SFI TRANSMISSION

COMPLEXITY SCIENCE FOR COVID-19

STRATEGIC INSIGHT: Physical distancing is necessary for reducing infections, but the timing of restrictive confinement makes all the difference.

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COVID-19 is revealing invisible ingredients in our contact networks — breath, touching, and physical surfaces. Understanding these networks is key to assessing how infectious diseases spread and how measures to extinguish epidemics are best deployed. The problem is that these same networks are a manifestation of our social freedoms and economy — and are both hard and dangerous to relinquish. This is basically why voluntary physical distancing is generally proving to be not enough to protect public health and health services.

Simple epidemiological "toy" models explain why, and to what degree, more restrictive confinement is necessary, and how communities and nations can be eased-out towards normalcy. These models can be revealing and can help with policy, but they come with operating instructions that even specialists can easily overlook.

The central concept in epidemiology found in toy models is the "basic reproductive number," usually referred to as R_0. R_0 is the expected number of new infections directly caused by a single infected person at the start of an epidemic (time t=0), and as the epidemic proceeds, the analogous measure is the "effective reproduction number," or R(t) (hereafter R). R is an average. So, an R=6 in a population of two infected and tens of susceptible individuals could mean that each infected six other people, or possibly that one infected zero and the other, 12. Calculating R for real epidemics can be complex[1]. Notably, this key number may differ from one place to another, change during the course of an epidemic, and, fortunately, be reduced by disease-control measures.

Estimates of R_0 for COVID-19 are consistently about 2.5, and, given infectious periods and times from infection to symptoms, this results in the number of cases currently doubling about every three days[2]. The power of exponential growth is clear: after one month or 10 doublings after the 100th case, about 100,000 confirmed cases would have occurred, had physical distancing and confinement measures not been put into place.

R is useful not only in understanding epidemics, but in developing control measures. Unsurprisingly, maintaining R below 1 for a sufficient period will progressively reduce case numbers to zero. The problem for COVID-19 is that not sufficiently lowering R below 1 will mean a more protracted epidemic, many people unnecessarily coming down with the disease, and a progressive strain on — if not the complete exhaustion of — health services. Such measures do indeed "flatten" the epidemic curve[3], and, with ever-fewer susceptible individuals in the population, eventually reduce R to 0 associated with "herd immunity" (formally, this occurs when the susceptible fraction of the population is less than 1-1/R).

This simple insight is very powerful for yet another reason. Simply touting reductions in R as the ultimate objective of epidemic control overlooks the fact that when the epidemic measures begin will determine the effectiveness of a given reduction in R. As a general rule, R needs to be reduced early to prevent an epidemic, but should it take off (as seen for virtually every country where COVID-19 cases have occurred), strict measures are necessary to enact a reset to near zero cases, as has recently been reported from China.

For example, starting from 100 infected individuals in a population of 50 million, lowering R from 2.5 to 1 will result in about 100 new infections about every two weeks, based on realistic epidemic parameters.[4, 5] This would mean on the order of several thousand cases in a year. But the same measures starting with a population with 100,000 infected people will produce several million infections over the same period. This assumes that people mix freely — real contact networks will result in far fewer new cases[6]. Nevertheless, the take-home message is that the size of the infectious population when measures are engaged is important in determining the degree of confinement, that is, the extent to which measures lower the baseline R_0. The near-complete lockdown in parts of China is case-in-point, where R approaching 0 was maintained for about two months, resulting in the virtual collapse of their epidemic. The question now for China — and soon for other nations easing out of strict confinement — is how physical distancing can be tuned to R≈1 or less, with the risk that failure to achieve this will produce a new epidemic.

REFERENCES

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4 Bjornstad. 2018. *Epidemics : Models and Data Using R*. Springer

5 http://gabgoh.github.io/COVID/index.html

6 Keeling & Eames. 2005. *J R Soc Interface* 2, 295-307. doi: 10.1098/rsif.2005.0051

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