Musician and Performers Aerosol Study Phase I: Exploratory Testing

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U of Maryland Team: Srebric, Milton, Zhu
Study Chairs: Weaver (NFHS), Spede (Clemson)

Recommendations based on first phase of testing can be found here: https://www.nfhs.org/articles/unprecedented-international-coalition-led-by-performing-arts-organizations-to-commission-covid-19-study/

Lead Funders

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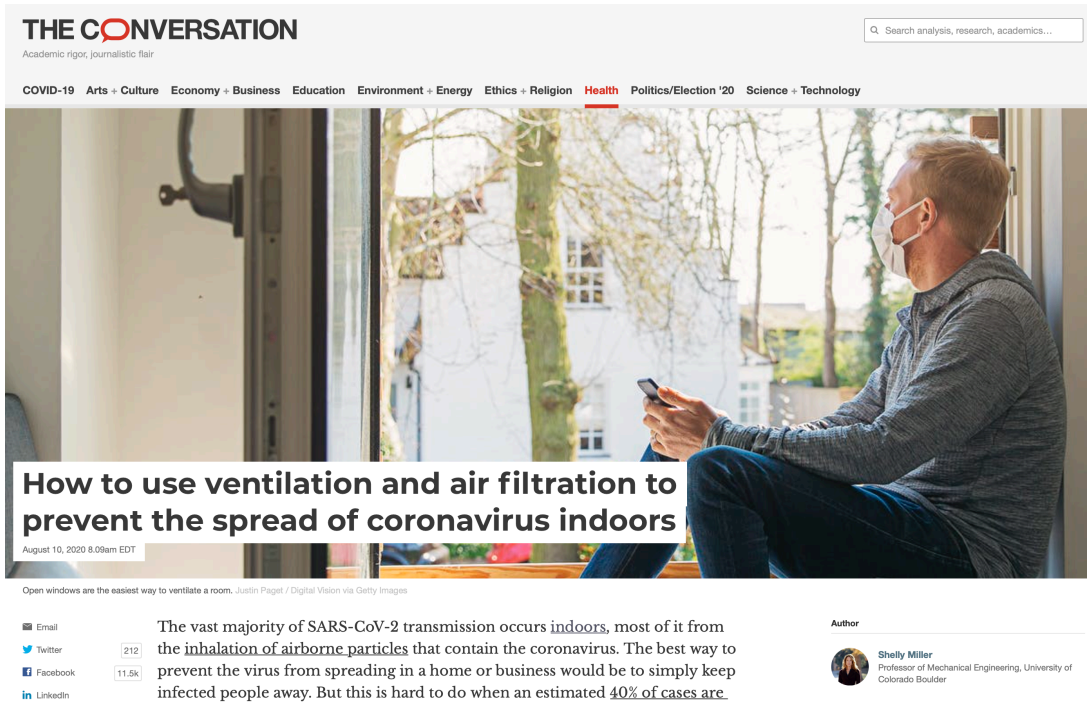
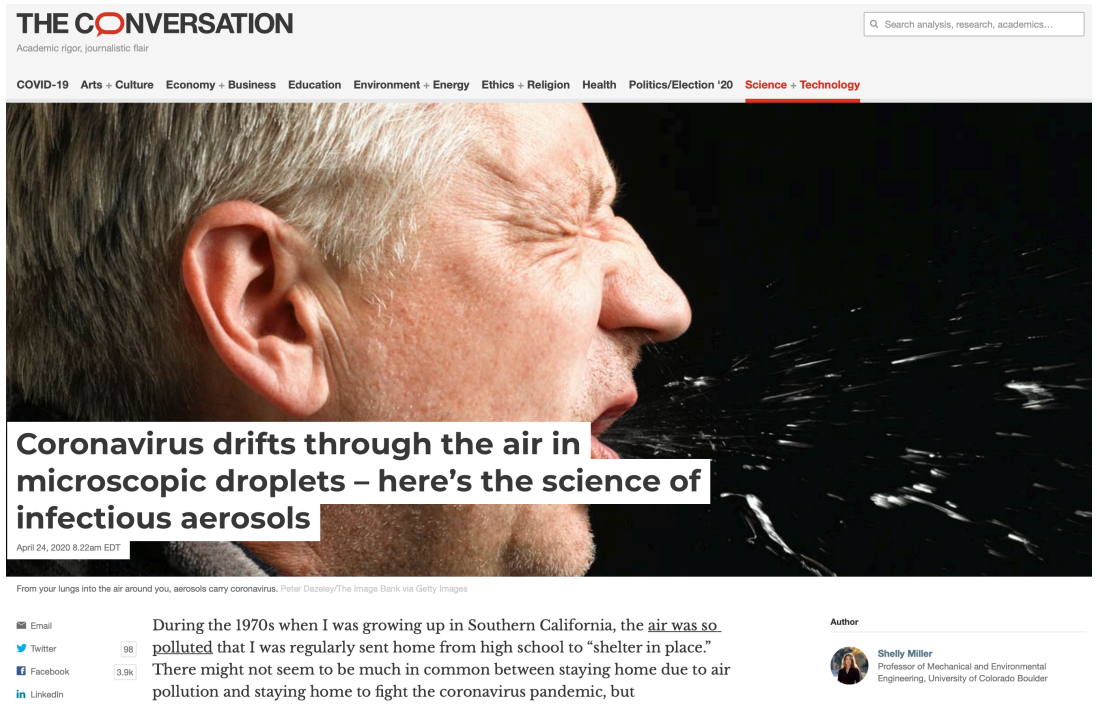
Contributing Organizations

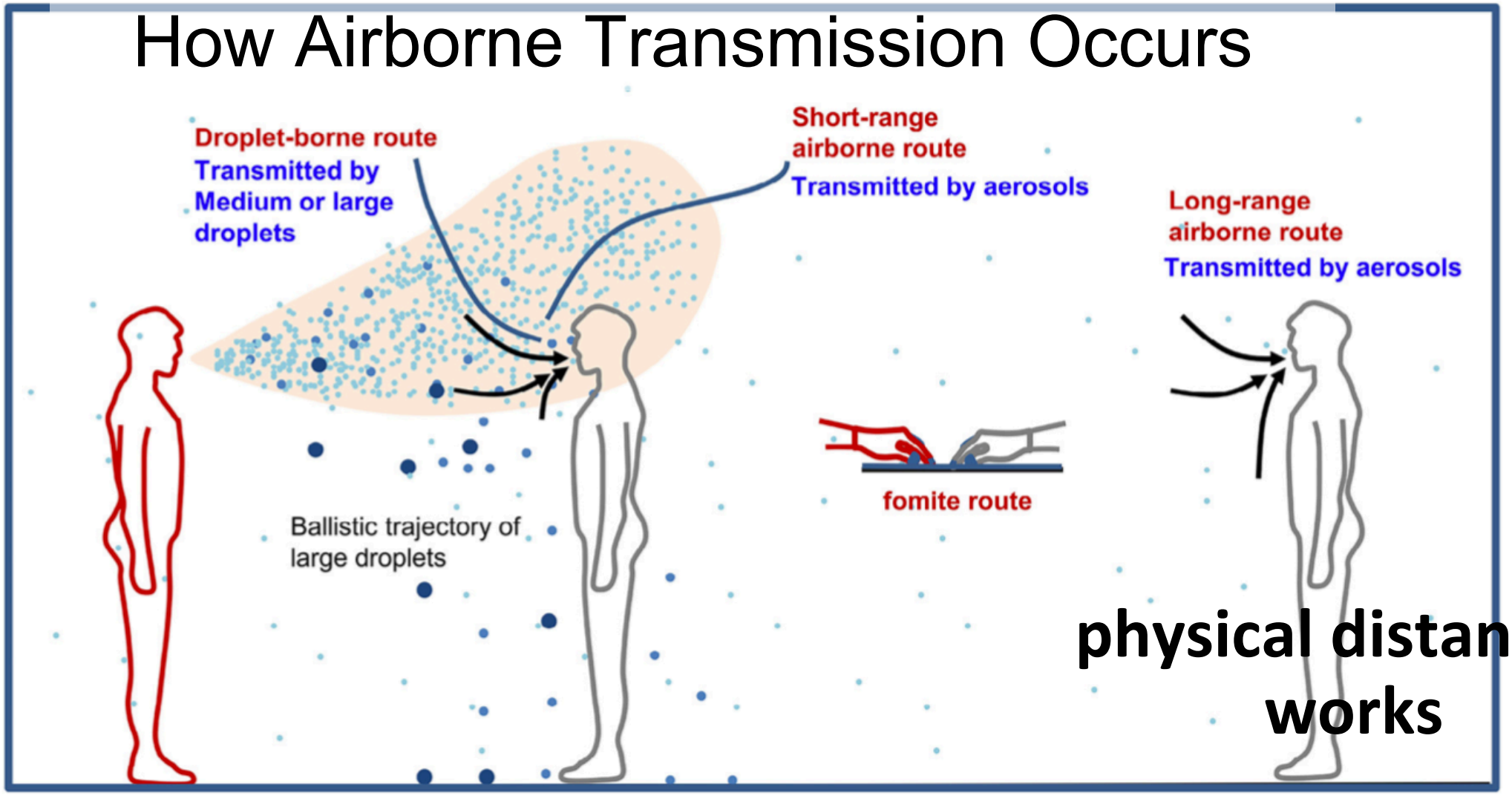
Short Primer on Aerosol Transmission and Exposure Risk Mitigation





How Airborne Transmission Occurs

Wei, J., Li, Y., 2016. Airborne spread of infectious agents in the indoor environment. American Journal of Infection Control 44, S102–S108



physical distancing works

2 m = 6 ft can keep you out of the short-range aerosol transmission plume

surgical face masks could prevent transmission of human coronaviruses and influenza viruses from symptomatic and asymptomatic individuals

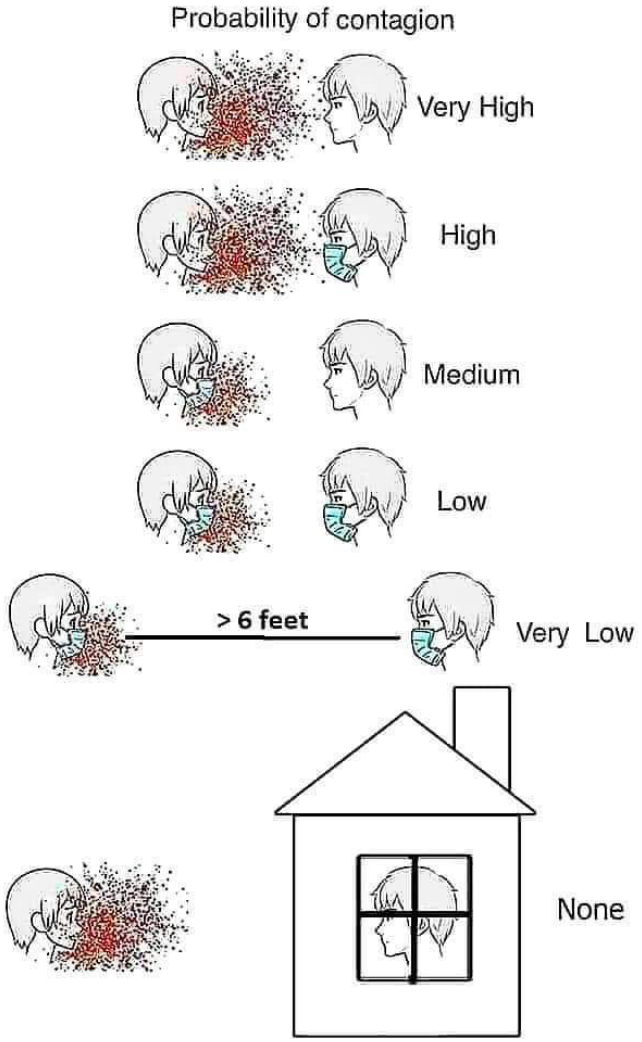
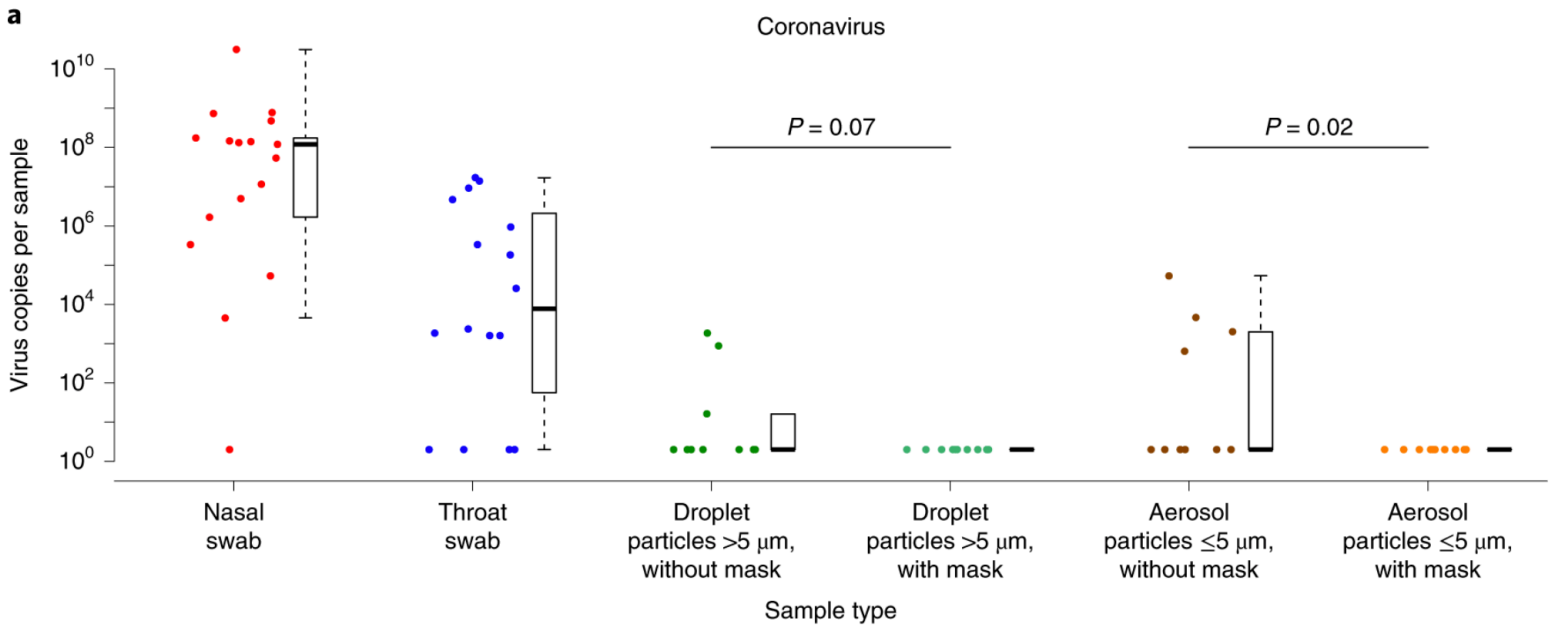


Fig. 1: Efficacy of surgical face masks in reducing respiratory virus shedding in respiratory droplets and aerosols of symptomatic individuals with coronavirus, influenza virus or rhinovirus infection.

From: Respiratory virus shedding in exhaled breath and efficacy of face masks



Leung, et al., 2020. Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nature Medicine*, pp.1-5.

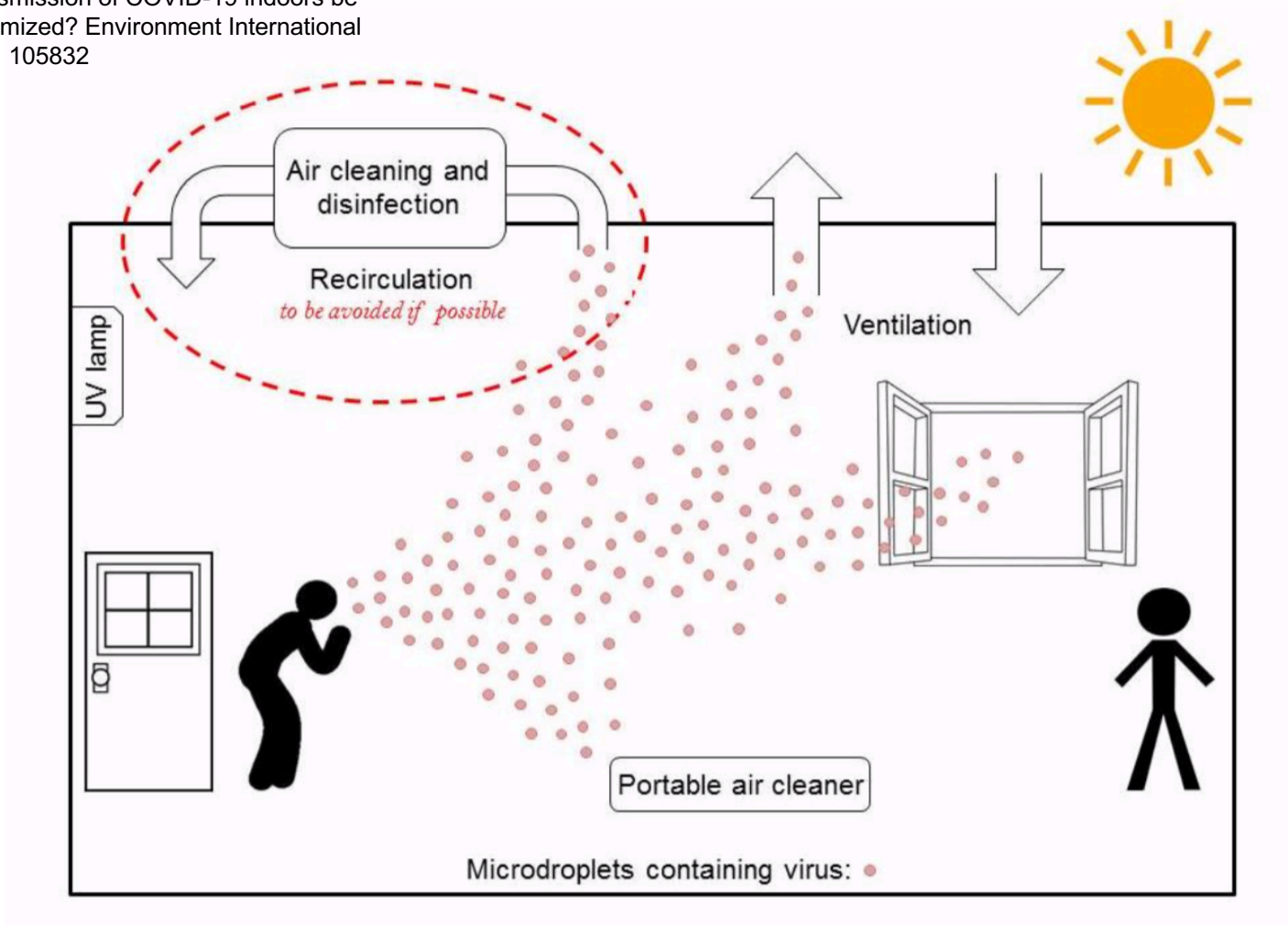
Compelling evidence to show significant transmission in crowded **poorly** **ventilated** spaces

- Clusters in Japan from in fitness gyms, restaurant boat on a river, hospitals, snow festival tented restaurants
- Ski-chalet associated transmission in France, ski-gondola transmission in Idaho
- Singapore Clusters from tourist shop, banquet dinner, church
- Church-associated clusters in South Korea and Washington state
- 3 family clusters in air-conditioned restaurant
- Among 7000+ cases in China 1 involved 2 in conversation outdoors

Ordinary speech aerosolizes significant quantities of respiratory particles. Some people are also super emitters (10-min conversation = cloud of 6000 aerosol articles)

Short-range airborne route dominates during talking and coughing during close contact (< 2 m). Large droplet dominates when > 100 um and within 0.2 m while talking

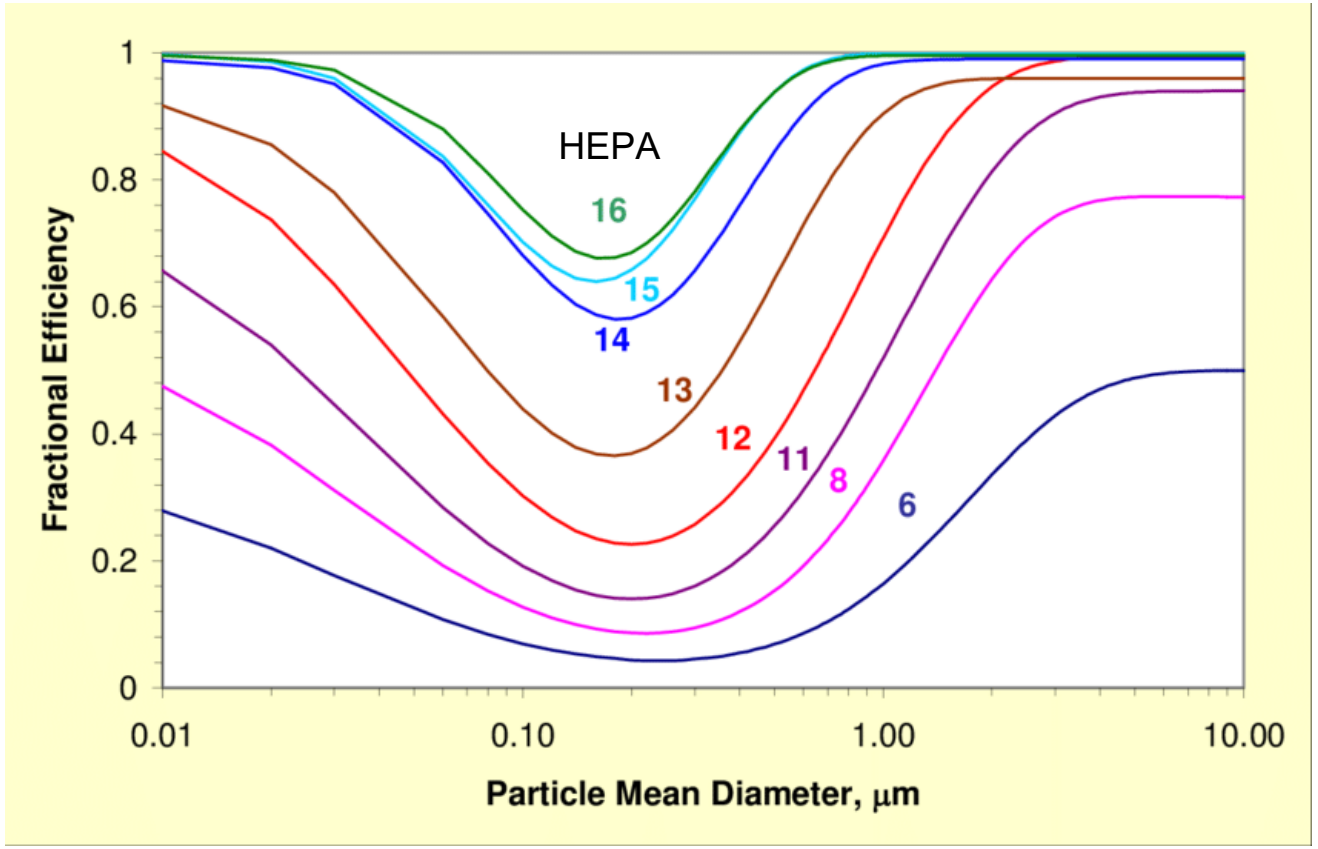
Morawska et al 2020. How can airborne transmission of COVID-19 indoors be minimized? Environment International 142, 105832



- **Ventilation** provides outdoor air to a space by natural or mechanical means
- Controls how quickly room air is removed/replaced over time
- Ventilation rates recommended for different spaces by ASHRAE
- Every space is different
- Homes/schools/office buildings

Air cleaners really work!

CADR = 260
Max flow = 340 cfm
Area for cleaning? 700 ft^2



Increase (clean) outdoor air supply

- building ventilation can be as effective as public health interventions
- existing ventilation rates may be too low to prevent or control airborne infectious diseases in indoors
- and might need to be increased by 10x

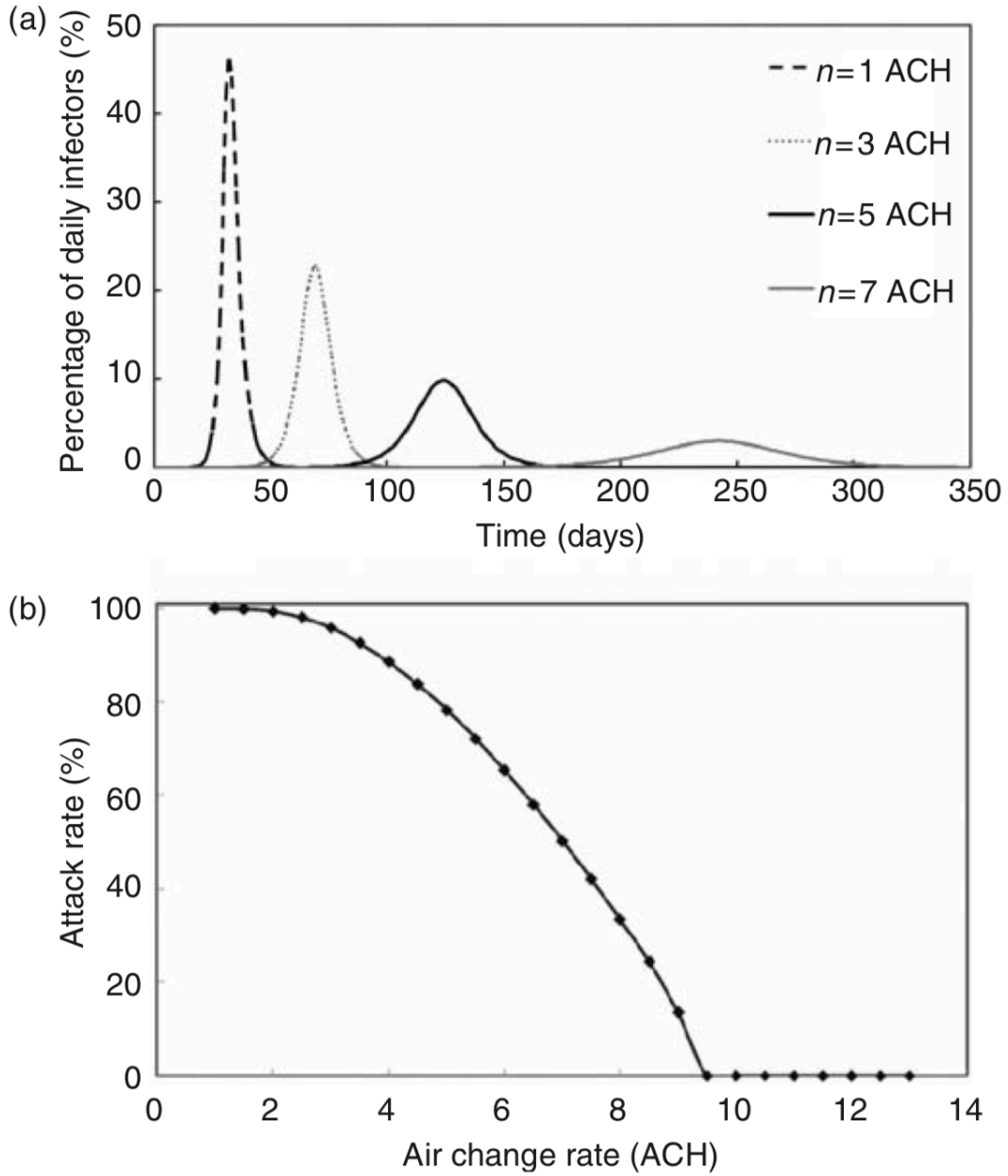


Fig. 2. The effect of increasing ventilation rate: (a) change of daily incidents, (b) change of overall attack rate.

Gao, X., Li, Y. and Leung, G.M., 2009. Ventilation control of indoor transmission of airborne diseases in an urban community. *Indoor and Built Environment*, *18*(3), pp.205-218.

What Ventilation Rate is needed?

	High Ventilation Dorm	Low Ventilation Dorm
CO2 concentrations in rooms	1230 ppm	1490 ppm
Dorm rooms' ventilation rates	6 L/s/person	2 L/s/person
Acute respiratory infections	2.1%	97.9%

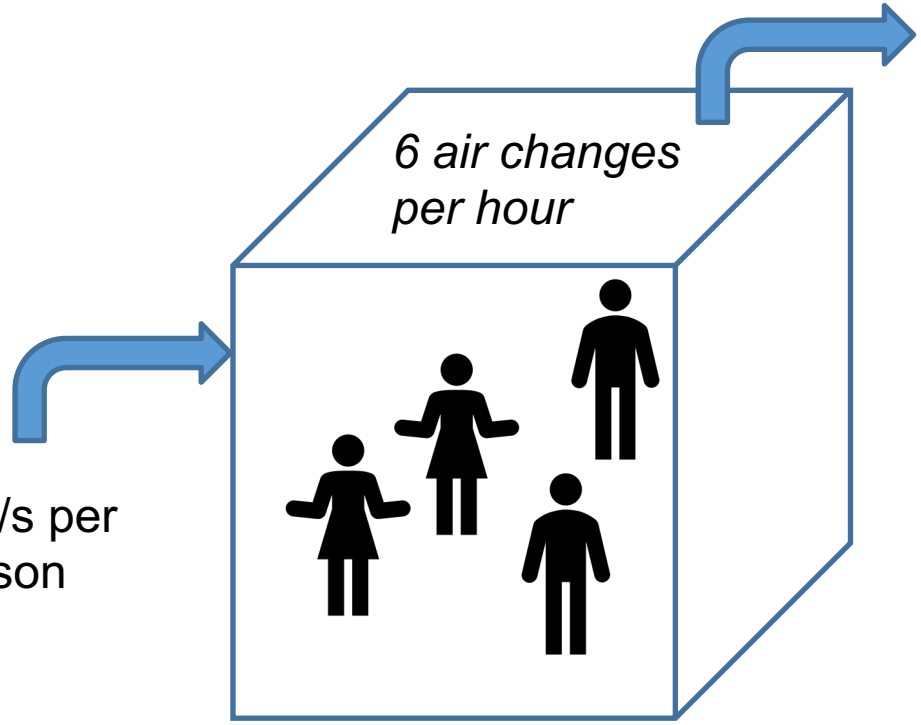
ventilation rates of < **5 L/s per person** may be impacting acute respiratory infections

Zhu S, Jenkins S, Addo K, et al. Ventilation and laboratory confirmed acute respiratory infection (ARI) rates in college residence halls in College Park, Maryland. *Environment International*. 2020;137:105537. doi:10.1016/j.envint.2020.105537

outdoor air supply rates **< 25 l/s per person** increase the risk of SBS symptoms, increase short-term sick leave, and decreased productivity

Wargocki P, Sundell J, Bischof W, et al. Ventilation and health in non-industrial indoor environments: report from a European Multidisciplinary Scientific Consensus Meeting (EUROVEN). *Indoor Air*. 2002;12(2):113-128. doi:10.1034/j.1600-0668.2002.01145.x

30 min will completely clear the room of contaminants at 6 ACH



Study Preliminary Results

Measurements at CU Boulder Air Quality Laboratory Testing Chamber

Phase I

- Flow visualization to understand the air flows that are released from wind instrument playing and singing
- Aerosol measurements within the major flows identified by the flow visualization
- Use CFD and published literature to explore mitigation question

Phase II

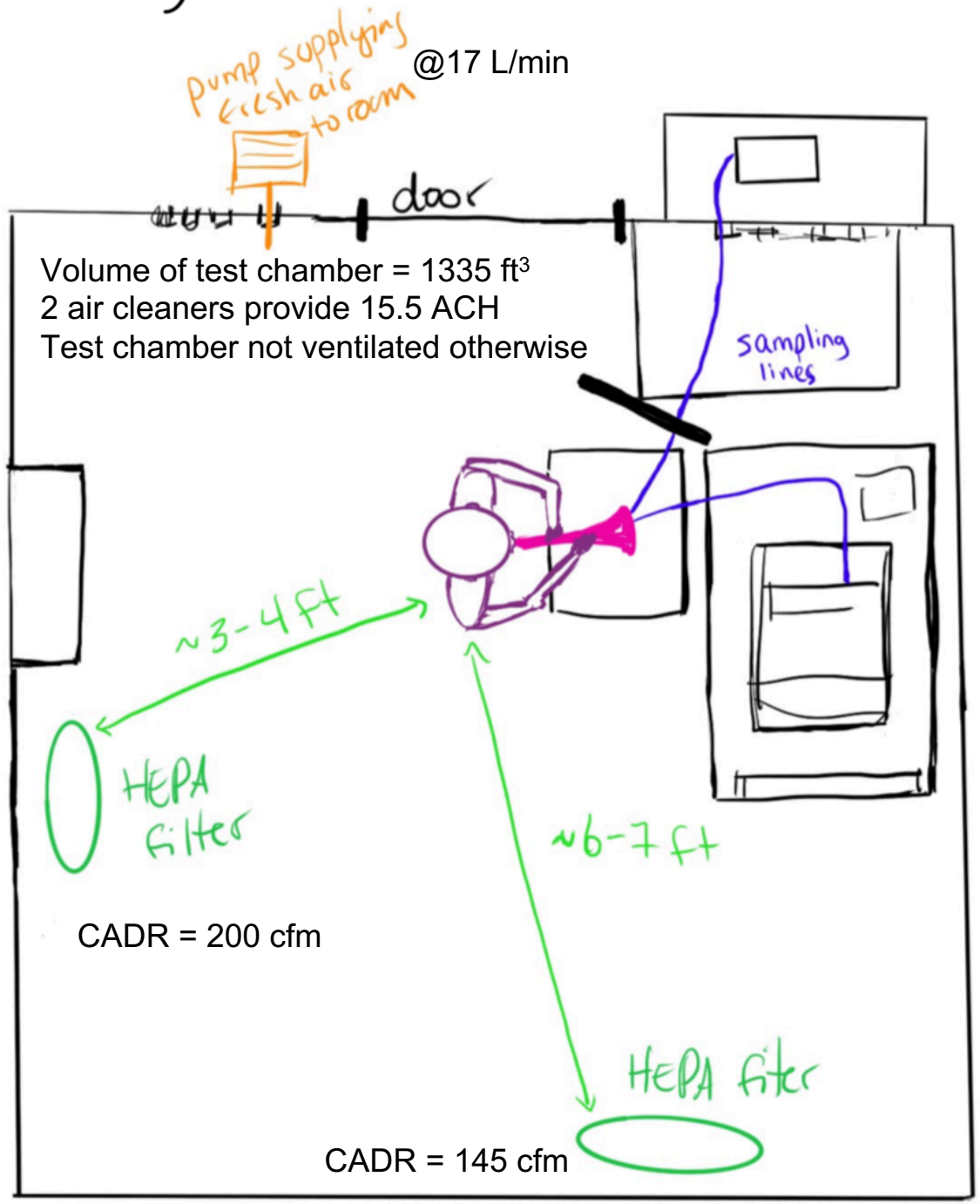
- Chamber studies to measure room aerosol concentrations from rehearsing with wind instruments

Phase III

- Small chamber measurements to assess emission rates (number of particles emitted per time)

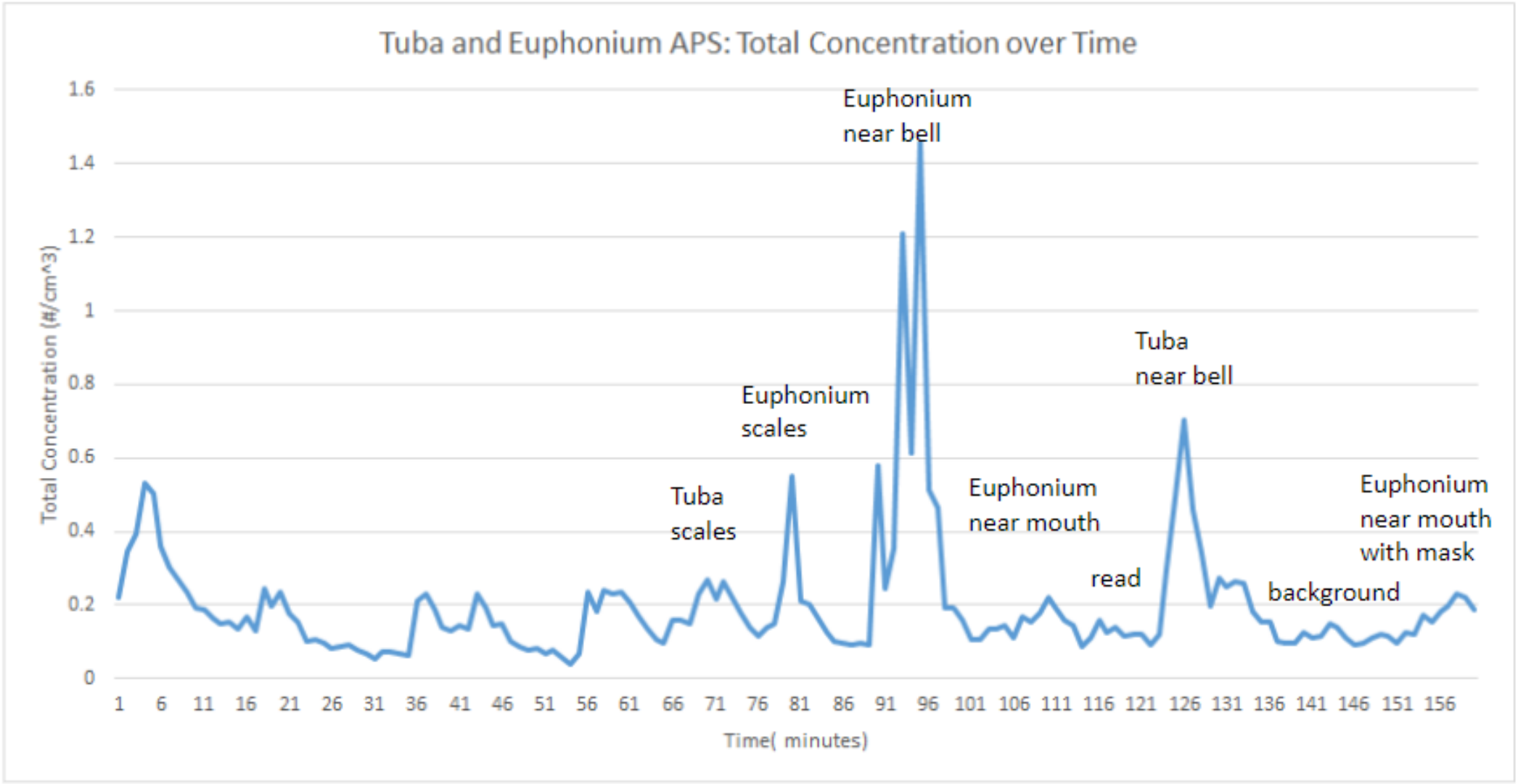
Phase IV

- Rehearsal room measurements at CU Boulder

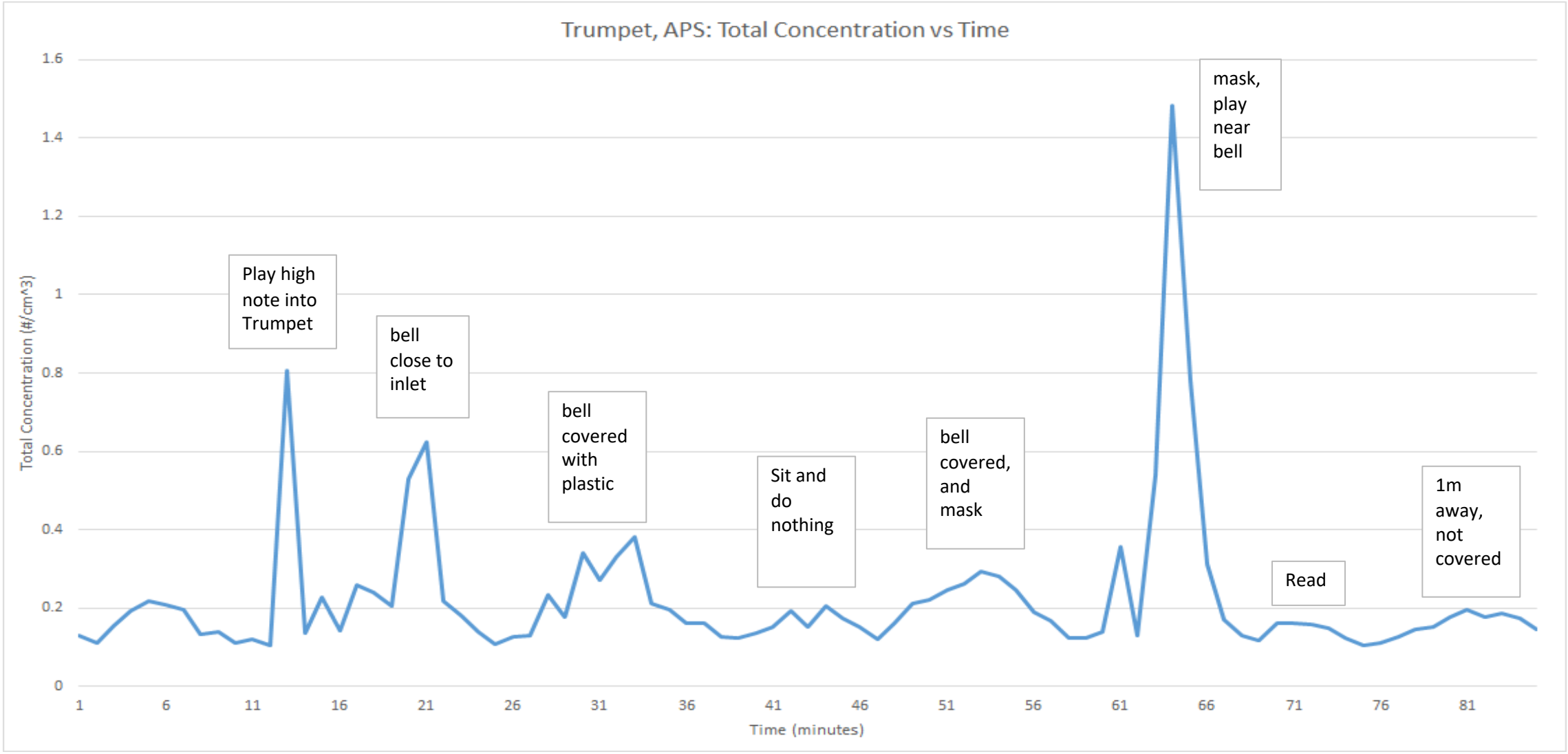


Low Brass

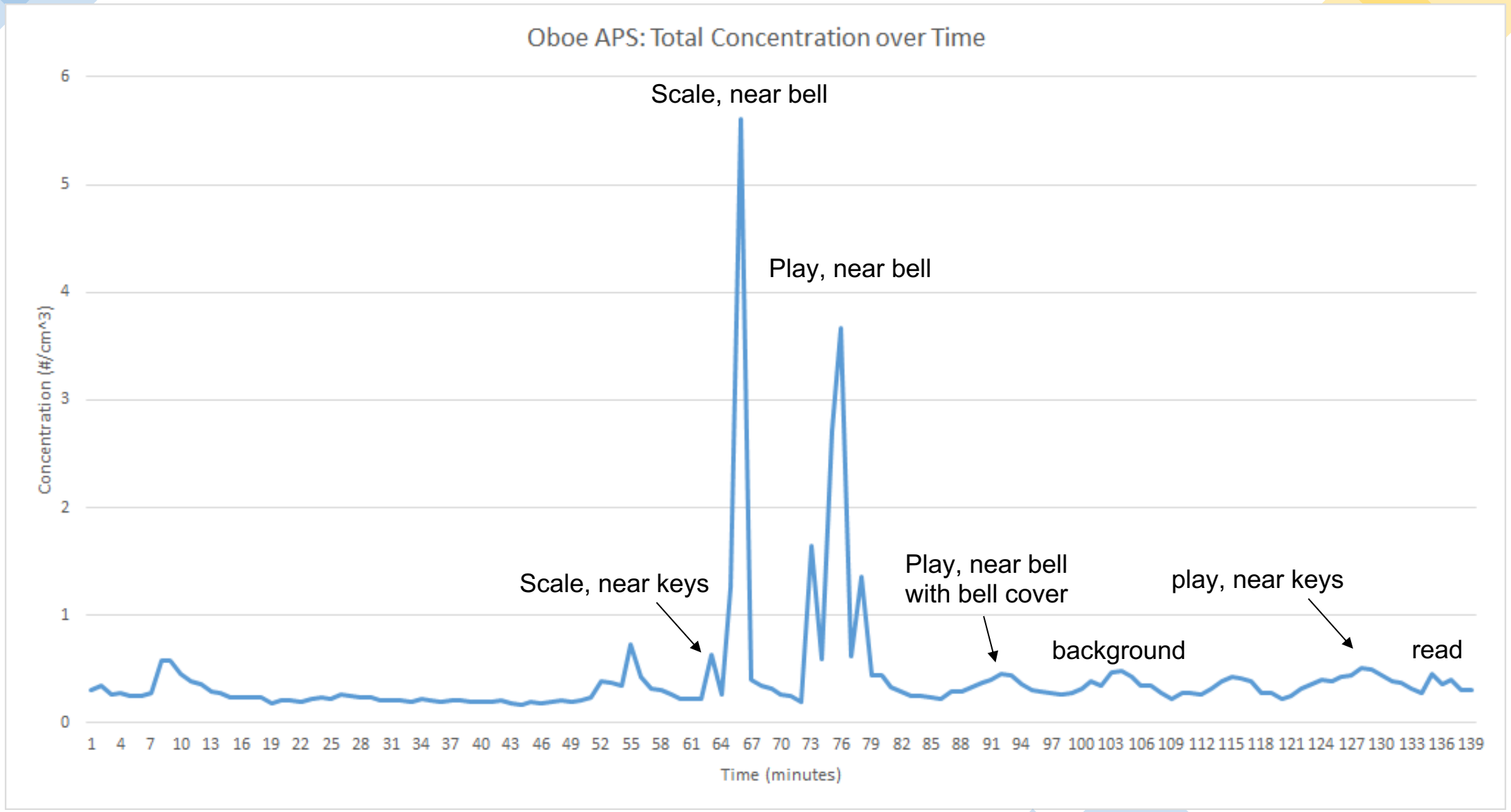
Particles sampled within the main flow plume
APS counts particles from 0.5 µm to ~10 µm diameter



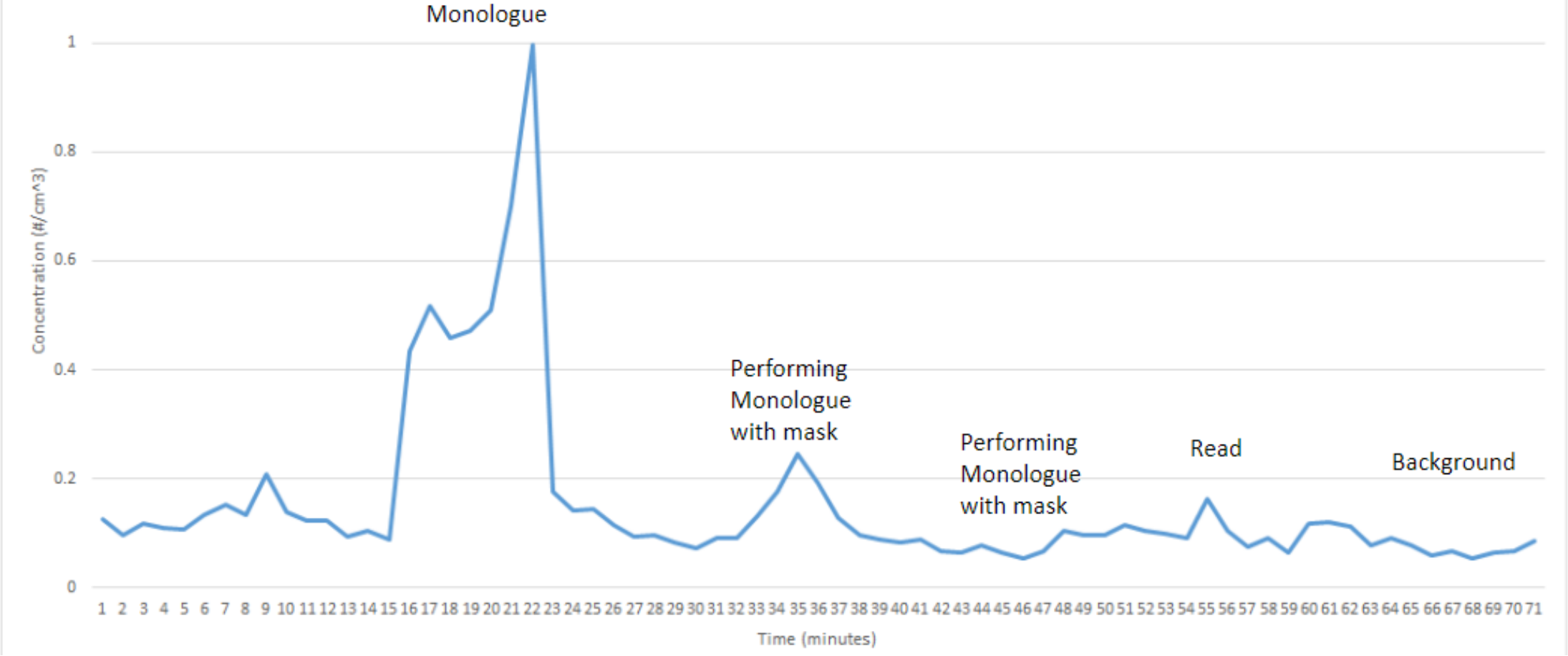
Trumpet


Trumpet, APS: Total Concentration vs Time
Total Concentration (#/cm^3)
Time (minutes)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
Play high note into Trumpet
bell close to inlet
bell covered with plastic
Sit and do nothing
bell covered, and mask
mask, play near bell
Read
1m away, not covered

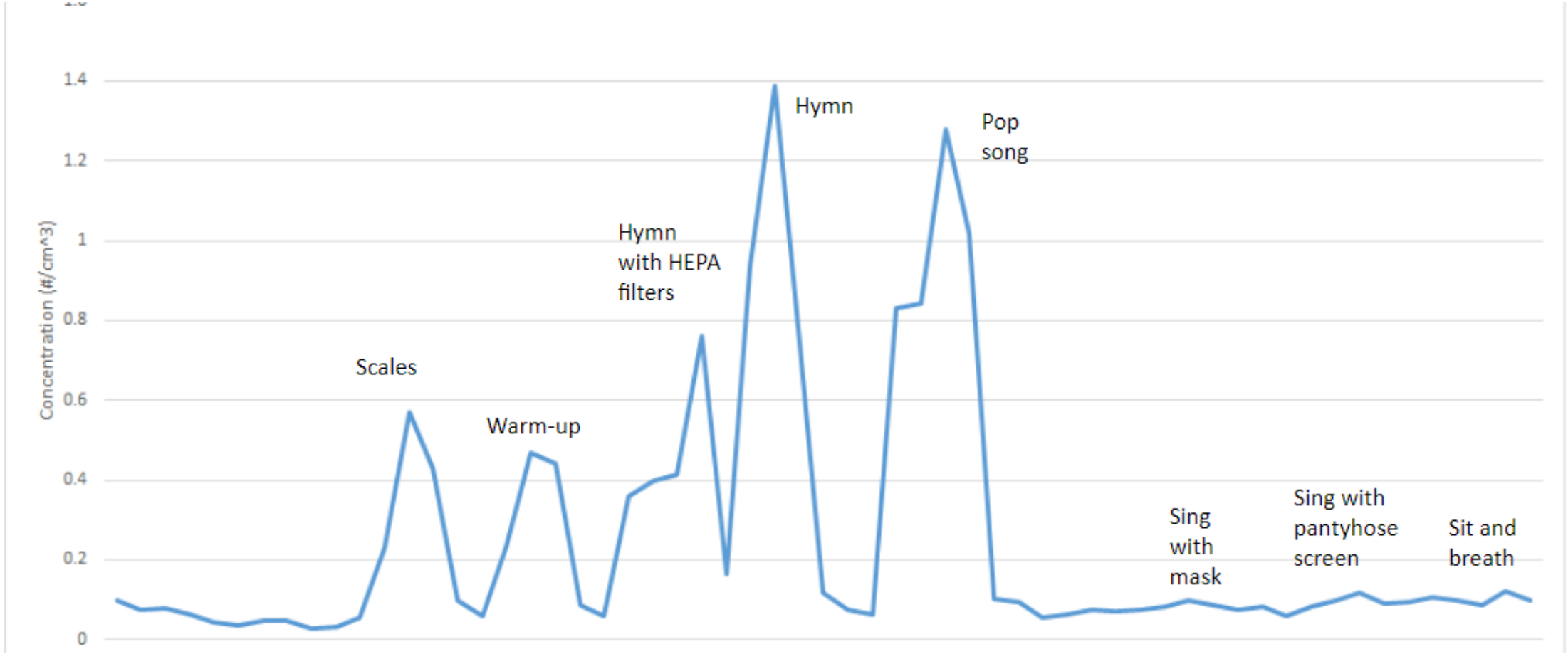
Oboe

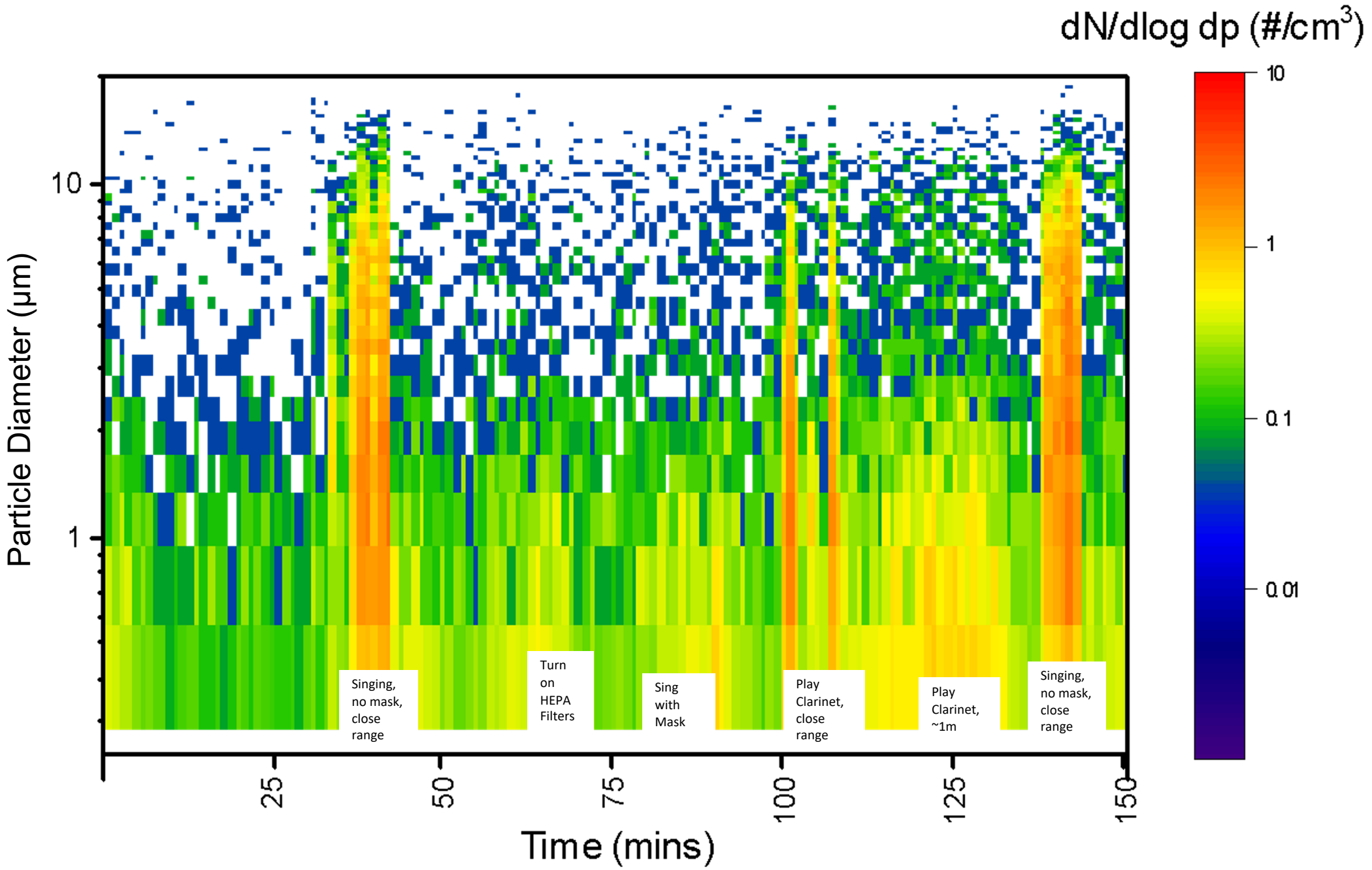

Oboe APS: Total Concentration over Time
Concentration (#/cm^3)
Time (minutes)
Scale, near bell
Play, near bell
Scale, near keys
Play, near bell with bell cover
background
play, near keys
read

Theatre APS


Monologue
Performing Monologue with mask
Performing Monologue with mask
Read
Background
Concentration (#/cm^3)
Time (minutes)
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71

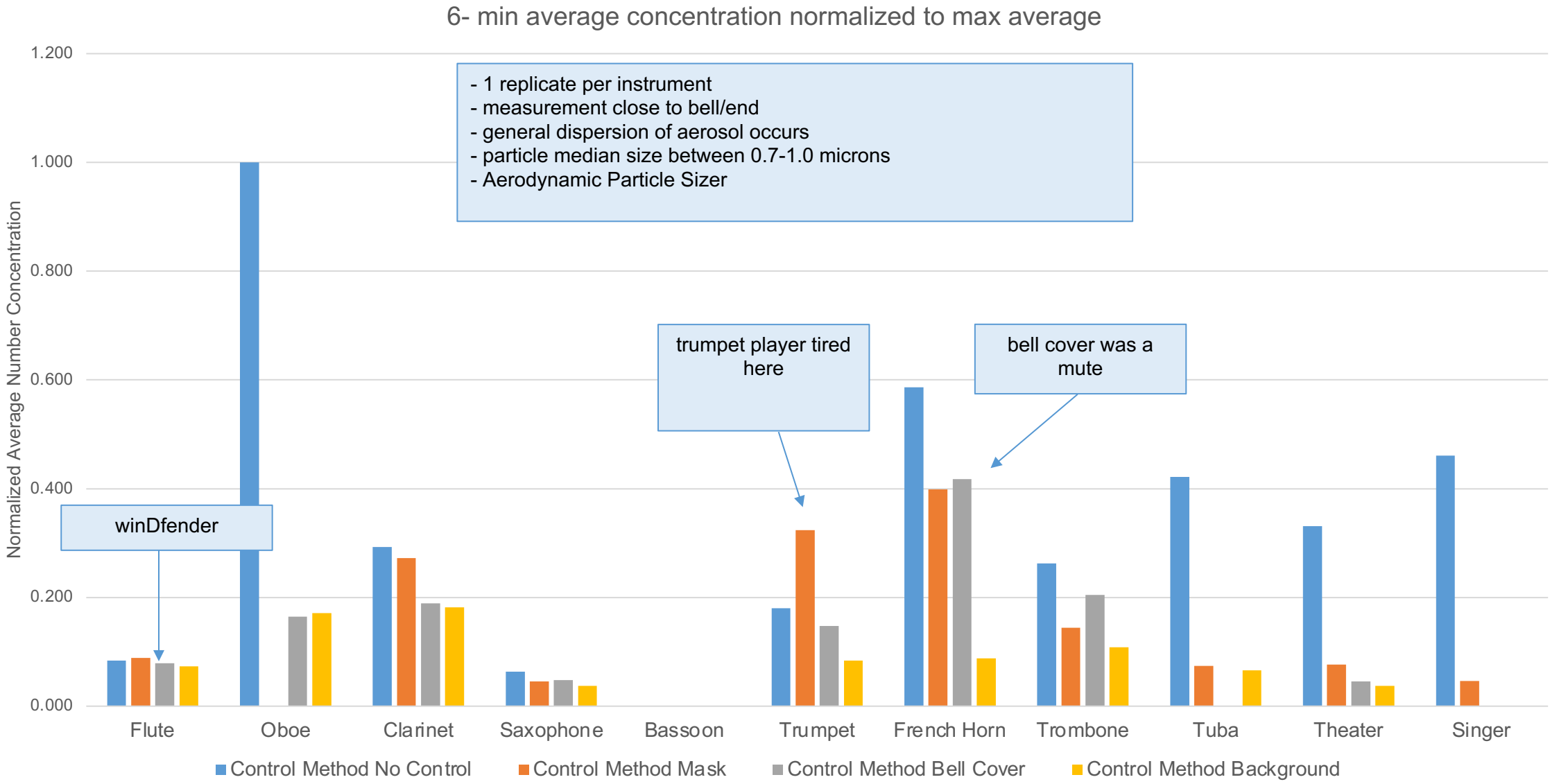
Singing (APS)


Concentration (#/cm^3)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Scales
Warm-up
Hymn with HEPA filters
Hymn
Pop song
Sing with mask
Sing with pantyhose screen
Sit and breath


dN/dlog dp (#/cm3)
10
1
0.1
0.01
Particle Diameter (µm)
10
1
25
50
75
100
125
150
Time (mins)
Singing, no mask, close range
Turn on HEPA Filters
Sing with Mask
Play Clarinet, close range
Play Clarinet, ~1m
Singing, no mask, close range

Prelim Results: Video (3 min)

Playing wind instruments releases airborne particles (aerosol). So does singing and projecting voice in theater performances. These particles are of the size range that transmits virus. Performing with mask and bell cover reduces emissions.



Computational Fluid Dynamics Modeling + Wells-Riley Infection Risk

- City@UMD team has analyzed the concentration of airborne COVID-19 particles in **one outdoor and two indoor case studies**
- **outdoor case study**
  - a musician in a light wind field of 1m/s (2.2 mph) at 10 m (33ft) above ground
- **Indoor Case 1**
  - both the supply and exhaust at the ceiling level, a typical ventilation system design
- **Indoor Case 2**
  - the supply at the ceiling and the exhaust at the floor

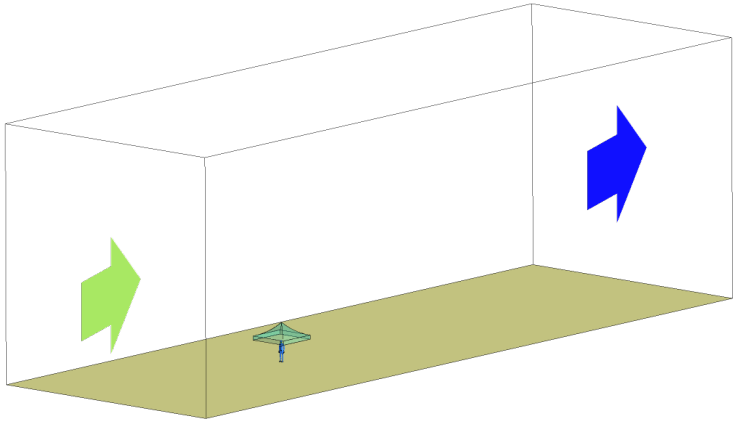
CFD Models

Outdoor Case (20 m × 60 m × 20 m)

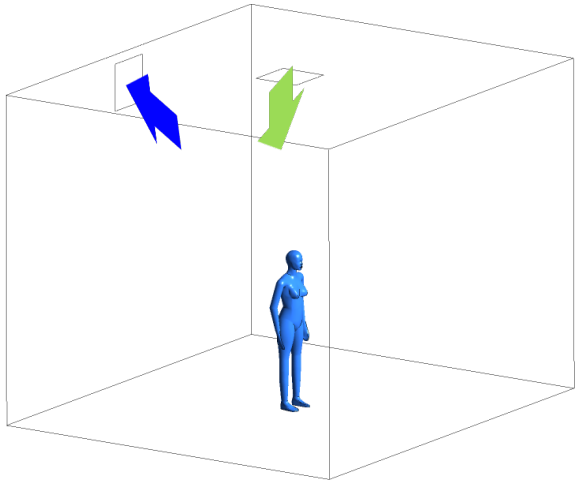
Inlet (green arrow):
Vel.: 1 m/s at elevation of 10 m Temp.: 22°C
at elevation of 1.5 m

Indoor Cases (4.5 m × 4.0 m × 3.5 m)

Inlet (green arrow):
Size: 0.5 m × 0.5 m
Vel: 0.21 m/s (3 ACH)
Temp.: 22°C



Outdoor Case



Indoor Case

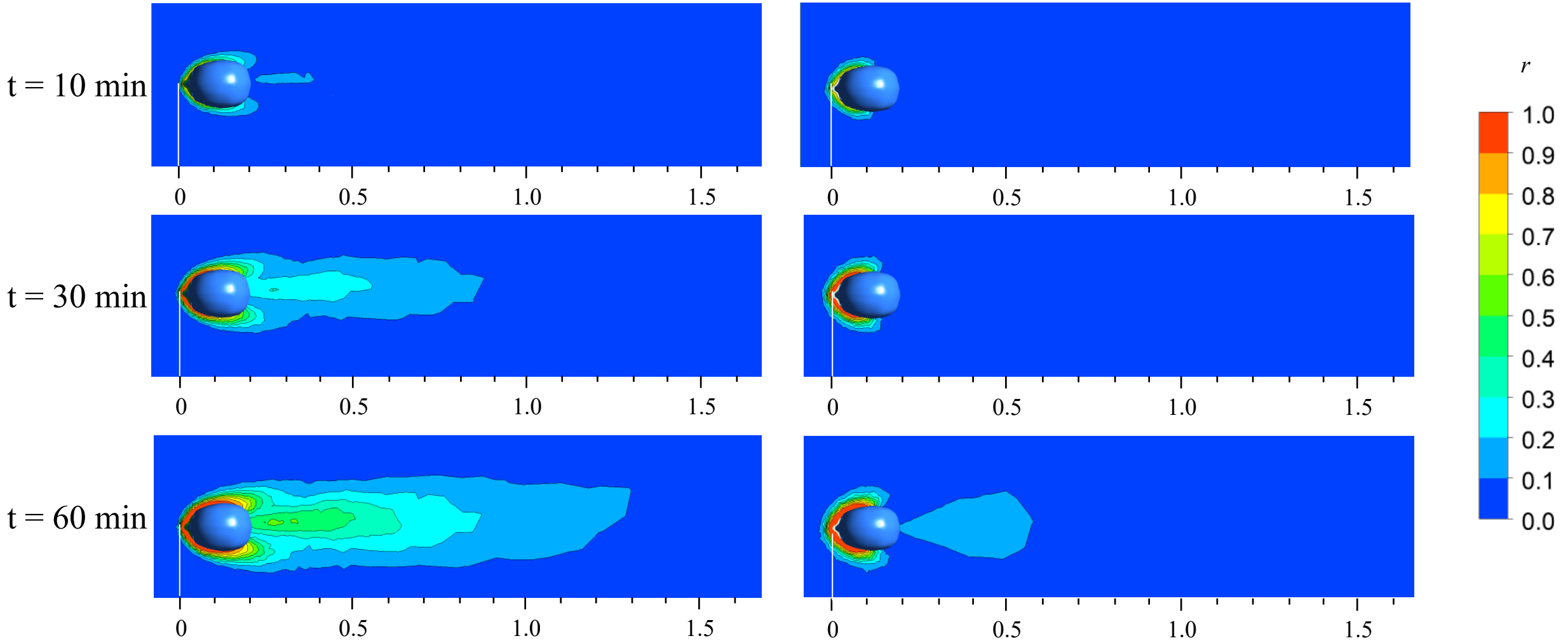
Human Body: Area of 1.47 m^2 and Heat flux of 23 W/m^2

Mask: Area of 107.7 cm^2, Velocity of 0.02 m/s (mass flow rate same as the exhaled air of the singer), and Temp. of 32°C

Covid-19 generation rate: 17.28 quant/hr with a 64% particle removal efficiency

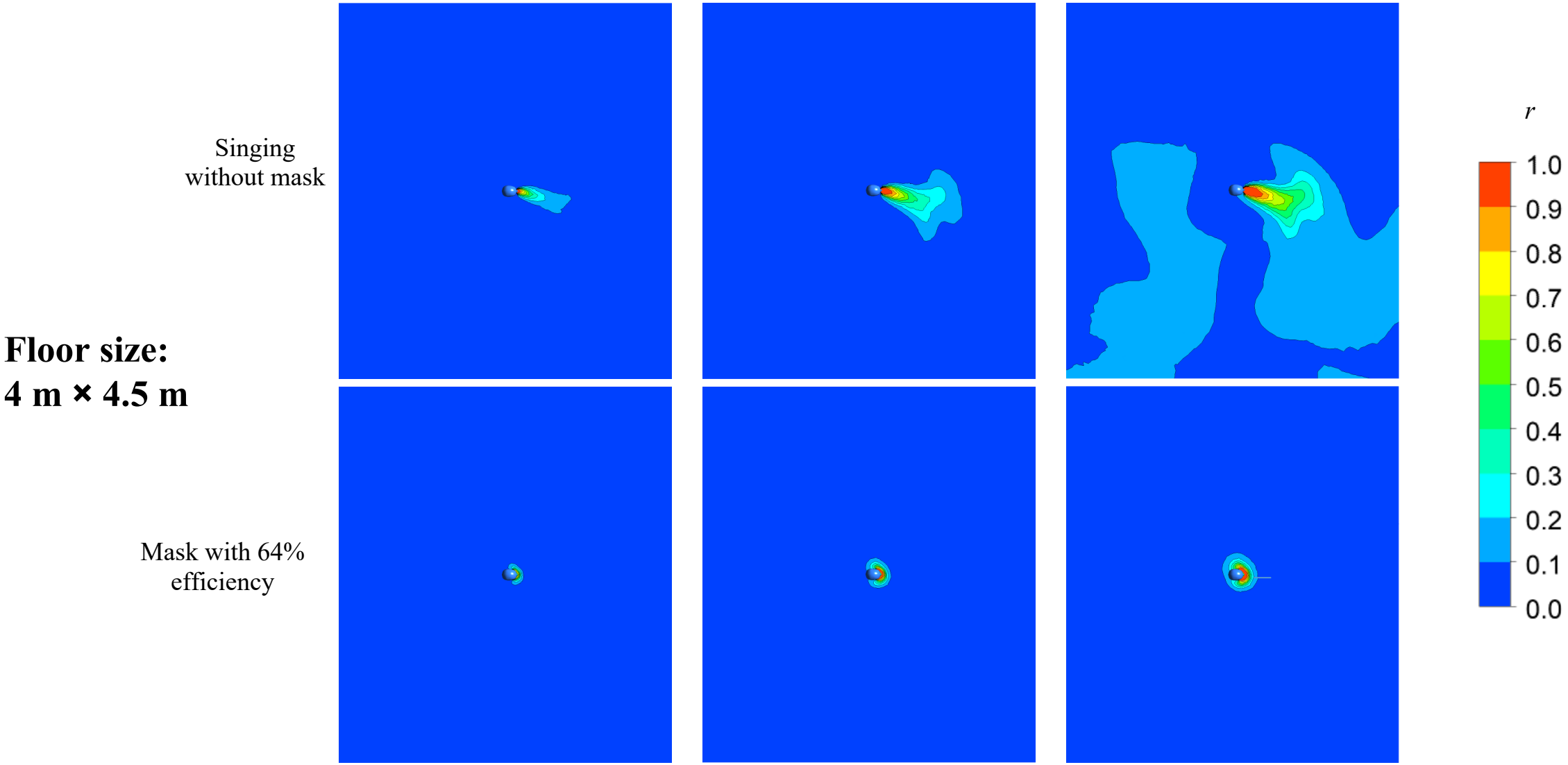
Outdoor Case: Impact of Tent/Masks on Infection Risk

Infection risk *r* by Wells-Riley equation at the height of mouth opening, with breathing rate of 8 L/min.

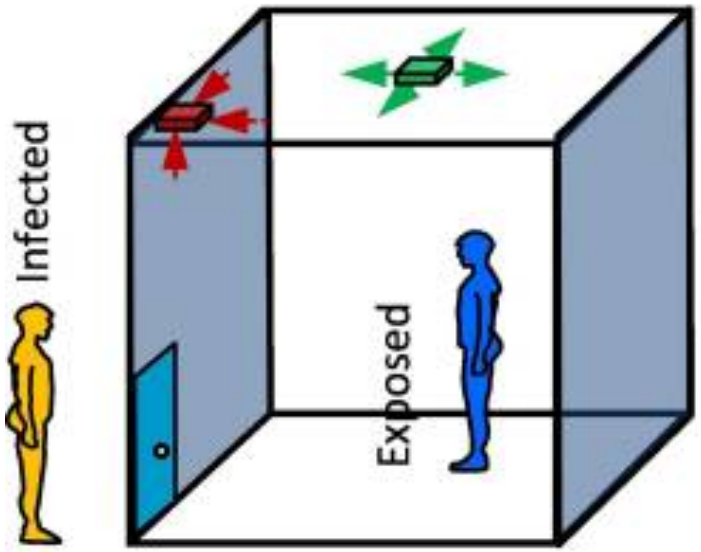


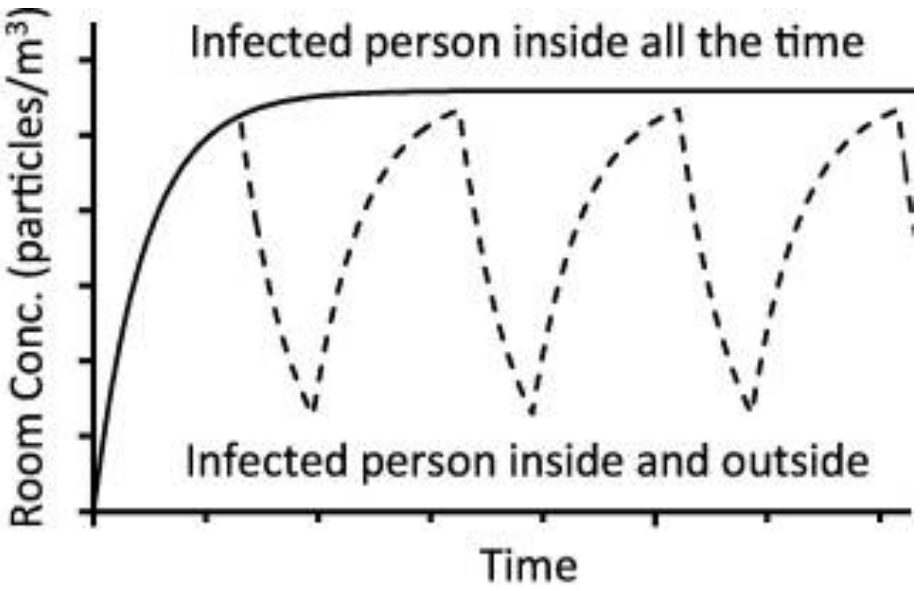
Indoor Case: Mask Impact on Infection Risk

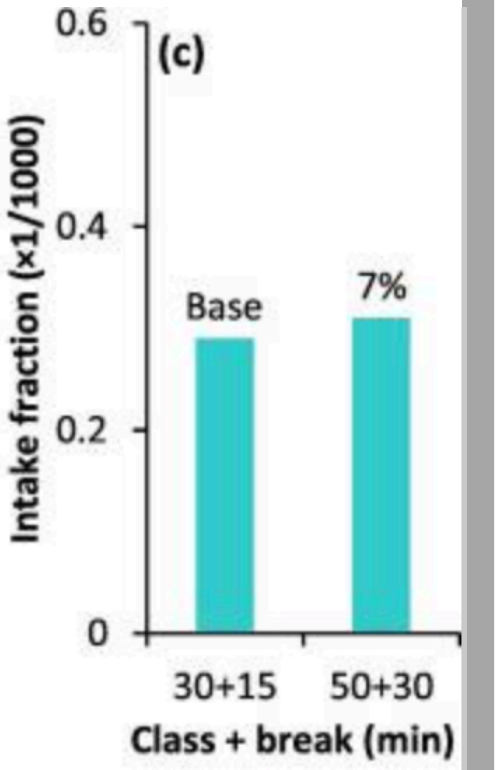
Infection risk r by Wells-Riley equation at the height of mouth opening, with breathing rate of 8 L/min.



One of our recommendations is to rehearse indoors for 30 min and take breaks equivalent to 1 air change, 3 would be best







Melikov AK, Ai ZT, Markov DG. Intermittent occupancy combined with ventilation: An efficient strategy for the reduction of airborne transmission indoors. *Sci Total Environ*. 2020;744:140908.

5 lessons of 30 min, 4 15 min breaks
3 lessons of 50 min, 2 30 min breaks

Preliminary Evidence-based airborne infectious disease controls musicians/singers

Masking for Wind Instruments

- Wear well-fitting efficient masks to play and sing
- Play with efficient bell/end covers reducing source dispersion
- Spatially distance 6 ft (9x6 for trombone)
  - Reduce viral loading, unsuspected transmission, social distance to get out of aerosol plume
- Minimize indoor time to 30 min, with breaks
- Increase outdoor air ventilation rates and distribute effectively
  - Do not use partitions, disrupts flow patterns
- Use air cleaning if minimal ventilation rate
  - if 3 ACH, add additional 3 ACH with air cleaning
- Wash hands and surfaces with soap, alcohol-based sanitizer
- Outdoors is best, tents with no sides ok

Huge thanks to our research team, our study chairs, sponsors, scientific colleagues, music educators, performers, players, students…

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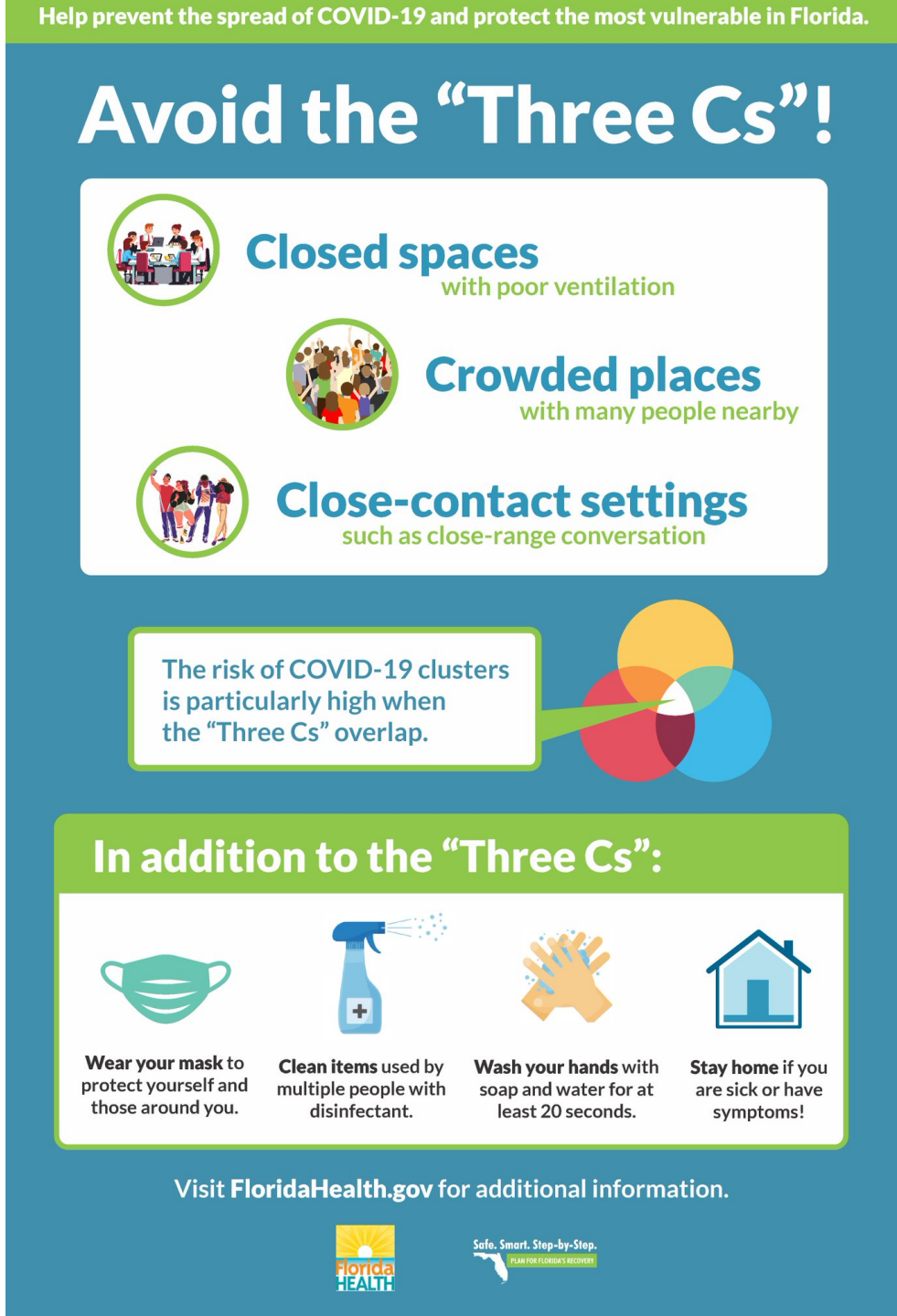

Additional study information can be found here:

https://www.nfhs.org/