

SPI-M: the general principles and assumptions on transmission of SARS-CoV-2

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Incidence rate and reproduction number

1. Incidence of infections is the number of new people who get infected each day (that would be daily infection incidence). R , the reproduction number, is the total number of new infections caused by one infectious person during the days that they are infectious. These two things are not the same. If $R > 1$ then incidence of infection will be increasing, If $R < 1$ then incidence of infection will be decreasing and if $R = 1$ then incidence of infection will remain the same each day.

At its simplest we think of R as the product of four numbers:

$$\begin{aligned} R = & \text{number of contacts each day} \\ & \times \\ & \text{probability of infection in a contact between an infectious person and a susceptible} \\ & \text{one} \\ & \times \\ & \text{duration of infectiousness} \\ & \times \\ & \text{number of susceptibles} \end{aligned}$$

As examples:

We can reduce the number of contacts per day with stay at home rules.

We can reduce the probability of infection with 2m rules whilst outside the home.

We can reduce the duration of infectiousness by asking people to self-quarantine if ill.

Most of our problems arise from the fact that the number of susceptibles is so very large (probably still most of the 66m of us). The reason vaccines have had such an enormous impact on public health is that they solve that part of the problem. I think its only fair to state that the easy vaccines have mostly been made. Furthermore, it is a reasonable rule of the thumb that a vaccine might be as good as (efficacious and long lasting) as immunity acquired after a noticeable infection, but not better.

So far we know how to run at $R=3$ (normal daily life) and at $R\sim 0.8$ (lockdown). We do not know if we can control R any more subtly than that.

General implications for risk of transmission

2. Transmission of any virus relies on particles of infectious material transferring from one host to another. Maintaining space between individuals and the surfaces they touch on which the virus can survive, will minimise transmission. As a result, there is likely a lower risk of transmission when and if social distancing is maintained. This is true across travel, work, school, household, and leisure settings. In general, it means that confined spaces where people are more likely to come into close proximity lead to an increased likelihood for transmission, as does increased duration of proximity or contact.
3. Consideration also needs to be given to how measures are brought in or relaxed, both individually, in batches, or all together. We also need to consider the risk profile of workplaces and people affected as measures are lifted, for example, younger people appear to be at lower risk, and people without children do not link to other households through educational establishments.
4. The reproduction number of the virus is affected by the number of infections per contact, the number of contacts, the duration of infectiousness, and the number of susceptible individuals in the population. In order to slow or suppress viral transmission across a network, we can act at any of those points. The current number of susceptible individuals, however, is very high, hence the need for drastic decreases in contacts to bring R below 1.

Individuals

5. Individuals who come into close contact with many people for an extended period are likely to be both at higher risk of infection and higher risk of infecting others. People in professions such as teachers, bar workers, hairdressers have higher contact rates. These individuals potentially act as linking “hubs” between households – in lockdown, such links have been severely limited and so have significantly decreased transmission. Health and social care workers and other key workers have remained at risk of infection and transmission.
6. For group gatherings, the important considerations for individual risk are the number of contacts each person makes, and the duration and intensity of those contacts. Larger groups gatherings, such as football matches, will not necessarily result in more contacts

being made per person if there is less exposure per person (i.e. a gathering of 50,000 people is not 10,000 times worse than a gathering of 5).

Networks

7. Individuals vary in their own contact rates, but the numbers of contacts their contacts have also varies. People with high contact rates with other individuals who also have high contact rates tend to form “core groups”. For example, professionals or trainers who contact teachers in different schools, form bridges between highly connected groups.
8. Around 50% of physical contacts happen in home settings. Leisure settings are important for both physical and non-physical contacts (30-35%), while work accounts for a large proportion of non-physical contacts (15-30%)¹.
9. Settings that bring together individuals from across several households are likely to be higher risk for transmission. Schools, workplaces, public transport, places of worship, and leisure facilities all create networks between households; the more households that are brought together, linked by individuals, the greater the potential for transmission through the network. For example, smaller businesses may create fewer links between households than a fully open school.
10. Networks need to remain as self-contained as possible to limit viral transmission. This can be achieved through rostering cohorts of staff, avoiding contact with new / different clients, and encouraging single- rather than multi-site working. BEIS² have released safety guidance with respect to COVID-19 that should be followed.
11. Leisure settings, by definition, bring individuals from different households together, often in small spaces for prolonged periods of time, through close congregation. This makes them inherently risky environments for viral transmission.
12. Some institutional settings, such as care or nursing homes, boarding schools, barracks, prisons, etc. are already self-contained, highly connected, networks and SARS-CoV-2 is likely to spread quickly and easily. As a result, all efforts should be made to prevent the virus entering such a setting in the first place i.e. shielding the whole institution and greatly reducing movement between them.

¹ POLYMOD and BBC contacts by context percentage

² <https://www.gov.uk/guidance/social-distancing-in-the-workplace-during-coronavirus-covid-19-sector-guidance>

Ranking of population risk of measures

13. It can be extrapolated that, overall, outdoor settings are less likely to lead to transmission, and this is somewhat supported by evidence that aerosol transmission is less effective than contact with infected droplets, and that UV exposure reduces survival of the virus out of doors. This does, however, depend on maintaining social distancing for the duration of time spent outside, and avoiding touching hard surfaces.
14. While it's not possible to explicitly model small differences between different settings, we can think in terms of an approximate ranking of the possible impact to **population risk** of a variety of measures. In general, the higher the rank, the more possible the impact on R (i.e. ix affects R more than i):
 - i. Outdoor relaxation and exercise, maintaining social distancing from anyone outside of your household, not touching any hard surfaces, not time limited – just distance / contact limited. For example, this could include sunbathing, picnicking in the park, or solo outdoor sports, such as fishing.
 - ii. Outdoor work maintaining social distancing, particularly during breaks / mealtimes, such as construction, park maintenance, etc. Garden centres (with cafés closed) may also fall into this category or the next.
 - iii. Indoor limited contacts of less than 10 mins, interactions of only 1-2 people that maintain social distancing, prevent loitering or congregating in places for any extended period. For example, this could include non-essential retail in **small** shops with limited customers at any one time.
 - iv. Opening large shops and shopping centres could encourage gathering and loitering of crowds in indoor, enclosed spaces, which increases the potential for proximity, length of exposure, and thus risk of transmission.
 - v. Outdoor playgrounds / gyms have multiple people touching hard surfaces, with no easy sanitation between individuals using equipment. This is partly balanced by likely UV degradation of virus particles.
 - vi. Outdoor mass gatherings happen infrequently, and precise risk will depend on the numbers of people attending, their duration, and how much social distancing can be maintained.
 - vii. Indoor mass gatherings happen infrequently and but inherently more risky than outdoor mass gatherings due to the confined space, and potential for bottlenecks of entry and exit routes.

- viii. Indoor cafés and restaurants, again, bring people together in close proximity. The risk could potentially be reduced by only allowing households to attend together (very hard to enforce) or limiting persons per table and extending distance between tables.
- ix. Indoor leisure activities, including but not limited to hairdressers, gyms, places of worship etc., lead to extensive person to person contact and so likely increase risk of viral transmission which is hard to mitigate. This would also include pubs, bars and clubs, which also bring together people from variety of households into a confined space. These sorts of activities happen frequently and constitute a relatively large proportion of people's time, increasing risk of viral transmission.