Characterization of Aerosols from Musical Performance and Risk Mitigation Related to COVID-19 Pandemic

Jun Wang, PhD, PE, CIH, CSP
Tiina Reponen, PhD; Sergey Grinshpun, PhD; James Bunte, PhD
Education and Research Center (ERC)

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Webinar Objectives

At the conclusion of this webinar, participants will be able to:
1. Describe the basic principles of aerosol transmission in relation to COVID-19 pandemic, including differences between aerosols and droplets.
2. Explain the effects of distances, ventilation conditions, and other factors on aerosol concentrations in a room.
3. Explain how singing, playing of wind instruments, or talking elevates aerosol concentrations in a room.
4. Identify potential engineering controls, personal protection, and proper guidelines to reduce risks of COVID-19 infection during practicing and teaching vocal and instrumental music.
• Record of the webinar is available at https://med2.uc.edu/eh/centers/erc/coronavirus-and-workplace-safety
• Post-event evaluations will be emailed to all who attend the live webinar
• Questions: erccoor@ucmail.uc.edu
• Contact investigator: Dr. Jun Wang jun.wang@uc.edu
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Acknowledgement

Team Music
Dr. James Bunte, Professor and Division Head of Performance Studies
Mr. Rayburn Dobson, Senior Director of Performance Operation
Musicians (by alphabetical order):
Mr. Tony Padilla Denis (French horn), Ms. Julianna Eidel (flute, piccolo), Ms. Christina Hazen (singer), Ms. Emery Hicks (trumpet), Ms. Carly Hood (saxophone), Ms. Kate Kilgus (clarinet), Mr. Austin Motley (trombone), Prof. Timothy Northcut (tuba), Mr. Kash Sewell (saxophone), Ms. Heather Verbeck (flute).

Team Aerosol
John Singletary, PhD student
Dr. Sergey Grinshpun, Professor and Director of CHRAS
Dr. Tiina Reponen, Professor and Director of UC-ERC
Dr. Michael Yermakov, Senior Research Associate
Outline

Aerosol COVID-19 And Music
Study at CCM
Risk Mitigation
COVID-19 Pandemic

- COVID-19 (disease) / SARS-CoV-2 (virus)
- Transmission route
  - Respiratory droplets
  - (close) contact with contaminated surface
  - *Potential airborne transmission*
- Incubation to onset time
  - Median of 4-5 days and up to 14 days
  - Reports of asymptomatic transmission
- Risk of seriously ill
  - Older people and people with medical conditions
- Currently no vaccine

Image source: CDC

Airborne Transmission

• Definition of aerosol
  – Solid or liquid particles suspended in air. (fume, dust, mist…)
  – A continuum of size
    nanometer
    micrometer
    millimeter

<table>
<thead>
<tr>
<th>Relative particle size</th>
<th>Carbon black</th>
<th>Paint pigment</th>
<th>Tobacco smoke</th>
<th>Human hair</th>
<th>Pollen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (μm)</td>
<td>0.001</td>
<td>0.1</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Size (Å)</td>
<td>100</td>
<td>1,000</td>
<td>10,000</td>
<td>100,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Molecular weight (Da)</td>
<td>100</td>
<td>1,000</td>
<td>10,000</td>
<td>100,000</td>
<td>500,000</td>
</tr>
</tbody>
</table>
Airborne Transmission

- Properties of aerosols related to SARS-CoV-2
  - Aerodynamic particle size
  - Particle residence time

Fine and ultrafine aerosols (< 1 micron)
- Stay in air longer
- Behave similarly to gas

Nuclei
- Briefly suspend
- Fall in certain distance

Small droplets (~5 micron)
- Travel like a “bullet”
- Sometimes visible

Large droplets (>100 micron)
- A dynamic process: formation, transformation, transmission and deposition of aerosols.
Evidences of Airborne Transmission

• Speculating aerosol transmission with some evidences
• Washington State choir practice event (March 2020)
  – 52 out of 60 get ill, 2 died. (Source: Hamner et al. MMWR)

• Amsterdam Mixed Choir (March 2020)
  – 102 out of 130 choristers infected, 4 died.
• Various reports on restaurants in China and other countries.
Two papers published on Emerging Infectious Diseases (Monthly CDC Publication) suggest possible airborne transmission.
Two studies show SARS-CoV-2 can suspend in air up to 3 hours and 16 hours.
Airborne Transmission

- WHO acknowledged possible airborne transmission (July 9th)
  - No absolute definitive proof
  - Strong evidence

- The potential implication of airborne transmission through fine and ultrafine aerosols:
  - 6 ft (~2 meter) distance may not be adequate in poorly ventilated environment
  - Loose fitting facemask, face shield, plexiglass barrier may not work

- Unknown infectious dose (viral load)
Studies on Breathing/Talking/Singing

• Aerosol emission from breathing, talking, coughing, and sneezing
  – There is a high variability between people

• Singing
  – high volume, high frequencies, high air flows, deep breathes, continuous voicing

• Wind instruments
  – Blow into a mouthpiece and resonator, air flow exits at various locations of the tube.
Implications of Airborne Transmission

• Potential impact
  – K-12 musical education program: children at risk
  – College education program: 1-on-1 teaching, indoor practicing
  – Symphony orchestra: overcrowding of musicians
  – Other choir/band performance (church, military, etc.)
  – Audiences of musical performance

Source: American Symphony Orchestra
Background of UC-CCM Study

- Initiated by researchers at UC to exam the effects of “return to campus”
  - Previously a dormitory
  - Teaching and practicing studios
  - Over 70 individual practice rooms

- Focus on aerosol concentration in the small to medium size studio room.

Memorial Hall, UC-CCM
Room characteristics
- Size: 10.5 ft x 22 ft x 8 ft (1848 cu. ft.)
- Temperature: 76 (±2.1) °F
- Humidity: 49 (±4) %RH
- Vent rate: 190 CFM (6 ACH) with recirculated air and isolated HVAC ducts
- Furniture placement limited options of social distancing

Room 374 of Memorial Hall
# Singing and Wind Instruments

- Two mezzo soprano singers
- Seven wind instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Material</th>
<th>Mouthpiece design</th>
<th>Tube design</th>
<th>Tube length</th>
<th>Bell design</th>
<th>Bell facing when performing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarinet</td>
<td>Wood</td>
<td>Single reed</td>
<td>Straight cylindrical</td>
<td>2 ft</td>
<td>Flared</td>
<td>Down at 45 degrees</td>
</tr>
<tr>
<td>Flute</td>
<td>Silver plated brass</td>
<td>Reedless</td>
<td>Straight</td>
<td>2 ft</td>
<td>Straight</td>
<td>Sideways</td>
</tr>
<tr>
<td>French horn</td>
<td>Brass</td>
<td>Brass mouthpiece</td>
<td>Conical many turns</td>
<td>12-13 ft</td>
<td>flared</td>
<td>backward</td>
</tr>
<tr>
<td>Saxophone</td>
<td>brass</td>
<td>Single reed</td>
<td>Concical 2 turns</td>
<td>4 ft</td>
<td>flared</td>
<td>Forward</td>
</tr>
<tr>
<td>Trombone</td>
<td>Brass</td>
<td>Brass mouthpiece</td>
<td>Mainly cylindrical till the bell</td>
<td>9 ft</td>
<td>flared</td>
<td>Forward</td>
</tr>
<tr>
<td>Trumpet</td>
<td>Silver plated brass</td>
<td>Brass mouthpiece</td>
<td>Mainly cylindrical till the bell</td>
<td>6.5 feet</td>
<td>flared</td>
<td>Forward</td>
</tr>
<tr>
<td>Tuba</td>
<td>Silver plated brass</td>
<td>Brass mouthpiece</td>
<td>Conical many turns</td>
<td>16 feet</td>
<td>flared</td>
<td>upward</td>
</tr>
</tbody>
</table>
Singing and Wind Instruments

Safety precautions during the study
- Minimize the contact between researchers and musicians
- Facemasks all the time except performing
- Disinfecting between musicians and sessions
Study Design

- Two types of sessions
  - Practicing: 100% singing/instrument playing
  - Teaching: 60% singing/instrument playing, 40% speech talking
  - Each session is 10 minutes, and triplicated with consistency
  - “Purging” of the room before and between each session

- Aerosol instrument placement
  - At performing point
  - 6 ft away, 6 ft sideway
  - 10 ft away
Aerosol Instruments

- Portable condensational particle counter (CPC)
  - “Enlarge” aerosols through thermal diffusion of isopropyl alcohol (IPA)
  - Detection of “enlarged” aerosols by laser counting
  - Detecting range: 10 nanometers to microns
  - Counting range: 100,000 # of particles per cubic centimeters
  - Sample interval: 5 seconds

Source: TSI
Other Study Considerations

• Baseline
  – Room background with and without people (breathing)

• Statistical testing
  – Three-way ANOVA with pairwise t-test (Holm-Šídák)
    • Singing/instruments
    • Sampling locations
    • Practicing/teaching
  – An alpha of 0.05 was determined as statistically significant
Average Room Concentration

Breathing versus background

- No statistical difference found between background and normal breathing ($p=0.4$)
- No statistical difference between locations ($p=0.082$)
Average Room Concentration

- Singing and trumpet
  - Singing elevated the room concentration by the most
  - Singing and trumpet were statistically different from other instruments ($p<0.001$)
Average Room Concentration

- Other instruments: higher than background but no difference between instruments
Time series data

• Sing and trumpet (statistically different from other instruments, $p<0.001$)
  – Singing increased room concentration by nearly 2000 counts / cm$^3$
Time Series Data (cont’d)

- Other wind instruments (no statistical difference, $p>0.05$)

- French horn
- Saxophone
- Trombone
- Flute
- Tuba
- Clarinet

Performing point
6 ft away
6 ft sideway
10 ft away
Portable HEPA Filtration Unit

Portable HEPA filtration unit
- Shown to be effective in some cases
- HEPA filtration filter
- UV lamp for germicide

Clean air delivery rate (CADR)
- Smoke (99) and dust (107)
- “2/3” rule for 8-ft height room
Time Series Data (cont’d)

- Singing with HEPA filtration

Portable HEPA filtration unit placed next to performing point was able to reduce particle concentration to 1/3 of background level.
Efficiency of HEPA Filtration

- Singing with HEPA filtration
Other Discrepancies

- Location matters
  - Concentrations at **performing point** is always higher ($p<0.001$)
  - No difference between 6 ft away and 6 ft sideway ($p=0.114$)
  - There is a difference between 6 ft away and 10 ft away ($p=0.025$)

- There is no statistical difference between practicing and teaching ($p=0.595$)
Summary of Study

• **Singing** significantly increased the room concentration of aerosol

• Most **wind instruments** increased the room concentrations, but at a relatively minor level comparing to background

• Normal **breathing** did not increase room concentrations significantly

• Aerosol concentrations decreased along the **distance** away from the performer

• Portable **HEPA filtration** unit at performing point help reducing aerosol concentration
Considerations

• Without definitive proof and known infectious dose, assuming SARS-CoV-2 virus is airborne and elevated aerosol concentrations increased risk of infection.

• Avoid indoor overcrowding of musicians, especially small and poorly ventilated room

• Singing has the great potential to generate and transmit potentially virus-laden aerosols, avoid group singing

• Act cautiously around wind instruments
Risk Mitigations

Emission point:
- Local exhaust capture (HEPA filtration with adequate CADR)
- Modifications of singing procedures and instruments

Transmission route:
- Increase distance beyond 6 ft
- Good ventilation that supplying fresh air

Receiving point:
- Loose and tight fitting facemasks
Conclusions

• Other considerations
  – Disinfect the instrument with alcohol wipes and UV exposure, avoid cross contamination by not sharing instruments
  – Assign practicing room by bubbles (group of people) and keep logs for contact tracing
  – Assessing ventilation conditions and other factors affecting indoor air quality

• Follow CDC guidelines and common sense

• More studies needed
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https://med2.uc.edu/eh/centers/erc/coronavirus-and-workplace-safety

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