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The University of Texas at Austin

COVID-19 risk assessment for public events — May 2022

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Overview

We describe a risk assessment framework to support event planning during COVID-19 waves. The method was developed in partnership with public health officials in Austin, Texas.

The framework is based on a previously published model [1]. The inputs to our calculations include the following:

- the local prevalence of COVID-19 [2],
- epidemiological properties of current variants,
- the structure of the event, including the number of attendees, types and duration of activities, density of interactions, and ventilation,
- COVID-related precautions for the event, including vaccine, testing, and face mask requirements, and
- local demographic information.

The risk assessment framework uses the above inputs to estimate the following quantities:

- the number of attendees likely to arrive infected,
- the reproduction number of COVID-19 at the event,
- the number of attendees likely to become infected at the event, and
- the number of additional infections that will occur in Austin in the subsequent four weeks, stemming from infections occurring at the event.

This report considers two case studies in Travis county (Austin, TX): (1) a business conference with 3,000 attendees and (2) an outdoor festival with 50,000 attendees. Overall, we find that

- Testing requirements before the event more effectively prevent attendees from arriving infected than vaccine requirements.
    - For the business conference case study, we compare entry testing—a negative test within 48 hours prior to the event—to a vaccine requirement that results in 95% of attendees vaccinated. The testing policy would result in an estimated 20 (95% CI: 5-30) attendees arriving infected; the vaccination policy would result in an estimated 30 (95% CI: 10-50) attendees arriving infected. Shortening the testing window to 24 hours prior to the event would reduce risks even further.
- Combining multiple mitigation strategies can effectively prevent transmission at events.
    - For the outdoor festival case study, a combination of vaccination, entry testing, and face mask requirements is estimated to reduce the number of infections stemming from the event in the subsequent four weeks from 895 (95% CI: 190-3,145) to 120 (95% CI: 10-460).
- Outdoor events are safer than indoor events.
    - Although the hypothetical outdoor festival is over ten times the size of the hypothetical business conference, we estimate that it will produce only double the number of infections within the community during and following the event.

COVID-19 risk assessment model for large events

To estimate event-related COVID-19 risks, we first estimate the number of attendees who will arrive infected, then the number of attendees who will be infected at the event, and finally the total number of infections in Austin stemming from the event over a four-week period. Our estimates are based on the following methods and assumptions:

- To estimate the number of attendees who will arrive infected, we use the method of our COVID-19 school risk dashboard [3] to estimate the incidence of COVID-19 in every US county and assume that probability of an attendee arriving infected is equal to the prevalence in their home county.
- We estimate transmission risks at events using an established model and published estimates for venue-specific transmission rates [1].
- We assume that fully vaccinated individuals have a 53% lower chance of infection and 10% lower chance of transmission compared with unvaccinated individuals, as has been estimated for the Delta variant [4]. For Omicron, it's thought that fully vaccinated

individuals experience a 65% lower chance of infection up to four weeks after vaccination but that this drops to 9% after 25 weeks; transmission risks have not yet been estimated [5].

- We assume that masking reduces transmission risk by 45% [6].
- We assume that entry testing for event attendees is 95% sensitive for detecting COVID-19 infections [7].
- We assume that event attendees remain in the county for at least one week following the event, and that these individuals will transmit at the current estimated county transmission rate while there. For many events, attendees are likely to travel outside of the metropolitan region, so our four week impact estimates are likely to be conservatively high.

Results

We present results from two hypothetical events in Austin, Texas—a business conference occurring during a pandemic surge and a large outdoor festival occurring when COVID levels are low. For each event, we estimate the baseline risks and the potential impacts of face mask, testing, and vaccination requirements.

Case Study 1: A one-day business conference with 3,000 attendees from Travis county on September 1, 2021 in Austin, Texas. At that time, a pandemic wave caused by the SARS-CoV-2 Delta variant had recently peaked in Austin and the prevalence of COVID-19 remained high. We estimate that 40 (95% CI: 20-65) of the participants would have arrived infected. We project that entry testing (negative test within 48 hours prior to the event) would have reduced the infected arrivals to 10 (95% CI: 5-25) whereas a vaccine requirement (that increased coverage from 57.8% to 95%) would have reduced this number to 30 (95% CI: 10-50). More stringent testing requirements would be expected to prevent even more introductions (Figure 1, Table 2).

Without precautionary measures, we estimate that the reproduction number of COVID-19 at such an event would be 3.75 (95% CI: 0.12-9.76) and that 135 (95% CI: 5-425) attendees would be infected at the event. A vaccine requirement would be expected to reduce the reproduction number to 2.56 (95% CI: 0.09-6.86) and the number of infections to 70 (95% CI: 0-215). Combining a vaccine and face mask requirement would further reduce these values to 1.32 (95% CI: 0.06-3.64) and 34 (95% CI: 1-127), respectively. Entry testing with a 48 hour requirement would prevent some cases from attending but not slow transmission at the event; entry testing without vaccination and face mask measures would be expected to result in 45 (95% CI: 0-150) infections at the event.

If infected attendees remained in Austin following the event, we estimate that the event would lead to an additional 600 (95% CI: 10-1,945) cases in Austin during the four weeks following the event. If the event adopted a vaccine or entry testing requirement, the expected four-week impact is reduced to 295 (95% CI: 5-1,135) or 175 (95% CI: 0-775) additional cases, respectively. If the event enforces a combination of vaccination, entry testing and face mask requirements, we estimate that the event would lead to only 350 (95% CI: 0-2355) new cases in Austin during this period.

Table 1: Specifications for the two case study events.

Input		Case 1: Business conference	Case 2: Outdoor festival
Event	Date	2021-09-01	2021-10-01
	Attendance	3,000	50,000
	Duration (hours)	4	6
	Vaccination rate	57.8%	60.9%
	Density[1]	Crowded	Crowded
	Mixing[2]	Well mixed	Well mixed
	Activity risk level[3]	Low risk	High risk
	Ventilation level[4]	Low	High
County	County	Travis, TX	Travis, TX
	Vaccination rate	57.8%	60.9%
	Rt	0.94	0.8

[1] Density refers to the number of individuals a single infected individual is likely to interact with at the event and can be Crowded or Dispersed as described in Table 6 and estimated in [1].
[2] Mixing defines how often people switch who they're interacting with and can be Well mixed or Podded as described in Table 6 and estimated in [1].
[3] Activity risk level refers to the inherent riskiness of an activity and can be Low or High risk as described in Table 6 and extrapolated from [1].
[4] Ventilation level can be either Low or High and is defined by the location of the event as defined in Table 6 and estimated in [8].

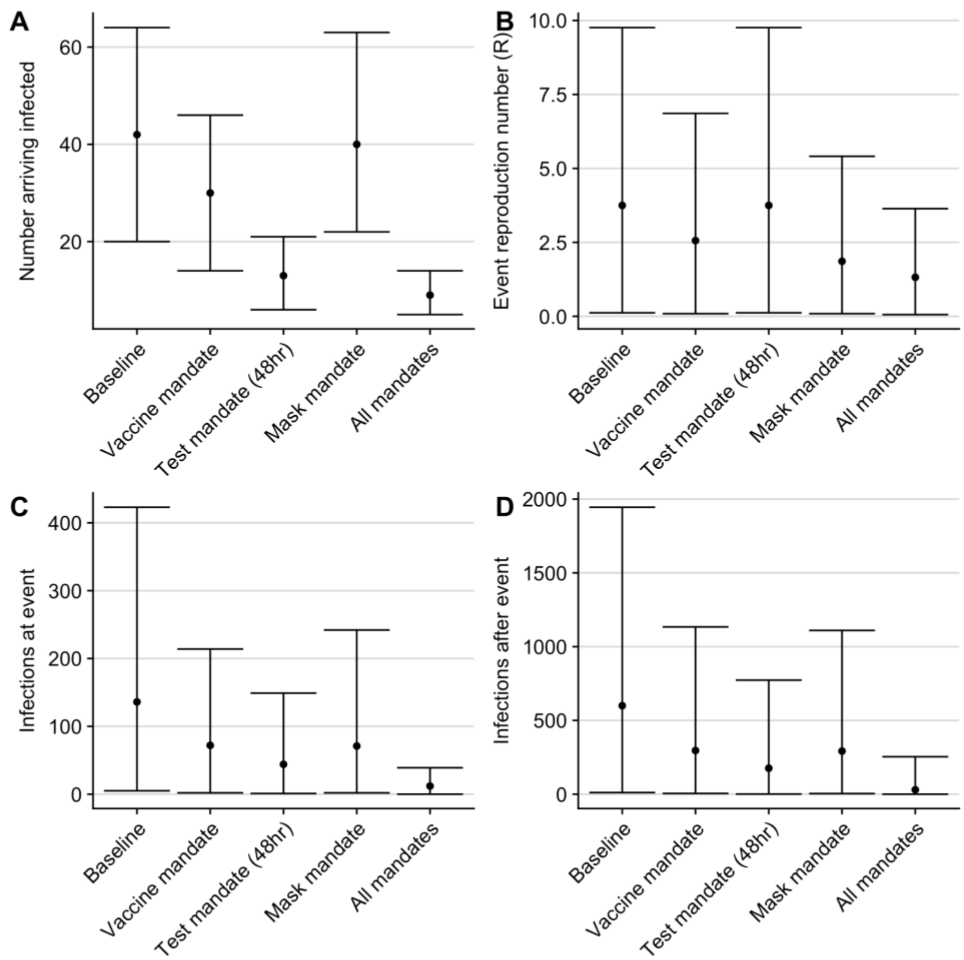

Figure 1: Estimated COVID-19 transmission risks for an indoor business conference with 3,000 attendees on September 1, 2021 in Austin, Texas, with different combinations of risk reducing measures. (A) Estimated number of attendees arriving infected. (B) Estimated event reproduction number. Event reproduction numbers above one indicate that each infected attendee is likely to infect more than one individual. (C) Estimated number of infections occurring at the event. (D) Estimated number of infections in Travis county stemming from the event during the four weeks following the event. For all figures, points indicate median estimates and bars indicate 95% confidence intervals across 500 stochastic simulations. We compare the anticipated burden across scenarios five scenarios including (1) one with no preventative efforts (Baseline), (2) one where participants are required to vaccinate (Vaccine mandate), (3) one where participants must receive a negative test at least 48 hours in advance of the event [Test mandate (48hr)], (4) one where masks are mandated at the event (Mask mandate), and (5) one that implements vaccine, 48 hour test, and mask mandates (All mandates).

Table 2: Estimated COVID-19 transmission risks for a four-hour indoor business conference with 3,000 attendees on September 1, 2021 in Austin, Texas. Values are medians and 95% confidence intervals from 500 stochastic simulations.

Precautionary measures		Risk Estimates			
Vaccine requirement	**Entry testing (negative test in specified window before event)**	**Number arriving infected**	**Event reproduction number**	**Infections at event**	**Combined event and community infections during next four weeks**
Face masks not required[5]					
Baseline (57.8%)	**24 hr**	5 (0-15)	3.75 (0.12-9.76)	25 (0-85)	100 (0-465)
	48 hr	10 (5-25)		45 (0-150)	175 (0-775)
	72 hr	20 (5-30)		60 (0-210)	255 (0-1,010)
	None	40 (20-65)		135 (5-425)	600 (10-1,945)
Vaccines required (95%)	**24 hr**	5 (0-20)	2.56 (0.09-6.86)	10 (0-45)	40 (0-270)
	48 hr	10 (5-15)		25 (0-70)	85 (0-440)
	72 hr	15 (5-25)		35 (0-105)	125 (0-540)
	None	30 (10-50)		70 (0-215)	295 (5-1,135)
Face masks required[5]					
Baseline (57.8%)	**24 hr**	5 (0-15)	1.86 (0.09-5.41)	15 (0-50)	35 (0-300)
	48 hr	10 (5-25)		20 (0-85)	85 (0-470)
	72 hr	20 (5-30)		30 (0-120)	115 (0-610)
	None	40 (20-65)		70 (0-245)	290 (0-1,110)
Vaccines required (95%)	**24 hr**	5 (0-20)	1.32 (0.06-3.64)	5 (0-25)	15 (0-200)
	48 hr	10 (5-15)		10 (0-40)	30 (0-255)
	72 hr	15 (5-25)		15 (0-60)	50 (0-355)
	None	30 (10-50)		35 (0-130)	130 (0-725)

[5] Transmission reduced 45% when face masks are required [6]

Case Study 2: An outdoor festival with 50,000 attendees from Travis county on October 1, 2021 in Austin, Texas. At that time, a pandemic wave caused by the SARS-CoV-2 Delta variant was receding, though the prevalence of COVID-19 remained moderately high. We estimate that 325 (95% CI: 195-470) of the participants would have arrived infected. We project that entry testing (negative test within 48 hours prior to the event) would have reduced the infected arrivals to 100 (95% CI: 60-150) whereas a vaccine requirement (that increased coverage from 60.9% to 95%) would have reduced this number to 235 (95% CI: 145-345). More stringent testing requirements would be expected to prevent even more introductions (Figure 2, Table 3).

Without precautionary measures, we estimate that the reproduction number of COVID-19 at such an event would be 0.86 (95% CI: 0.25-2.61) and that 275 (95% CI: 70-875) attendees would be infected at the event. A vaccine requirement would be expected to reduce the reproduction number to 0.6 (95% CI: 0.18-1.71) and the number of infections to 145 (95% CI: 30-490). Combining a vaccine and face mask requirement would further reduce these values to 0.35 (95% CI: 0.1-1.02) and 80 (95% CI: 20-255), respectively. Entry testing with a 48 hour requirement would prevent some cases from attending but not slow transmission at the event; entry testing without vaccination and face mask measures would be expected to result in 90 (95% CI: 20-300) infections at the event.

If infected attendees remained in Austin following the event, we estimate that the event would lead to a total of 895 (95% CI: 190-3,145) cases in Austin including those infected during and up to four weeks following the event. If the event adopted a vaccine or entry testing requirement, the expected four-week impact is reduced to 480 (95% CI: 80-1,620), or 285 (95% CI: 40-1,155) total cases, respectively. If the event enforces a combination of vaccination, entry testing and face mask requirements, we estimate that the event would lead to only 75 (95% CI: 5-375) new cases in Austin during this period.

Table 3: Estimated COVID-19 transmission risks for a six-hour outdoor festival with 50,000 attendees on October 1, 2021 in Austin, Texas. Values are medians and 95% confidence intervals from 500 stochastic simulations.

Precautionary Measures		**Risk Estimates**			
Vaccine requirement	**Entry testing (negative test in specified window before event)**	**Number arriving infected**	**Event reproduction number**	**Infections at event**	**Combined event and community infections during next four weeks**
Face masks not required[6]					
Baseline (57.8%)	**24 hr**	60 (35-90)	0.86 (0.25-2.61)	50 (10-180)	175 (15-640)
	48 hr	100 (60-150)		90 (20-300)	285 (40-1,155)
	72 hr	145 (90-215)		125 (30-420)	415 (70-1,525)
	None	325 (195-470)		275 (70-875)	895 (190-3,145)
Vaccines required (95%)	**24 hr**	45 (25-65)	0.6 (0.18-1.71)	25 (5-100)	80 (5-375)
	48 hr	75 (45-110)		45 (10-165)	140 (20-575)
	72 hr	105 (65-160)		65 (15-235)	210 (25-740)
	None	235 (145-345)		145 (30-490)	480 (80-1,620)
Face masks required[6]					
Baseline (57.8%)	24 hr	60 (35-90)	0.49 (0.15-1.4)	30 (5-100)	90 (5-375)
	48 hr	100 (60-150)		50 (10-165)	155 (20-610)
	72 hr	145 (90-215)		70 (15-240)	235 (35-850)
	None	325 (195-470)		155 (35-520)	520 (115-1,705)
Vaccines required (95%)	24 hr	45 (25-65)	0.35 (0.1-1.02)	15 (0-55)	40 (0-210)
	48 hr	75 (45-110)		25 (5-90)	75 (5-375)
	72 hr	105 (65-160)		40 (5-115)	120 (10-460)
	None	235 (145-345)		80 (20-255)	260 (35-930)

[6] Transmission reduced 45% when face masks are required [6]

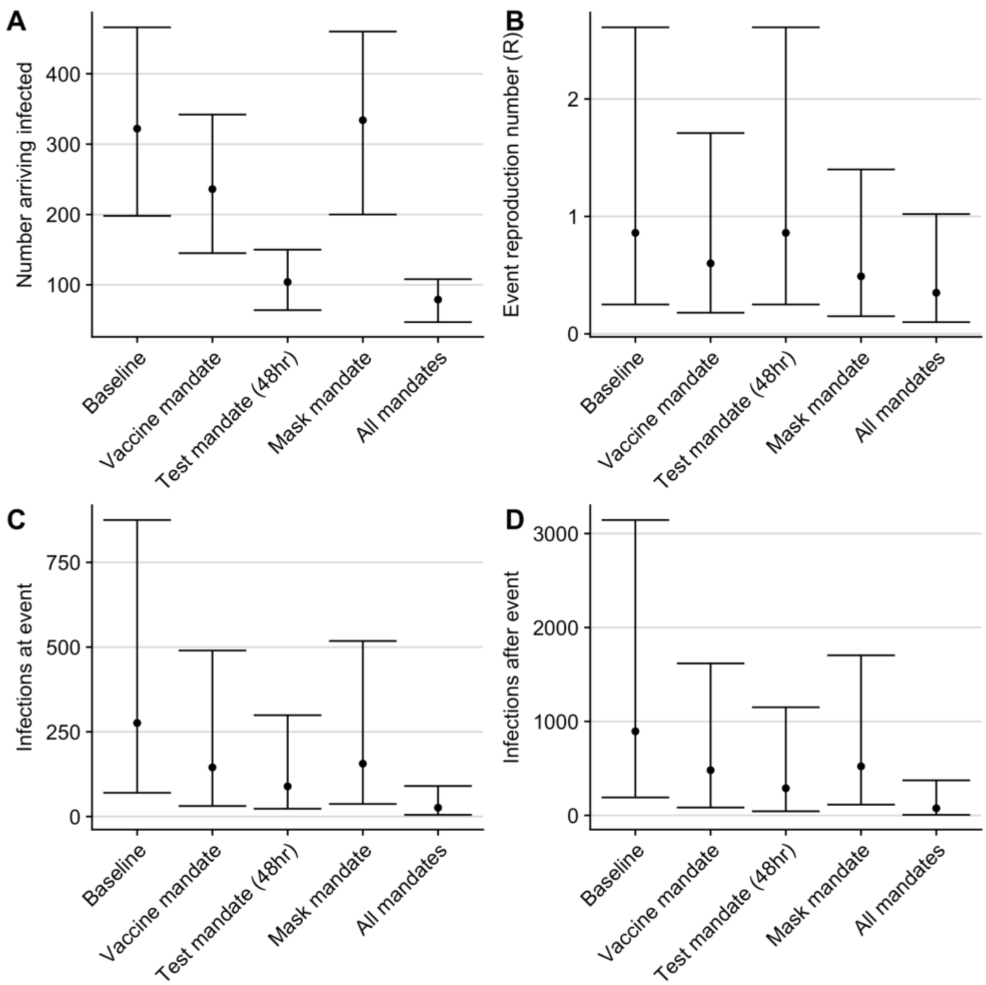

Figure 2: Estimated COVID-19 transmission risks for an outdoor music festival with 50,000 attendees on October 1, 2021 in Austin, Texas, with different combinations of risk reducing measures. (A) Estimated number of attendees arriving infected. (B) Estimated event reproduction number. Event reproduction numbers above one indicate that each infected attendee is likely to infect more than one individual. (C) Estimated number of infections occurring at the event. (D) Estimated number of infections in Travis county stemming from the event during the four weeks following the event. For all figures, points indicate median estimates and bars indicate 95% confidence intervals across 500 stochastic simulations. We compare the anticipated burden across scenarios five scenarios including (1) one with no preventative efforts (Baseline), (2) one where participants are required to vaccinate (Vaccine mandate), (3) one where participants must receive a negative test at least 48 hours in advance of the event [Test mandate (48hr)], (4) one where masks are mandated at the event (Mask mandate), and (5) one that implements vaccine, 48 hour test, and mask mandates (All mandates).

Discussion

When planning an event, there are three key factors that will determine the risks of COVID transmission and consequences for the surrounding community. The first is the structure of the event—its size, duration, density, and venue. Limiting the number of attendees, physically spacing out activities, and selecting outdoor and well-ventilated sites can significantly mitigate risks. The second factor is the state of the pandemic. If COVID-19 is surging in cities from which attendees are arriving, then the risks of introductions will be high. If the pandemic is severely straining the local healthcare system, overflow of infections from the event into the community could be catastrophic. The final factor is risk-reduction measures. Event planners can significantly mitigate the immediate and downstream risks by requiring proof of vaccination, a negative COVID test just prior to the event, and/or wearing face masks during the event.

Our framework makes a number of critical assumptions that may not hold for all events, especially as SARS-CoV-2 and our arsenal of medical countermeasures continues to evolve. We have adapted a published model that assumes event transmission rates that were estimated from a small and potentially biased sample of events that occurred early in the pandemic [1]. The analysis presented in this report assumes transmission rates and vaccine efficacy that were estimated for the Delta SARS-CoV-2 variant. As the virus continues to evolve, these values can and should be updated. Finally, we assume that event risks are limited to on-site activities. We do not consider transmission risks associated with unofficial gatherings that might occur adjacent to an event, particularly for larger and multi-day events.

Methods

We developed a framework for predicting the impact of large events on local SARS-CoV-2 epidemiological dynamics which estimates four distinct outcomes: (1) the number of infectees attending the event, (2) the reproduction number of the event based on its characteristics, (3) the number of attendees infected at the event, and (4) the number of community infections stemming from the event in the subsequent four-week period. Our methods are based on previous studies of school-based [9] and event-based [1] SARS-CoV-2 transmission risks.

Estimating infected attendees

The number of initially infected attendees (I_0) is a function of the prevalence of disease of attendees (P_e) and the number of attendees of the event (N_e). We assume a binomial relationship as:

$$I_0 \sim Binom(p = P_e, n = N_e)$$

Previously we assumed that the prevalence of disease amongst event attendees was equal to the prevalence of disease in the county of the event ($P_e = P_c$). More events are taking precautions to reduce the prevalence of disease in attendees, so we now incorporate the impact that such interventions will have on the prevalence of disease. Specifically we estimate the impact that two common precautions (negative test requirements and vaccination mandates) will have on reducing the prevalence of disease amongst attendees as:

$$P_e = P_c \cdot m_t \cdot m_v$$

Where m_t and m_v are the impact that testing and vaccination mandates will have on reducing the prevalence of disease of attendees. We calculate the prevalence of disease in a county by estimating the number of currently infected individuals from recent case data provided by the New York Times [10]. The CDC estimates that infections are underreported by a factor of 4.2 (95% CI: 3.6 – 4.9), but we assume that the underreporting reporting is distributed according to a uniform distribution from 3.0 to 7.0 to incorporate more uncertainty and the potential for more underreporting as testing efforts have fallen behind infections in the midst of a pandemic surge [11,12]. P_c on a given day can be calculated by multiplying the sum of the reported case counts from the previous seven days by the underreporting rate and dividing the quantity by the population of the county.

$$P_c(t) = \frac{\sum_{T=t-7}^{t} C_c(T) \cdot \rho}{n_c}$$

$$\rho \sim unif(\min = 3, \max = 7)$$

where, t, is the date of interest, ρ is the underreporting rate, $C_c(T)$ is the reported case count in a county for a specific day, T, and n_c is the population in the county.

We base estimates for the reduction of infected attendees from testing requirements based on the delay between testing and the event alongside the sensitivity and specificity of the test. We conservatively assume that people get tested on the first day to fulfill the testing requirement, i.e. if the requirement is a negative test within 72 hours, individuals will get tested exactly 3 days before the event, so the mitigation impact can be described as:

$$m_t = 1 - (1 - \frac{T_{tested}}{T_{infectious}}) \cdot S_t \cdot C$$

Where T_{tested} is the number of days before the event that individuals are tested, $T_{infectious}$ is the duration of infection, S_t is the sensitivity of the test, and C is compliance with the testing requirement. Assuming a seven day infectious period, 95% sensitivity of the tests, and 100% testing compliance, 72, 48, and 24 hour test requirements would reduce infected attendee counts by 54%, 68%, and 82% respectively.

We calculate m_v as the relative risk of an attendee of the event coming infected compared with the average person in the population due to vaccination as:

$$m_v = \frac{1 - VE_{inf} v_e}{1 - VE_{inf} v_c}$$

Where v_e and v_c are the proportion vaccinated at the event and county respectively and VE is the vaccine efficacy against infection, which we assume to be 53% against infection based on previous estimates for the Delta variant [13].

Estimating the event reproduction number

The framework within [1] proposes four key factors to consider in estimating the risk of an event: (1) the transmission potential, (2) the density, (3) the mixing of attendees, and (4) the duration. They quantify risk as the event reproduction number (R_e), which describes the expected number of infections caused by a single infected individual that attends the event as:

$$R_e = \frac{k \cdot T}{\tau} \cdot (1 - e^{(-\beta \cdot \tau)})$$

Where k captures the density of the event and is the number of infected individuals contacted per time period, T is the total duration of the event, τ captures the mixing and is the number of groups an average person interacts with, and β captures the transmission potential and is the probability that an infected person transmits to a contact. We draw from parameter and uncertainty values estimated in [1] to inform our baseline risk assessments for k, τ, and the baseline transmission rate β_0 which we use to get β (Table 1). Transmission rates were estimated for events that occurred early in the pandemic where few mitigative measures were in place such as masking, ventilation, and vaccination. We therefore convert β_0 to β using supplemental event characteristics as:

$$\beta = \beta_0 \cdot b_m \cdot b_e \cdot b_v$$

Where b_m is the impact that mask mandates have on transmission, b_e is the impact that the environment (e.g. ventilation differences like outdoors versus indoors events) has on transmission, and b_v is the impact that vaccination has on transmission. For the delta variant, we assume that vaccinated people are 10% less likely to transmit [4] and 53% less likely to get infected [13], so we estimate b_v as:

$$b_v = (0.47 \cdot v_e + 1 \cdot (1 - v_e)) \cdot (0.9 \cdot v_e + 1 \cdot (1 - v_e))$$

Where v_e is the estimated vaccination rate of the event. Parameter values for all event characteristics can be found in Table 1.

Table 6: Event parameterization by scenario

Scenario		Parameter value	Reference
Test mandate impact (reduction in infected attendees)	No mandate	1	
	Mandated (72, 48, or 24hr)	(0.54, 0.68, 0.82)	
Vaccination rates (v_e and v_c)			
Event density (k)	Dispersed	$k \sim U(1, 10)$[1]	[1]
	Crowded	$k \sim U(10, 30)$[1]	
Event mixing (τ)	Podding	$\tau = T$	[1]
	Well-mixed	$\tau = 1$	
Event setting (β_0)	Low risk	$\beta \sim U(0, 0.15)$[1]	[1]
	High risk	$\beta \sim U(0.1, 0.4)$[1]	
Event masking (b_m)	Unmasked	$b_m = 1$	[6]
	Masked	$b_m = 0.55$	
Event environment (b_e)	Low ventilation (e.g. indoors)	$b_e = 1$	[8]
	High ventilation (e.g. outdoors)	$b_e \sim G(shape = 9, rate = 168.3)$[2]	

[1] Indicates the parameter is drawn from a uniform distribution of the specified parameters
[2] Indicates the parameter is drawn from a gamma distribution of the specified parameters

Estimating total infections from the event

Using estimates for the initially infected attendees (I_0), and the reproduction number (R_e), we can estimate the probability that any of the remaining attendees are infected as:

$$p_i = 1 - (1 - \frac{R_e}{N_e - I_0})^{I_0}$$

Assuming that every infection event is independent from each other, we can then model the new infections that occur at the event (I_e) according to a binomial distribution as:

$$I_e \sim binom(n = (N_e - I_0), p = p_i)$$

Estimating four week community infections

We estimate the four week community infections from the event assuming that each infected individual transmits in the community independently from one another according to a negative binomial distribution with a mean of the county reproduction number specified by the user (R_c), and with a dispersion parameter of 0.1 as estimated previously [14]. We sample infections for four generations of transmission stemming from those initially infected at the event, and sum the event and subsequent infections to obtain an estimate of the total infection impact of the event. We estimate the County reproduction number for the specific event dates using estimates provided by the UT COVID-19 Modeling Consortium projections dashboard for the Austin MSA [15].

Obtaining estimates

We sample from the parameter distributions described above to obtain 500 samples for the number of infected attendees, the event reproduction number, the estimated number of infections occurring at the event, and the four-week infections caused by the event. We then summarize these samples according to their means and 95% confidence intervals to portray their underlying uncertainty.

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