Living with virions [and Ro]

Description

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Smartphones canâ??t yet take your temperature and diagnose if you are carrying an infection. But developers are designing smartphone apps to trace if youâ??ve been in contact with someone who has COVID-19. The most promising contact tracing apps enable smartphones to exchange short encrypted messages when they are within range of one another. That happens automatically and invisibly to the user of the phone.

The short messages are called â??keysâ?• or â??chirps.â?• They are transmitted via Bluetooth and stored on your phone. If you later test positive for COVID-19, a medical official can release the keys and upload them to a server. The server will identify which phone owners you were in contact with and notify those people, i.e. it will notify their phones, anonymously. The phones of those people will alert their users to take action, such as getting tested, or to isolate. Apple (iPhone) and Google (Android) are installing the capability for encrypted Bluetooth key exchange in their operating systems to support such apps. A recent article in The Telegraph provides a helpful explanation of how the apps function. Encryption is needed to keep this information secure and private.

The analogy between information transmission and the contagion is well established. Think of â??computer viruses.â?• With contact tracing, units of information get transmitted invisibly. No one in the transmission pool need be aware this is happening. Itâ??s a secret. Thatâ??s a bit like the transmission of a virus. The viruse analogy prompted me to think about how viruses spread.

Virology 101

Viruses need organic hosts to survive and multiply. By most accounts, coughs and sneezes benefit the host (i.e. the human, the carrier or the vector). WebMD says: â??While annoying, coughs that are â??productiveâ?? get germy mucus out of your lungs when youâ??re sickâ?•. But respiratory viruses have evolved and adapted to promote and exploit their hostâ??s coughing. The expulsion of infected air and fluids provides a means for the virus particles (virions) to spread so they can infect other carriers. Virions also lie on surfaces and move into potential carriers who make contact some time later.

Virions canâ??t survive too long or multiply without living host cells. Once in their new hosts, virions occupy cells in the respiratory system, multiply and spread further when the host coughs, splutters, spits, sneezes, weeps, speaks, sings and exhales. Other humans in close contact acquire the virus through such excretions. The cycle continues throughout human populations.

Modelling viruses

News reports now pay a lot of attention to how researchers model the spread of viruses. Iâ??ve stripped the modelling for spreading infections to the bare minimum so that I can understand it. For a virus to spread through a population, itâ??s usual for one infected person to infect more than one other before the original carrier feels sick enough to isolate themselves. Letâ??s say every sick person infects just two others over a period of one day. Starting with one infected person, after a day there will be 2 more infected, the next day 4, then 8, etc.

By the tenth day there will be over one thousand new people infected. Thatâ??s 2 to the power of 10 = 1,024. After twenty days there will be just over 1 million new infections. Thatâ??s the well known exponential growth curve, and itâ??s easy enough to model with a spreadsheet program. The first graph below shows the growth of new cases. If everyone recovers in a day and then is no longer a carrier then the graph also represents the total number of people infected on any day since the introduction of the virus.

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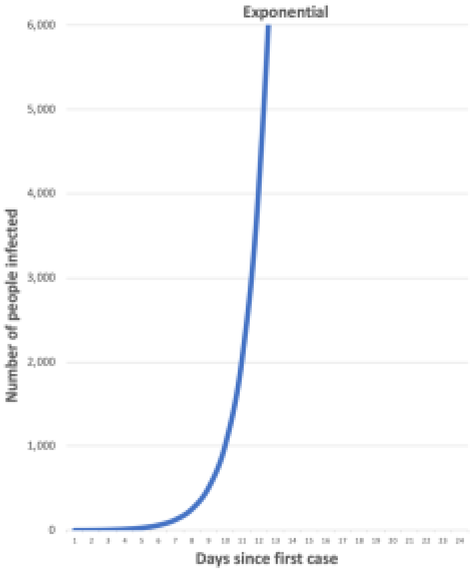
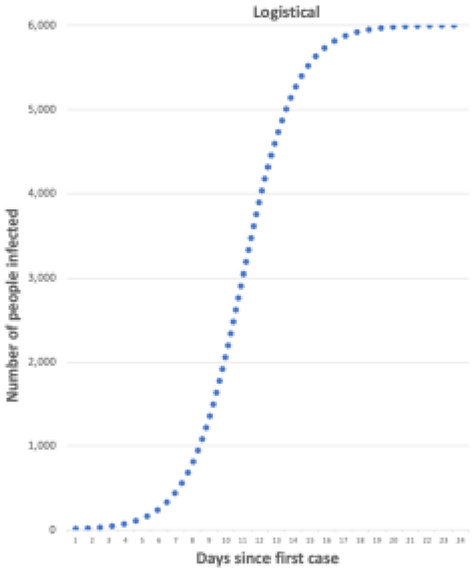
The rate of growth here is 2.0. That rate is called R0 (R naught). With an R0 = 2.0, the number of infections doubles with every current case. If R0 is 3.5 then on average each infected person will infect 3.5 others. If R0 is 1.0 then the number of people infected will stay stable. If it is less than 1.0 then the number of people infected will decline.

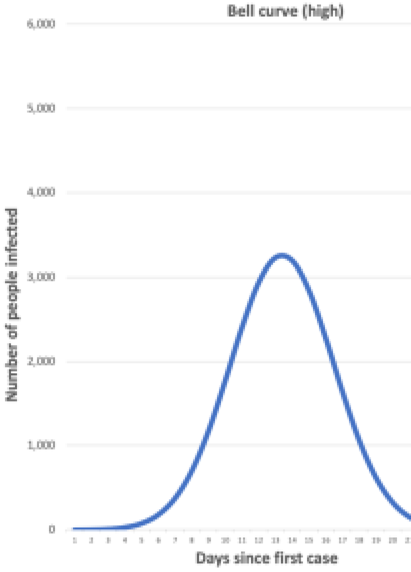
Limited resources

Resources for the virus will be limited. So the curve will eventually flatten. The virus will run out of humans to infect. It will get harder for the virions to encounter and take occupancy in eligible hosts. The logistical model of the second graph shows this dampening effect. The logistical model applies to many cases of population growth (humans, plants, penguins, yeasts and viruses). Itâ??s possible to model that on a spreadsheet as I show here. The height, slope and curviness of the graph depends on a number of variables in the environment the virus is operating in, not least the total population available. I set the maximum here to 6,000 people. Human population pools are normally much bigger than that, and not everyone in the population will end up infected. Itâ??s very difficult to predict where an infection curve will plateau. It assumes the unlikely scenario that no one tries or is able to mitigate the spread of the infection.

Stasis for viral infection (the top of the logistical curve) for humans is pretty grim, as it implies a huge number of infections. It implies the human population has to put up with a very high and constant percentage of people who are infected and perhaps reinfected. More likely the number of cases will reduce after the plateau, but it will be followed by a series of waves, as has occurred in the case of plagues and pandemics prior to the era of modern medicine, hygiene, water supply, etc.







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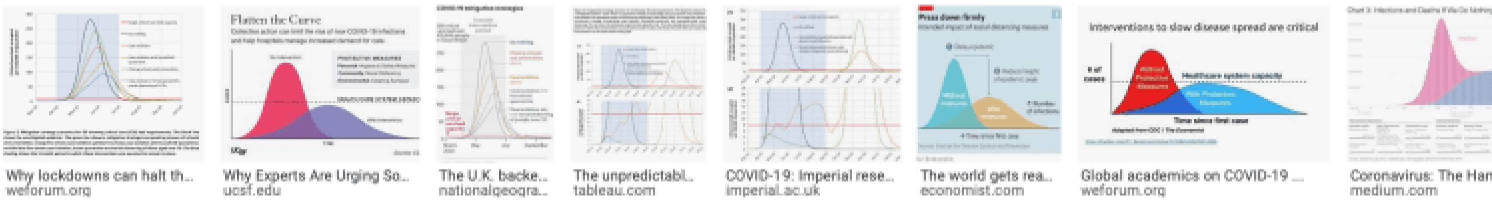
Thankfully, people develop immunity, the sick get confined, and the population as a whole takes precautions via enhanced isolation and improved hygiene. Some of the sources I list in the Bibliography give the R0 for COVID-19 as between 1.5 and 3.5. But the R0 depends on the environment as well as the proclivities of the virus. The third graph above shows a more likely trajectory. The numbers of people infected slopes off. Here I assume the rate at which people get infected starts out at R0=3.5 and then drops geometrically over time. At around day 14, the R0 starts to drop below 1, reaching 0.31 by day 24. A steady reduction in infection rate produces this bell shaped curve.

Until recently, the government was showing us that bell-shaped curve and labelling it the â??do-nothingâ?• curve. But for the curve to come down like that would require mitigation measures. By my understanding, the idealised â??do-nothingâ?• curve is really something like the logistical curve above.



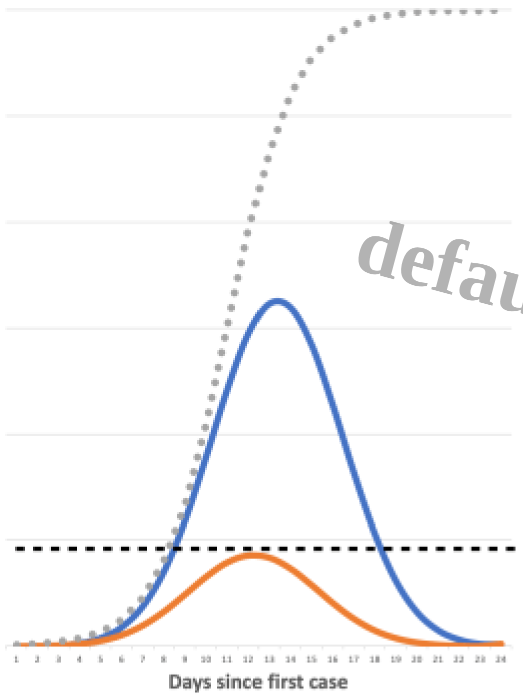
Modelling experts also express the rate of increase in days. Over how many days does the number of infected people double? Thereâ??s an online calculator to help work that out: Omni. For COVID-19 the rate has varied between 2 and 10 days: the longer the better as it brings the curve down sooner.

Coping

The human misery from the virus, and the curve, is compounded by the limited resources available to cope, not least hospital facilities to treat the number of extreme cases. Itâ??s well known that the challenge for any community is to keep the *rate* of infection, R0, as low as possible to ensure that the number of cases does go down, and to a level below the line showing how many people can be treated with the resources available.

Here are the last two graphs overlaid. I added a third, orange graph in which R0 drops from 3.5 to 0.21. I didnâ??t model it this way, but you could think of the vertical axis as the accumulated number of people in hospital on any day. The horizontal black line is some notional limit to hospital or ICU facilities. The extreme case of the grey dotted logistical curve where thereâ??s no mitigating action would run off the screen if this was to scale. These graphs are usually presented logarithmically, i.e. the higher numbers are compressed to emphasise the differences amongst the smaller numbers.

I recall feeling anxious as the graph of new cases (or deaths) in the UK was on the ascent. We waited for the flattening of the curve, and then evidence of its downward trajectory.



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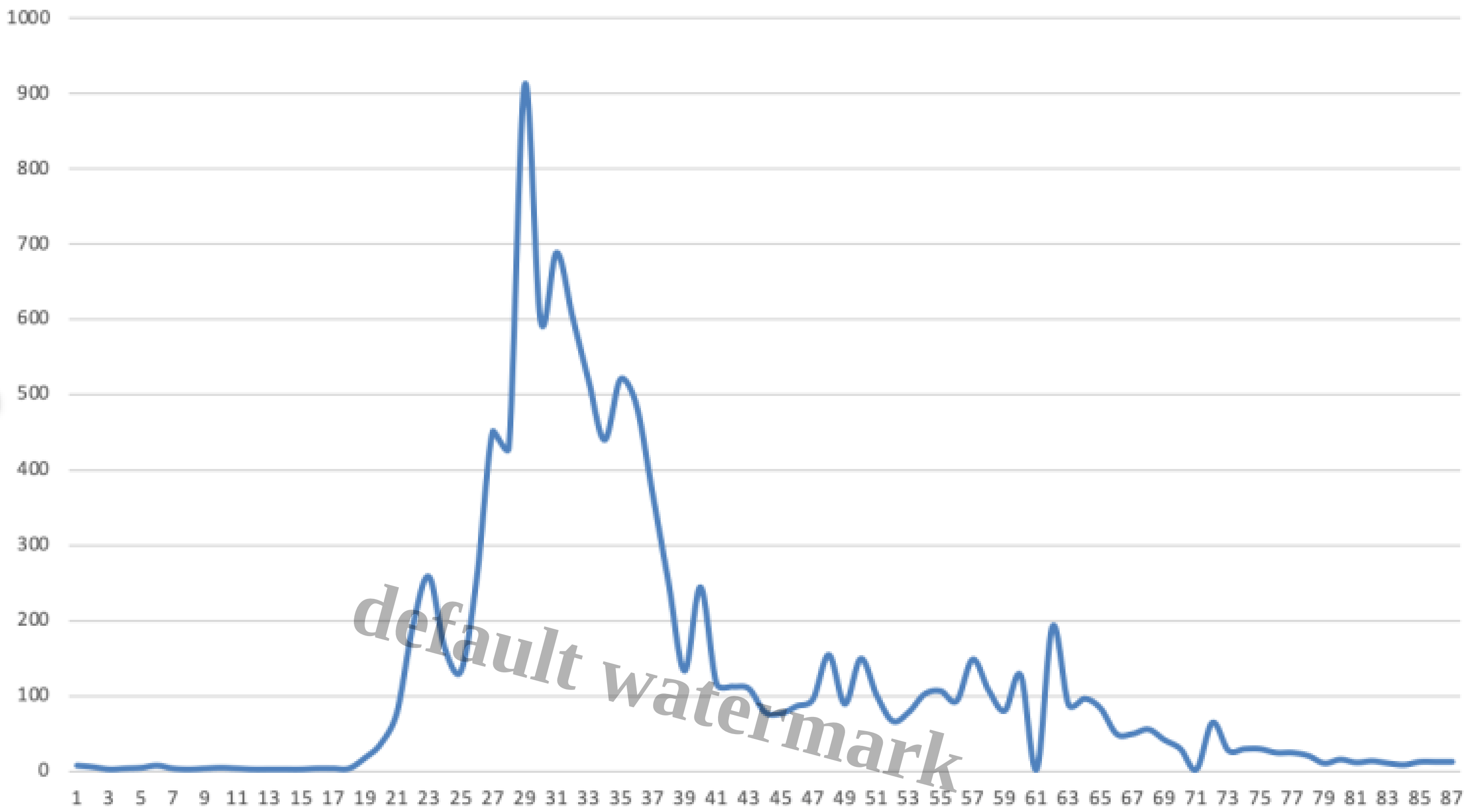
Actual data

So far, South Korea is the one country that has gone through the curve and with reasonably reliable data. I downloaded and graphed the data for South Korea to see how close it is to the shape of a bell curve. Itâ??s spiky. This is the daily count of new cases between 1 March 2020 and 27 April 2020. Itâ??s the same data graphed on the *Financial Times* Coronavirus tracking site, though they use a logarithmic chart. The *FT* shows the trajectory for various countries overlaid on a logarithmic chart.



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Managing the curve

Numerous public announcements remind us that there are three methods that help the curve to drop, i.e. that lower the R0 over time. Thereâ??s a good demonstration of the maths here: 3Blue1Brown.

- Avoid transmission between carriers and potential carriers by minimising human to human contact. Tactics range from isolation and quarantining to keeping a distance between people and banning large gatherings.
- Limit carriers from entering the population pool to prevent or delay the introduction of the virus: by isolating those known to be infected; and banning or reducing travel by carriers into the community. That tactic applies to individual households, cities, countries, islands, etc.
- When a vaccine is available, inoculate enough of the population so that the virus canâ??t survive in a sufficient number of hosts to sustain significant growth of infections in the population.

I started this exercise to set the ground for considering how contact tracing via smartphones works. Contact tracing is really a means of introducing targeted isolation. If youâ??ve been in contact with someone with the disease then how likely is it that you are also a carrier and should be isolated before you infect others? Even my simple modelling shows just how sensitive the spread of infection is to the average rate of transmission in a community, R0.

If on average, each infected person infects two others then the numbers of cases explodes over a few weeks to something like the logistical curve. As the average infection rate gets lower, and the quicker this reduction in rate happens, the smaller the curve. Thatâ??s why the experts say that contact tracing apps need only be used by 60% of the population to make an appreciable impact on the population as a whole.

With each of these mitigation tactics there are two factors in play: the effect of these measures for the population as a whole, and for individuals. When looking at whole populations, a small change in the average number of people any individual infects makes a big difference. It also makes a difference to the individuals as well who might see such measures as reducing personal risk. Presumably that will be a major incentive for enough people to adopt the contact tracing app when itâ??s available.

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Category

1. Nature

Tags

1. contact tracing
2. covid-19
3. encryption
4. R0
5. virus

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