
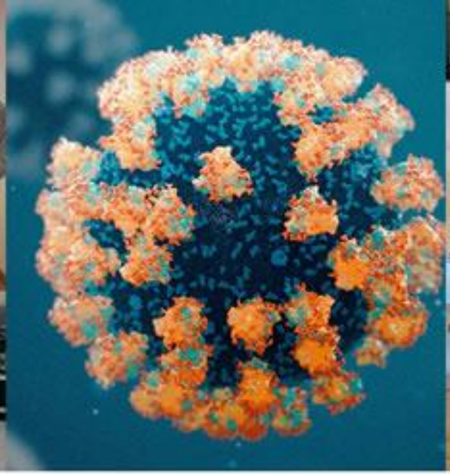


Characterization of Aerosols from Musical Performance and Risk Mitigation Related to COVID-19 Pandemic

Jun Wang, PhD, PE, CIH, CSP

Tiina Reponen, PhD; Sergey Grinshpun, PhD; James Bunte, PhD

University of Cincinnati Education and Research Center

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University of Cincinnati College-Conservatory of Music

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Education and Research Center (ERC)

- **Mission:** to reduce work-related injuries and illnesses by performing prevention research and by providing high-quality professional education programs in occupational health and safety
- Funded by the National Institute for Occupational Safety and Health (NIOSH)
- Sponsor of this webinar and future webinars

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- Website: http://med.uc.edu/eh/centers/erc
- ERC Blog:http://eh.uc.edu/category/erc-blog

CERKL: https://cerkl.com/uc-erc#.WYMjCYQrJhE

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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.

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- 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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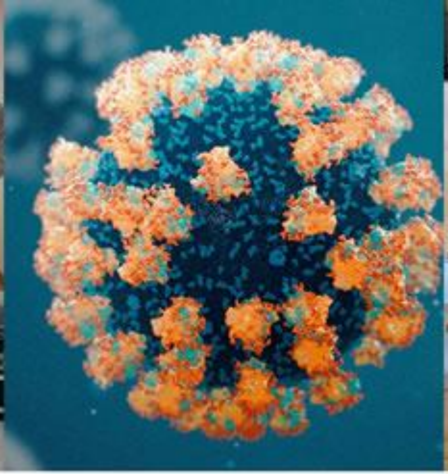


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Acknowledgement

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

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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

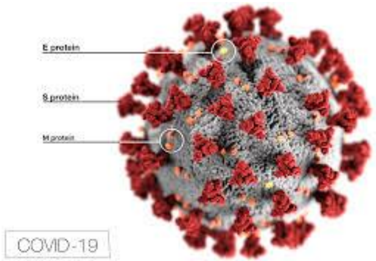
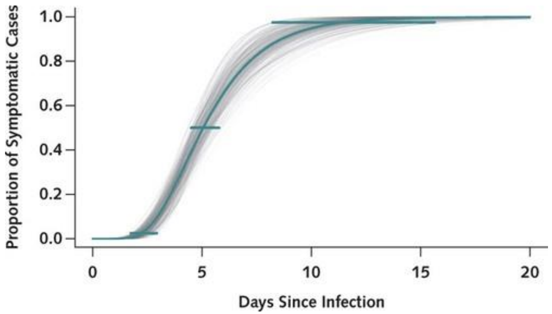


Image source: CDC



Lauer et al. Ann. Int. Med. 2020

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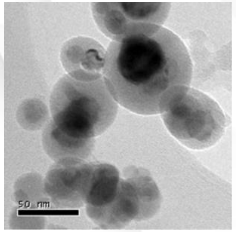
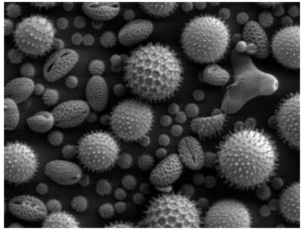
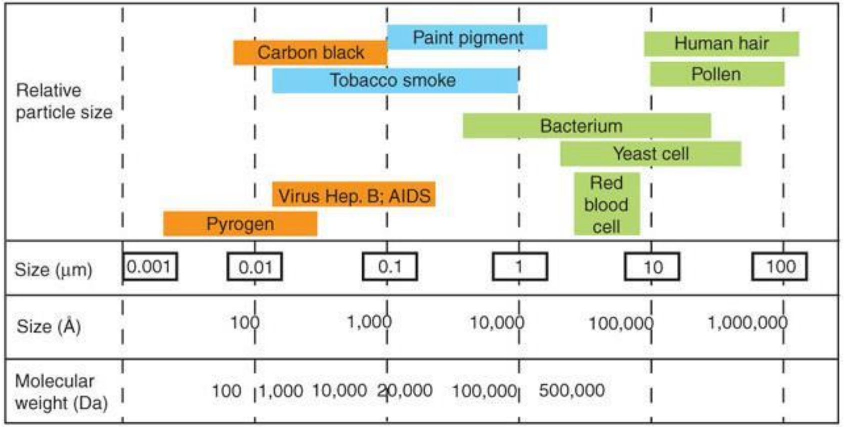
Airborne Transmission

- Definition of aerosol
  - Solid or liquid particles suspended in air. (fume, dust, mist…)



  - A continuum of size
    nanometer
    micrometer
    millimeter



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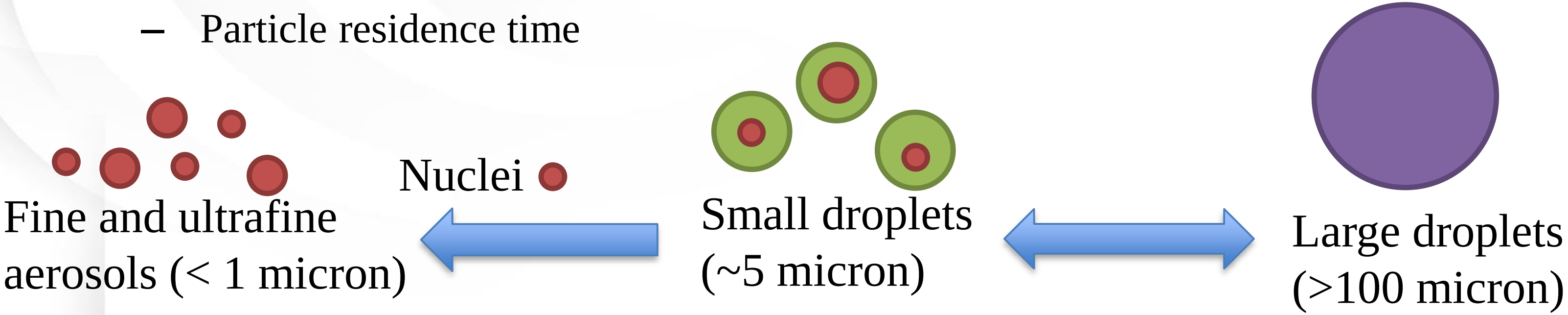
Airborne Transmission

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



Stay in air longer
Behave similarly to gas

Briefly suspend
Fall in certain distance

Travel like a “bullet”
Sometimes visible

  - A dynamic process: formation, transformation, transmission and deposition of aerosols.

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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.

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COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020

Jianyun Lu,[1] Jieni Gu,[1] Kuibiao Li,[1] Conghui Xu,[1] Wenzhe Su, Zhisheng Lai, Deqian Zhou, Chao Yu, Bin Xu, Zhicong Yang

Author affiliations: Guangzhou Center for Disease Control and Prevention, Guangzhou, China (J. Lu, K. Li, C. Xu, W. Su, C. Yu, Z. Yang); Guangzhou Yuexiu District Center for Disease Control and Prevention, Guangzhou, China (J. Gu, Z. Lai, D. Zhou, B. Xu)

DOI: https://doi.org/10.3201/eid2607.200764

During January 26–February 10, 2020, an outbreak of 2019 novel coronavirus disease in an air-conditioned restaurant in Guangzhou, China, involved 3 family clusters. The airflow direction was consistent with droplet transmission. To prevent the spread of the virus in restaurants, we recommend increasing the distance between tables and improving ventilation.

From January 26 through February 10, 2020, an outbreak of 2019 novel coronavirus disease (COVD-19) affected 10 persons from 3 families (families A–C)

[1]These authors contributed equally to this article.

Cluster of Coronavirus Disease Associated with Fitness Dance Classes, South Korea

Sukbin Jang, Si Hyun Han, Ji-Young Rhee

Author affiliation: Dankook University Hospital, Dankook University College of Medicine, Cheonan, South Korea

DOI: https://doi.org/10.3201/eid2608.200633

During 24 days in Cheonan, South Korea, 112 persons were infected with severe acute respiratory syndrome coronavirus 2 associated with fitness dance classes at 12 sports facilities. Intense physical exercise in densely populated sports facilities could increase risk for infection. Vigorous exercise in confined spaces should be minimized during outbreaks.

By April 30, 2020, South Korea had reported 10,765 cases of coronavirus disease (COVID-19) (*1*); ≈76.2% of cases were from Daegu and North Gyeongsang provinces. On February 25, a COVID-19 case was detected in Cheonan, a city ≈200 km from Daegu. In response, public health and government officials from Cheonan and South Chungcheong Province activated the emergency response system. We began active surveillance and focused on identifying possible COVID-19 cases and contacts. We interviewed consecutive confirmed cases and found all had participated in a fitness dance class. We traced contacts back to a nationwide fitness dance instructor workshop that was held on February 15 in Cheonan.

Fitness dance classes set to Latin rhythms have

Two papers published on Emerging Infectious Diseases (Monthly CDC Publication) suggest possible airborne transmission

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The NEW ENGLAND JOURNAL of MEDICINE

CORRESPONDENCE

Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1

TO THE EDITOR: A novel human coronavirus that is now named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (formerly called HCoV-19) emerged in Wuhan, China, in late 2019 and is now causing a pandemic.[1] We analyzed the aerosol and surface stability of SARS-CoV-2 and compared it with SARS-CoV-1, the most closely related human coronavirus.[2]

We evaluated the stability of SARS-CoV-2 and SARS-CoV-1 in aerosols and on various surfaces and estimated their decay rates using a Bayesian regression model (see the Methods section in the Supplementary Appendix, available with the full text of this letter at NEJM.org). SARS-CoV-2 nCoV-WA1-2020 (MN985325.1) and SARS-CoV-1 Tor2 (AY274119.3) were the strains used. Aerosols (<5 μm) containing SARS-CoV-2 ($10^{5.25}$ 50% tissue-culture infectious dose [$TCID_{50}$] per milliliter) or SARS-CoV-1 ($10^{6.75-7.00}$ $TCID_{50}$ per milliliter) were generated with the use of a three-jet Collison nebulizer and fed into a Goldberg drum to create an aerosolized environment. The inoculum resulted in cycle-threshold values between 20 and 22, similar to those observed in samples obtained from the upper and lower respiratory tract in humans.

Our data consisted of 10 experimental conditions involving two viruses (SARS-CoV-2 and SARS-CoV-1) in five environmental conditions (aerosols, plastic, stainless steel, copper, and cardboard). All experimental measurements are reported as means across three replicates.

SARS-CoV-2 remained viable in aerosols throughout the duration of our experiment (3 hours), with a reduction in infectious titer from $10^{3.5}$ to $10^{2.7}$ $TCID_{50}$ per liter of air. This reduction was similar to that observed with SARS-CoV-1, from $10^{4.3}$ to $10^{3.5}$ $TCID_{50}$ per milliliter (Fig. 1A).

SARS-CoV-2 was more stable on plastic and

Persistence of Severe Acute Respiratory Syndrome Coronavirus 2 in Aerosol Suspensions

Alyssa C. Fears, William B. Klimstra, Paul Duprex, Amy Hartman, Scott C. Weaver, Kenneth S. Plante, Divya Mirchandani, Jessica Ann Plante, Patricia V. Aguilar, Diana Fernández, Aysegul Nalca, Allison Totura, David Dyer, Brian Kearney, Matthew Lackemeyer, J. Kyle Bohannon, Reed Johnson, Robert F. Garry, Doug S. Reed[1], and Chad J. Roy[1]

Author affiliations: Tulane University School of Medicine, New Orleans, Louisiana, USA (A.C. Fears, R.F. Garry, C.J. Roy):; University of Pittsburgh, Pittsburgh, Pennsylvania, USA (W.B. Klimstra, P. Duprex, A. Hartman, D.S. Reed); University of Texas Medical Branch, Galveston, Texas, USA (S.C. Weaver, K.S. Plante, D. Mirchandani, J.A. Plante, P.V. Aguilar, D. Fernández); U.S. Army Medical Research Institute of Infectious Diseases, Fort Detrick, Maryland, USA (A. Nalca, A. Totura, D. Dyer, B. Kearney); National Institute of Allergy and Infectious Diseases, National Institutes of Health, Fort Detrick, Maryland, USA (M. Lackemeyer, J.K. Bohannon, R. Johnson)

Suggested citation for this article

Abstract

We aerosolized severe acute respiratory syndrome coronavirus 2 and determined that its dynamic aerosol efficiency surpassed those of severe acute respiratory syndrome coronavirus and Middle East respiratory syndrome. Although we performed experiment only once across several laboratories, our findings suggest retained infectivity and virion integrity for up to 16 hours in respirable-sized aerosols.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a readily transmissible zoonotic pathogen and the etiologic agent of the coronavirus disease (COVID-19) pandemic (1). To determine aerosol stability of the virus, we measured the dynamic (short-term) aerosol efficiencies of SARS-CoV-2 and compared its efficiency with SARS-CoV and Middle East respiratory syndrome coronavirus (MERS-CoV).

On T… | The … | Con… | Sugg… | Figu… | Figu… | Figu… | Dow… | Appe… | RIS [… | Altm…

Two studies show SARS-CoV-2 can suspend in air up to 3 hours and 16 hours.

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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)

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Studies on Breathing/Talking/Singing

- Aerosol emission from breathing, talking, coughing, and sneezing
  - Several studies show production of aerosol around microns (Asadi et al. 2019 Sci. Rep., Johnson et al. 2011 J. Aerosol Sci., Lindsley et al. 2016)
  - Visualization of aerosol production. (Tang et al. PloS One 2011,Anfinrud et al. NEJM 2020, Tellier et al. BMC Infect Dis 2019)
  - 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.

Tang et al. PloS One 2011

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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

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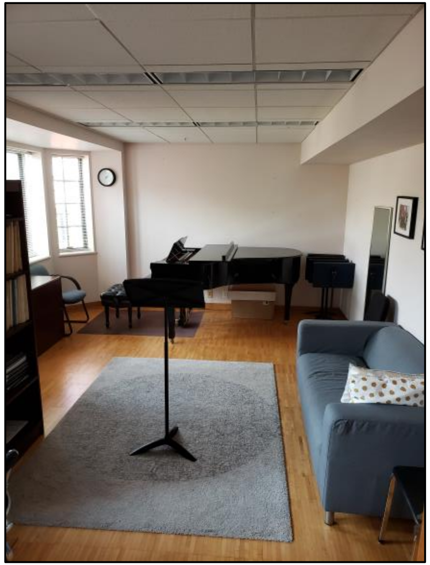
Background of UC-CCM Study

- Initiated by researchers at UC to exam the effects of “return to campus”

Memorial Hall, UC-CCM

- Previously a dormitory
- Teaching and practicing studios
- Over 70 individual practice rooms



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

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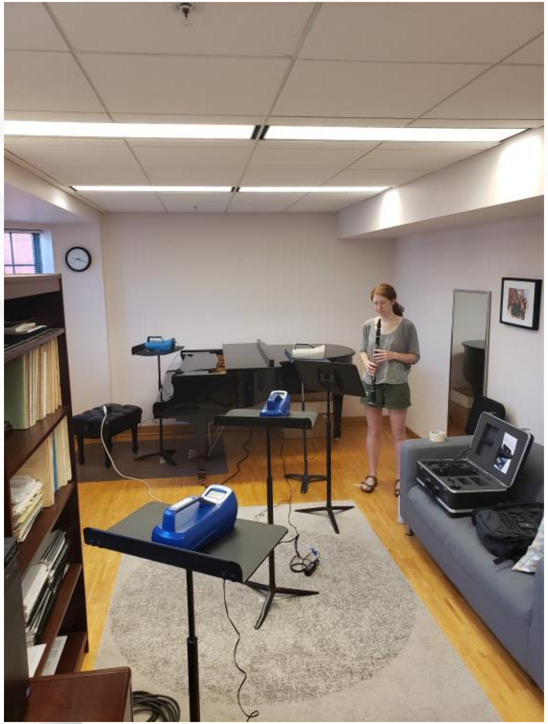
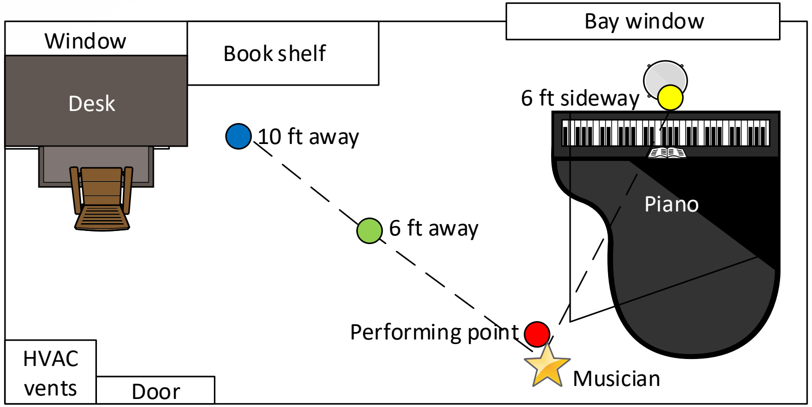
Testing Room



Room 374 of Memorial Hall

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



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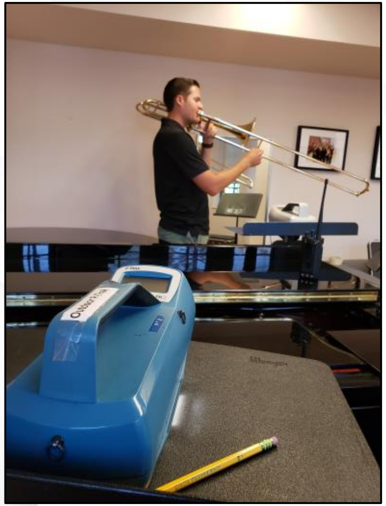
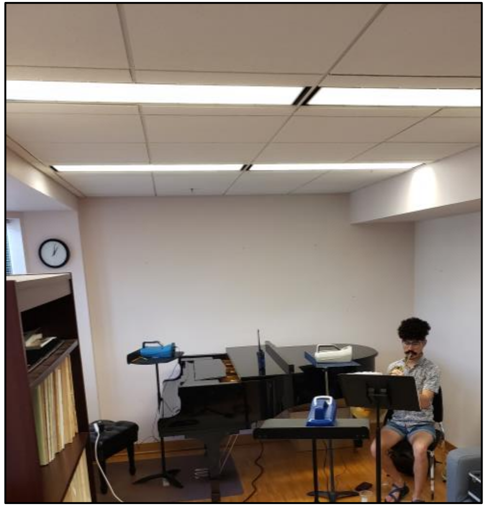
Singing and Wind Instruments

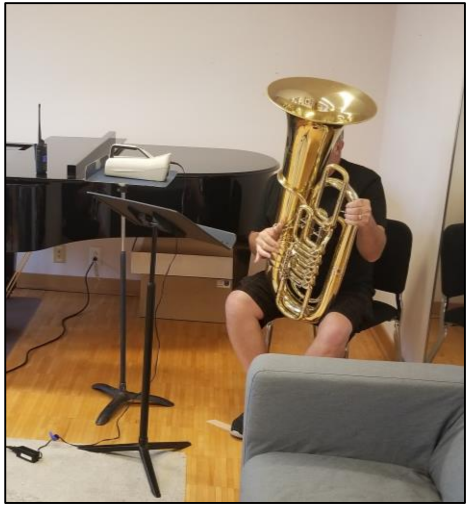
- Two mezzo soprano singers
- Seven wind instruments

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

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

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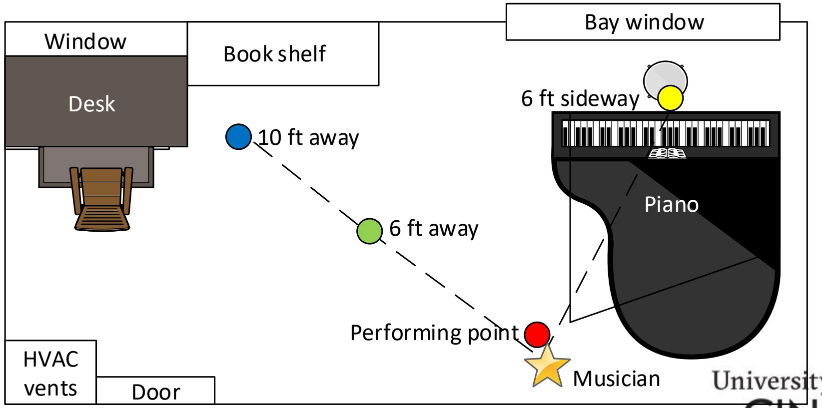
Study Design

- 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



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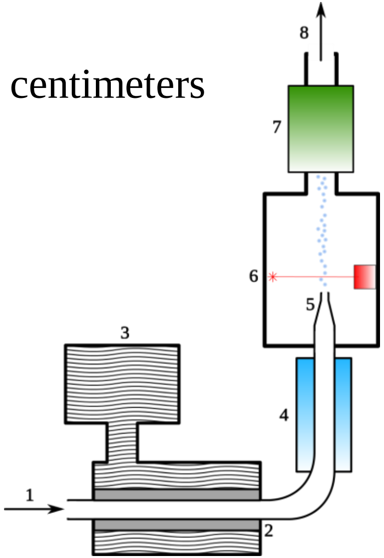
Aerosol Instruments

- 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

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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

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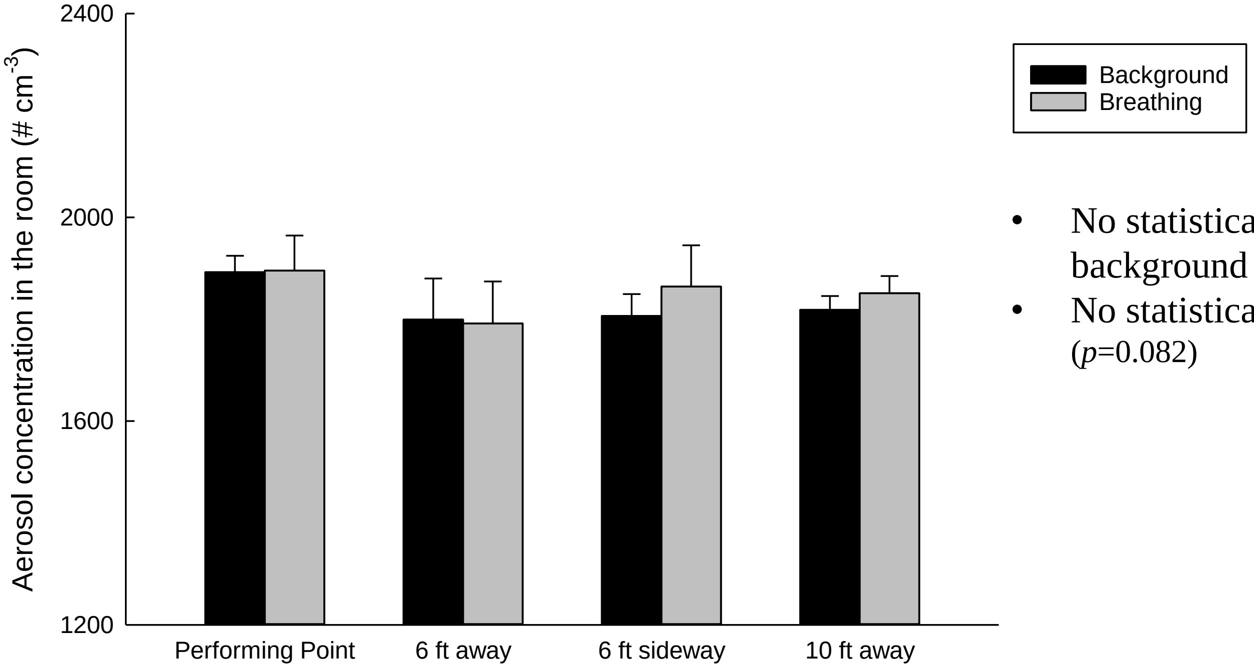
Average Room Concentration

- Breathing versus background



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

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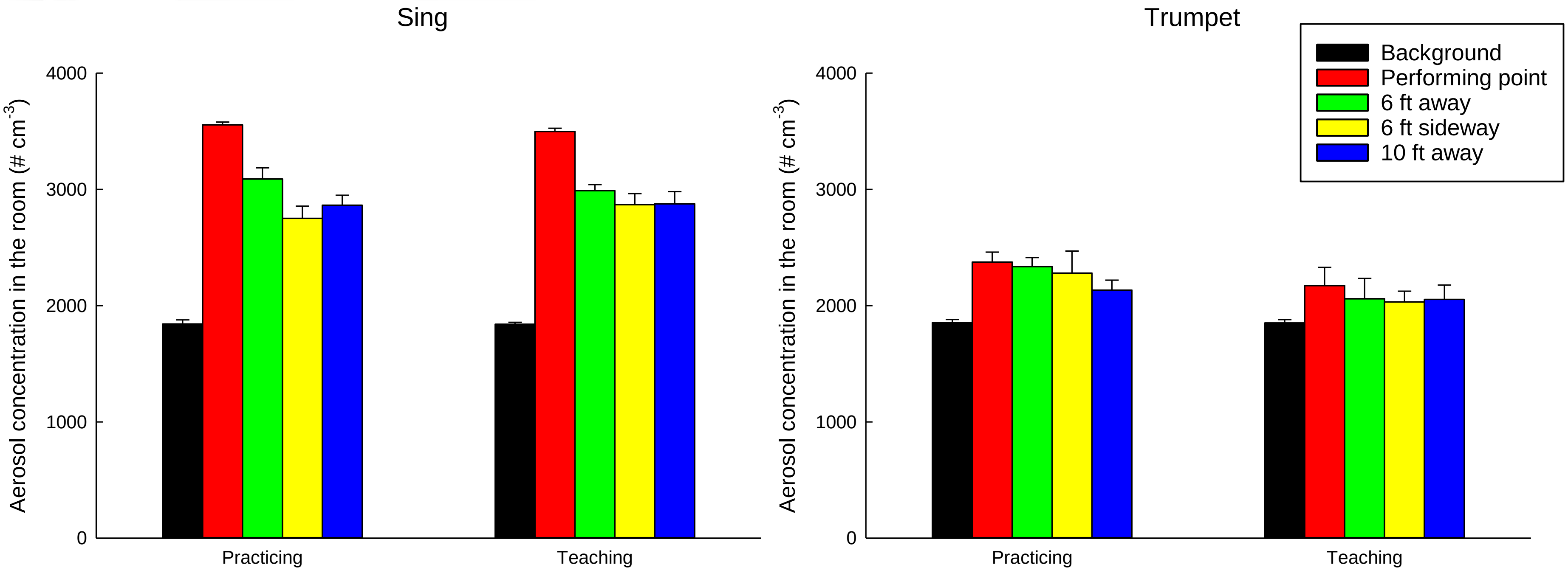
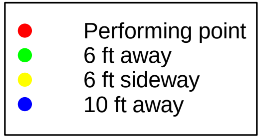
Average Room Concentration

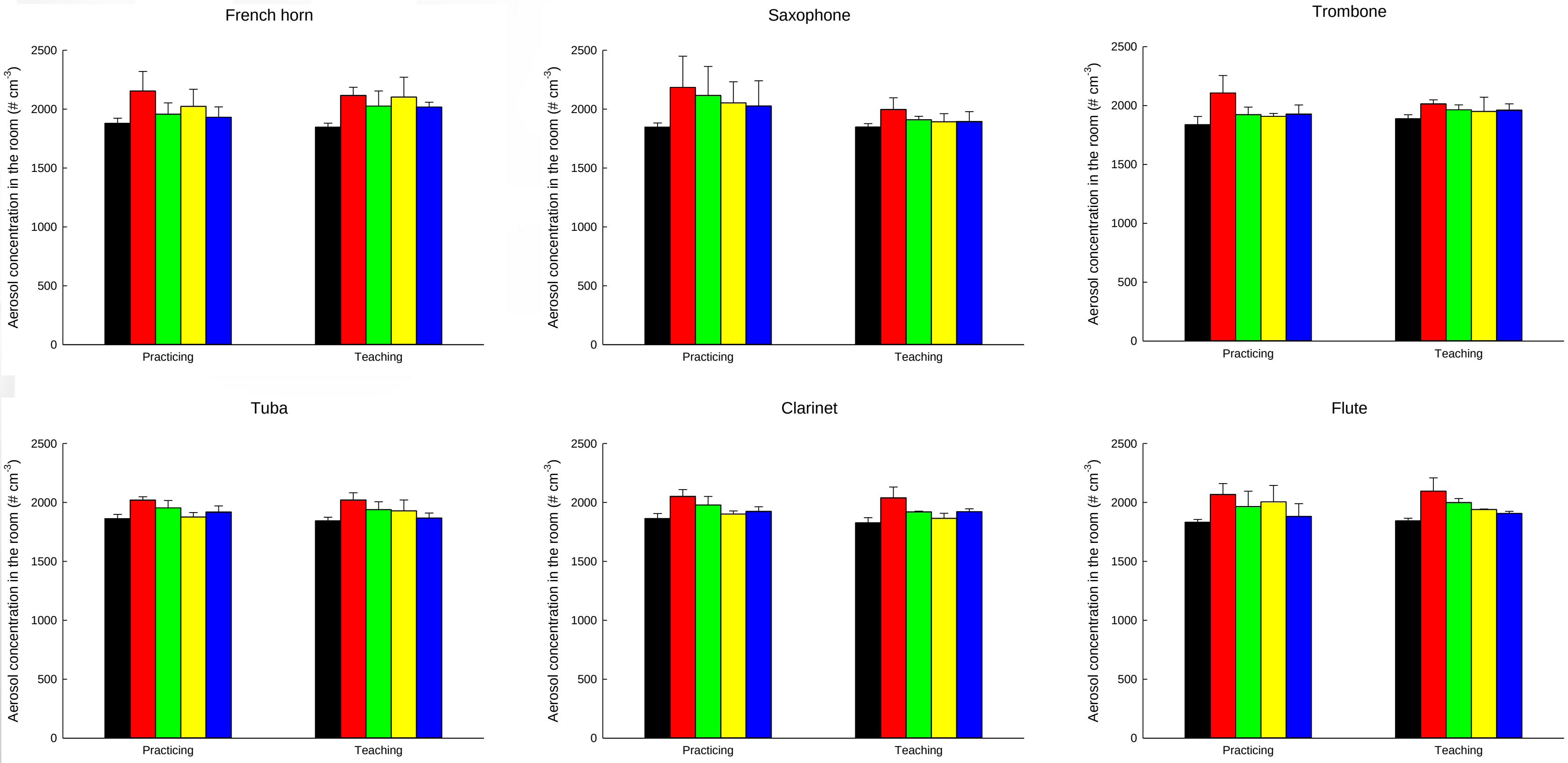
- Singing and trumpet
  - Singing elevated the room concentration by the most
  - Singing and trumpet were statistically different from other instruments ($p<0.001$)



Average Room Concentration

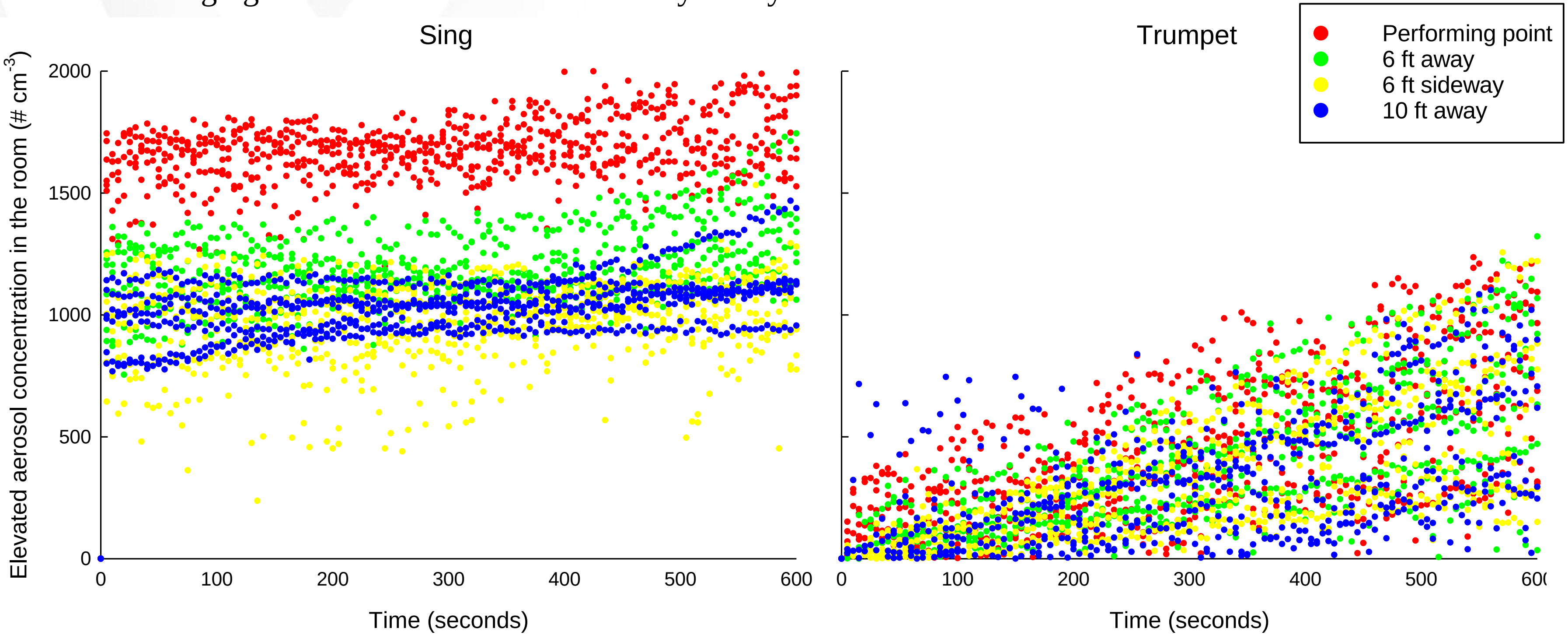
- Other instruments: higher than background but no difference between instruments





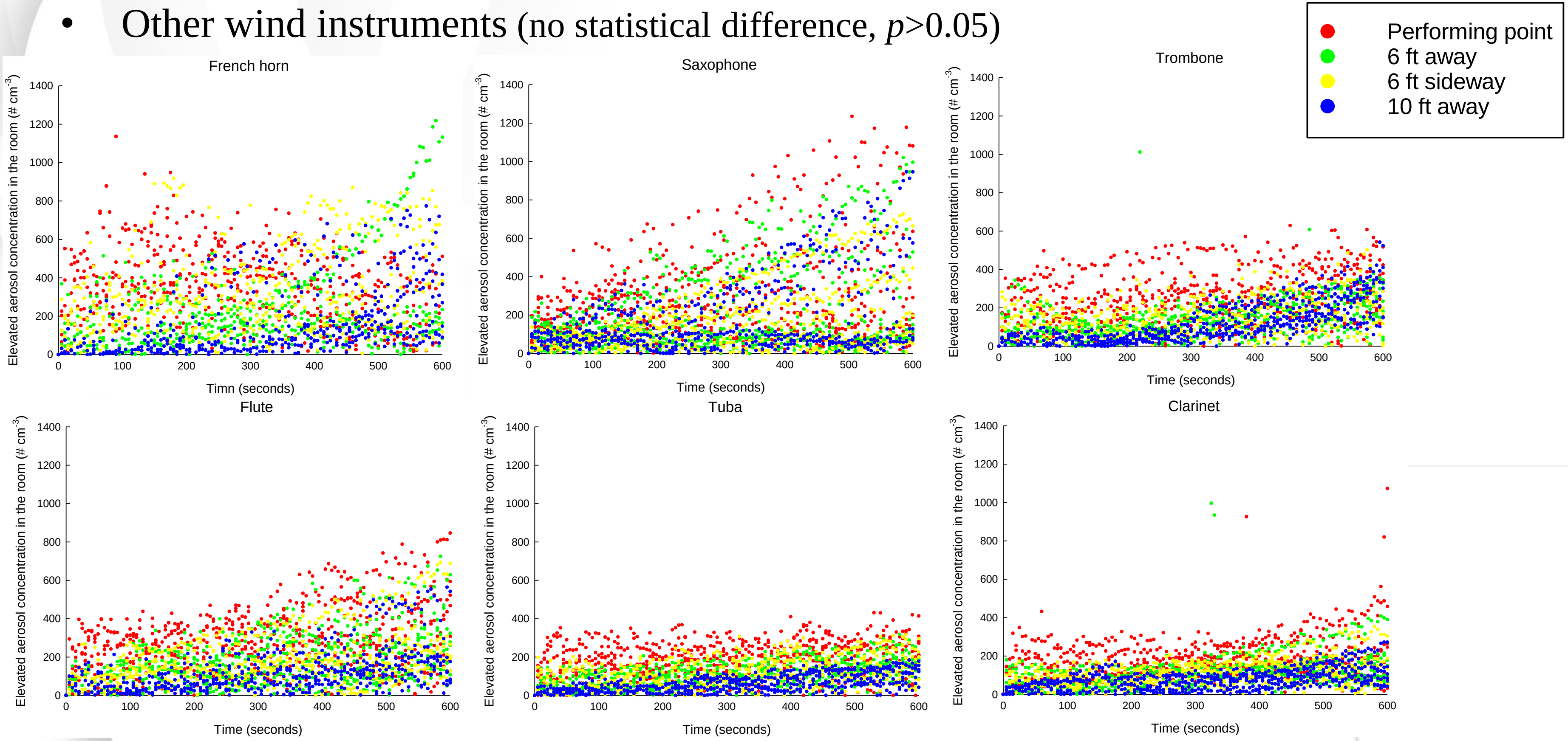
Time series data

- 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)

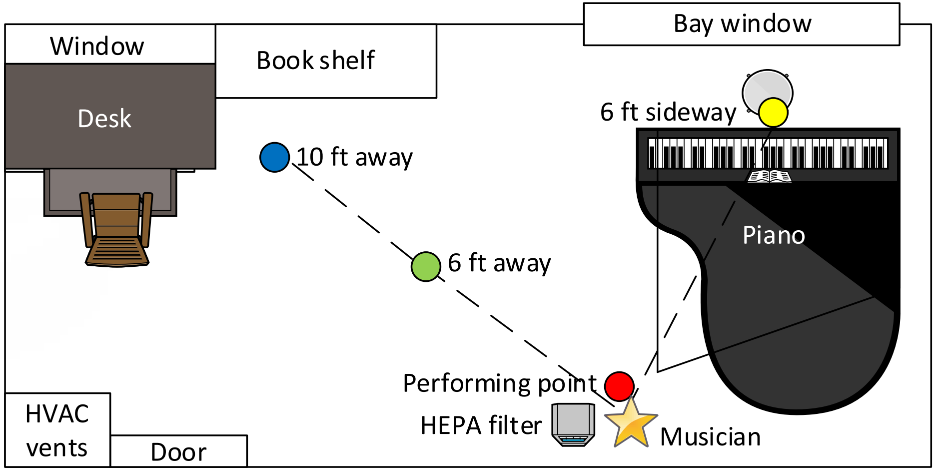
- Other wind instruments (no statistical difference, $p>0.05$)



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

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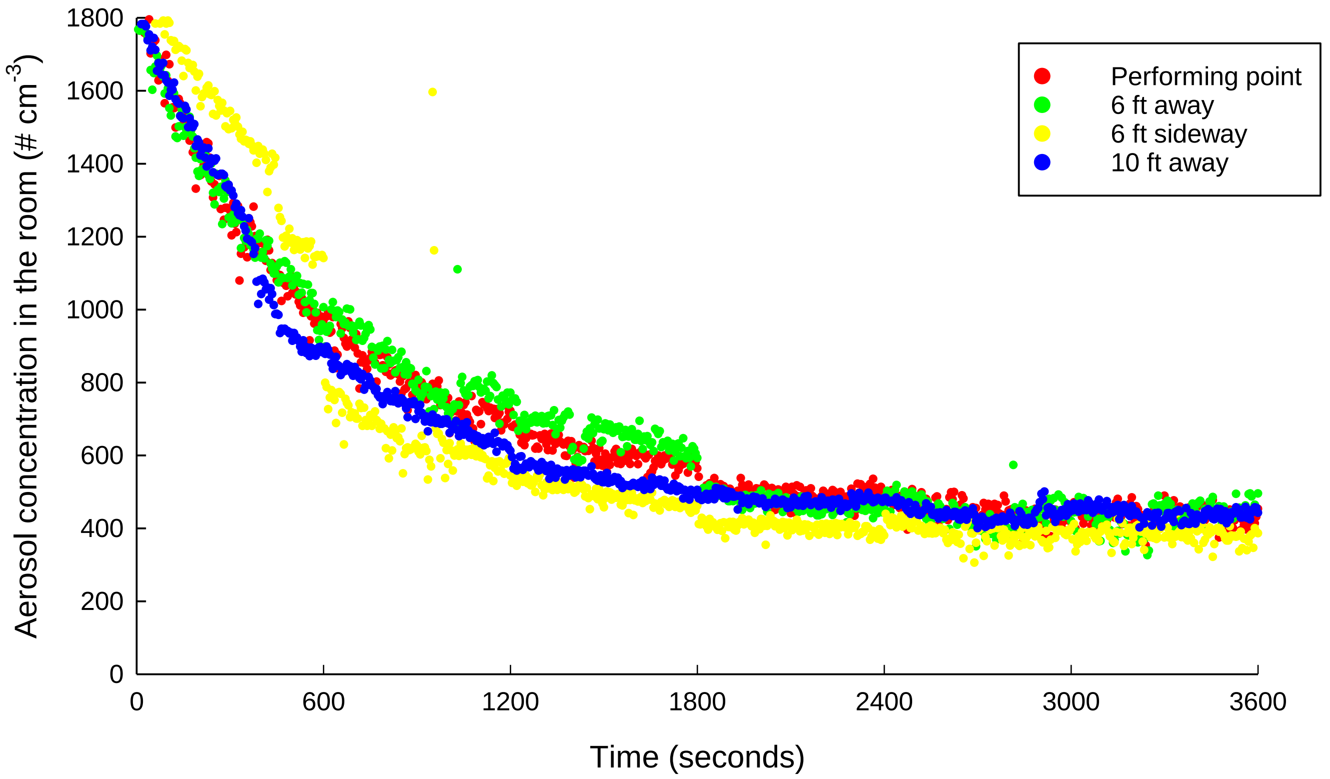
Time Series Data (cont'd)

- 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.

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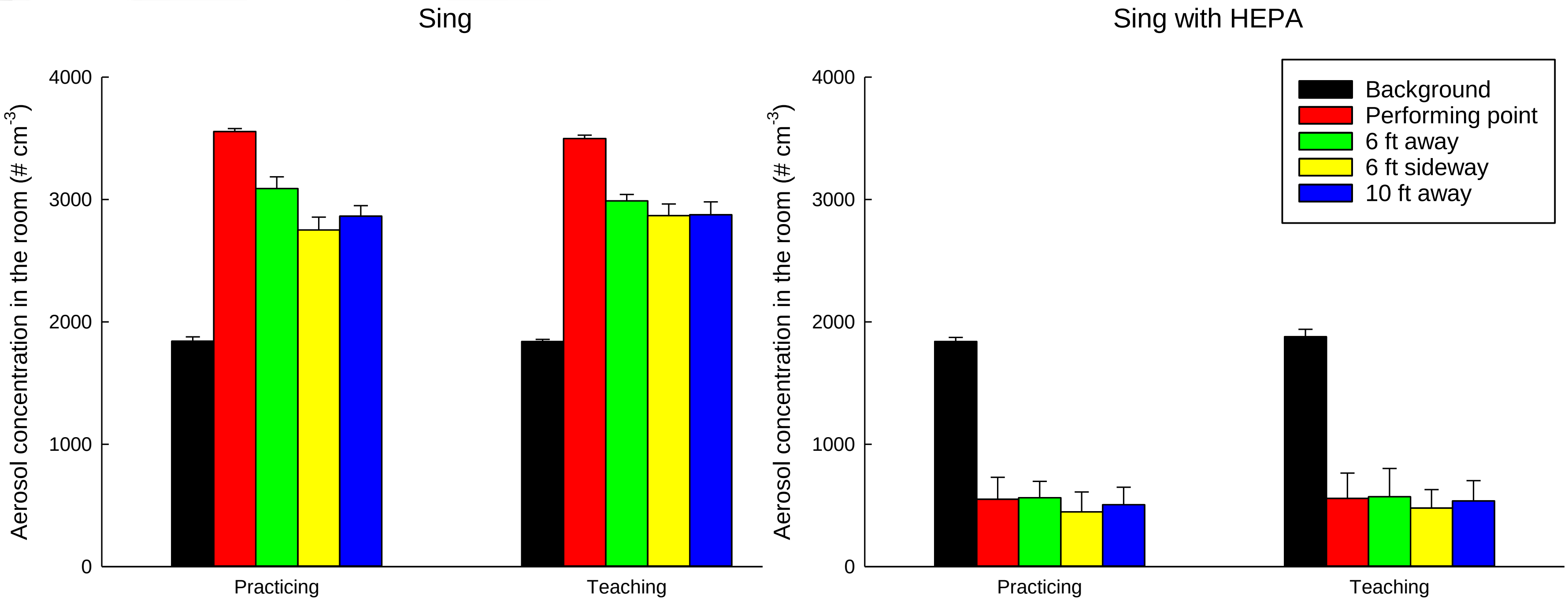
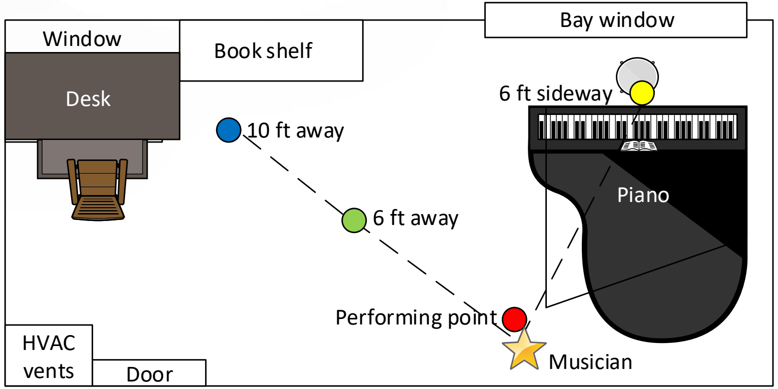
Efficiency of HEPA Filtration

- 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 ($p=0.595$)

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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

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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

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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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- 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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