Northern Ireland Assembly

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Robert Barry

When 'R' we going to get back to high fives, hugging strangers and kissing the Blarney Stone?

Summary

The UK Government and the devolved Governments in Northern Ireland, Scotland and Wales have recently announced their plans for gradually lifting the lockdown restrictions that were introduced to bring the spread of the COVID-19 disease under control. These plans have been informed by the latest scientific advice and, in particular, the 'all important' R number.

This briefing note describes the epidemiological concept 'R', and examines its usefulness and limitations as a compass for guiding us through the mists of this plague.

1 Introduction

> *"The risk is that a complicated number is released without context into a world that doesn't know how to think about it."*
> Ed Yong[1]

The 'R number' that most of us non-epidemiologists had never heard of before appears to be driving Government policies everywhere and determining how we lead our lives.

Driven by the latest scientific advice and the latest estimates of R, the UK Government is following the example of many other countries and has begun the process of slowly relaxing lockdown restrictions in England. The devolved Governments of Northern Ireland, Scotland and Wales are being a bit more cautious in terms of the timing, but have now published their lockdown exit plans.

However, all this hinges on the 'all important' R number. If that creeps back to 1 or above, restrictions would have to be re-introduced.

The UK Government has declared that R is currently running somewhere between 0.5 and 0.9 for the UK. Scotland's R number is estimated to be between 0.7 and 1, while Wales has narrowed their R number down to around 0.8. The Northern Ireland First Minister has been even more precise, recently quoting a figure of 0.79, stating that it needed to be reduced further before restrictions can begin to be lifted.[2]

2 What is R?

R is just a number. Most people will have heard by now, from politicians and the media, that R is a number that can be used to estimate the rate at which the COVID-19 disease is spreading. The concept is defined as the average number of secondary infections produced by a single infectious individual. In the simplest of terms, if R is above 1 (i.e. an infectious person is, on average, passing the infection on to more than one other person) then the outbreak is expected to continue and to spread exponentially. If, however, it can be kept below 1 the outbreak will be kept under control and will eventually die out.

The R number can refer to either the basic reproduction number, known as R nought or R zero (R_0), or the effective reproduction number (R_e or R_t).

R_0 describes how many people each infected person will infect on average at the start of a disease outbreak, assuming that everyone is susceptible and there is no pre-existing immunity in the population.

The number of 'susceptibles' falls as people develop immunity (following exposure or through vaccination) or die. The progression of the disease is then measured by the *effective* reproduction number, R_e (sometimes called R_t or just R). This represents the number of people in a population who can be infected by an individual at any specific time after the initial onset of the disease. It changes as the population becomes increasingly immune, either following infection or by vaccination, and also as people die. In the absence of a vaccine, R_e can also

[1] Ed Yong, 'The Deceptively Simple Number Sparking Coronavirus Fears', The Atlantic, 28 January 2020 - https://amp.theatlantic.com/amp/article/605632/

[2] BBC article, 12 May 2020 - https://www.bbc.co.uk/news/uk-northern-ireland-52624048

be affected by changes in people's behaviour, such as hand washing, self-isolation and social distancing.

R_0 and R_e are often confused or just referred to as the R number. When politicians refer to R during the present pandemic they are generally referring to the effective reproduction number.[3]

3 How is R calculated?

Epidemiologists can calculate R_0 using individual-level contact tracing data obtained at the onset of the epidemic. However, this information may not be readily available or easy to obtain. So the more commonly used approach is to obtain R_0 indirectly from changes over time in population-level incidence data (e.g. change over time in the number of new cases or the number of deaths). By making a number of assumptions based on whatever information is available, they can construct equation-based or 'agent-based' (computer simulation) models without tracking individuals.[4]

While the concepts may be sound the estimates may not be, however. It is important to note that the value of R_0 varies considerably in the models used in the COVID-19 pandemic. One systematic review[5] reported that the mean of 29 reported values of R_0 from 21 studies was estimated at 3.32, with a range of 1.9 to 6.49. All the studies reviewed were from China. In a statement on 23 January about the outbreak of COVID-19 the World Health Organization[6] gave a preliminary R_0 estimate of between 1.4 and 2.5.

This variation in methods and results has led science journalist Ed Yong[7] to conclude that "R_0 is not easy to calculate."

It is also important to be aware that the accuracy or otherwise of estimates of R_e will depend on the assumptions made, which may be erroneous, the quality of the data, which may be poor, and the epidemiological model used, which may distort the outcome.

In making this point, Jeffrey Aronson and his colleagues[8] at the Centre for Evidence-Based Medicine remind us of the wise words of the British statistician George Box:

> *"All models are wrong but some models are useful."*

While Governments across the world are relying on these models to help guide decisions in this pandemic, their desire to keep the message to the public as simple as possible may

[3] See, for example, the recent BMJ article by Elisabeth Mahase, 'Covid-19: What is the R number?', BMJ 2020;369:m1891 doi: 10.1136/bmj.m1891 (Published 12 May 2020) - https://www.bmj.com/content/bmj/369/bmj.m1891.full.pdf

[4] See, for example, the recent *Nature* article by David Adam, 'Special report: The simulations driving the world's response to COVID-19', Nature 580, 316-318, 2 April 2020 - https://www.nature.com/articles/d41586-020-01003-6

[5] Yousef Alimohamadi, Maryam Taghdir, Mojtaba Sepandi, 'The Estimate of the Basic Reproduction Number for Novel Coronavirus disease (COVID-19): A Systematic Review and Meta-Analysis', Journal of Preventative Medicine and Public Health, 20 March 2020 - https://www.jpmph.org/journal/view.php?doi=10.3961/jpmph.20.076

[6] World Health Organization 'Statement on the meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-nCoV)', 23 January 2020 - https://www.who.int/news-room/detail/23-01-2020-statement-on-the-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov)

[7] Ed Yong, 'The Deceptively Simple Number Sparking Coronavirus Fears', The Atlantic, 28 January 2020 - https://amp.theatlantic.com/amp/article/605632/

[8] Jeffrey K Aronson, Jon Brassey, Kamal R Mahtani '"When will it be over?": An introduction to viral reproduction numbers, R0 and Re' Centre for Evidence-Based Medicine, Nuffield Department of Primary Care Health Sciences,University of Oxford, 14 April 2020 - https://www.cebm.net/covid-19/when-will-it-be-over-an-introduction-to-viral-reproduction-numbers-r0-and-re/

overcome the need to pay attention to the caveats that come with the figures. The scientists behind these models have warned that much information about how the virus spreads is still unknown and must be estimated or assumed, which of course limits the precision of forecasts. An earlier version of the Imperial College model, for example, estimated that the virus would be about as severe as influenza in necessitating the hospitalisation of those infected. That turned out to be incorrect.[9]

Many of these models are unique to individual academic groups that have been developing them for years, although the mathematical principles are similar. The simplest models make basic assumptions, such as that everyone has the same chance of catching the virus from an infected person because the population is perfectly and evenly mixed, and that people with the disease are all equally infectious until they die or recover. More advanced models subdivide people into smaller groups (e.g. by age, sex, health status, occupation, geographical location) with varying assumptions about different groups.

All these models require information that can only loosely be estimated at the start of an epidemic, such as the proportion of infected people who die, and the basic reproduction number (R_0). The modellers at Imperial College estimated in their 16 March report[10] that 0.9% of people infected with COVID-19 would die; that the R_0 was between 2 and 2.6; and that people who don't show symptoms can still spread the virus 4.6 days after infection; that others can spread the virus from 12 hours before they develop signs of disease; and that the latter group is 50% more infectious than the former.[11]

They also surmised that there is no natural immunity to COVID-19 (so the entire population starts out as being susceptible) and that people who recover from COVID-19 are immune to reinfection in the short term.

And none of that takes account of the changing behaviour of the virus itself as it continues to mutate.[12]

As the scientists discover more about the virus, they continue to update many of the variables in their models. In the 26 March report[13] on the global impact of COVID-19, the Imperial College team revised their 16 March estimate[14] of R_0 upwards to between 2.4 and 3.3. In their 30 March report,[15] on the spread of the virus in 11 European countries, the researchers put it somewhere in the range of 3 to 4.7.[16]

[9] David Adam, 'Special report: The simulations driving the world's response to COVID-19', Nature 580, 316-318, 2 April 2020 - https://www.nature.com/articles/d41586-020-01003-6

[10] MRC Centre for Global Infectious Disease Analysis, Imperial College London, COVID-19 Report 9 – 'Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand', 16 March 2020 - https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-9-impact-of-npis-on-covid-19/

[11] David Adam, 'Special report: The simulations driving the world's response to COVID-19', Nature 580, 316-318, 2 April 2020 - https://www.nature.com/articles/d41586-020-01003-6

[12] See, for example, the work on this in Iceland, reported by Roger Highfield, 'Coronavirus: Hunting down COVID-19', Science Museum Group, 27 April 2020 - https://www.sciencemuseumgroup.org.uk/blog/hunting-down-covid-19/

[13] MRC Centre for Global Infectious Disease Analysis, Imperial College London, COVID-19'Report 12 – 'The global impact of COVID-19 and strategies for mitigation and suppression', 26 March 2020 - https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-12-global-impact-covid-19/

[14] MRC Centre for Global Infectious Disease Analysis, Imperial College London, COVID-19 Report 9 – 'Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand', 16 March 2020 - https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-9-impact-of-npis-on-covid-19/

[15] MRC Centre for Global Infectious Disease Analysis, Imperial College London, COVID-19 Report 13 – 'Estimating the number of infections and the impact of non-pharmaceutical interventions on COVID-19 in 11 European countries', 30 March 2020 - https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-13-europe-npi-impact/

[16] David Adam, 'Special report: The simulations driving the world's response to COVID-19', Nature 580, 316-318, 2 April 2020 - https://www.nature.com/articles/d41586-020-01003-6

4 How useful is R?

Despite this uncertainty and all its limitations, R is useful, at least in theory, as long as the limitations are understood and it is used alongside other available information.

It can be used, for example, in conjunction with other information, to forecast demand for hospital beds, demand for ICU beds, number of ventilators required, or likely number of deaths under different scenarios.

The basic reproduction number R_0 provides a useful baseline and an indication of a disease's potential. It can also be used to estimate the proportion of the population that would have to become immunised (either by acquiring the disease and recovering, or by vaccination) to attain herd immunity. Herd immunity occurs when a significant proportion of the population has become immune. The larger the number of people who are immune in the population, the lower the likelihood that a susceptible person will come into contact with an infected person. It is more difficult for diseases to spread between individuals if large numbers are already immune as the chain of infection is broken.[17]

The herd immunity threshold is the proportion of a population that need to be immune to reduce the value of R to 1. It can be calculated using the formula 1 minus $1/R_0$.

If the threshold for herd immunity is surpassed, then the effective reproduction ratio R_e will reduce to less than 1 and the number of cases of infection decreases, which in theory will bring an end to the epidemic. For example, if R_0=2.8, then around 64% of the population (i.e. 1 minus 1 divided by 2.8, expressed as a percentage) would have to be immunised to reach the threshold.

In its most basic form, R (whether it be R_0 or R_e) is essentially the product of three factors:[18]

- The average rate of contact between susceptible and infected individuals
- The probability of infection given contact between a susceptible and infected individual
- The duration of infectiousness

However, very little of this information is easily obtainable. Even the duration of infectiousness can only be estimated within a range of values as there is some debate about when an individual becomes infectious before displaying symptoms. An article by epidemiologists at the Australian National University[19] reports that the infectious period is thought to start 1 to 3 days before symptoms are displayed and in the first 7 days after symptoms begin i.e. a total of 8 to 10 days. The Imperial College team use an estimate based on the infectious period starting 12 hours before symptoms with an average infectious duration time of 6.5 days.[20]

[17] 'HealthKnowledge Public Health Textbook, Research Methods, Chapter 1a – Epiemiology, '' Epidemic theory (effective & basic reproduction numbers, epidemic thresholds) & techniques for analysis of infectious disease data (construction & use of epidemic curves, generation numbers, exceptional reporting & identification of significant clusters)' Maria Kirwan, 2009 (Updated by Saran Shantikumar, 2018) - https://www.healthknowledge.org.uk/public-health-textbook/research-methods/1a-epidemiology/epidemic-theory

[18] See, for example, HealthKnowledge article above and also J.H. Jones, Stanford University, 'Notes on R0', 13 April 2019 - http://web.stanford.edu/class/earthsys214/notes/Jones_R0_notes2019.pdf

[19] Housen, T., Parry, A.E. & Sheel, M., Australian National University, 'How long are you infectious when you have coronavirus?', The Conversation, 12 April 2020 - https://theconversation.com/how-long-are-you-infectious-when-you-have-coronavirus-135295

[20] MRC Centre for Global Infectious Disease Analysis, Imperial College London, COVID-19 Report 9 – 'Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand', 16 March 2020 - https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-9-impact-of-npis-on-covid-19/

In the absence of direct information available on the movements of infected and susceptible members of the population and the numbers who have acquired immunity through recovery, these models will generally estimate R indirectly from other sources. Available information on tests results, hospital admission rates, average recovery times, death rates, duration of hospital stay prior to discharge (or death), etc., together with a number of key assumptions about different groups, can all be used to feed into the wide range of models available.[21]

Governments can do very little about the susceptibility or duration of infectiousness in the absence of effective treatment or a vaccine. The focus therefore has to be on reducing contact between people and reducing the risk of transmission to control the spread of the disease.

By prohibiting large gatherings, encouraging people to stay at home, and restricting movement within the population, the rate of contacts is reduced.

By encouraging people to wash their hands and to stay two metres apart when mixing with other members of the public, and by providing personal protective equipment for those in high risk occupations, the probability of the infection being transmitted is reduced. The wearing of masks in public places or on public transport, where close contact may be unavoidable, may help to reduce the risk further.

R can be useful in helping to assess the rate at which the disease is spreading at any given time and the extent of any action required to bring the disease under control. For example, reducing contacts between infected and susceptible individuals by 70% should, in theory (assuming everything else remains constant), reduce an R value of 2.8 to around 0.8. Increasing contacts back to 50% of their original level, however, would bring that R value back up to 1.4, indicating the likelihood of further exponential spread of the disease. That is a simplified example of the sort of reasoning that is taking place at present using R.

5 The caveats

While R provides a useful indication of the potential of the disease, helps to inform policy in the fight against the disease, and gives some indication of what progress has been made in that fight, it is necessary to be aware of its limitations. The information going into the equations used to estimate R is far from perfect. Some of the problems that the scientists are faced with at the moment are as follows:

1) They do not know for sure how many people might be infected. The number of reported cases will depend on how many are being tested and who is being tested. A recent pilot survey carried out by the Office for National Statistics (ONS)[22] produced an estimate of 0.27% of the population (excluding nursing homes, hospitals and other institutions), However, the confidence interval for this was stated to be between 0.17% and 0.41%, and this was based on 33 individuals testing positive, with some question marks over the number of false-positive and false-negative results. While there are plans to expand the survey and to include test results for antibodies, the figures are of limited use at present.

[21] See, for example, the American Hospital Association's 'Compendium of Models that predict the spread of COVID-19' - https://www.aha.org/guidesreports/2020-04-09-compendium-models-predict-spread-covid-19

[22] Office for National Statistics, 'Coronavirus (COVID-19) Infection Survey pilot: England', 14 May 2020 - https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/coronaviruscovid19infectionsurveypilot/england14may2020

2) Without reliable information on the number of people who have been infected, it is not possible to estimate the number in the population who may have acquired immunity and therefore the number who may still be susceptible. The antibody test part of the ONS infection survey may help to provide some information on that in the future, however.

3) The roll out of increased testing to more people and to different groups makes it difficult to identify an underlying trend in the number of infections. As the number of tests are increased, the likelihood of identifying new cases is also increased, so it is impossible to say how much of any change over time is due to the rate of spread of the virus. Also, as the people being tested do not provide a random sample, the number of cases cannot be used to estimate the number in the population who have been infected. So the figures for new cases or the cumulative number of cases are of little value, other than to give an indication of the least number of people infected.

4) While the average incubation period is thought to be somewhere around 5 days (with a range of 2-14 days), different studies have come up with different estimates.[23] So this is another source of uncertainty. It is not possible therefore to trace the disease back to the time of infection, except through contact tracing.

5) The duration of infectiousness appears to vary greatly, according to the severity of the disease. As pointed out earlier, estimates of the average duration of infectiousness also vary, with some uncertainty around how soon before displaying symptoms an individual might become infectious. Also, some people may be infectious without displaying any symptoms. These people may be less infectious than those with symptoms, but they are impossible to identify without testing.

6) Death rates can change as more vulnerable people die, leaving the disease with less vulnerable people to kill. Death rates can also change due to hospitals getting better at treating the disease. While changes in death rates can be mitigated to some extent by making different assumptions about different age groups or different ethnic groups, there are many other factors, such as obesity and various comorbidities, which have been linked to vulnerability.

7) The problem of delays in the reporting and registering of deaths has been well documented. Also, the different sets of figures produced from daily reports and from death registrations does not help. The average time period between infection and death added to delays in reporting means that information on deaths will always be 3 to 4 weeks behind the actual spread of infections.[24] Uncertainty around the duration of the time lag, in itself, presents a problem for the models used.

8) Hospital admissions data provide a useful indication of trends in the spread of the disease, but do not include people being treated in care homes or those who may be seriously ill or dying at home. It also suffers from the same time lag problem as data on

[23] See, for example, Worldometer on Coronavirus incubation period - https://www.worldometers.info/coronavirus/coronavirus-incubation-period/

[24] Based on Lancet article (by Verity et al, 30 March 2020) giving an estimate of around 18 days between the onset of symptoms and death - https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(20)30243-7/fulltext - and adding an estimated average of 5 days for symptoms to develop, plus a couple of days for reporting delays.

deaths, although with hospital admissions occurring around 3-6 days after the onset of symptoms the time lag would only be around 1 to 2 weeks.[25]

9) The time lag between infection and the availability of data to input into the models means that any R values produced are, in fact, historical (i.e. at best, R reflects what was happening a few weeks previously). This limits the value of R for surveillance purposes, as it is out of date and a lot can change in the activity of the virus in a few weeks.[26]

10) Many assumptions have to be made in the various models used, such as the assumption that the entire population is susceptible at the outset of the disease, the assumption of immunity after recovery from the disease, or the assumption used by the Imperial College team that infected people with symptoms are 50% more infectious than infected people without symptoms. All these assumptions lead to a potentially large range of error in the numbers produced by the models.

Given the uncertainty that arises from all of this, R and many of the other numbers associated with COVID-19 must be interpreted with considerable caution. The many assumptions and estimates built into the models, the quality of the data, and the time lag in the data, could potentially lead to wrong decisions being taken at the wrong time, if too much reliance is placed on a single number.

6 Where 'R' we now?

If a vaccine can be found and the proportion of the population that have acquired immunity can be deduced (using antibody tests), R_0 can be used to estimate the remaining proportion of the population that have to be vaccinated. In doing so, however, regional variations in R_0 need to be taken into account as R_0 varies with population urbanisation or 'lived density'.[27] Also, certain more vulnerable and high risk sub-groups (e.g. older people, vulnerable ethnic groups, health and social care workers) would have to be targeted in any vaccination programme.

While R does vary according to 'lived density' and other regional specific factors, the proliferation of regional Rs emerging does not help when it comes to policy making. The USA has a different R number for every state, with hugely varying confidence intervals attached to each of them.[28] The UK and its devolved administrations have their own separate estimates of R, and different R numbers have lately appeared for different regions in England. The existence of regional Rs render the R at a national level fairly meaningless. Different councils in England have decided to be guided by their own regional circumstances when it comes to following Government advice on, for example, returning to schools.[29]

[25] See article by Sarah Jarvis on disease timeline - 'Coronavirus: how quickly do COVID-19 symptoms develop and how long do they last?', Patient.info, 7 April 2020 - https://patient.info/news-and-features/coronavirus-how-quickly-do-covid-19-symptoms-develop-and-how-long-do-they-last

[26] See Telegraph article by Sarah Knapton on this point, 'The 'R' rate: Is it reliable and how might reopening schools impact it?', 18 May 2020 - https://www.telegraph.co.uk/news/2020/05/17/r-rate-reliable-might-reopening-schools-impact/

[27] See article by Alasdair Rae on the concept of 'lived density', 'Think your country is crowded? These maps reveal the truth about population density across Europe', The Conversation, 23 January, 2018 - https://theconversation.com/think-your-country-is-crowded-these-maps-reveal-the-truth-about-population-density-across-europe-90345

[28] See https://rt.live/

[29] Financial Times article, 18 May 2020 – 'At least 300 UK primary schools will not open to more pupils on June 1' - https://www.ft.com/content/5c4fd44a-c938-4362-b382-b68382be83fe

Different regional administrations can now use their own R number to support their decision to take a different path from the one recommended at a national level. How far will this go? Do we need different Rs for different settings (e.g. care homes, hospitals) as well as different geographical areas? Within Northern Ireland, for example, do we need different Rs for different council areas? Should a Northern Ireland R be applied equally to Belfast and Belleek?

In the meantime, it is necessary to continue indefinitely with what the Imperial College COVID-19 team refer to as 'non-pharmaceutical interventions' or, to use the more appropriate term, 'suppression strategies'.

In their 25 January report[30], the Imperial College team concluded that control measures would need to block well over 60% of transmission to be effective in controlling the outbreak. It looks like that target has been achieved with the R number now less than 1 just about everywhere, albeit with a huge social and economic cost and untold collateral damage.

They also concluded (in their 16 March report[31]) that such measures would have to be maintained until a vaccine becomes available (potentially 18 months or more), given the prediction that transmission will quickly rebound if interventions are relaxed. In addition, they suggested that a policy of intermittent social distancing (triggered by trends in disease surveillance) could be introduced. This would allow interventions to be relaxed temporarily in relative short time windows, but it would be necessary to quickly re-introduce control measures if or when case numbers began to rise again.

That is why it is necessary to continuously monitor R (or the growing number of Rs, along with other data on hospital admissions, ICU beds occupied, etc.) at least until the end of 2021. The results of this monitoring, along with observations of the unfolding events in other countries, will most likely determine the extent and nature of our social and economic activity for the next 18 months or so.

The scientists who are grinding out the R numbers are undoubtedly aware of all the caveats and weaknesses in their methods. Such awareness, however, appears to be lacking in the message presented to the public by Government Ministers. In their attempts to keep the message simple and to convey a sense of being in control of the situation, they will no doubt be inclined to quote the latest R number, without confidence intervals and caveats, in support of their actions.

Increased testing and contact tracing will hopefully improve the estimates of R, assuming the UK and the devolved administrations can catch up in this area with other countries[32], such as Germany, South Korea and New Zealand.

If Governments follow the R number slavishly, however, and the estimates are too high, the population will be paying a higher price than necessary in terms of social, economic and collateral damage. If the estimates of R are too low, there is the risk of easing restrictions too early, potentially giving rise to additional unnecessary deaths and prolonged misery. In the

[30] MRC Centre for Global Infectious Disease Analysis, Imperial College London, COVID-19 Report 3 – 'Transmissibility of 2019-nCoV', 25 January, 2020 - https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-3-transmissibility-of-covid-19/

[31] MRC Centre for Global Infectious Disease Analysis, Imperial College London, COVID-19 Report 9 – 'Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand', 16 March 2020 - https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-9-impact-of-npis-on-covid-19/

[32] See NI Assembly Research Paper 'COVID-19: Testing for Sars-CoV-2 in the UK; and the Use of Testing and Contact Tracing in Selected Countries', 4 May 2020 - http://www.niassembly.gov.uk/globalassets/documents/raise/publications/2017-2022/2020/health/1820.pdf

end, it all boils down to making the right judgement call and not relying too heavily on the numbers.

Ville Aula, a researcher at the London School of Economics,[33] refers to the misplaced trust that the media and the public have in the COVID-19 numbers that are being rolled out every day, and concludes that:

> *"Ultimately, the constant stream of empty numbers will grant us neither certainty nor solace."*

Time will tell whether or not our trust in R is misplaced.

[33] LSE article by Ville Aula, 'The public debate around COVID-19 demonstrates our ongoing and misplaced trust in numbers', 15 May, 2020 - https://blogs.lse.ac.uk/impactofsocialsciences/2020/05/15/the-public-debate-around-covid-19-demonstrates-our-ongoing-and-misplaced-trust-in-numbers/