

International Coalition of Performing Arts Aerosol Study Report 3:

This report has been generated as a guide and should not be used as the only source for determining the risk level of participating in performing arts activities. Prior to conducting activities, the local or state health department should be consulted to ensure that activities are being conducted in a manner appropriate to the health conditions in your area.

Page 1One Page Overview of Current Study Results

Page 2 Appendix A – Aerosol Production and Mitigation Effects

Page 3 Appendix B – Efficacy of Bell Covers and Masks

Page 4 Appendix C – Keyhole Expellation of Aerosol

Page 5 Appendix D – APS Data Sheets

Page 10..... Appendix E – CFD Modeling of Singers in a Rehearsal Space

Page 11 Appendix E – CFD Modeling of Clarinetists in a Rehearsal Space

Page 12Appendix G – General Procedures

Page 13 More information and next steps

International Coalition Performing Arts Aerosol Study

Dr. James Weaver (NFHS) and Dr. Mark Spede (CBDNA), Chairs

Dr. Shelly Miller, University of Colorado Boulder and Dr. Jelena Srebric, University of Maryland, Lead Researchers

Recommendations from The International Performing Arts Aerosol Study

These results are preliminary and will be further defined as the study continues. We are providing these preliminary results to assist in the safer return to performing arts activities. This study focuses strictly on the distribution of respiratory aerosol that is generated while playing wind instruments, singing, acting, speaking, dancing, and in a simulated aerobic activity, which may potentially contain virus. This study did not use a live virus and therefore cannot be used to determine specific infection rates. However, this study is based on previous research that shows the virus which causes COVID-19 can travel in respiratory aerosol. This study then was designed to identify performing arts activities that generate respiratory aerosol including volume, direction, density, and mitigation strategies. Aerosol is defined as solid or liquid particles suspended in a gas.

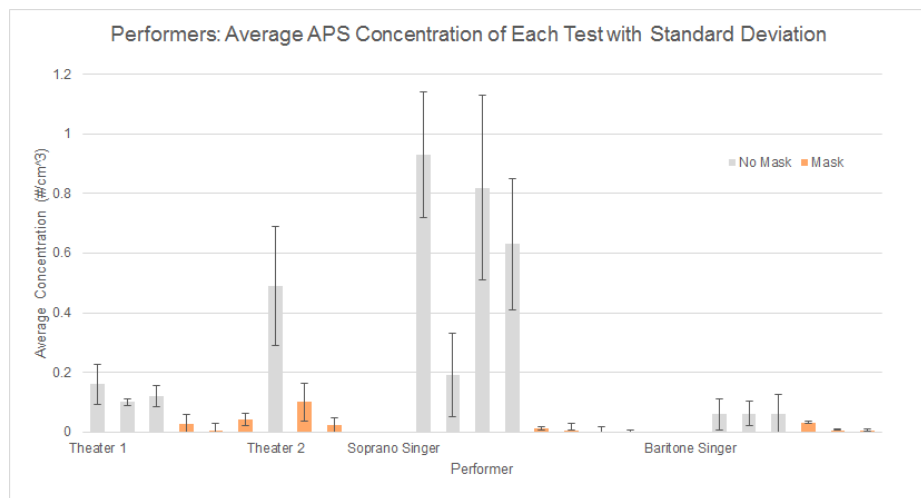
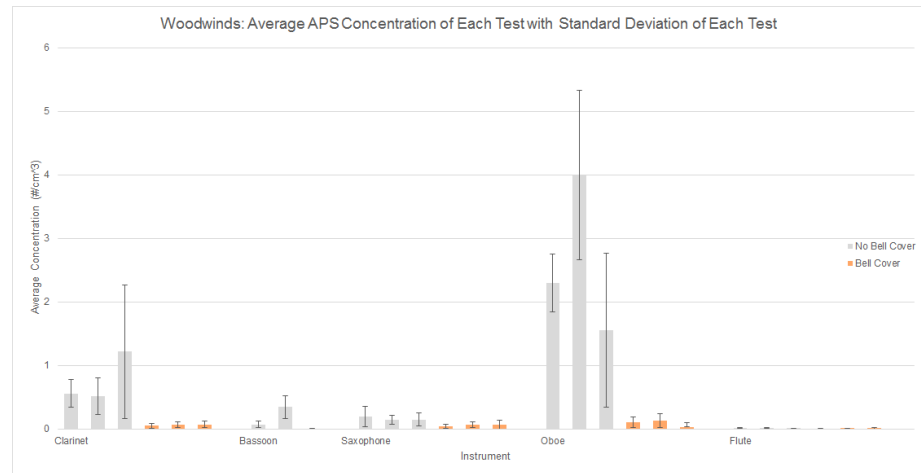
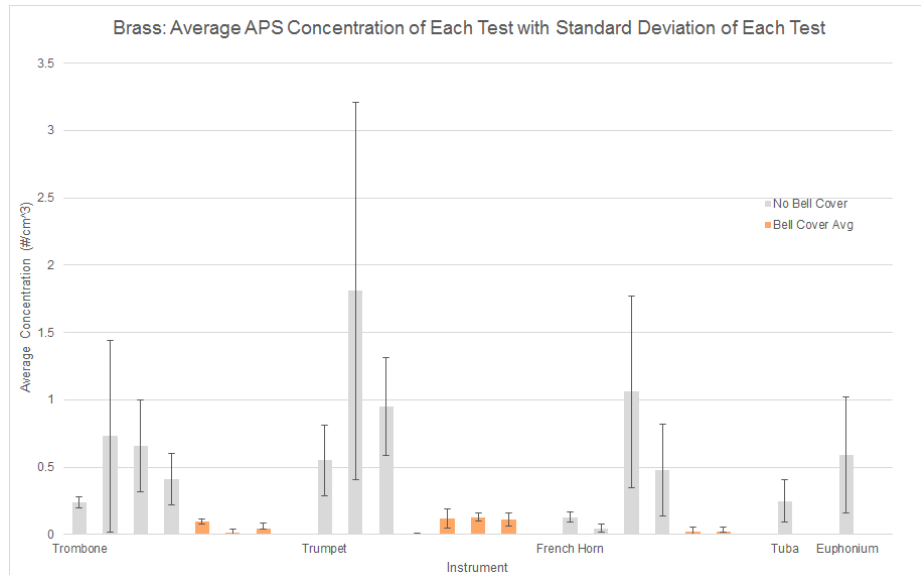
- We are entering month 5 of a 6-month study, utilizing two independent labs at the University of Colorado – Boulder and the University of Maryland
- Wind instruments and singing produce aerosol, which vary by instrument as well as intensity. The produced aerosol amount is, on average, similar across all instrument types and singing with the exception of the oboe. Most aerosol is being expelled from the bell of the instruments and from the mouth of the performers.
- At this time, it appears that if players wear surgical style masks with a slit for mouthpiece AND bell covers, aerosol emission is reduced between 60% and 90%. (See Appendix B)
- Flutes and recorders create a minimal amount of aerosol and it is recommended to play flute with the [headjoint between their mouth and mask](#). Recorder should use the slitted mask used with woodwinds. Both the flute and recorder should use a cloth “mask” at the end of the barrel.
- Bell covers for woodwinds and brass should be made with a multi-layer cover with the center layer being made of MERV-13 filter material, or a 3-layer surgical style mask using a standard such as GB/T32310.
- Singers produce aerosol at similar rates as woodwinds and brass. The amount of aerosol varies depending on consonants, vowels, intensity, and pitch. Singers wearing a well fit 3-layer surgical style mask reduces aerosol emission. (See Appendix A)
- Face shields are only effective at close range to stop large droplets; they do not prevent aerosol from being inhaled or released unless a mask is also worn.
- Plexiglass partitions or barriers between musicians are not recommended due to room HVAC system design limitations. "Dead zones" or areas where aerosol can build-up are a concern of plexiglass partitions are used.
- Rehearsal space recommendations in order of preference:
 - Outdoor rehearsals, using individual mitigation techniques described above.
 - Indoors with elevated outdoor air exchange rate from HVAC.
 - Indoors with typical outdoor air exchange rate from HVAC plus recirculation air through MERV 13 filters or addition of appropriately sized HEPA air cleaners.
 - Indoors with outdoor air exchange rate from open windows supplemented with appropriately sized HEPA air cleaners when airflow is reduced under certain outdoor wind conditions.

Please refer to the Association for Heating, Ventilating and Air-Conditioning Engineers (ASHRAE) guidance on ventilation during COVID-19: <https://www.ashrae.org/technical-resources/resources>

- General procedures (See Appendix G)
 - Masks must be worn at all times. Multi-layered bell covers must be used by all wind instruments
 - CDC guidelines for social distancing of 6x6 feet, with 9x6 for trombone players.
 - Indoors limited to 30 minutes followed by a minimum of one air exchange rate (ACH), preferably 3 ACH, to change the air indoors with outside air.
 - Increase ACH to HVAC maximum, add HEPA Filtration designed for the size of the room.
 - Practice good hygiene by washing hands, using sanitizers, and preventing uncontrolled spit valve release.

Appendix A

Each bar is the time average of each test. Each test was 4 - 5 minutes in length; the APS averages over 1 minute for each sample, each test is 4 or 5 APS samples. The error bars show the standard deviation of each test.



Appendix B

Sampling performed at the bell does not take into account what is expelled at the keyholes. Bell covers diffuse the air coming out of an instrument bell, causing the plume to not be as concentrated. The samples are also not as concentrated as when playing without a bell cover. The efficiency percentages below are related to the aerosol produced in Appendix A. It is important to identify the reference to the background aerosol levels between Appendix C, to fully understand the depth of the mitigated aerosol release.

Example A: Saxophone has an overall aerosol release of 0.7 pp cm³ unmitigated and an aerosol release of 0.32 pp cm³ (64% reduction) with a bell cover, placing mitigated saxophone just above background levels of aerosol.

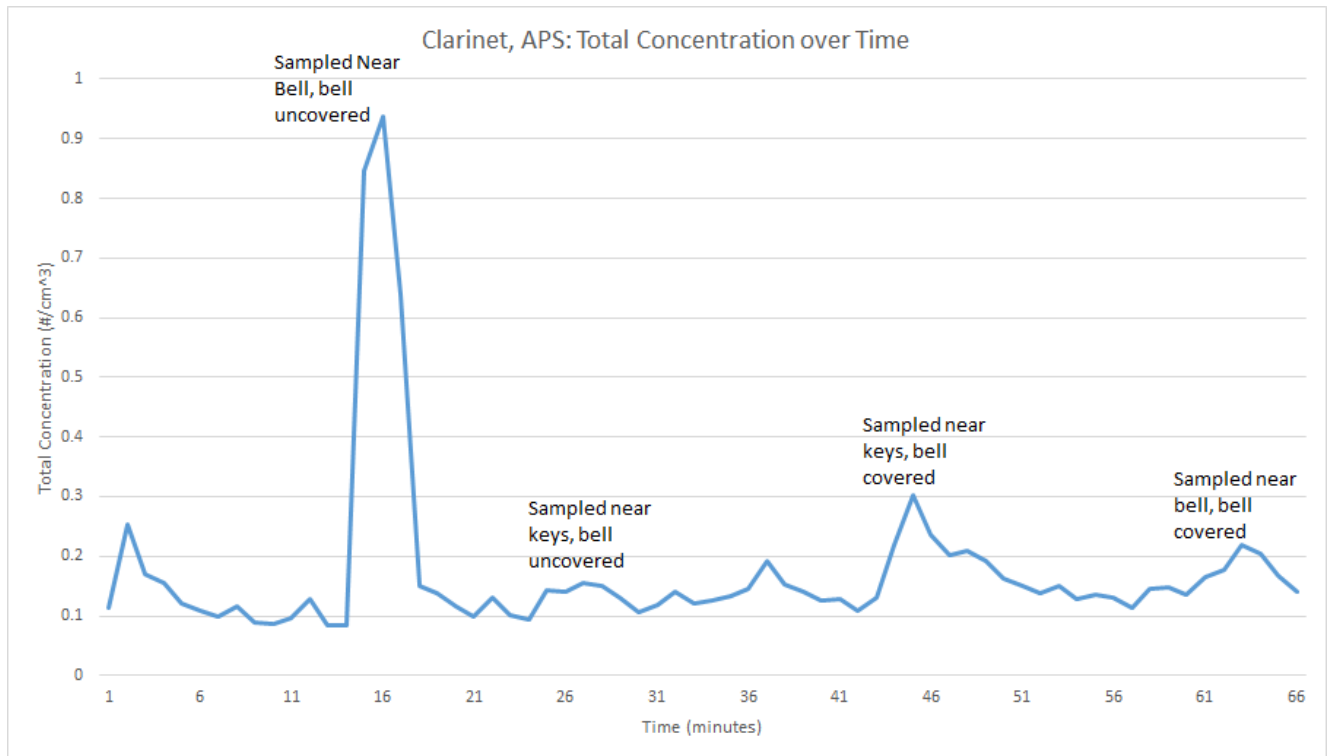
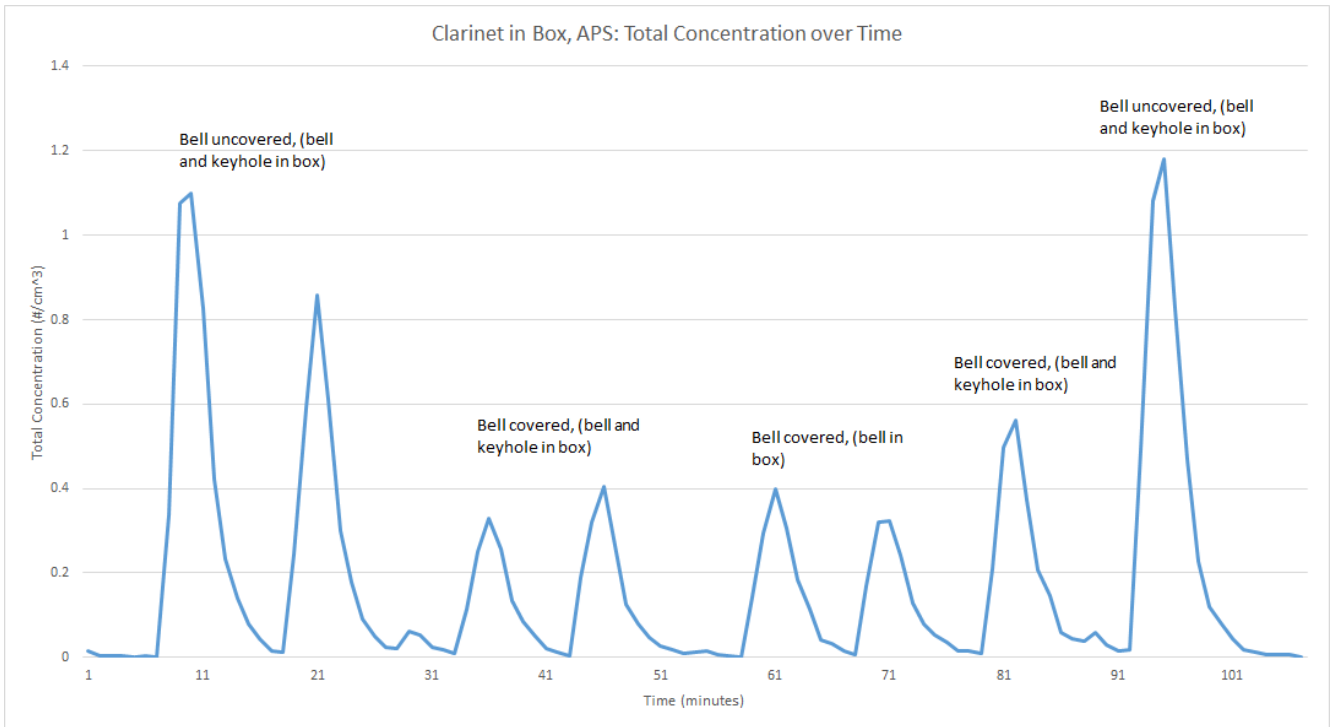
Example B: Oboe has an overall aerosol release of 4.00 pp cm³ unmitigated and an aerosol release of 0.5 pp cm³ (96% reduction) with a bell cover, placing mitigated oboe in line with other mitigated instruments and singers.

Instrument	Efficiency Calculated, Sampled at Bell / Mouth
Saxophone	64%
Flute	67%
Baritone Singer*	79%
Theater 1*	80%
Clarinet	87%
Theater 2*	88%
Bassoon	89%
Trombone	89%
Trumpet	92%
French Horn	95%
Oboe	96%
Soprano Singer*	98%

* Measurements taken at the participants' mouth

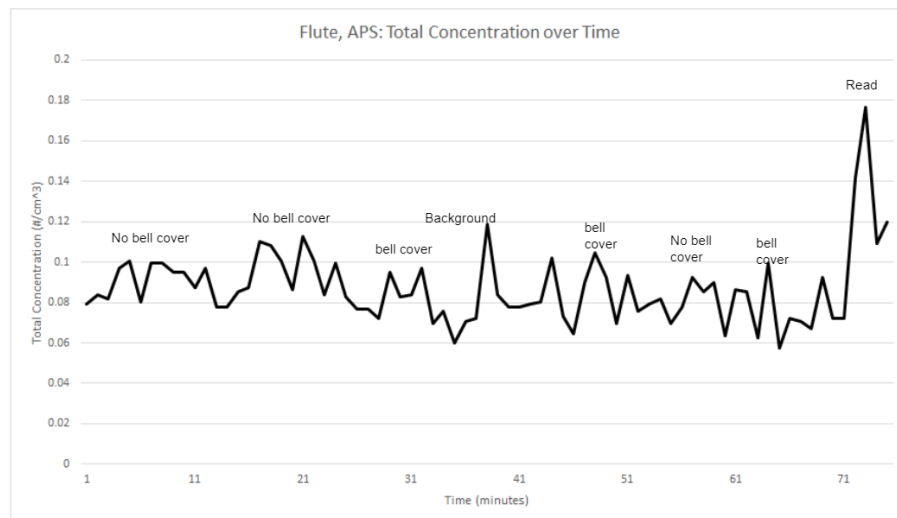
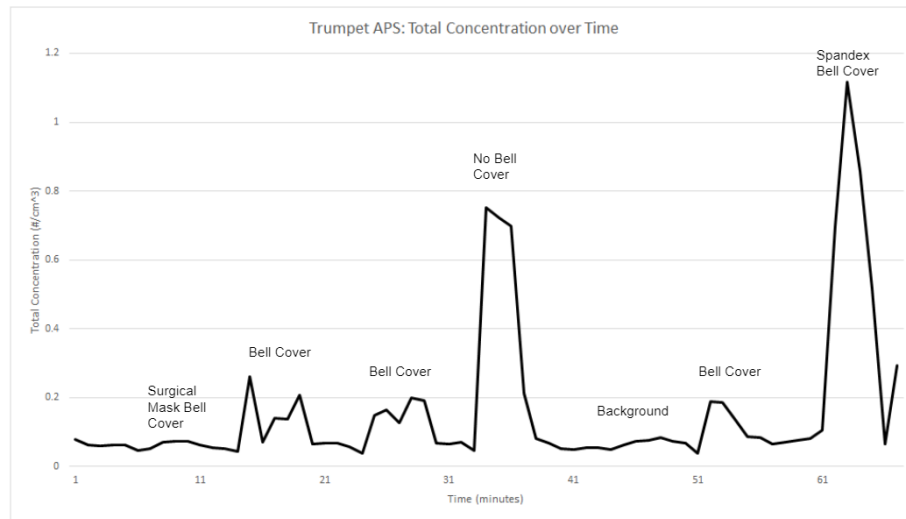
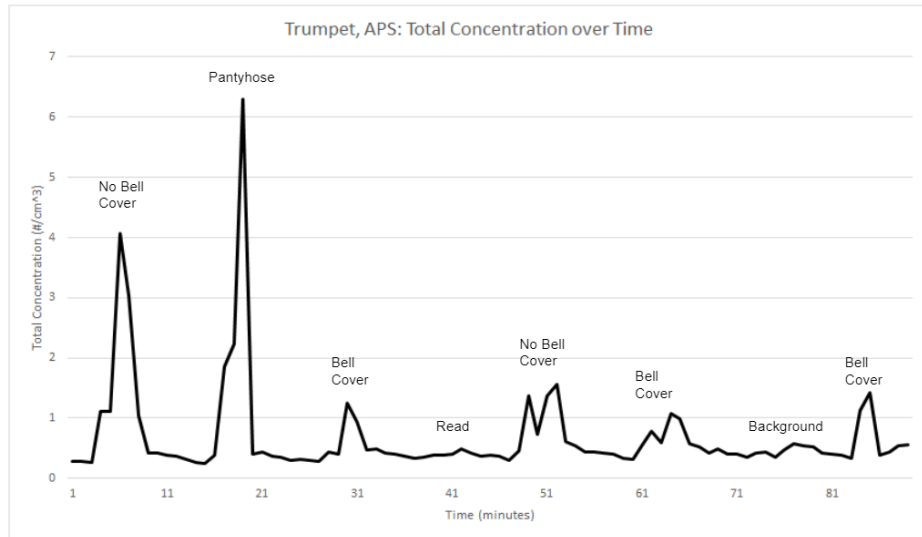
Appendix C

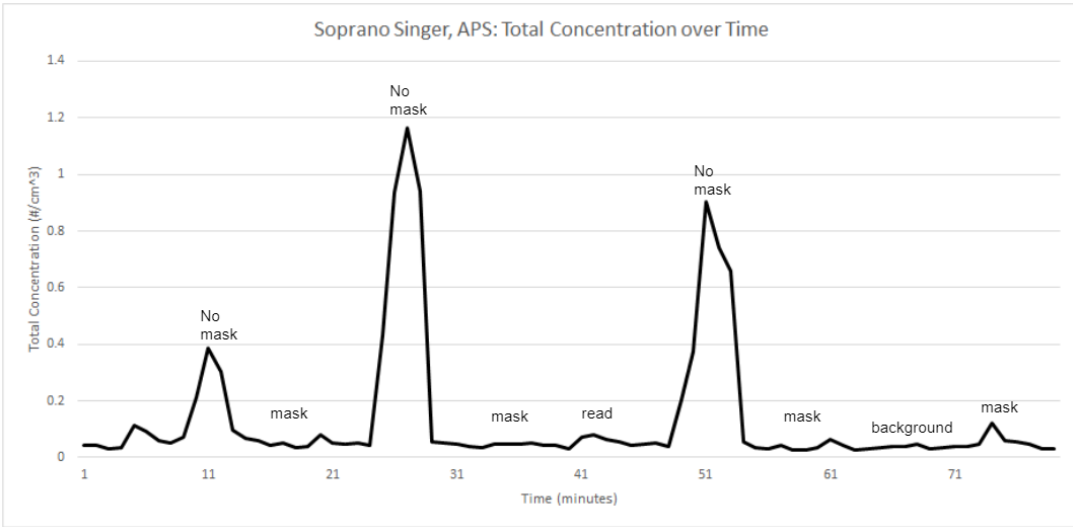
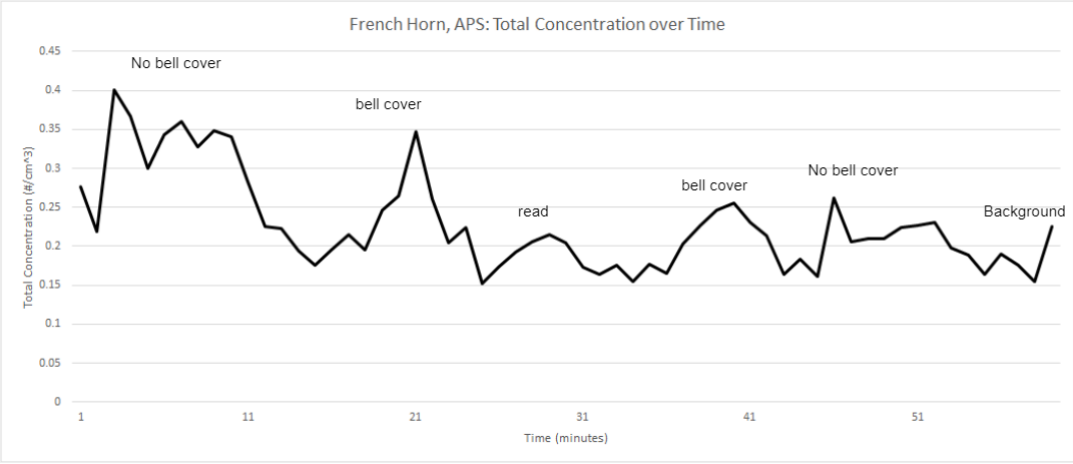
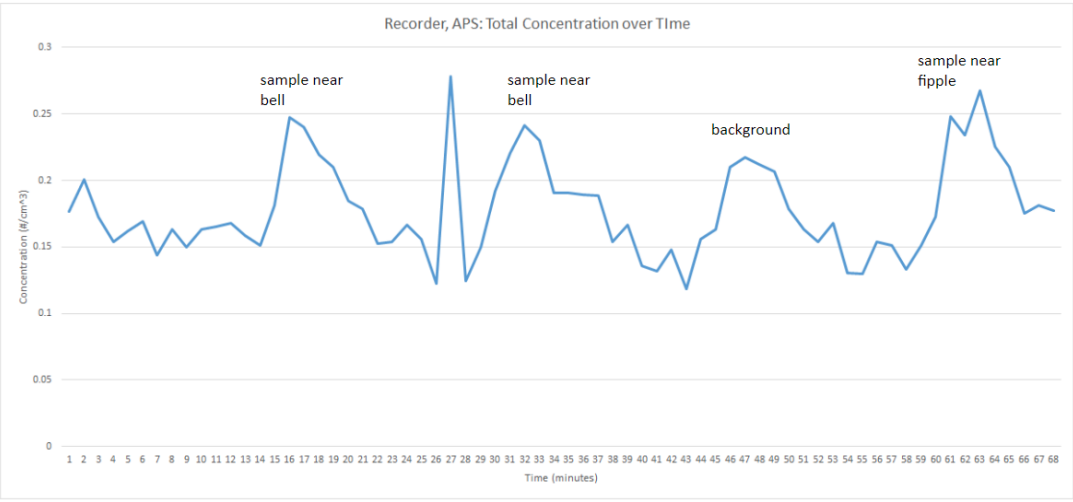
Experiments to determine amount of aerosol being expelled from woodwind keyholes were performed using an 3-layer surgical-type mask rubber-banded to the bell. Played C just over the upper register for 4 minutes for each test. Efficiency (including expelled aerosol of keyhole): 59%

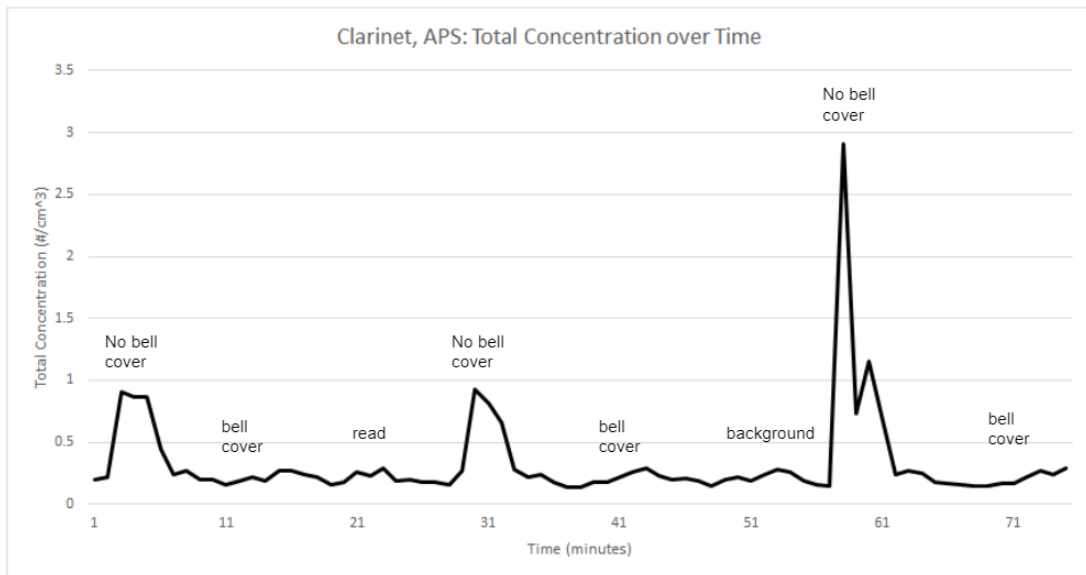
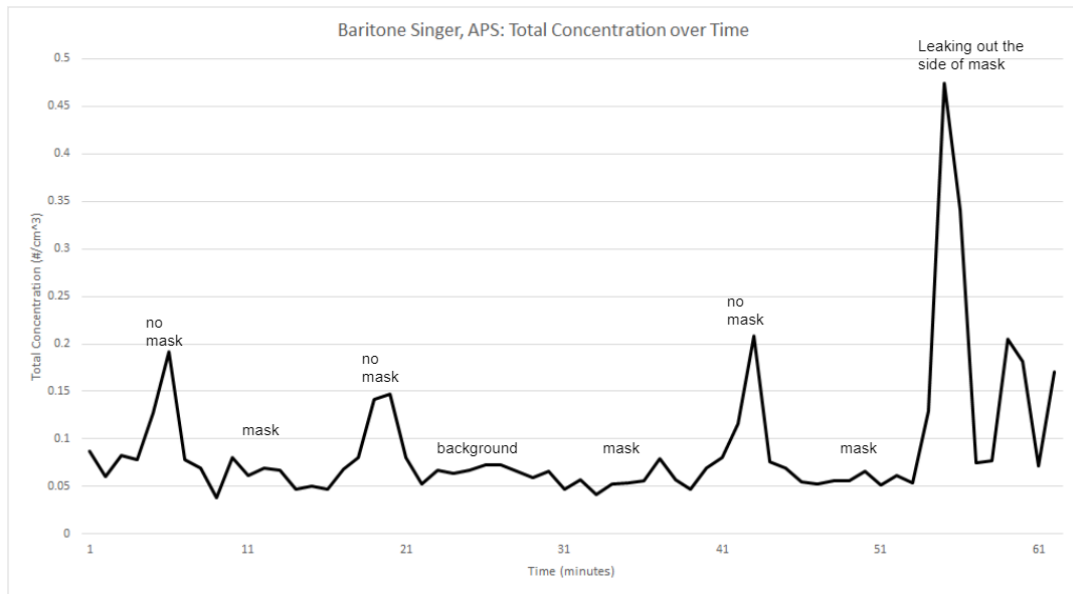


Appendix D

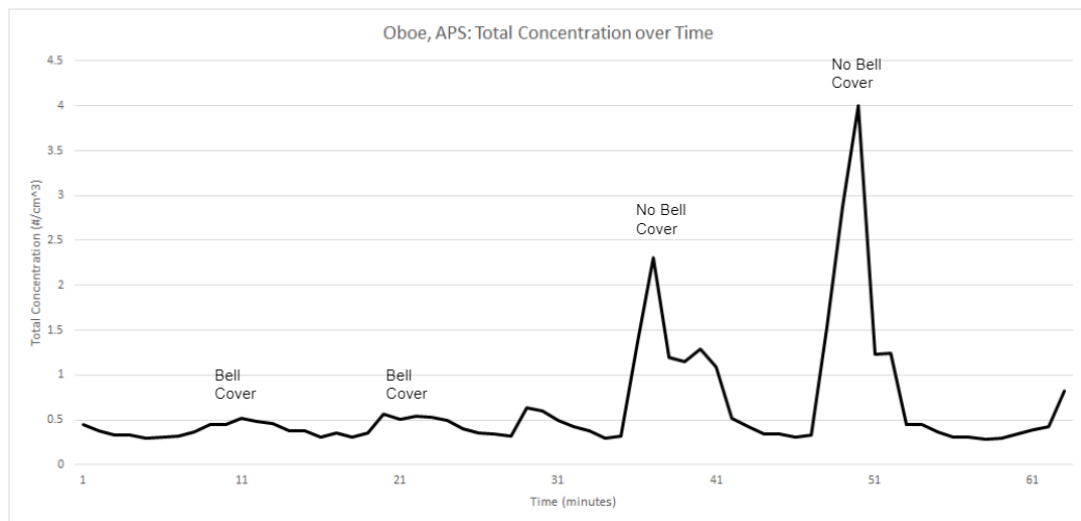
The following graphs depict the amount of aerosol produced over time. Also depicted are the differences between unmitigated performance and using mitigations designed in this study. All bell covers are a multi-layer bell cover with a MERV-13 filter material between layers unless otherwise labeled. All vocalists and actors were using a 3-layer surgical-style mask.



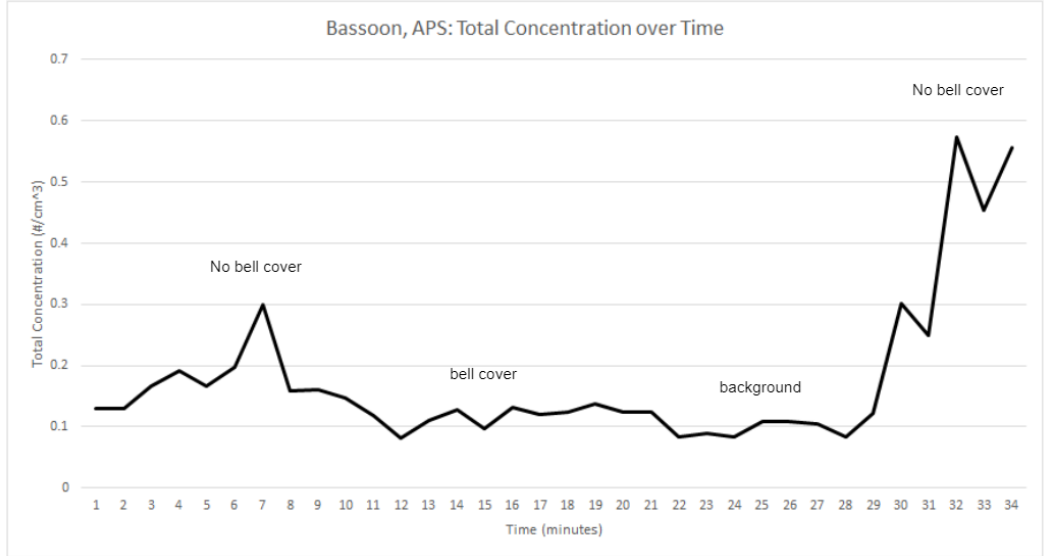
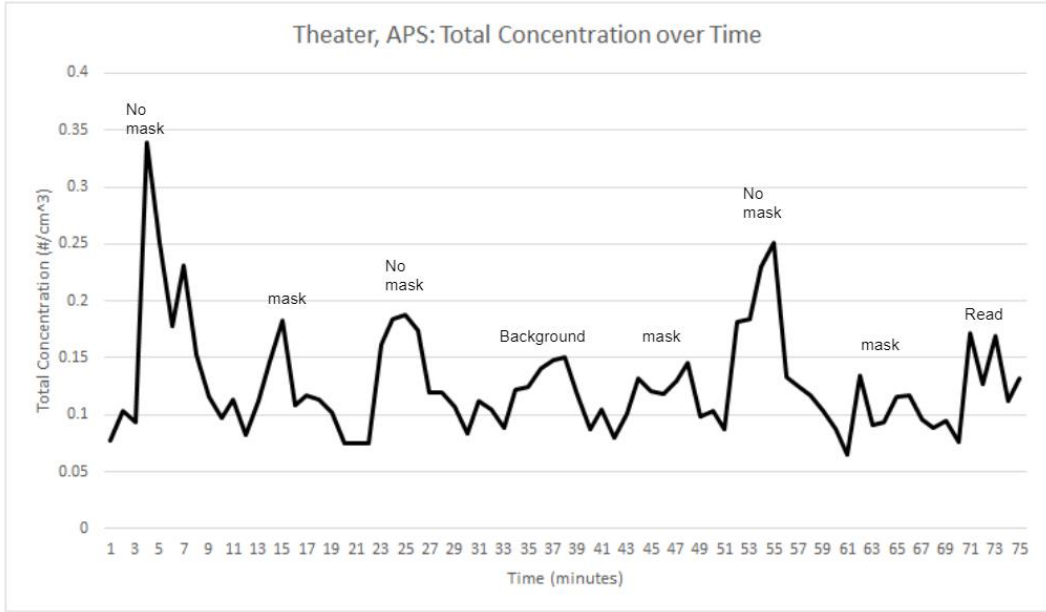
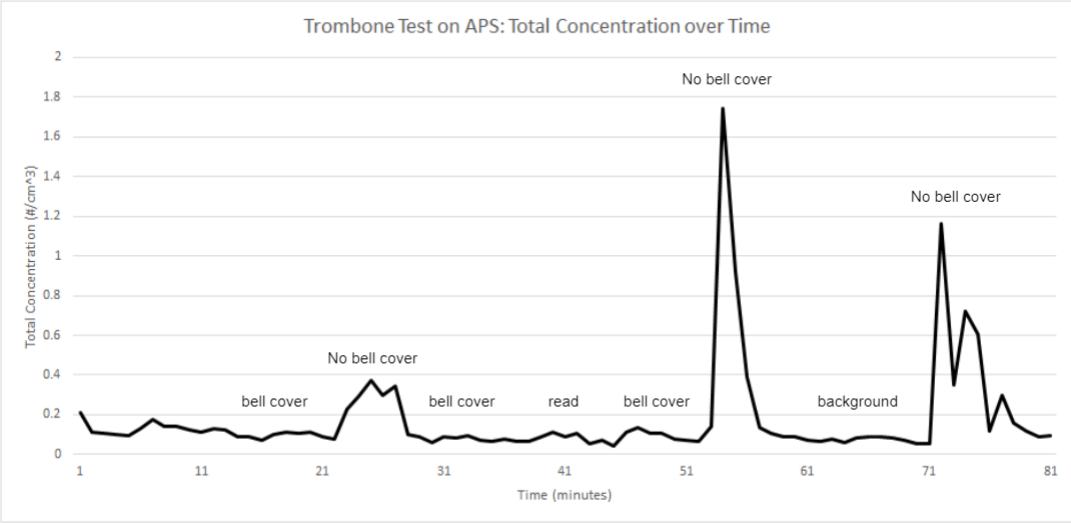


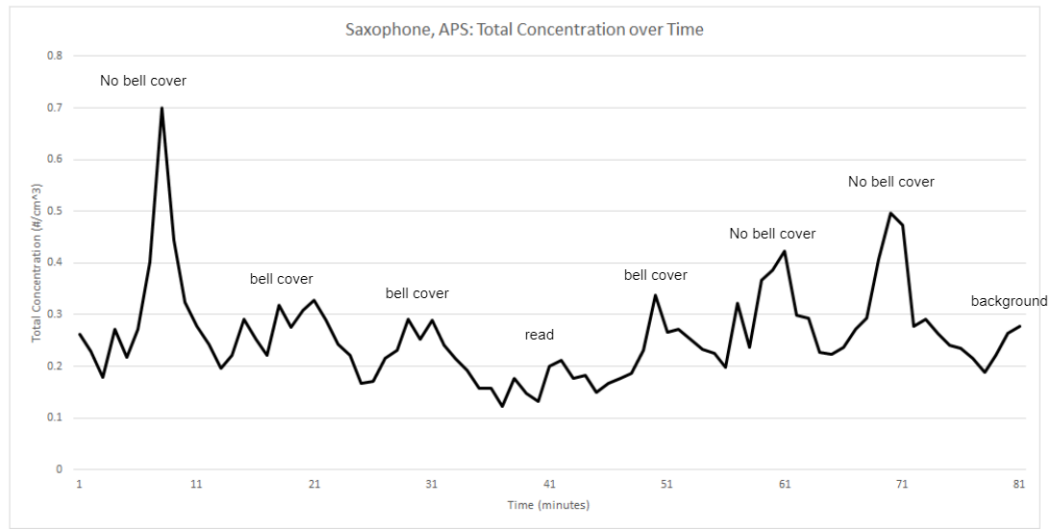


* Bell cover is a 3-layer surgical-style mask rubber banded to the bell.



* Bell cover is a 3-layer surgical-style mask rubber banded to the bell.

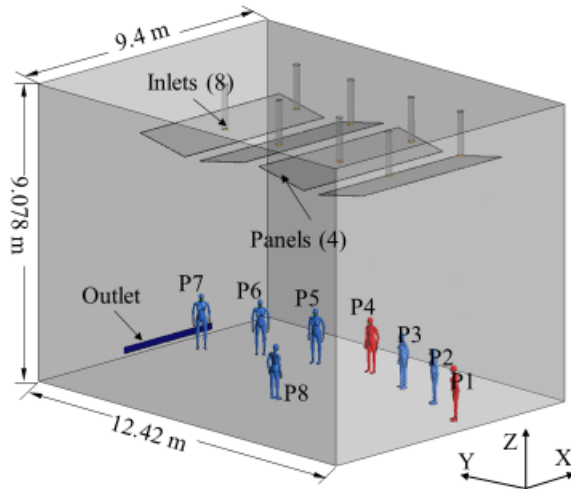




Appendix E

The following is a model of a rehearsal room with seven singers present. The first model shows the placement and airflow. The second set of models represents the differences between masked and unmasked singers in the room. The bluer shades represent a lower risk with yellow, orange, and red representing an increased risk of infection (Note: P8 represents the conductor).

Modeling of UC Rehearsal Hall with Singers



Rehearsal Hall Room:

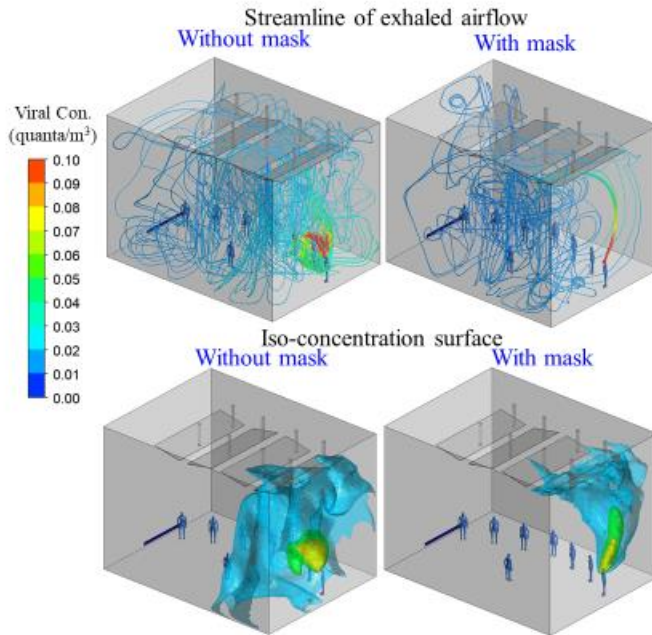
- Inlet:
 $d = 0.2 \text{ m}$, $v = 3.774 \text{ m/s}$ (3.2 ACH), $T = 22^\circ\text{C}$ (71.6°F)
- Outlet:
3.6 m (X) \times 0.2 m (Z)
- Walls & other solid surfaces:
adiabatic

Human body:

- All body surface:
 $convective \text{ heat flux} = 23 \text{ W/m}^2$
- Mouth of the infected singer (P1):
 $A = 3.8 \text{ cm}^2$, $v = 0.56 \text{ m/s}$, $T = 33^\circ\text{C}$ (91.4°F),
 $S = 48 \text{ quanta/hr}$ for COVID-19 virus
- Nostril of the susceptible singers & director:
 $A = 3.3 \text{ cm}^2$, $v = 1.679 \text{ m/s}$ (14 L/min, 1.8 met)

❖ In the simulation, P1 was assumed to do constant exhalation with the susceptibles were assumed to do constant inhalation.

Spread of Viral Aerosols from P1



Infection risk for susceptible singers & director after 60 minutes (%).

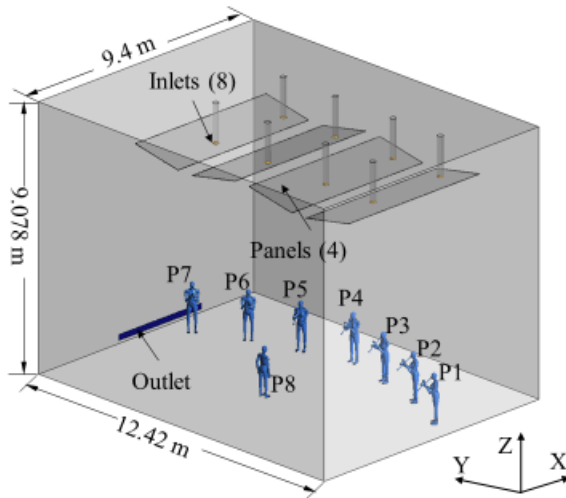
	P2	P3	P5	P6	P7	P8	Well-mixed
No mask	11	4	2	3	3	3	2.85e-04
With mask	2	1	1	1	1	1	5.25e-05
Reduction in risk	85%	61%	57%	60%	62%	58%	82%

- It is assumed that wearing a mask can filter 48.83% of aerosols for susceptible people.¹⁾
- “Well-mixed” show the risk under the perfectly mixed ventilation conditions resulting in an underestimate of risk.
- P2 has a high risk to be infected by P1 if not wearing a mask.
- Wearing a mask reduced the infection risk by over 57% for each susceptible person.
- However, indoor airflow rates could be increased to improve mixing and reduce the risk.

Appendix F

The following is a model of a rehearsal room with seven clarinetists present. The first model shows the placement and airflow. The second set of models represents the differences between the use of bell covers and no bell covers being used in the room. The bluer shades represent a lower risk with yellow, orange, and red representing an increased risk of infection (Note: P8 represents the conductor).

Modeling of UC Rehearsal Hall with Clarinet Players



Rehearsal Hall Room:

- Inlet:
 $d = 0.2 \text{ m}$, $v = 3.774 \text{ m/s}$ (3.2 ACH), $T = 22^\circ\text{C}$
- Outlet:
 $3.6 \text{ m (X)} \times 0.2 \text{ m (Z)}$
- Walls & other solid surfaces:
adiabatic

Human body:

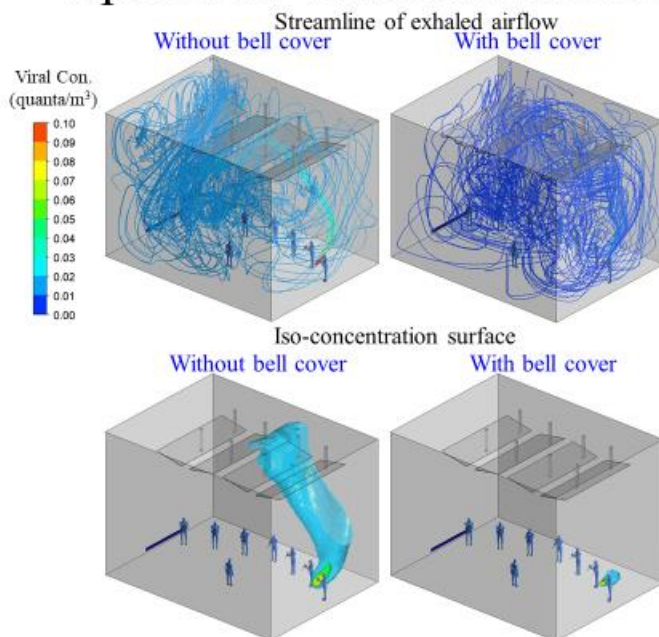
- All body surface:
 $convective \text{ heat flux} = 23 \text{ W/m}^2$
- Nostril of the susceptible clarinet players & director:
 $A = 3.3 \text{ cm}^2$, $v = 1.679 \text{ m/s}$ (14 L/min, 1.8 met)

Clarinets:

- Solid surface:
adiabatic
- Bell opening:
 $d = 6 \text{ cm}$, $v = 0.3 \text{ m/s}$ & $T = 23.5^\circ\text{C}$ when having a cover,
and $v = 0.9 \text{ m/s}$ & $T = 23.7^\circ\text{C}$ when having no cover

❖ In the simulation, P1 was assumed to play the clarinet with the susceptibles were assumed to do constant inhalation.

Spread of Viral Aerosols from P1



Infection risk for susceptible clarinet players & director after 60 minutes (%).

Source	P2	P3	P5	P6	P7	P8	Well-mixing
No cover	3	3	3	3	3	3	2.85e-04
With cover	1	1	1	1	1	1	1.03e-04
Reduction in risk	56%	60%	59%	62%	64%	64%	64%

- The bell cover is assumed to have the same particle removal efficiency as a surgical mask: 64%.
- The susceptible people do not wear a mask.
- “Well-mixed” show the risk for the perfectly mixed ventilation resulting in an underestimate of risk.
- Due to good air mixing in lower layers of room, with the same source strength, viral aerosols from playing clarinet resulted in a similar concentration distribution at the height of mouth as a whole, as well as the risk for the susceptible people except for P2.
- Using a bell cover greatly reduced the viral aerosol concentration at the height of month, resulting a reduction in infection risk by over 56%.

Masks	<ul style="list-style-type: none"> • Student • Instruments • Materials
Distance	<ul style="list-style-type: none"> • 6-foot CDC guidance • Applies indoors and outdoors • 9x6 for trombone
Time	<ul style="list-style-type: none"> • 30-minute rehearsal • Clear room for minimum 1 air change before next rehearsal period
Air Flow	<ul style="list-style-type: none"> • Outdoors is best • HEPA Filtration • ACH Rates
Hygiene	<ul style="list-style-type: none"> • Spit Valves • Handwashing • Storage Areas


5 Principal Takeaways

Mask Fitting Importance

<p>Poor fitting mask</p> <ul style="list-style-type: none"> • Gaps on the sides • Nose not covered • Loose around the edges • All of the above are poor fitting in their own right
<p>Better fitting mask</p> <ul style="list-style-type: none"> • No gaps on the sides • Nose covered • A fairly good fit around the edges
<p>Well fitting mask</p> <ul style="list-style-type: none"> • No gaps • Nose covered • Tight around the edges • Should leave a mask outline once removed

KEEPING ARTS ED SAFE AT SCHOOL

MASK Everything!




ACTORS
SINGERS
DANCERS

INSTRUMENTALISTS
INSTRUMENTS

TEACHERS

DISTANCE 6 FEET with Mask



TIMING

OUTDOOR

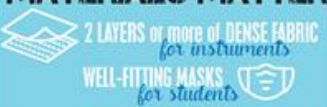
- Playing Instruments, Singing, Acting, or Dancing (Masks strongly recommended)
- 30 minute blocks with 6ft spacing
- 5 minute pause between blocks

INDOORS

- Playing Instruments, Singing, Acting, or Dancing (Masks required)
- 30 minutes with 6 ft spacing
- Minimum one air change between class


MATERIALS MATTER

2 LAYERS or more of DENSE FABRIC for instruments
WELL-FITTING MASKS for students




Proper HYGIENE


Instruments
Spaces
People




AIREFLOW / FILTRATION

Good ventilation and air change rate for the space.





Source: International Coalition of Performing Arts Aerosol Study 8/6/2020 <http://dx.doi.org/10.1101/2020.08.06.20111111> • <https://www.artbed.org/covid19>



Further Information and Next Steps:

Study Information:

[Main Coalition Page](#)

[FAQ Page](#)

[Submit a question](#)

[YouTube Video of 3rd Data Release](#)

Risk Assessment Tools:

[University of Colorado Boulder risk assessment tool:](#)

[Harvard-UC Boulder Portable Air Cleaner Calculator for Schools.v1.1](#)

Standards Resources:

[CDC Mask Information](#)

[ASHRAE](#)

Video on Transmission:

[Transmission of Respiratory Infectious Diseases - Video](#)

The final report and publications are expected in January 2021.