Literature Review on Outdoors/Groups
May 31, 2020

Summary
In general, it seems that what we know about disease transmission suggests people are much less likely to get infected outdoors. Evidence from contact tracing and analysis of super spreading events supports this analysis. Indeed, in one instance in which an infected individual exposed others in a confined space and outdoors, the transmissions appear to happen entirely in the confined space. There seems to be increasing evidence that a small number of individuals are responsible for a large number of transmissions, often as a result of super spreading events which are occurring inside.

There appear to be three different ways to think about the relationship between outdoor events and virus transmission: 1. An understanding of disease transmission dynamics and implications for outdoors versus/indoors. 2. contact tracing that implicates transmission that happened outdoors, 3. Evidence of a super spreading event associated with outdoor activity (just a special case of contact tracing).

Recommendations
1. Cautiously allow outdoor events.
2. Continue monitoring studies from contact tracing and super spreading events to see if examples of outdoor transmission emerge.
3. Consider increasing requirements around number of bathrooms outdoor events are expected to provide per person.

Disease Transmission Dynamics
1. Aerosol transmission appears to be a primary mechanism of transmission; the CDC has updated their guidelines to emphasize airborne transmission and downplay transmission from surfaces.
2. The outdoors can be tough on the virus (UV, temperature), reducing transmission outside.
3. Air flow dynamics means that the virus is much less likely to reach densities that increase the probability of transmission.
4. There seems to be increasing evidence that a small number of individuals are responsible for most transmissions.
5. There is evidence of viral RNA on surfaces getting put back up in the air; hence disinfection important to reduce airborne transmission.
6. Bathrooms can concentrate the virus, with aerosolization happening in confined spaces from urine, faeces, and breathing.

Contact Tracing
1. Very little evidence from contact tracing that transmission happening outside.
2. One study suggested that transmission was almost 20x as likely inside.

Super Spreading Events
1. No evidence of super spreading events happening primary outside
2. Example that compared spread in outdoor venue versus confined space found spread entirely from confined space.

1. Prather, Wang, and Schooley, Science, May 27, 2020
https://science.sciencemag.org/content/early/2020/05/27/science.abc6197

1. Virus transmission happens through droplets (greater than 5 micrometers and aerosols, less than 5 micometers)
2. Traditional measures focused on droplets and ignored aerosols
3. Aerosols may cause more severe infection because they transfer virus in alveolar region of lungs, which allows the virus to escape the immune system
4. WHO's recommendation on 6 feet based upon droplet studies in 1930's. Aerosols can stay airborne for hours, accumulate over time, at distances much further than 6 feet
5. Viral concentrations more rapidly diluted outdoors
6. Virus inactivated by UV and impacted by temperature, humidity, and pollution (aerosols)
7. If you can smell cigarette smoke, you are picking up aerosols
8. Indoors virus concentrations in aerosols will increase through time
9. Wear masks indoors, even when 6 feet apart
10. Masks recommended; countries with universal masking have had fewer problems

2. Morawska and Cao, Environmental International, June 2020,
https://www.sciencedirect.com/science/article/pii/S016041202031254X

1. Hard to detect airborne viruses empirically because of challenges to sampling, but good mechanistic reasons to believe it is happening, and plenty of empirical evidence that airborne transmission has happened.
2. Aerosol transmission demonstrated for Covid1 and thus likely for covid2
3. Airborne transmission main form of transmission in indoor spaces for covid1 where analyzed (Hong Kong Prince of Wales Hospital, Toronto health care facilities)
4. Focus on indoors because:
    a. Build-up of airborne virus-carrying droplets
    b. High stability of virus indoors
    c. Larger density of people

3. Qian, et al. Preprint, Indoor transmission of SARS-CoV-2
https://www.medrxiv.org/content/10.1101/2020.04.04.20053058v1

1. Analyzed 318 case reports in China involving 3 or more cases
2. Home outbreaks were most common and then transport
3. They only found 1 instance of outdoor outbreak and it only involved 2 cases

4. Liu, et al. Nature, published online April 27, 2020
https://www.nature.com/articles/s41586-020-2271-3_reference.pdf

1. Measured aerosols in 2 Wuhan hospitals
2. Viral aerosols at high levels in toilet areas (patient's breath or aerosolization from faeces or urine), but low in isolation wards and well ventilated patient rooms
3. They did find 2 heavily trafficked outside sites that had moderate levels of viral RNA
4. Sanitization did seem to reduce viral densities
5. Toilets should be ventilated and sanitized
6. Sanitizing surfaces is important because aerosols get resuspended with disturbance

5. Kupferschmidt, Science, May 19,2020
1. The parameter K describes how much a disease clusters

2. One estimate indicates K is higher (less clustering) then MERS or SARS
3. Another estimate is that possibly 10% of the cases cause 80% of the spread
4. Most large transmission clusters involve aerosol transmission
5. Shouting or singing may be involved with high transmission rates

6. Nishiura, preprint (cited by Kupferschmidt)
https://www.medrxiv.org/content/10.1101/2020.02.28.20029272v2.full.pdf

1. Based upon contact tracing, the odds of a primary case transmitting in a closed environment was 19x that in an outdoor environment (95 CL: 6-58)

7. Endo et al, preprint (cited by Kupferschmidt)
https://wellcomeopenresearch.org/articles/5-67

1. Matched model to data from different infected countries
2. 10% of the cases cause 80% of the spread (K=0.1)
3. This estimate similar for MERS and SARS
4. Lower than estimate of K found by Qifang Bi et al, which Endo et al believe was overestimate
5. Transmission could be drastically reduced by reducing rare superspreading events

8. Stadnytskyi et al. PNAS, May 13, 2020
https://www.pnas.org/content/early/2020/05/12/2006874117

1. They used laser to visualize speech droplets (not aerosols)
2. Speech generates airborne droplets that can transmit the disease and remain airborne 10 minutes or longer in confined spaces
3. The reason it mentions confined spaces is because the air needs to be stagnant to maintain sufficient densities of virus for transmission

9. CDC
https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html, accessed May 30, 2020

1. Transmission can occur by touching a surface with a virus, but this is not thought to be the main mode of transmission
2. Airborne person-person spread seems to be main mode of transmission
3. May be spread by people not showing symptoms

10. Kay, Quillette, April 23, 2020 (cited by Erin Bromage)
https://quillette.com/2020/04/23/covid-19-superspreader-events-in-28-countries-critical-patterns-and-lessons/

1. Created database of 58 super spreading events
2. 19 involved parties/liquor-fueled mass attendance events (weddings, engagements, birthdays), 9 linked to church/missionary work, 6 business networking, 5 funerals
3. Almost all took place indoors, though some were mixed outdoor-indoor events
4. Seems to happen whenever large groups of people in confined spaces are in each other's faces
5. Not examples of SSE involving theatres, mass transit, opera, symphony

11. Blocken et al, preprint, Towards aerodynamically equivalent COVID19 1.5 m social distancing for walking and running, (cited by Vox April 24, 2020, **Why you're unlikely to get the coronavirus from runners or cyclists)**

http://www.urbanphysics.net/Social%20Distancing%20v20_White_Paper.pdf

1. Aerodynamics study looking at airborne transmission when two individuals are walking or running
2. Exposure can happen for people in slipstream at distances much greater than 6 feet
3. Only analyzed whether virus present, not whether sufficient load to cause transmission

12. Riley. Environment International, 1982. Indoor Airborne Infection
https://www.sciencedirect.com/science/article/pii/0160412082900435

1. Airborne infection primarily happens inside because dilution happens rapidly outside

13. Santarpia et al. 1 Transmission Potential of SARS-CoV-2 in Viral Shedding Observed at the University of Nebraska Medical Center, preprint (cited by Smithsonian **How Coronavirus Spreads through the Air: What We Know So Far)**
https://www.medrxiv.org/content/10.1101/2020.03.23.20039446v2.full.pdf

1. Sampled for viral RNA in the air and on stuff at a hospital in Nebraska
2. Food in the air and on stuff
3. Suggests disinfection important as is respiratory infection

14. Doremalen et al. New England Journal of Medicine. March 17, 2020. Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1
https://www.nejm.org/doi/full/10.1056/NEJMc2004973?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%3dpubmed

1. Evaluated stability of covid1 and covid2 on surfaces and in aerosols
2. Two viruses have similar stability in surfaces and in air
3. Aerosol and fomite transmission plausible

15. Ye Shen et al., Airborne transmission of COVID-19: epidemiologic evidence from two outbreak investigations, preprint
https://www.researchgate.net/publication/340418430_Airborne_transmission_of_COVID-19_epidemiologic_evidence_from_two_outbreak_investigations

1. Analyzed outbreak involving two buses going to a single outdoor event
2. Analyzed outbreak in conference room
3. People who shared a bus with an infected person got sick, people on the other bus did not, even though they participated in the same outdoor event
4. Distribution of seating of people who got sick implicated air flow as key
5. 50% exposed in a conference room with no circulation got sick