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SARS-CoV-2 Far Field (>2m) Transmission Risk and the Role of Ventilation

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CIBSE Natural Ventilation Chair

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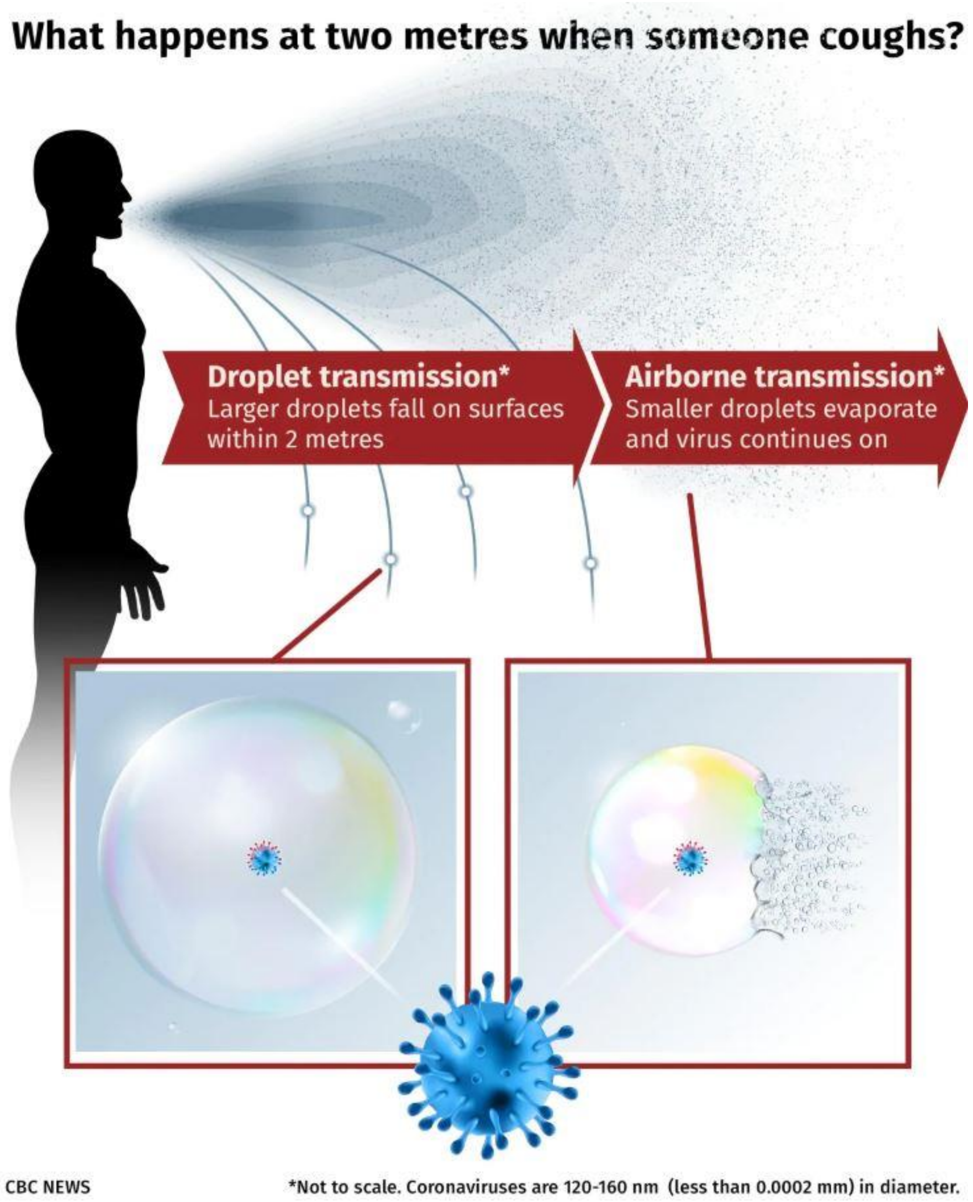
Aerosols



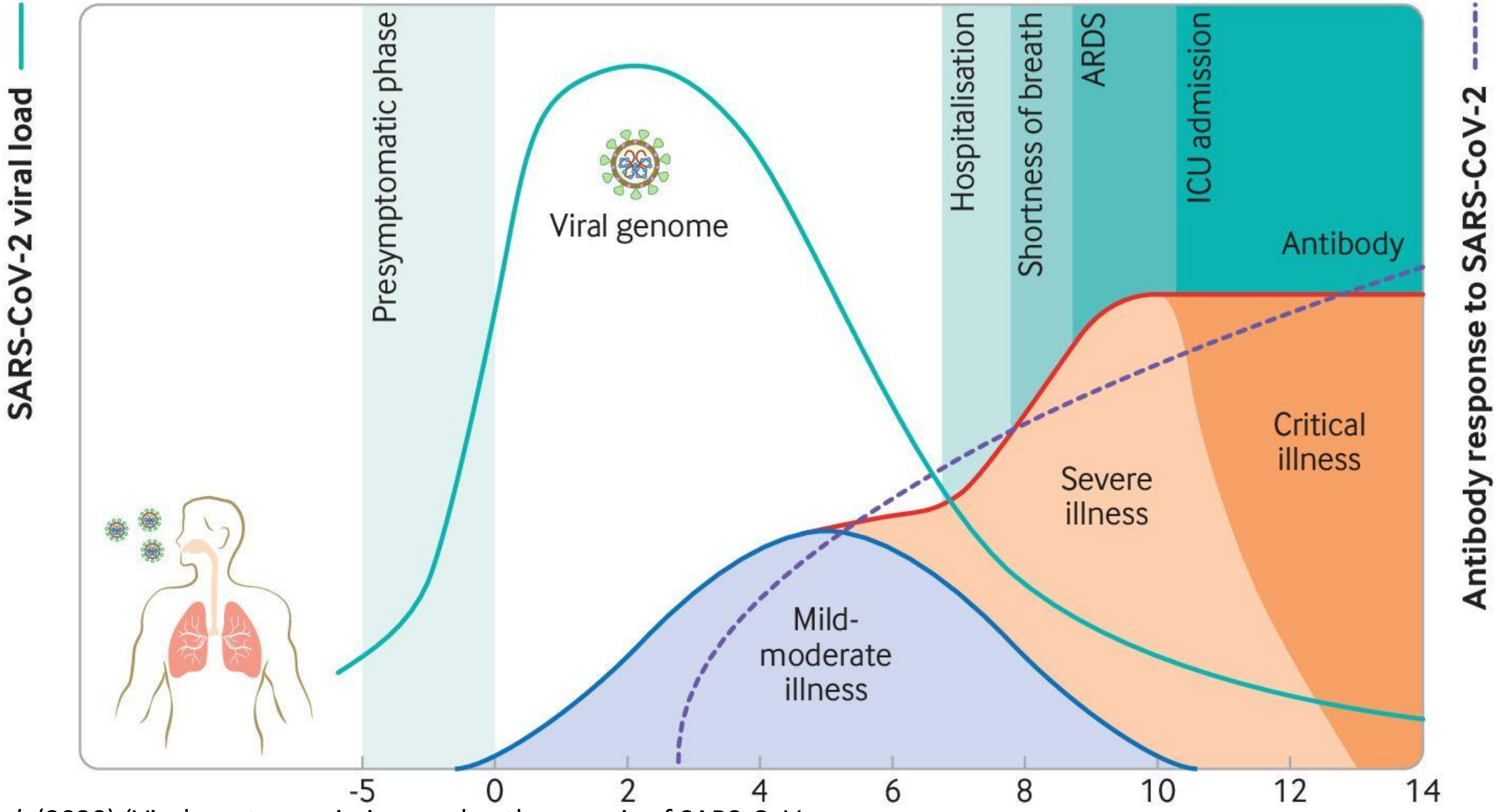
Respiratory Activity	Relative aerosol emission[1]
Breathing	1
Talking	5
Singing	30

[1]Derived from Morawska, L. *et al.* (2009) ‘Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities’, *Journal of Aerosol Science*, 40(3), pp. 256–269. doi: 10.1016/j.jaerosci.2008.11.002.

See Jones, B. *et al.* (2020) ‘Modelling uncertainty in the relative risk of exposure to the SARS-CoV-2 virus by airborne aerosol transmission in Buildings’, B*uilding and Environment*. 191:107617 doi:10.1016/j.buildenv.2021.107617

Aerosols

Viral load



Cevik, M. *et al.* (2020) 'Virology, transmission, and pathogenesis of SARS-CoV-2', *BMJ (Clinical research ed.)*, 371, p. m3862. doi: 10.1136/bmj.m3862

Mass balance

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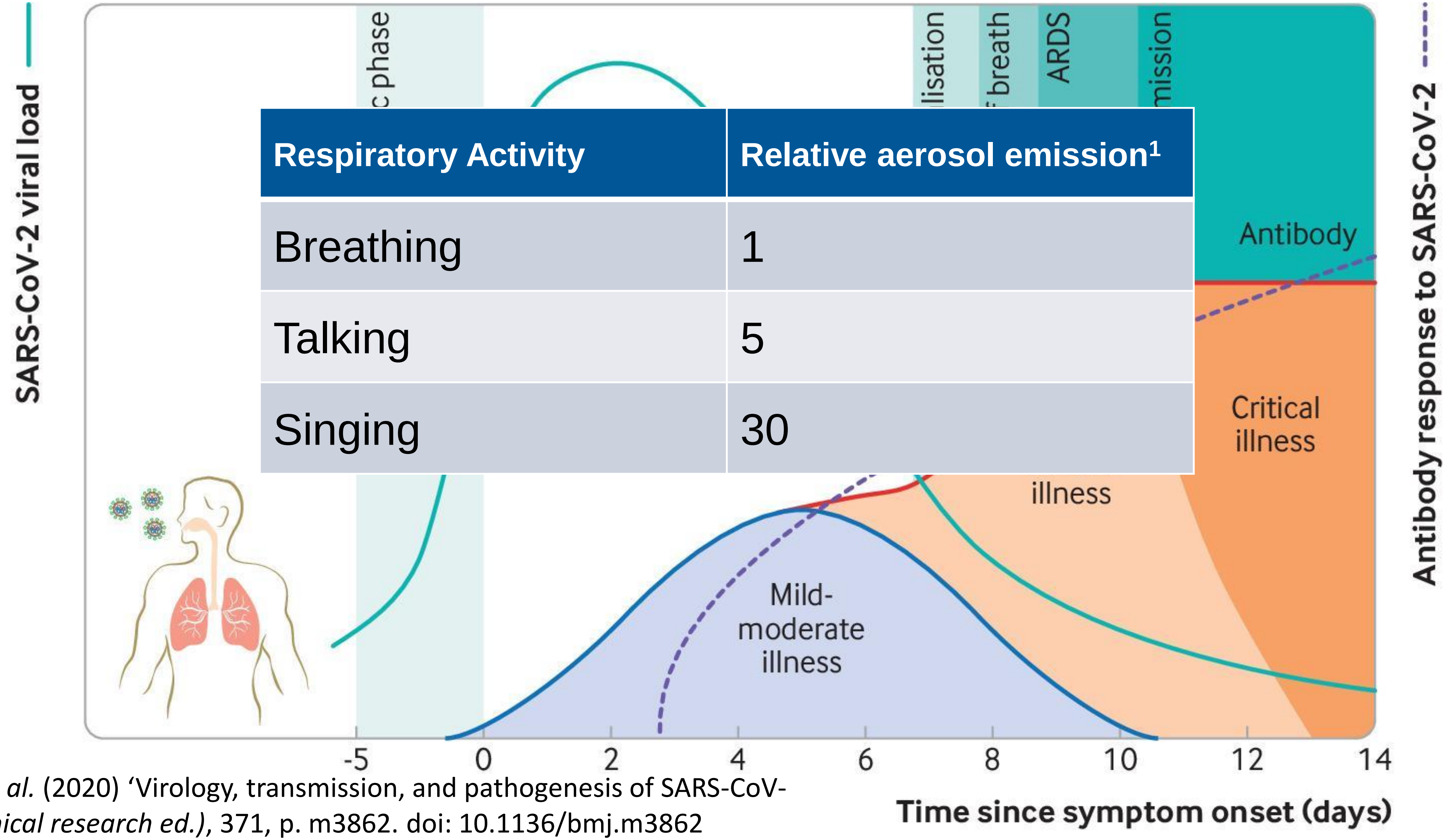

Cevik, M. *et al.* (2020) 'Virology, transmission, and pathogenesis of SARS-CoV-2', *BMJ (Clinical research ed.)*, 371, p. m3862. doi: 10.1136/bmj.m3862

Processes for a general model

Jones, B. *et al.* (2020) 'Modelling uncertainty in the relative risk of exposure to the SARS-CoV-2 virus by airborne aerosol transmission in Buildings', *Building and Environment*. 191:107617
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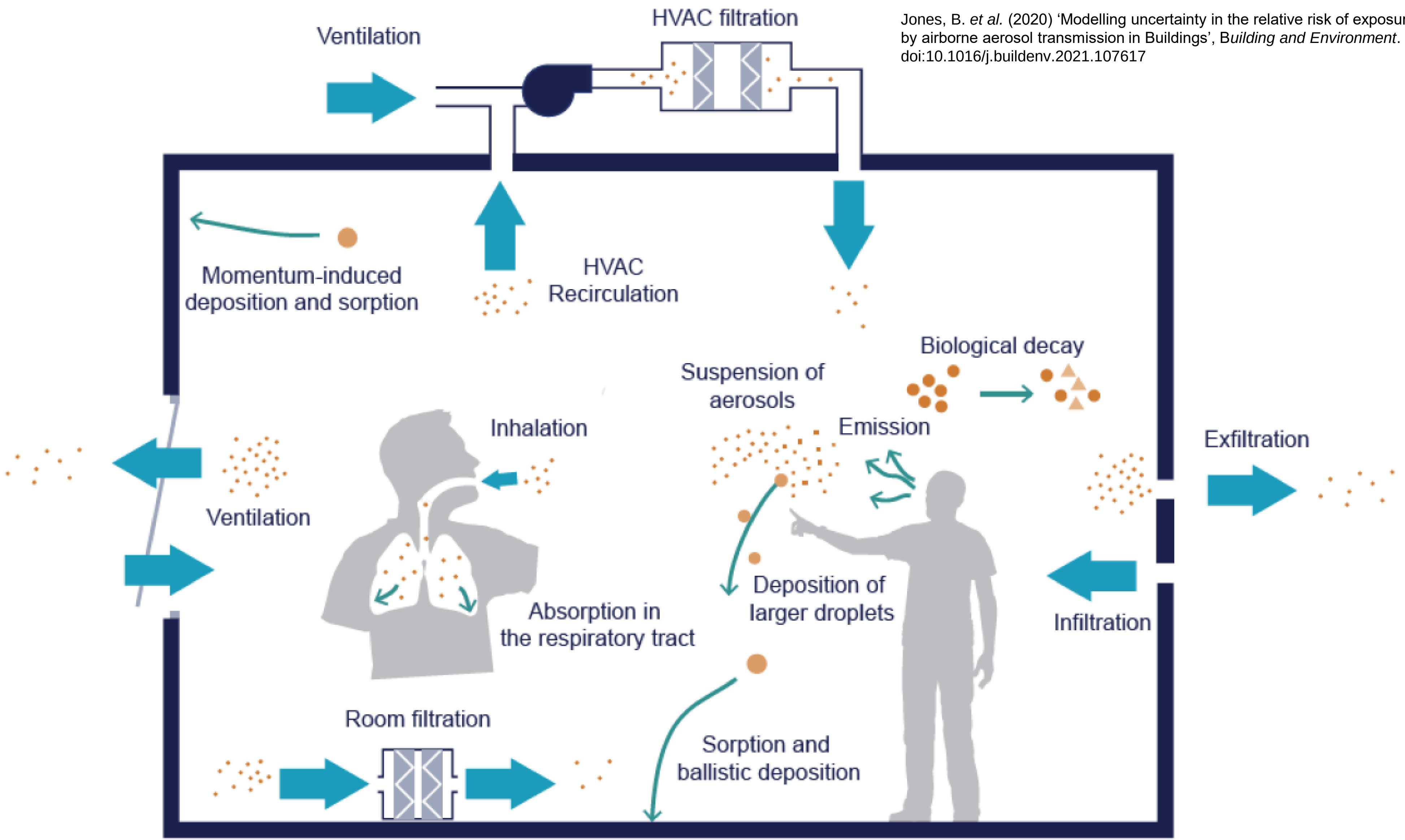
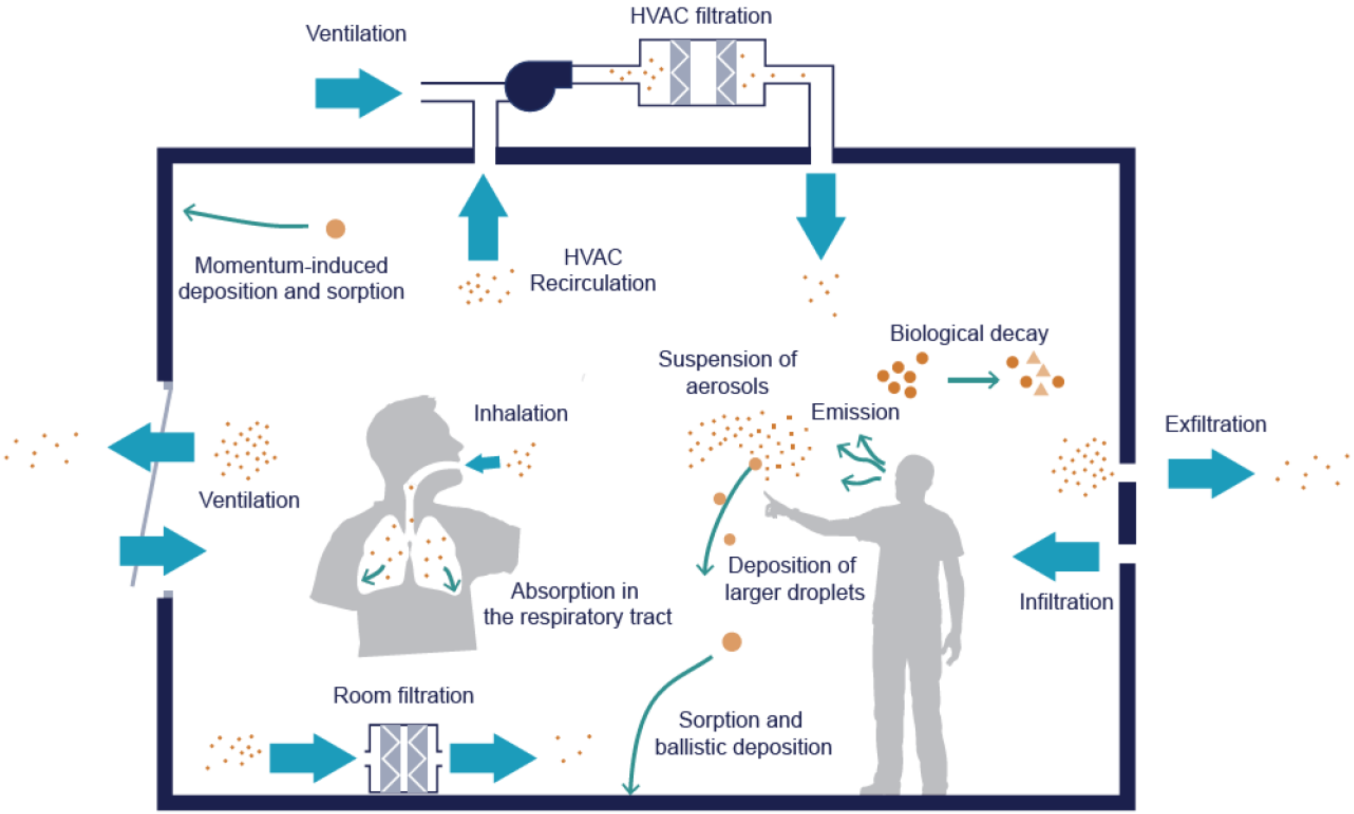


Image courtesy of Patrick Sharpe & Catherine O'Leary.

Mass balance

1. Gains
    1. Emission from a person
    2. Entry from outside via ventilation
    3. Entry from outside via infiltration
    4. Virus already present in the space
2. Losses
    1. Dilution via ventilation
    2. Surface deposition
    3. Biological decay and UVC denaturing
    4. Respiratory tract absorption
    5. Filtration



Mass balance

1. Gains
    1. Emission from a person
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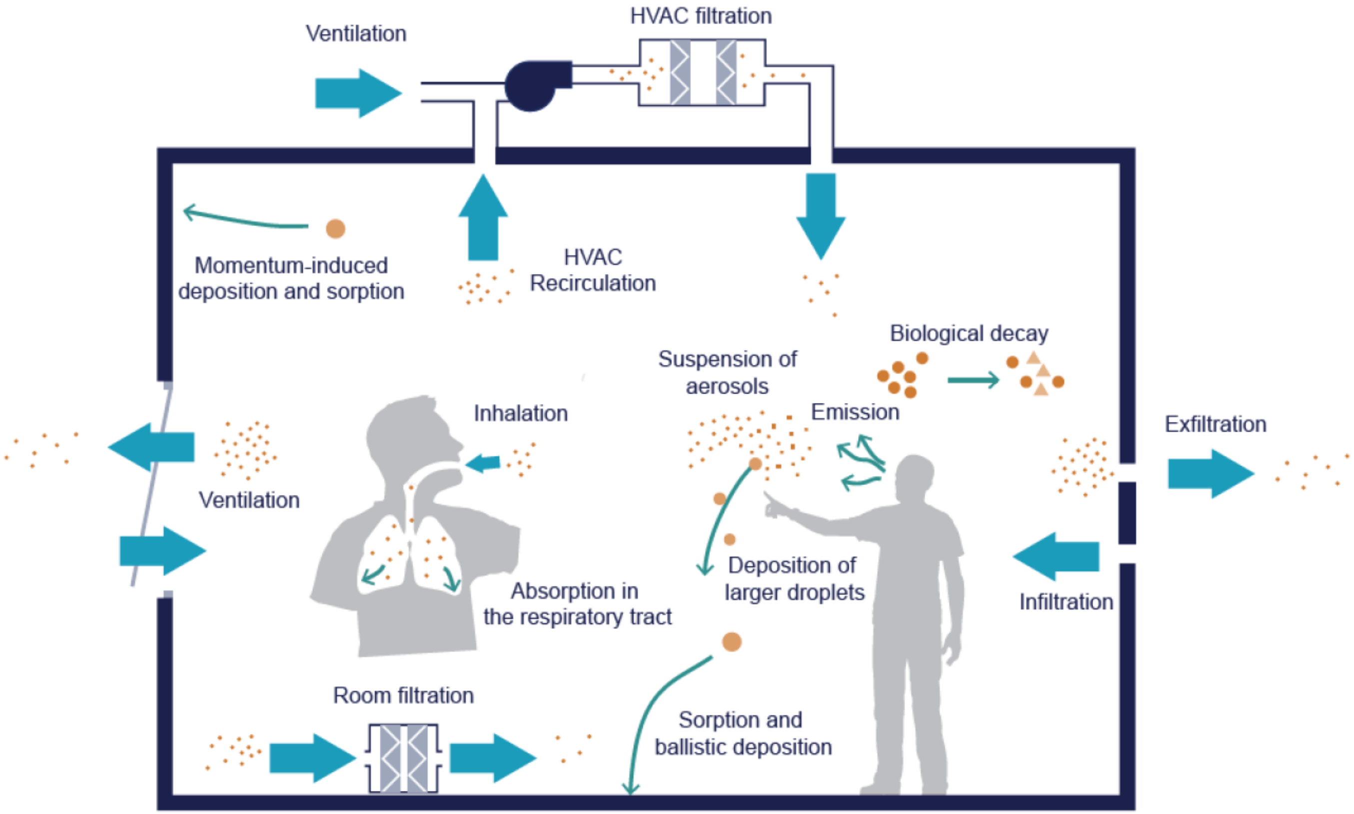

Number of viral genome RNA copies in a space, *n*

1. Gains
   1. Emission from a person, G (#/s)
   2. Entry from outside via ventilation [none]
   3. Entry from outside via infiltration [none]
   4. Virus already present in the space [none]
2. Losses
   1. Dilution via ventilation, ψ (s^{-1})
   2. Surface deposition, ϒ (s^{-1})
   3. Biological decay and UVC denaturing, λ (s^{-1})
   4. Respiratory tract absorption, ζ (s^{-1})
   5. Filtration, ω (s^{-1})

Here, ϕ = ψ + ϒ + λ + ζ + ω

The steady state number of viral genome copies in a space as a function of time is:

$$n_{ss} = \frac{G}{\phi}$$

Number of viral genome RNA copies in a space, *n*

1. Gains
   1. Emission from a person, G (#/s)
   2. Entry from outside via ventilation [none]
   3. Entry from outside via infiltration [none]
   4. Virus already present in the space [none]
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   1. Dilution via ventilation, ψ (s^{-1})
   2. Surface deposition, ϒ (s^{-1})
   3. Biological decay and UVC denaturing, λ (s^{-1})
   4. Respiratory tract absorption, ζ (s^{-1})
   5. Filtration, ω (s^{-1})

Here, $\phi = \psi + \Upsilon + \lambda + \zeta + \omega$

The steady state number of viral genome copies in a space is:

$$n_{ss} = \frac{G}{\phi}$$

The concentration of viral genome copies is space dependent

$$n_{ss}/m^3$$

Susceptible adult male inhales approx. $0.54m^3$ per hour at rest, a proportion of virus will deposit in respiratory tract

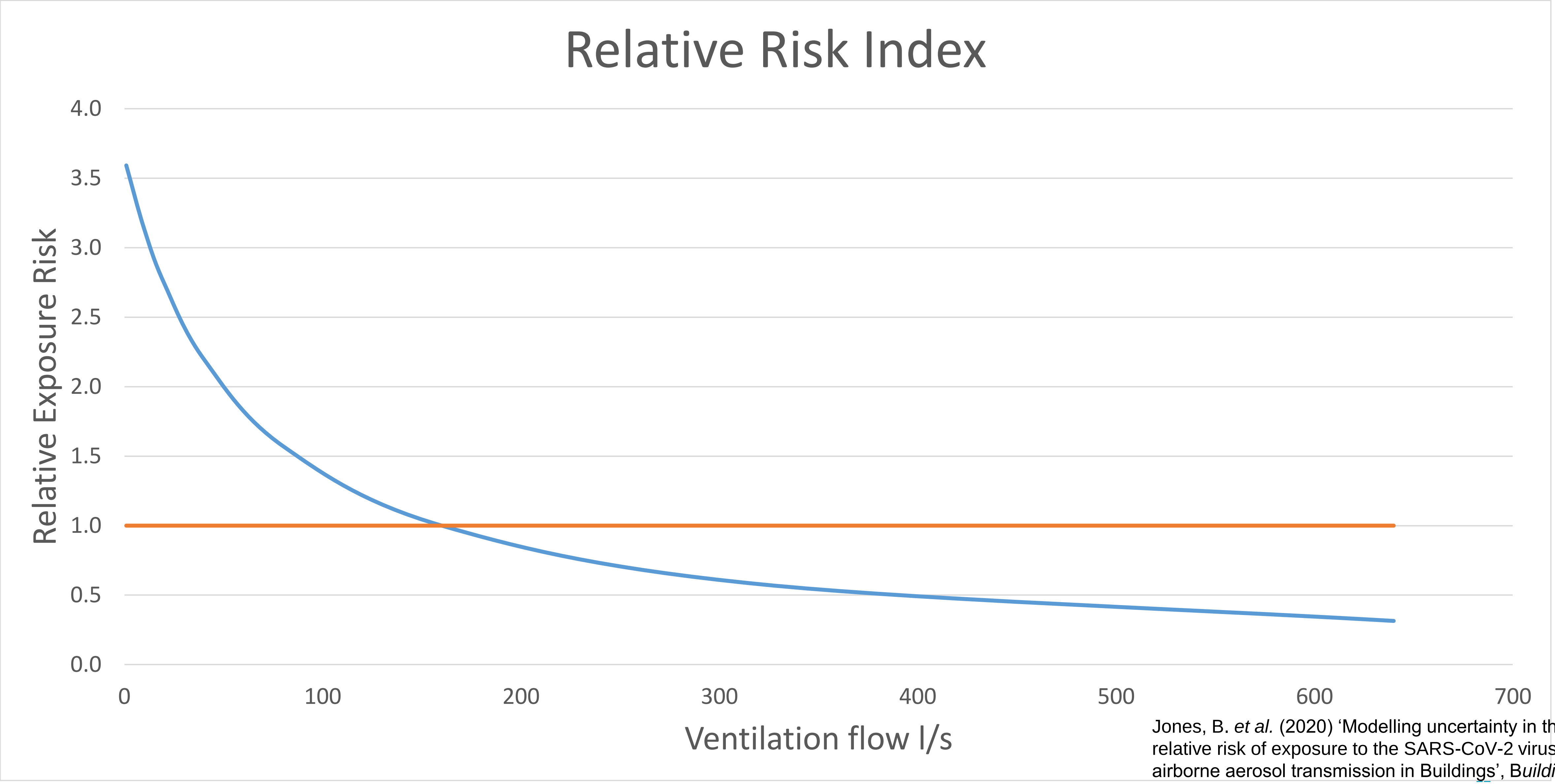
Relative Exposure Risk

$$Relative\ Exposure\ Index = \frac{\sum n_{Scenario\ \ x}}{\sum n_{Defined\ \ scenario}}$$

Input	Value
Room Volume	148.5m^3
Number of Occupants	32
Breath rate	0.44m^3/hr
Respiratory activity	75% breathing, 25% talking
Occupation time	7 hr
Air flow rate	160l/s (equivalent 5l/s/p)

UK Junior School Classroom

Relative Exposure Risk – role of ventilation



148m^3 junior classroom, 32 person, 7 hour, 25% talking, 75% breathing

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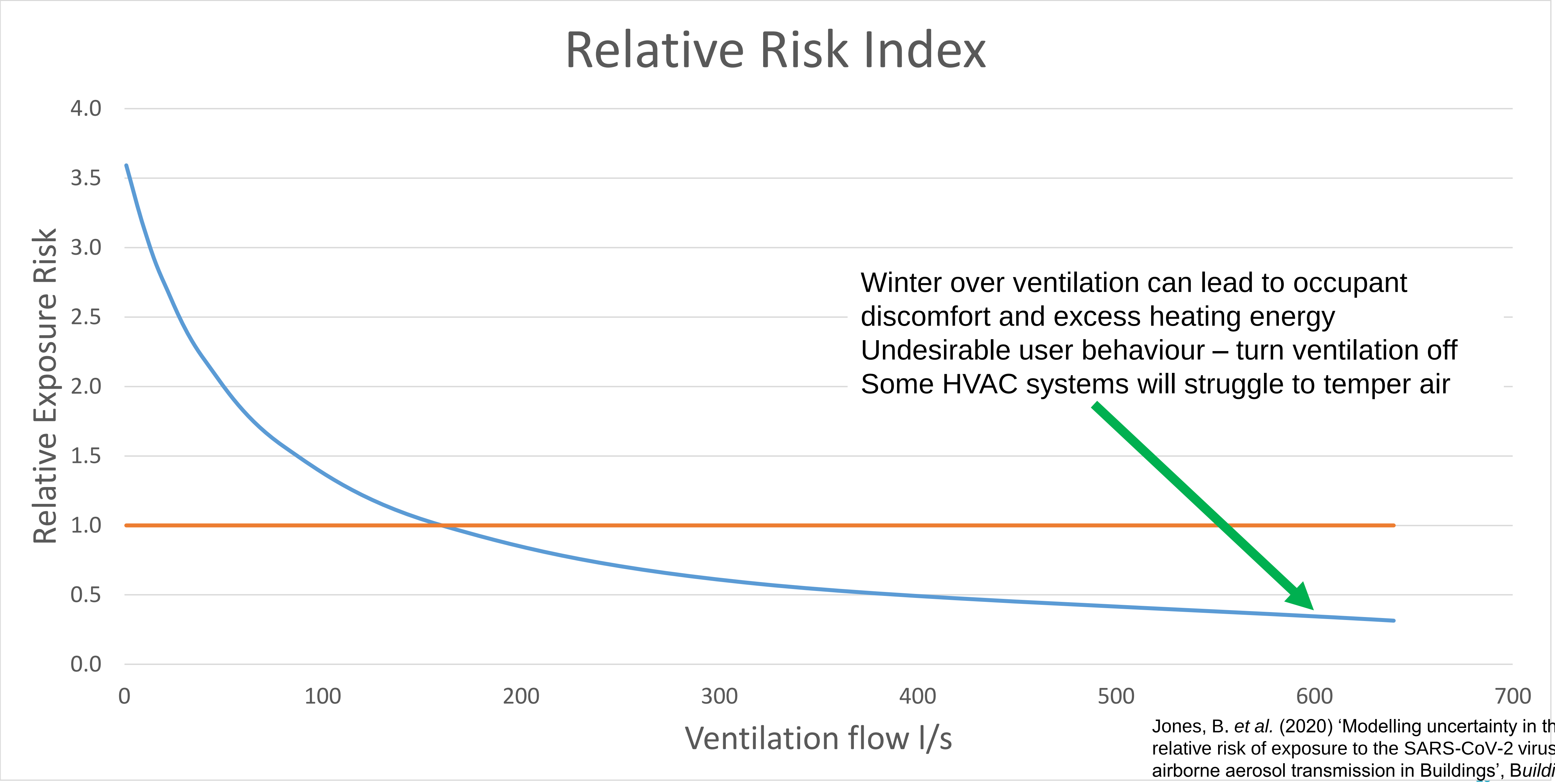
Relative Exposure Risk – role of ventilation



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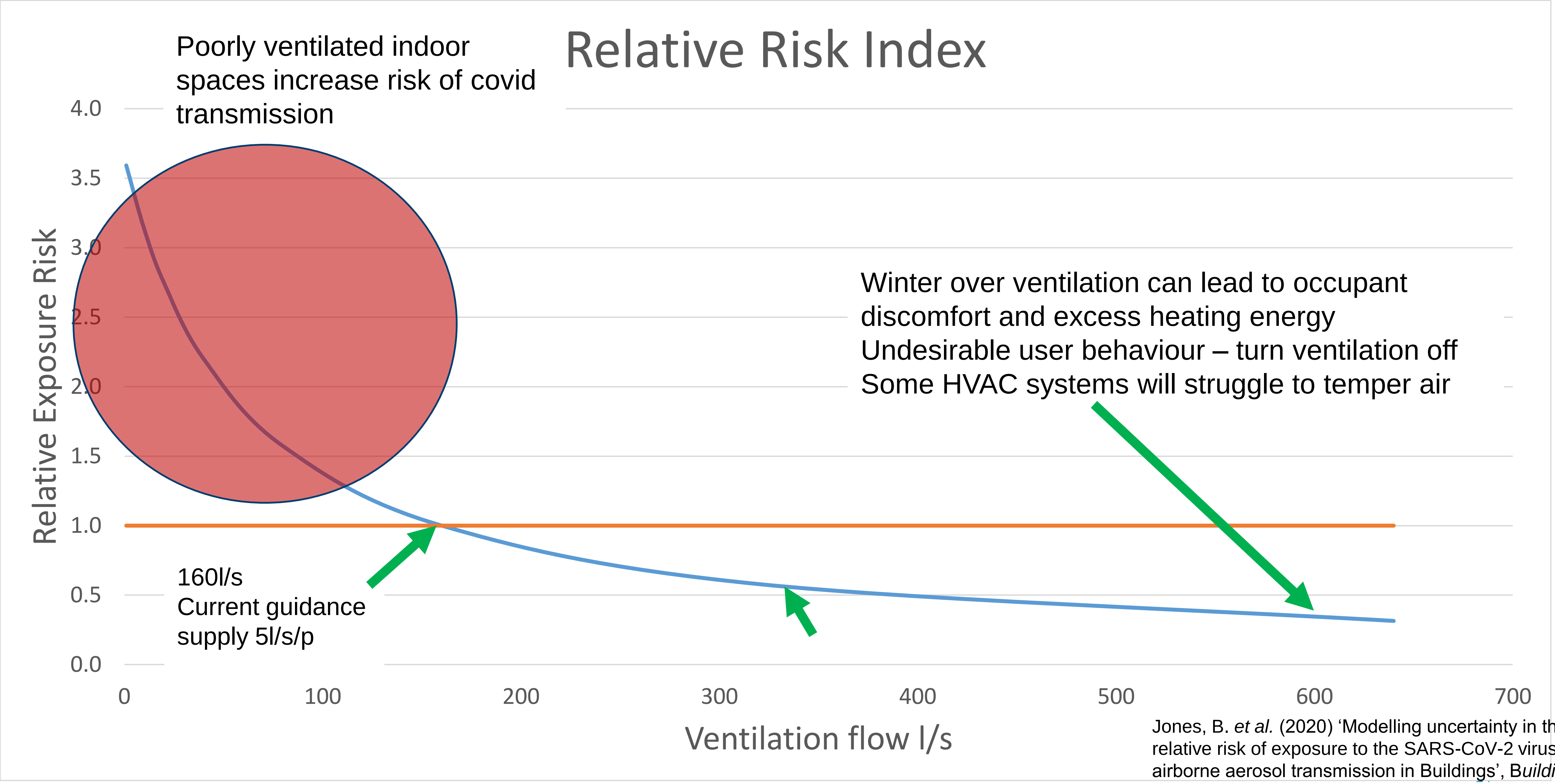
Relative Exposure Risk – role of ventilation



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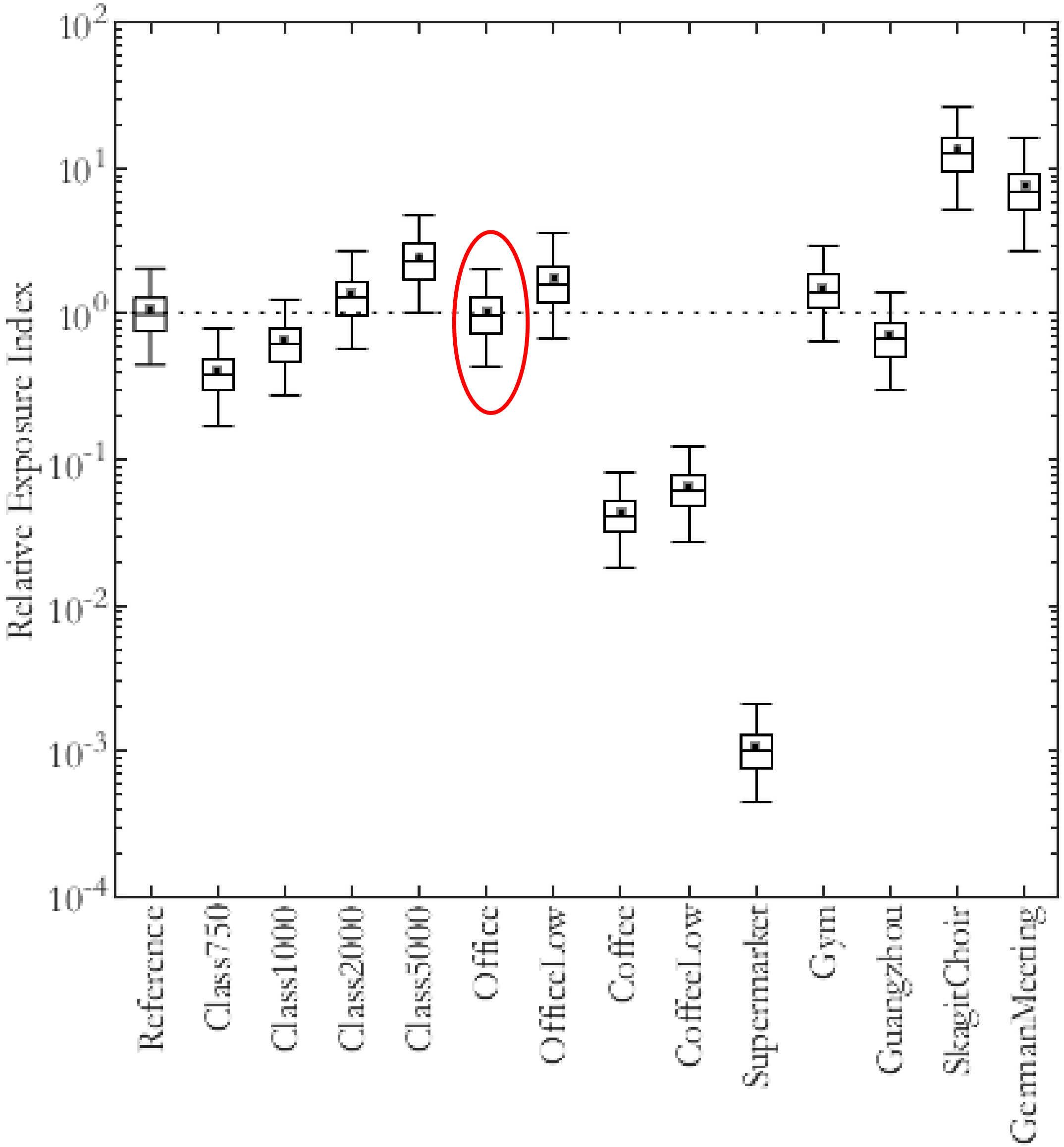
Relative Exposure Risk [all scenarios]



Relative Exposure Risk – 20 Person space

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Ventilation flow 200l/s (10l/s/person) Respiratory Activity

Event RER – 20 People, Time (h)

Volume	1	2	3	4	5	6	7	8	9	10	11	12
3000												
2500												
2000												
1500												
1000												
800												
600												
300												
150												
100												
50												

Individual RER – 20 People, Time (h)

Volume	1	2	3	4	5	6	7	8	9	10	11	12
3000												
2500												
2000												
1500												
1000												
800												
600												
300												
150												
100												
50												

Carbon dioxide concentration (ppm) – 20 People, Time (h)

Volume		1		2		3		4		5		6		7		8		9		10		11		12
3000	557	607	651	691	726	757	784	809	830	849	866	882	895	907	917	927	935	942	949	955	960	964	968	972
2500	567	625	675	719	757	789	818	842	863	882	897	911	923	933	942	950	957	963	968	972	976	979	982	984
2000	582	651	709	757	797	830	858	882	901	917	931	942	952	960	966	972	977	980	984	986	989	990	992	993
1500	607	691	757	809	849	882	907	927	942	955	964	972	978	983	986	989	992	993	995	996	997	997	998	998
1000	651	757	830	882	917	942	960	972	980	986	990	993	995	997	998	998	999	999	999	1000	1000	1000	1000	1000
800	681	797	870	917	947	966	979	986	991	994	996	998	999	999	999	1000	1000	1000	1000	1000	1000	1000	1000	1000
600	726	849	917	955	975	986	993	996	998	999	999	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
300	849	955	986	996	999	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
150	955	996	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
100	986	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
50	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Ventilation flow 100l/s (5l/s/person) Respiratory Activity

Event RER – 20 People, Time (h)

Volume	1	2	3	4	5	6	7	8	9	10	11	12
3000												
2500												
2000												
1500												
1000												
800												
600												
300												
150												
100												
50												

Individual RER – 20 People, Time (h)

Volume	1	2	3	4	5	6	7	8	9	10	11	12
3000												
2500												
2000												
1500												
1000												
800												
600												
300												
150												
100												
50												

Carbon dioxide concentration (ppm) – 20 People, Time (h)

Volume		1		2		3		4		5		6		7		8		9		10		11		12
3000	558	613	665	713	759	802	843	881	917	951	983	1013	1042	1068	1093	1117	1139	1160	1180	1199	1216	1233	1248	1263
2500	569	634	694	750	802	851	896	938	977	1013	1047	1079	1108	1135	1160	1184	1206	1226	1245	1263	1280	1295	1309	1322
2000	586	665	737	802	862	917	967	1013	1055	1093	1128	1160	1190	1216	1241	1263	1283	1302	1319	1335	1349	1362	1374	1385
1500	613	713	802	881	951	1013	1068	1117	1160	1199	1233	1263	1290	1314	1335	1353	1370	1385	1398	1409	1420	1429	1437	1444
1000	665	802	917	1013	1093	1160	1216	1263	1302	1335	1362	1385	1404	1420	1433	1444	1453	1461	1467	1473	1477	1481	1484	1487
800	701	862	991	1093	1175	1241	1293	1335	1368	1395	1416	1433	1446	1457	1466	1473	1478	1483	1486	1489	1491	1493	1494	1495
600	759	951	1093	1199	1277	1335	1378	1409	1433	1450	1463	1473	1480	1485	1489	1492	1494	1495	1497	1498	1498	1499	1499	1499
300	951	1199	1335	1409	1450	1473	1485	1492	1495	1498	1499	1499	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
150	1199	1409	1473	1492	1498	1499	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
100	1335	1473	1495	1499	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
50	1473	1499	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500

Ventilation flow 20l/s (1l/s/person) Respiratory Activity

Event RER – 20 People, Time (h)

Volume	1	2	3	4	5	6	7	8	9	10	11	12
3000												
2500												
2000												
1500												
1000												
800												
600												
300												
150												
100												
50												

Individual RER – 20 People, Time (h)

Volume	1	2	3	4	5	6	7	8	9	10	11	12
3000												
2500												
2000												
1500												
1000												
800												
600												
300												
150												
100												
50												

Carbon dioxide concentration (ppm) – 20 People, Time (h)

Volume		1		2		3		4		5		6		7		8		9		10		11		12
3000	560	619	677	734	791	847	903	958	1012	1065	1118	1171	1222	1273	1324	1373	1423	1471	1519	1567	1614	1660	1706	1751
2500	571	642	711	780	847	914	979	1044	1108	1171	1232	1293	1354	1413	1471	1529	1586	1642	1697	1751	1805	1858	1910	1961
2000	589	677	763	847	930	1012	1092	1171	1248	1324	1398	1471	1543	1614	1683	1751	1818	1884	1948	2012	2074	2135	2195	2254
1500	619	734	847	958	1065	1171	1273	1373	1471	1567	1660	1751	1840	1927	2012	2094	2175	2254	2331	2406	2479	2551	2621	2689
1000	677	847	1012	1171	1324	1471	1614	1751	1884	2012	2135	2254	2369	2479	2586	2689	2789	2885	2977	3066	3152	3235	3315	3393
800	720	930	1131	1324	1507	1683	1851	2012	2165	2312	2452	2586	2714	2837	2954	3066	3173	3276	3374	3467	3557	3642	3724	3802
600	791	1065	1324	1567	1796	2012	2215	2406	2586	2756	2916	3066	3208	3341	3467	3586	3697	3802	3901	3994	4082	4164	4242	4315
300	1065	1567	2012	2406	2756	3066	3341	3586	3802	3994	4164	4315	4449	4568	4674	4767	4850	4923	4989	5046	5098	5143	5184	5219
150	1567	2406	3066	3586	3994	4315	4568	4767	4923	5046	5143	5219	5279	5326	5363	5393	5415	5434	5448	5459	5468	5475	5480	5484
100	2012	3066	3802	4315	4674	4923	5098	5219	5304	5363	5405	5434	5454	5468	5477	5484	5489	5492	5495	5496	5497	5498	5499	5499
50	3066	4315	4923	5219	5363	5434	5468	5484	5492	5496	5498	5499	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500

20 People — Event RER | 20 People — Individual RER | 20 People — Carbon dioxide concentration (ppm)

Ppm (colour scale): 300, 400, 600, 800, 1000, 1100, 1200, 1300, 1400, 1500, 1800, 2000, 2500, 3000, 4000, 5000

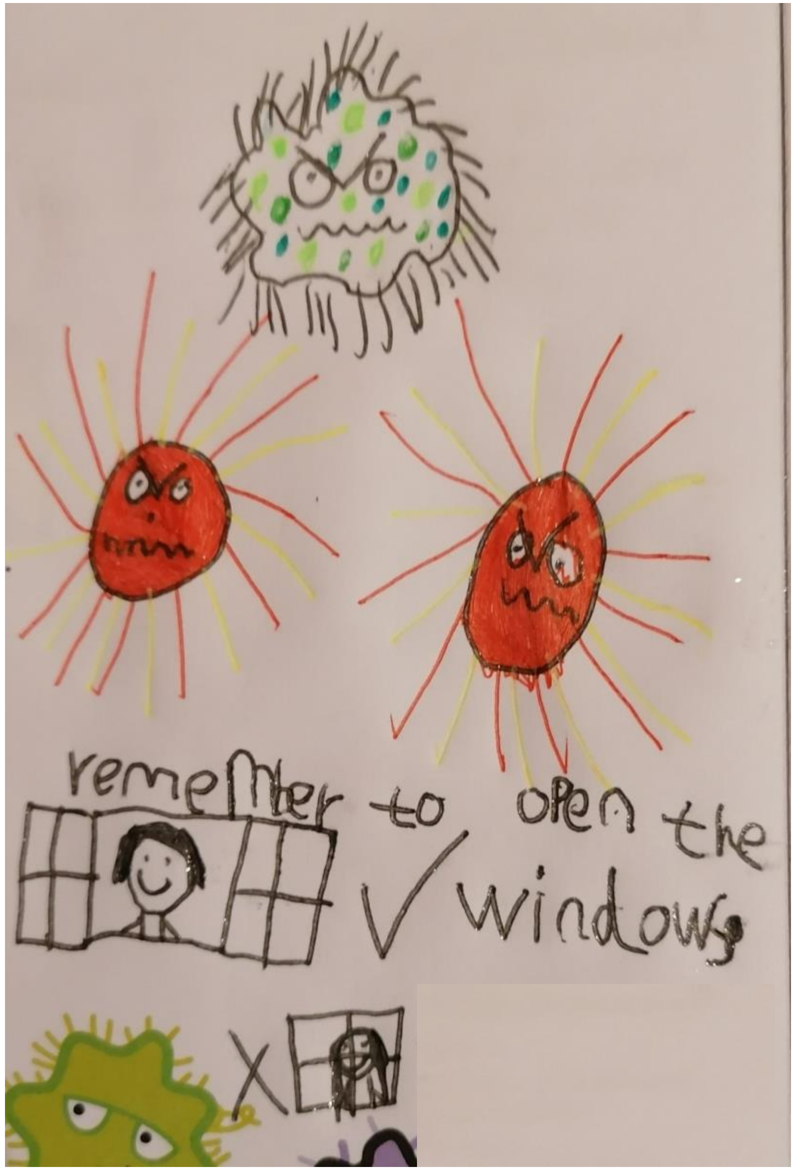
RER (colour scale): >=10, 9, 8, 7, 6, 5, 4, 3, 2, <=1

Individual RER assumes single infector present, event RER assumes probability of infector present.
Respiratory activity assumed to be 25% talking 75% breathing

Ventilation

- Increasing ventilation will decrease far field transmission risk
- Far field transmission events can still occur
- We would expect fewer far field secondary transmission events in better ventilated spaces

- Reduce exposure, face coverings, social distancing, hygiene



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Modelling uncertainty in the relative risk of exposure to the SARS-CoV-2 virus by airborne aerosol transmission in well mixed indoor air

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