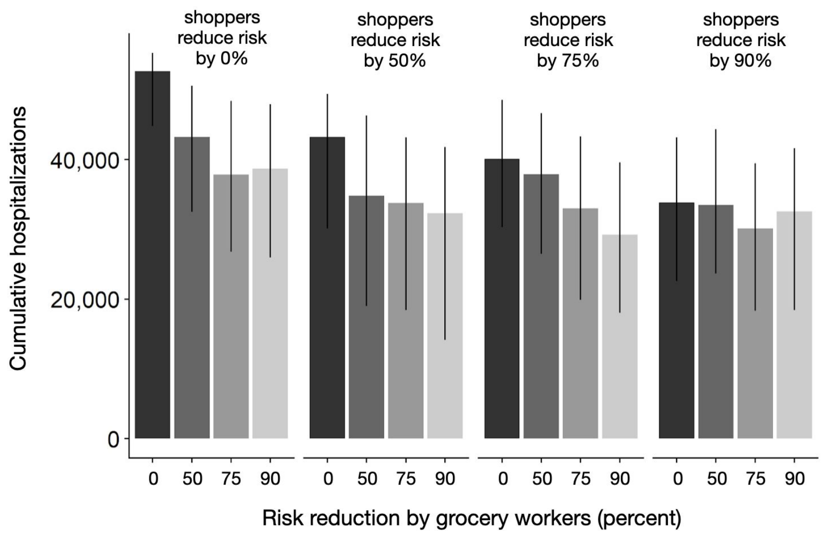

Figure 5. The projected impact of transmission-reducing measures taken by grocery workers and shoppers on the cumulative COVID-19 hospitalizations through August 17, 2020 in the Austin-Round Rock MSA, assuming that the March 24th *Stay Home-Work Safe* order has reduced community transmission by 75%. Each panel represents different levels of *precautionary measures* among shoppers, while the gray shading represents different levels of precaution among grocery workers, from none to a 90% reduction in workplace transmission. The impact of such measures is greater when taken by grocery workers than shoppers, but both are needed to mitigate the risks.

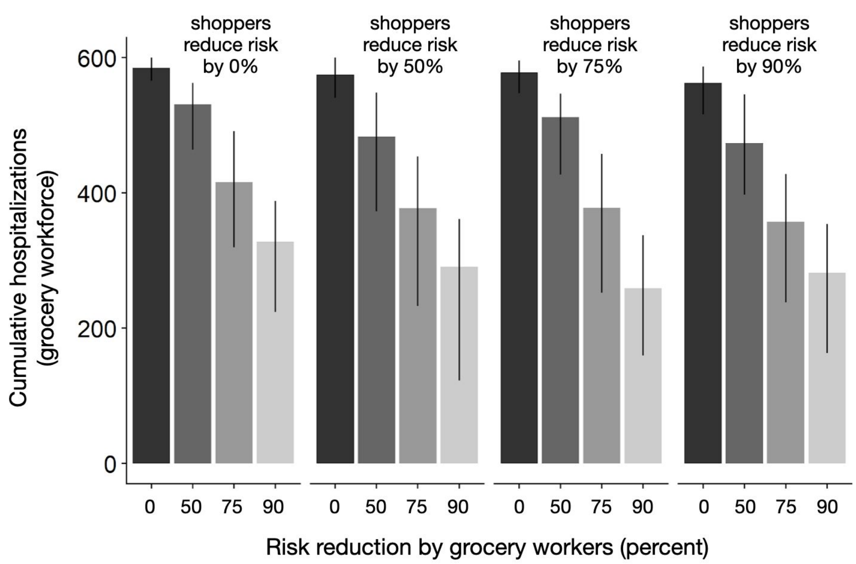

Figure 6. The projected impact of transmission-reducing measures taken by grocery workers and shoppers on the cumulative COVID-19 hospitalizations in the population of grocery workers through August 17, 2020 in the Austin-Round Rock MSA, assuming that the March 24th *Stay Home-Work Safe* order has reduced community transmission by 75%. Each panel represents different levels of *precautionary measures* among shoppers, while the gray shading represents different levels of precaution among grocery workers, from none to a 90% reduction in workplace transmission. The impact of such measures is greater when taken by grocery workers than shoppers, but both are needed to mitigate the risks.

Appendix

COVID-19 Epidemic Model Structure and Parameters

The model structure is diagrammed in Figure A1 and described in the equations below.
For each age and risk group, we build a separate set of compartments to model the transitions between the states: susceptible (S), exposed (E), symptomatic infectious (I^Y), asymptomatic infectious (I^A), symptomatic infectious that are hospitalized (I^H), recovered (R), and deceased (D). The symbols S, E, I^Y, I^A, I^H, R, and D denote the number of people in that state in the given age/risk group and the total size of the age/risk group is $N = S + E + I^Y + I^A + I^H + R + D$.
The model for individuals in age group a and risk group r is given by:

$$\frac{dS_{a,r}}{dt} = -\sum_{i\in A}\sum_{j\in K}(I^Y_{i,j}\omega^Y + I^A_{i,j}\omega^A + E_{i,j}\omega^E)\beta\phi_{a,i}/N_i$$

$$\frac{dE_{a,r}}{dt} = \sum_{i\in A}\sum_{j\in K}(I^Y_{i,j}\omega^Y + I^A_{i,j}\omega^A + E_{i,j}\omega^E)\beta\phi_{a,i}/N_i - \sigma E_{a,r}$$

$$\frac{dI^A_{a,r}}{dt} = (1-\tau)\sigma E_{a,r} - \gamma^A I^A_{a,r}$$

$$\frac{dI^Y_{a,r}}{dt} = \tau\sigma E_{a,r} - (1-\pi)\gamma^Y I^Y_{a,r} - \pi\eta I^Y_{a,r}$$

$$\frac{dI^H_{a,r}}{dt} = \pi\eta I^Y_{a,r} - (1-\nu)\gamma^H I^H_{a,r} - \nu\mu I^H_{a,r}$$

$$\frac{dR_{a,r}}{dt} = \gamma^A I^A_{a,r} + (1-\pi)\gamma^Y I^Y_{a,r} + (1-\nu)\gamma^H I^H_{a,r}$$

$$\frac{dD_{a,r}}{dt} = \nu\mu I^H_{a,r}$$

where A and K are all possible age and risk groups, ^{A}, ^{Y}, ^{H} are relative infectiousness of the I^A, I^Y, E compartments, respectively, β is transmission rate, $_{a,i}$ is the mixing rate between age group a, $i \in A$, ^{A}, ^{Y}, ^{H} are the recovery rates for the I^A, I^Y, I^H compartments, respectively, σ is the exposed rate, τ is the symptomatic ratio, π is the proportion of symptomatic individuals requiring hospitalization, η is rate at which hospitalized cases enter the hospital following symptom onset, ν is mortality rate for hospitalized cases, and μ is rate at which terminal patients die.

We model stochastic transitions between compartments using the τ-leap method[10,11] with key parameters given in Table S1. Assuming that the events at each time-step are independent and do not impact the underlying transition rates, the numbers of each type of event should follow Poisson distributions with means equal to the rate parameters. We thus simulate the model according to the following equations:

$$S_{a,r}(t+1) - S_{a,r}(t) = -P_1$$

$$E_{a,r}(t+1) - E_{a,r}(t) = P_1 - P_2$$

$$I^A_{a,r}(t+1) - I^A_{a,r}(t) = (1-\tau)P_2 - P_3$$

$$I^Y_{a,r}(t+1) - I^Y_{a,r}(t) = \tau P_2 - P_4 - P_5$$

$$I^H_{a,r}(t+1) - I^H_{a,r}(t) = P_5 - P_6 - P_7$$

$$R_{a,r}(t+1) - R_{a,r}(t) = P_3 + P_4 + P_6$$

$$D_{a,r}(t+1) - D_{a,r}(t) = P_7 \text{ ,}$$

with

$$P_1 \sim \text{Pois}(S_{a,r}(t)F_{a,r}(t))$$

$$P_2 \sim \text{Pois}(\sigma E_{a,r}(t))$$

$$P_3 \sim \text{Pois}(\gamma^A I^A_{a,r}(t))$$

$$P_4 \sim \text{Pois}((1-\pi)\gamma^Y I^Y_{a,r}(t))$$

$$P_5 \sim \text{Pois}(\pi\eta I^Y_{a,r}(t))$$

$$P_6 \sim \text{Pois}((1-\nu)\gamma^H I^H_a)$$

$$P_7 \sim \text{Pois}(\nu\mu I^H_{a,r}(t))$$

and where $F_{a,r}$ denotes the force of infection for individuals in age group a and risk group r and is given by:

$$F_{a,r}(t) = \sum_{i \in A} \sum_{j \in K} (I^Y_{i,r}(t)\omega^Y + I^A_{i,r}(t)\omega^A + E_{i,j}(t)\omega^E)\beta_{a,i}\phi_{a,i}/N_i$$

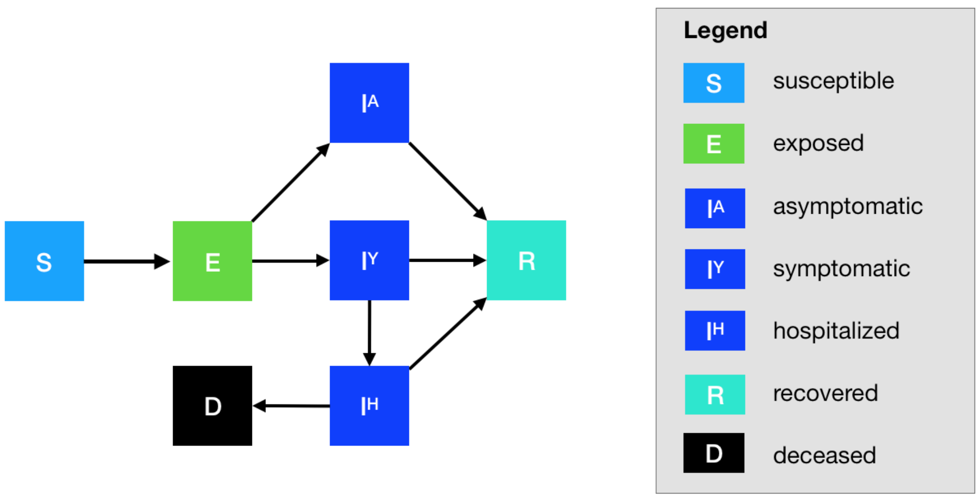

Figure A1. Compartmental model of COVID-19 transmission in a US city. Each subgroup (defined by age and risk) is modeled with a separate set of compartments. Upon infection, susceptible individuals (S) progress to exposed (E) and then to either symptomatic infectious (I^Y) or asymptomatic infectious (I^A). All asymptomatic cases eventually progress to a recovered class where they remain protected from future infection (R); symptomatic cases are either hospitalized (I^H) or recover. Mortality (D) varies by age group and risk group and is assumed to be preceded by hospitalization.

Table A1. Initial conditions, school closures and social distancing policies

Variable	Settings
Initial day of simulation	2/15/2020
Initial infection number in locations	1 symptomatic case in 18-49y age group
School closure	3/14/2020 - 8/17/2020
Social distancing reduction in contacts	Main population contacts α, two scenarios: [0.75, 0.9] Grocery workers work contacts γ, four scenarios: [0, 0.5, 0.75, 0.9] Grocery shoppers contacts σ, four scenarios: [0, 0.5, 0.75, 0.9]
Social distancing dates	3/24/2020 - 8/17/2020
Age-specific and day-specific contact rates	Home, work, other and school matrices provided in Tables A4.1-A4.4. $work_{GW}$ and $other_{GS}$ are grocery workers' work and grocery store (subset of other locations) contact matrices respectively α, γ, σ represent social distancing in the main population, grocery workers work contacts and grocery shoppers contacts respectively ● From 2020-03-1 to 2020-03-13 $Weekday = home + school + work + other + work_{GW} + other_{GS}$ $Weekend = home + other + work_{GW} + other_{GS}$ $Weekday\ holiday = home + other + work_{GW} + other_{GS}$ ● From 2020-03-14 to 2020-03-24 $Weekday = home + work + other + work_{GW} + other_{GS}$ $Weekend = home + other + work_{GW} + other_{GS}$ $Weekday\ holiday = home + other + work_{GW} + other_{GS}$ ● Starting 2020-03-25 $Weekday = (1-\alpha) * (home + work + other) + (1-\gamma) * work_{GW} + (1-\sigma) * other_{GS}$ $Weekend = (1-\alpha) * (home + other) + (1-\gamma) * work_{GW} + (1-\sigma) * other_{GS}$ $Weekday\ holiday = (1-\alpha) * (home + other) + (1-\gamma) * work_{GW} + (1-\sigma) * other_{GS}$

Table A2. Model parameters[a]

Parameters	Best guess values	Source
R_0: reproduction number	2.6	Derived from fitted model
δ: doubling time	2.8 days	Derived from fitted model
β: transmission rate	0.035	Fitted[a] to daily COVID-19 hospitalizations in Austin-Round Rock MSA
γ^A: recovery rate on asymptomatic compartment	Equal to γ^Y	
γ^Y: recovery rate on		Verity et al. [12]

symptomatic non-treated compartment	$\frac{1}{\gamma^Y} \sim \text{Triangular}(21.2, 22.6, 24.4)$	
τ : symptomatic proportion (%)	82.1	Mizumoto et al.[9]
σ : exposed rate	$\frac{1}{\sigma} \sim \text{Triangular}(5.6, 7, 8.2)$	Lauer et al.[8]
P: proportion of pre-symptomatic transmission (%)	12.6	Du et al.[13]
ω^E : relative infectiousness of infectious individuals in compartment E	$\omega^E = \frac{(\frac{YHR}{\eta} + \frac{1-YHR}{\gamma^Y})\omega^Y \sigma P}{1-P}$	
ω^A : relative infectiousness of infectious individuals in compartment I^A	0.4653	Set to mean of ω^E
IFR: infected fatality ratio, age specific (%)	Low risk: [0.0009, 0.0022, 0.0339, 0.2520, 0.6440] High risk: [0.0092, 0.0218, 0.3388, 2.5197, 6.4402]	Age adjusted from Verity et al.[12]
YFR: symptomatic fatality ratio, age specific (%)	Low risk: [0.0011165, 0.0027 , 0.0412, 0.3069, 0.7844] High risk: [0.0112, 0.0265, 0.4126, 3.0690, 7.8443]	$YFR = \frac{IFR}{1-\tau}$
h : high-risk proportion, age specific (%)	[8.2825, 14.1121, 16.5298, 32.9912, 47.0568]	Estimated using 2015-2016 Behavioral Risk Factor Surveillance System (BRFSS) data with multilevel regression and poststratification using CDC's list of conditions that may increase the risk of serious complications from influenza[14–16]
rr : relative risk for high risk people compared to low risk in their age group	10	Assumption

[a]Values given as five-element vectors are age-stratified with values corresponding to 0-4, 5-17, 18-49, 50-64, 65+ year age groups, respectively.

Table A3 Hospitalization parameters

Parameters	Value	Source

γ^H: recovery rate in hospitalized compartment	1/14	14 day-average from admission to discharge (UT Austin Dell Med)
YHR: symptomatic case hospitalization rate (%)	Low risk: [0.0279, 0.0215, 1.3215, 2.8563, 3.3873] High risk: [0.2791, 0.2146, 13.2154, 28.5634, 33.8733]	Age adjusted from Verity et al. [12]
π: rate of symptomatic individuals go to hospital, age-specific	$\pi = \frac{\gamma^Y * YHR}{\eta + (\gamma^Y - \eta) YHR}$	
η: rate from symptom onset to hospitalized	0.1695	5.9 day average from symptom onset to hospital admission Tindale et al.[17]
μ: rate from hospitalized to death	1/14	14 day-average from admission to death (UT Austin Dell Med)
HFR: hospitalized fatality ratio, age specific (%)	[4, 12.365, 3.122, 10.745, 23.158]	$HFR = \frac{IFR}{YHR(1-\tau)}$
ν: death rate on hospitalized individuals, age specific	[0.0390, 0.1208, 0.0304, 0.1049, 0.2269]	$\nu = \frac{\gamma^H HFR}{\mu + (\gamma^H - \mu) HFR}$

[a] The parameter β is fitted through least-squares minimization in SciPy/Python.[18] Given a value of β, a deterministic simulation is run based on central values for each parameter, from which we can compute the total numbers of daily hospitalizations $\bar{H}_t$. Using a trust region method the algorithm minimizes the sum $S(\beta)$ of squared daily differences between these estimated hospitalizations and the actual ones H_t: $S(\beta) = \sum_t (H_t - \bar{H}_t)^2$. The optimizing function runs until the resulting value of $S(\beta)$ does not get any smaller.

Number of grocery workers

The number of grocery workers in the Austin - Round Rock metropolitan area is estimated from the number of employees per industry reported in the American Community Survey's Public Use Microsample Data [19]. Across Texas, there are an estimated 321,000 individuals working in supermarkets, grocery stores, and convenience stores as of 2018, representing 1.12% of the population. Applying this proportion to the Austin-Round Rock MSA population of 2.17 million people yields an estimated 24,000 grocery workers.

Derivation of contact matrices

Contact matrices with only five age groups are denoted by C_{ij}^X where *X* represents the location of contact: H (home), S (school), W (work) or O (other locations). The five groups correspond to the following age bins: 0-4, 5-17, 18-49, 50-64 or 65+ years. We make the simplifying assumption that grocery workers are all in the 18-49 group, and we use *p* to denote the proportion of 18-49y olds who are grocery workers.

We construct a new set of contact matrices in which grocery workers form a separate subgroup (*g*) and denote them using $\tilde{C}_{ij}^{X}$. We make the simplifying assumption that grocery workers work seven days per week, which can be adjusted by δ below.

We assume that while at work grocery workers interact with the entire population, and that the main population interacts with grocery workers as part of their contacts at other locations. To determine those contacts we assume that grocery workers have δ times as many contacts at work as the average 18-49 year-old individual due to the nature of their work. So on average a grocery worker has $\delta \cdot \sum_j C_{18-49,j}^{W} = \sum_j \tilde{C}_{g,j}^{W}$ contacts a day. Denoting by GW the total number of grocery workers the total number of contacts all grocery workers have in a day is $GW \cdot \sum_j \tilde{C}_{g,j}^{W}$.

We assume that $\pi = 20\%$ of all work contacts grocery workers have are with other working grocery workers, then we estimate the number of contacts a person in each age group has with grocery workers while at a grocery store, as a multiple gs of contacts with 18-49 year olds, such that the total number of contacts equals the grocery workers' work contacts with the main population. Denoting by Pop_i the total population in group *i*, that multiple gs is such that:

$$gs \cdot \sum_i \tilde{C}_{i,18-49}^{O} \cdot Pop_i = \sum_i \tilde{C}_{i,g}^{O,gs} \cdot Pop_i = GW \cdot (1-\pi) \cdot \sum_j \tilde{C}_{g,j}^{W}$$

From this we set the number of work contacts a grocery worker has with each group according to the formula below. We note that in this case the number of work contacts grocery workers have with each age group is not a direct multiple of the work contacts of the average 18-49 individual, however the total number of contacts still is and given all age groups have similar transmissibility and susceptibility to COVID-19 this is not an issue.

$$\tilde{C}_{g,i}^{W} = \tilde{C}_{i,g}^{O,gs} \cdot \frac{Pop_i}{Pop_g}.$$

Additionally the main population and grocery workers have regular contacts at other locations outside of grocery stores. Those are directly proportional to contacts with 18-49 year-old individuals and are impacted by social distancing measures. Then the total contacts at other locations with grocery workers are equal to:

$$\tilde{C}_{ig}^{O} = p \cdot C_{i,18-49}^{O} + \tilde{C}_{ig}^{O,gs}.$$

Contacts the main population has with individuals in the 18-49 group are adjusted accordingly. When modeling social distancing measures the grocery workers' work contacts and the contacts the main population has with grocery workers at a grocery store are not impacted. Indeed given grocery shopping is an essential activity making grocery workers essential, people still go to grocery stores and these contacts still happen. When social distancing measures reducing contacts by α are implemented the contacts at other locations with grocery workers become:

$$\tilde{C}^{O}_{ig}(\alpha) = (1-\alpha)\cdot p\cdot C^{O}_{i,18-49} + \tilde{C}^{O,gs}_{ig} \quad .$$

The contacts at home and at school are estimated assuming homogeneous mixing of the entire population so, for X equal to home or school:

$$\tilde{C}^{X}_{ig} = p\cdot C^{X}_{i,18-49}$$
$$\tilde{C}^{X}_{i,18-49} = (1-p)\cdot C^{X}_{i,18-49}$$
$$\tilde{C}^{X}_{gj} = C^{X}_{18-49,j}$$

The contact matrices with 5 age groups and with grocery workers are included below, where we estimated 24,285 grocery workers in the Austin-Round Rock metropolitan area and $\delta = 2$.

Original 5-age groups contact matrices

Table A4.1 Home contact matrix. Daily number contacts by age group at home.

	0-4y	**5-17y**	**18-49y**	**50-64y**	**65y+**
0-4y	0.5	0.9	2.0	0.1	0.0
5-17y	0.2	1.7	1.9	0.2	0.0
18-49y	0.2	0.9	1.7	0.2	0.0
50-64y	0.2	0.7	1.2	1.0	0.1
65y+	0.1	0.7	1.0	0.3	0.6

Table A4.2 School contact matrix. Daily number contacts by age group at school.

	0-4y	5-17y	18-49y	50-64y	65y+
0-4y	1.0	0.5	0.4	0.1	0.0
5-17y	0.2	3.7	0.9	0.1	0.0
18-49y	0.0	0.7	0.8	0.0	0.0
50-64y	0.1	0.8	0.5	0.1	0.0
65y+	0.0	0.0	0.1	0.0	0.0

Table A4.3 Work contact matrix. Daily number contacts by age group at work.

	0-4y	5-17y	18-49y	50-64y	65y+
0-4y	0.0	0.0	0.0	0.0	0.0
5-17y	0.0	0.1	0.4	0.0	0.0
18-49y	0.0	0.2	4.5	0.8	0.0
50-64y	0.0	0.1	2.8	0.9	0.0
65y+	0.0	0.0	0.1	0.0	0.0

Table A4.4 Others contact matrix. Daily number contacts by age group at other locations.

	0-4y	5-17y	18-49y	50-64y	65y+
0-4y	0.7	0.7	1.8	0.6	0.3
5-17y	0.2	2.6	2.1	0.4	0.2
18-49y	0.1	0.7	3.3	0.6	0.2
50-64y	0.1	0.3	2.2	1.1	0.4
65y+	0.0	0.2	1.3	0.8	0.6

Updated contact matrices with subgroup for grocery workers

Table A5.1 Home contact matrix. Daily number contacts by age group at home assuming 24,285 grocery workers in Austin MSA.

	0-4y	5-17y	18-49y	50-64y	65y+	Grocery
0-4y	0.5	0.9	1.9	0.1	0.0	0.0
5-17y	0.2	1.7	1.9	0.2	0.0	0.0
18-49y	0.2	0.9	1.6	0.2	0.0	0.0
50-64y	0.2	0.7	1.2	1.0	0.1	0.0
65y+	0.1	0.7	1.0	0.3	0.6	0.0
Grocery	0.2	0.9	1.6	0.2	0.0	0.0

Table A5.2 School contact matrix. Daily number contacts by age group at school assuming 24,285 grocery workers in Austin MSA.

	0-4y	5-17y	18-49y	50-64y	65y+	Grocery
0-4y	1.0	0.5	0.4	0.1	0.0	0.0
5-17y	0.2	3.7	0.9	0.1	0.0	0.0
18-49y	0.0	0.7	0.8	0.0	0.0	0.0
50-64y	0.1	0.8	0.4	0.1	0.0	0.0
65y+	0.0	0.0	0.1	0.0	0.0	0.0
Grocery	0.0	0.7	0.8	0.0	0.0	0.0

Table A5.3 Work contact matrix. Daily number contacts by age group at work assuming 24,285 grocery workers in Austin MSA.

	0-4y	5-17y	18-49y	50-64y	65y+	Grocery
0-4y	0.0	0.0	0.0	0.0	0.0	0.0
5-17y	0.0	0.1	0.4	0.0	0.0	0.0
18-49y	0.0	0.2	4.4	0.8	0.0	0.0
50-64y	0.0	0.1	2.8	0.9	0.0	0.0
65y+	0.0	0.0	0.1	0.0	0.0	0.0
Grocery	0.4	1.2	5.4	1.3	0.5	2.3

Table A5.4 Others contact matrix. Daily number contacts by age group at other locations assuming 24,285 grocery workers in Austin MSA.

	0-4y	5-17y	18-49y	50-64y	65y+	Grocery
0-4y	0.7	0.7	1.7	0.6	0.3	0.1
5-17y	0.2	2.6	2.0	0.4	0.2	0.1
18-49y	0.1	0.7	3.1	0.6	0.2	0.2
50-64y	0.1	0.3	2.1	1.1	0.4	0.1
65y+	0.0	0.2	1.2	0.8	0.6	0.1
Grocery	0.1	0.7	3.1	0.6	0.2	0.2

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