SFI TRANSMISSION

COMPLEXITY SCIENCE FOR COVID-19

STRATEGIC INSIGHT: **Group size matters when it comes to how many people should gather in one place. Let's use mathematical models to pin down consistent guidelines for complicated situations.**

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Beginning in early March, 2020, conflicting advice about COVID-19 emanated from local, state, and federal leaders, as well as from public health spokespeople. While there was unanimous agreement that some level of social distancing was critical to reducing the daily incidence of new COVID-19 cases, there was wide disagreement as to what group size should be allowed. Through the media, one learned that group size should be limited to 200, or maybe to 50, or maybe to 20, or maybe to 10. On the same day, you could learn that you could attend a large lecture but not a sports event or political rally, or you could go to a bar or restaurant but not a concert hall, or you attend a small dinner party with friends but not a restaurant. Eventually many regions of the US settled on home confinement, which implies group sizes of at most a handful.

So what is the effect of group size on the transmission rates of infectious disease? This question raises many secondary questions. How long does one stay within a group — perhaps two hours at a ball game, but all day in kids' classrooms — and how does that interact with group size? How thoroughly within a group does transmission occur? Surely somebody in the bleachers cannot directly infect someone in a box seat above home plate. And what about whether the group is indoors or outdoors; what about wind and humidity?

Clearly, it's complicated. But, to get at least a very simple insight, we can make some very simple assumptions and obtain a back-of-the-envelope result. Let us suppose that you are in a group of size n_0, and that there are N_0 such groups in a total population of size $n_0N_0 = P_0$. Moreover, we assume that if an infected individual happens to be in a particular group, then everyone in that group becomes infected. Finally, assume there is no mixing among groups. Both of those last two assumptions are readily altered, but let's look at this simplest case first.

We further assume that the group you are in, A, is comprised of your friends and/or family members. Hence, a simple but useful measure of your expected damage is the probability that an initially-infected individual happens to be in your group multiplied by the number of people in the group.

Suppose that initially the population contains a single infected individual. That individual could be equally likely to be in each of the groups, and so the probability that it is in the group that you happen to be in will be proportional to 1/(number of groups). Multiplying by the number of individuals in the group, your expected damage is proportional to n_0/N_0.

How does n_0/N_0 depend on group size, n_0? Because $N_0 = P_0/n_0$, the expected damage to you varies as n_0^2. In other words, a doubling of allowable group size results in a four-fold increase in your expected damage. Group size matters a lot!

Suppose, instead of assuming that everybody in a group gets infected if one of the initially infected people is in the group, we assume that the number of infected in a group increases as the square root of the group size (the bleachers are far from home plate). Then it is easy to show that the damage to you varies as $n_0^{3/2}$.

Suppose we allow inter-group mixing. Then, depending on the rate of mixing, the infection rate, the duration of infectiousness in a person, and other factors having to do with the spatial pattern of mixing such as distance over which one mixes, the expected damage can become much larger, but the dependence on group size probably does not ever become steeper than the quadratic dependence derived above.

Clearly, more sophisticated modeling is needed here. It is imperative that, as we emerge from strict social distancing some months from now, we don't go straight from group sizes of two or three or four to unlimited group gatherings, lest we trigger a resurgence in infection.

So what's the magic number? There isn't a single answer. However, because group size matters a lot, the precautionary principle urges us to err on the side of small group-size restrictions. If mathematics informs our decisions, then as we eventually ramp up our sociality and return to some approximation of normality, we can do so with more clarity than was available when we went into quarantine.

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