Covid-19 Infection via Aerosol Particles
Comparative Assessment of Interior Spaces with regard to their Situationally Dependent R Value

[1]Martin Kriegel, [1]Anne Hartmann

[1]Hermann Rietschel Institute: Research Cluster for Energy, Comfort, and Health in Buildings, Technical University of Berlin

DOI: http://dx.doi.org/10.14279/depositonce-11387
Version: 02/10/2021

Translated by Nicolas Seth Reeves

Introduction

The deciding factor with regard to the risk of infection via aerosol particles in enclosed spaces is the size of the dose of inhaled particles.
This dose depends on:

- The strength of the particle-emitting source [rate of emission]
- Respiratory activity of the source and the recipient
- Concentration of aerosols in the space
- Amount of time spent in the space

The wearing of a MNS {mouth-and-nose protection} or MNB {mouth-and-nose covering} mask somewhat reduces the emission of aerosols and the number of aerosols inhaled. Breathing, speaking, singing, etc. also influence aerosol emission; respiratory activity varies with physical activity, which, in turn, changes the number of aerosols emitted and the amount breathed in by a healthy person. In addition, a room's airflow regulates the number of aerosol particles in the air (concentration). Finally, the amount of time spent in a space determines the dose of aerosol particles that are ultimately inhaled.

Comparative Assessment of Interior Spaces

The determination of absolute risk of infection via aerosol particles is not yet sufficiently grounded in evidence. However, the necessary dose {required to become infected} can be ascertained quite well. To do so, known respiratory flow rates for various activities [1-3] and {aerosol-emitting} source strengths [4-8] are used in combination with as well as data pertaining to relevant norms and guidelines [9-11] for the ventilation of interior spaces, which *{sic}* set standards for per-capita ventilation rates in rooms designed for different purposes. Characteristic usage values were used to represent a person's amount of time spent in a given interior space. The comparisons below assume that AHA+L {following distancing rules, heeding hygiene guidelines, and wearing recreational masks plus ventilating the space regularly} rules, as well as the guidance of the BAuA {Bundesanstalt für Arbeitsschutz und Arbeitsmedizin} and the UBA {Umweltbundesamt} [12, 13], are followed.

The wearing of a mouth-and-nose-covering mask for regular use or a mouth-and-nose-protection mask for medicinal use has a total filtration efficiency of 50% [14]. This value represents the combined effect of the reduced particle emission of the infected person and the healthy persons' {heightened} filtration capacity while inhaling. Even if this assumption proved to be incorrect, it would only have an affect on our comparative assessment in cases where a hypothetical scenario in which individuals are wearing masks is being compared to a scenario in which individuals are not wearing masks.

In the following assessment, it is always assumed that an infected person is occupying the space together with other health people. The overall probability that a given space even contains an infected person is not taken into account.

Figure 1 displays selected interior spaces and usage types. For each scenario, the amplification relative to an arbitrary R_s value ≤ 1 is given. The calculation of the R_s value can be derived from reference [15]. The R_s value represents the number of persons infected by an infected person who is present in the interior space at the same time. Even if the individual R_s values turned out to be insufficiently evidence-based, this error would have no bearing on the accuracy of the comparative assessment {between different scenarios}; were this indeed the case, each of the depicted bars would be displaced either to the right or to the left by an equal distance {scaled by a common factor?}.

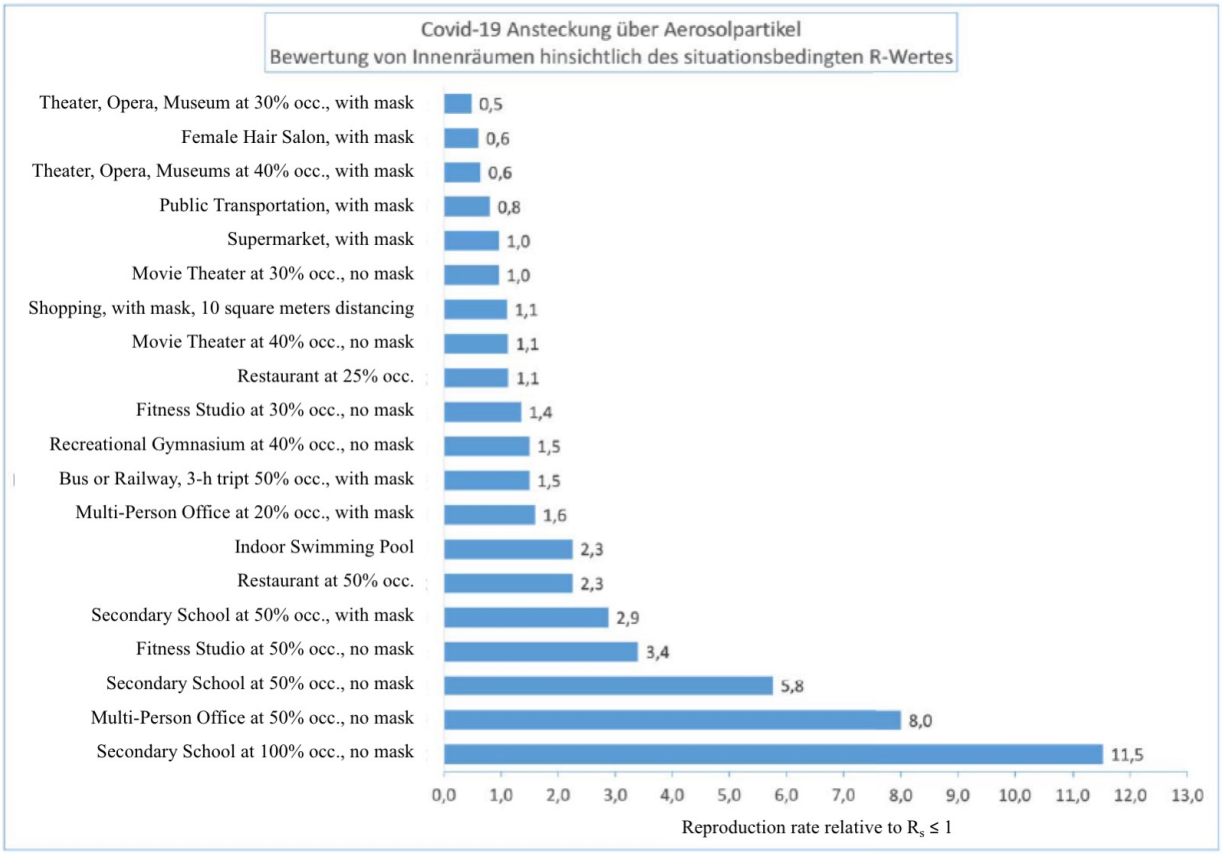

Figure 1: Comparative depiction of ordinary interior space situations

Explanatory Example:

A person at the supermarket has an infection risk of ≤ 1. This means that in this situation, a maximum of one additional person will become infected. In comparison, the multi-person office at 50% occupancy, without mask wearing at one's workstation, has an infection risk value of 8. This means that the risk in this case is 8 times higher than at the supermarket.
On the other hand, a visit to the theater with 30% occupancy and mask wearing, even at one's own seat, is only half as risky as a visit to the supermarket.

The range of scenarios depicted in Figure 1 can be expanded to include others, as desired.

Boundary conditions {Parameters} for the comparison depicted in Figure 1:

Interior Space	Time spent in space (hours)	standard maximum air volume flow rate (m3/hr/person)	Characteristic Activity Intensity
office 50% full without mask	8	30	II
office 20% full with mask	8	30	II
high school without mask 100% full	6	25	II
high school 50% full without mask	6	25	II
high school 50% full with mask	6	25	II
public transport with mask	0.5	20	II
supermarket with mask	1	25	III
hair salon with mask	2	20	II
Shopping with mask und 10 qm/Person	2	20	III
Restaurant 50% full	1.5	20	II
Restaurant 25% full	1.5	20	II
Theater Opera Museum 30% full with mask	2	30	II
Theater Opera Museum 40% full with mask	2	30	II
Movie theater 30% full without mask	2	30	II
Movie theater 40% full without mask	2	30	II
Fitness studio 50% full without mask	1.5	40	IV
Fitness studio 30% full without mask	1.5	40	IV
Recreational gym 50% full without mask	1	30	IV
Indoor pool	2	40	IV
Bus or train 3hr trip 50% full	3	30	II

Table 1: Selection of boundary conditions {parameters?} for the comparative assessment of interior spaces

Activity Intensity Levels as Boundary Conditions {Parameters?}:

Next to the strength of emission of aerosols through breathing, speaking, singing, etc., the type of activity also affects the respiratory flow rate. Taken together, these impact the number of exhaled, potentially-virus-laden aerosol particles and affect, in turn, the volume of potentially contaminated air inhaled by healthy persons [1-8, 15].

I. Lying down, breathing
II. Sitting, standing, breathing, speaking
III. Light physical activity, walking, breathing, speaking occasionally
IV. Heavy physical activity, playing sports, speaking occasionally in a loud voice

Conclusion:

Situationally dependent R_s values for the shared occupancy of various interior spaces can be estimated based on the infection risk model outlined in reference [15]. Due to the dynamically changing scientific understanding of infection probability, particularly with regard to mutant strains, comparative assessment of interior spaces, taking into account protective measures, constitutes a method for evaluating everyday situations. This is because the bars in Figure 1 would shift either to the right or the left in parallel fashion in response to changes in the medicinal assessment of the infectious capability {of Covid-19}.

Bibliography:

[1] A. Cordova and I. Latasa, "Respiratory flows as a method for safely preventing the coronvirus transmission (COVID-19)," *Apunts Sports Medicine,* vol. 55, pp. 81-85, 2020.
[2] J. Jiang, R. Hanna, M. Willey and A. Rieves, "The measurement of airflow using Singing helmet that allows free movement of the jaw," *Journal of Voice,* vol. 30, no. 6, pp. 641-648, 2016.
[3] R. Dumond, S. Gastinger, H. Rahman, A. Le Faucheur, P. Quinton, H. Kang and J. Prioux, "Estimation of respiratory volume from thoracoabdominal breathing distances: comparison of two models of machine learning," *European Journal of Applied Physiology,* vol. 117, pp. 1533-1555, 2017.
[4] Asadi, S.; Wexler, A.S.; Cappa, C.D.; Santiago Barreda, S.; Bouvier, N.M.; Ristenpart, W.D. Aerosol emission and superemission during human speech increase with voice loudness. Sci. Rep. 2019, 9, 2348
[5] Asadi, S.; Wexler, A. S.; Cappa, C. D.; Barreda, S.; Bouvier, N. M.; Ristenpart, W. D. Effect of voicing and articulation manner on aerosol particle emission during human speech, PLOSOne 15(1), https://doi.org/10.1371/journal.pone.0227699
[6] Hartmann, A.; Lange, J.; Rotheudt, H.; Kriegel, M. Emission rate and particle size of bioaerosols during breathing, speaking and coughing, PrePrint 10.14279/depositonce-10331
[7] Morawska, L.; Johnson, G.R.; Ristovski, Z.D.; Hargreaves, M.; Mengersen, K.; Corbett, S.; Chao, C.Y.H.; Li, Y.; Katoshevski, D. Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities. J. Aerosol Sci. 2009, 40, 256–269.

[8] Gregson, F. K. A.; Watson, N. A.; Orton, C. M.; Haddrell, A. E.; McCarthy, L. P.; Finnie, T. J. R.; Gent, N.; Donaldson, G. C.; Shah, P. L.; Calder, J. D.; Bzdek, B. R.; Costello, D.; Reid, J. P. Comparing the Respirable Aerosol Concentrations and Particle Size Distributions Generated by Singing, Speaking and Breathing, Preprint, ChemRXiV,
[9] DIN V 18599-10 Energetische Bewertung von Gebäuden - Berechnung des Nutz-, End- und Primärenergiebedarfs für Heizung, Kühlung, Lüftung, Trinkwarmwasser und Beleuchtung - Teil 10: Nutzungsrandbedingungen, Klimadaten
[10] EN 13779 Lüftung von Nichtwohngebäuden - Allgemeine Grundlagen und Anforderungen für Lüftungs- und Klimaanlagen und Raumkühlsysteme
[11] Technische Regeln für Arbeitsstätten, ASR 3.6 Lüftung
[12] Umweltbundesamt: Lu¨ften in Schulen, Empfehlungen des Umweltbundesamtes zu Luftaustausch und effizientem Lu¨ften zur Reduzierung des Infektionsrisikos durch virushaltige Aerosole in Schulen 5 Technische Universität Berlin | Hermann-Rietschel-Institut | Fachgebiet Energie, Komfort und Gesundheit in Gebäuden | Marchstr. 4 D-10587 Berlin
[13] BAuA, Hrsg., 2020. Infektionsschutzgerechtes Lu¨ften - Hinweise und Maßnahmen in Zeiten der SARS-CoV-2- Epidemie.
[14] Schumann, L.; Lange, J.;Rotheudt, H.; Hartmann, A.; Kriegel, M.; Experimentelle Untersuchung der Leckage und Abscheideleistung von typischen Mund-Nasen-Schutz und Mund-Nasen-Bedeckungen zum Schutz vor luftgetragenen Krankheitserregern, PrePrint 10.14279/depositonce-10857
[15] Kriegel, M.; Buchholz, U.; Gastmeier, P.; Bischoff, P.; Abdelgawad, I. Hartmann, A.; Predicted Infection Risk for Aerosol Transmission of SARS-CoV-2; PrePrint 10.1101/2020.10.08.20209106