WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Mathematics behind Social Distancing

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ABSTRACT

Social distancing practices refers to the changes in behavior that prevents the transmission of a highly infectious disease by reducing contact rates between susceptible individuals and infected individuals who may transmit the disease. The article explores the ways in which such practices can lower the gravity of an epidemic however, the benefits of social distancing are determined by the extent to which it is used by individuals. Individuals are often hesitant to pay the costs ingrained in social distancing, and this can dampen its effectiveness as a control measure. This article also formulates the utmost importance of physical distancing by stating the simple mathematics behind it. The key parameters in the analysis are the basic reproduction number and the efficiency of physical distancing.

Introduction

Whenever humankind is hit by a crisis, we humans always look to science for help. Not because scientists are exemplary, but because science is one of the best ways humans have come up with to understand the immense complexities of this universe and devised the ways to fix it when it's broken. As we all continue to battle novel coronavirus COVID-19, terms like "social distancing" and "quarantine" have become the new hot topics. In the absence of a vaccine or any other full proof clinical remedy, what we all must do is to follow the guidelines issued by the medical authorities.While we all may call it social distancing, the technology still allows us to interact socially with our near and dear ones while not being physically present there. However, The World Health Organization refers to it as physical distancing: deliberately increasing the physical space between people remaining socially active.

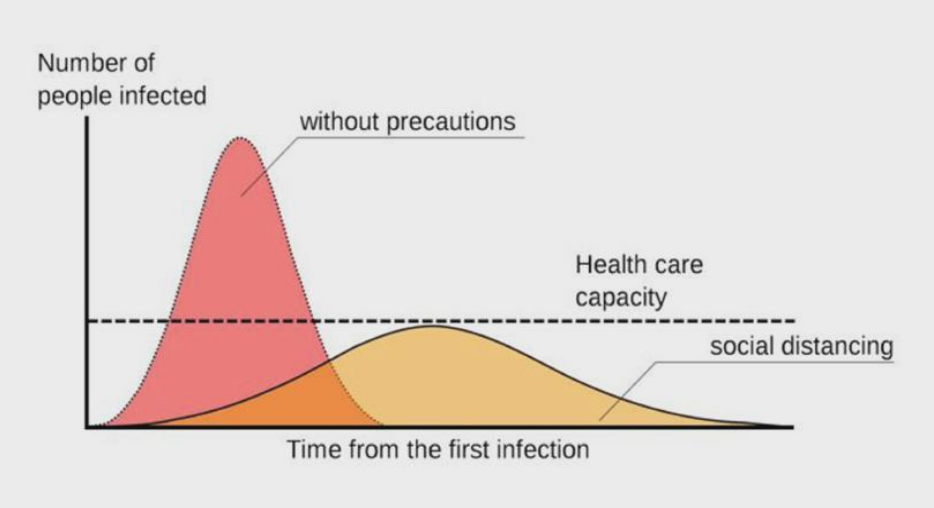
How exactly will social distancing help us?

During the outbreak of SARS, measures like social distancing were not of prime importance. One of the prominent reasons behind this was the fact that individuals suffering from infectious SARS displayed clear symptoms. As a result, the outbreak could be controlled by finding and isolating symptomatic cases. However, the situation for Covid-19 is somehow different due to the wide spectrum of symptoms shown by the infected individuals.

Before understanding physical distancing it's important to apprehend how Coronavirus is transmitted. It is spread by respiratory droplets produced by sneezing and coughing. If you breathe in the droplets, or they land on your eyes, nose, or mouth you are at risk of getting infected. Here comes the concept of social distancing. Researches show that these droplets do not travel more than 6 feet. We can interrupt human to human transmission by keeping a distance from people and avoiding all forms of physical contact.

This will help but not fix the problem.

Practicing social distancing will slow down the outbreak. It will enable "flattening of the curve", which is slowing the curve and decreasing its peak so that fewer people are sick at a time. If the curve flattens, the outbreak will last longer. But simultaneously the number of people arriving in the hospital each day needing critical care decreases. Given the limited count of hospital beds and ICUs and already strained healthcare facilities, this way we reduce the burden on them and can keep up with the soaring demands.



What's the mathematics behind it?

Aristotle the legendary Greek philosopher said, "Man is by nature a social animal." All of us, in our daily lives, mingle with dozens of people. Those people connect with other people, who interact with others, forming a large network that links everyone in the society.

When you are infected, you can easily spread the virus to other people. The basic reproduction number (R_0) is used to measure the transmission potential of a disease. It is the average number of secondary infections produced by a typical case of an infection in a population where everyone is susceptible. A figure greater than 1.0 gives rise to exponential growth in the number of infected cases, whereas a figure of 1.0 or less means the virus will die off.

Hypothesis

Researchers speculated that the basic reproduction rate of coronavirus is 2.5. This means that on average an infected person will spread the virus to 2.5 other people. We can optimistically expect that the reproduction rate will decrease in the near future, with the development of an effectual vaccine and a better understanding of the virus.

A median five-day incubation period was assumed by the scientists, during which an infected person will unknowingly spread the virus to other people. After this period, the person will begin to develop symptoms, instantly self-quarantine, and no longer pose threat to public health.

It was also presumed that in a day an infected person will, on average, form close associations with five uninfected, healthy individuals. It was also speculated that there is a 10% probability that each interaction will pass on the virus.

Lastly, the studies believed that there exists a direct linear correlation between social interaction and the basic reproduction rate (R_0). This implied that when an infected person reduces his physical contact with others by 50%, then their chances of transmitting the disease also decreases by 50%.

Staying home can save lives- the number speaks

IN CASE OF NO SOCIAL DISTANCING

$$Number\ of\ individuals\ affected\ in\ a\ day = (Number\ of\ close\ associations) * (Probability\ of\ passing\ on\ the\ virus)$$

$$= 5 * 10\%$$

$$= 0.5$$

Hence in a day, an infected person will spread the virus to 0.5 unhealthy individuals.

As we are considering that an infected person will continue to spread the virus for 5 days before showing symptoms and quarantining himself.

$$R_0 = 0.5 * 5 = 2.5$$

This indicates that a single infected person will pass on the disease to 2.5 healthy individuals in 5 days.

$$After\ 10\ days \quad 2.5 * 2.5 = 6.25$$

$$After\ 15\ days \quad 6.25 * 2.5 = 15.62$$

$$1, 2.5, 6.25, 15.62 \ldots..$$

This is a geometric progression with common ratio $r = 2.5$ and first term $a = 1$

Sum of n term of Geometric progression, $S_n = a(1-r)^n / 1 - r$

After 30 days(7 cycles of 5 days) number of infected individuals $S_7 = 1(1-2.5)^7 / 1 - 2.5$

$$= 406.23$$

Hence after 30 days a single infected person will infect 406 healthy individuals.

Now, there are only two ways to reduce R_0, which are-

Decreasing the probability of passing the virus in each interaction from 10% to a lower figure. In the absence of a vaccine, we cannot change this figure.

Limiting the networks formed by reducing the close association each person makes. This can be done by practicing social distancing.

IN CASE OF 50% LESS EXPOSURE

$$Number\ of\ close\ associations\ = 5 - (50\%\ of\ 5)$$

$$= 5 - 2.5 = 2.5$$

$$R_0 = (Number\ of\ close\ associations) * (Probability\ of\ passing\ on\ the\ virus) * 5$$

$$R_0 = 2.5 * 10\% * 5$$

$$R_0 = 1.25$$

This indicates that a single infected person will pass on the disease to 1.25 healthy individuals in 5 days.

IN CASE OF 75% LESS EXPOSURE

$$Number\ of\ close\ associations\ = 5 - (75\%\ of\ 5)$$

$$= 5 - 3.75 = 1.25$$

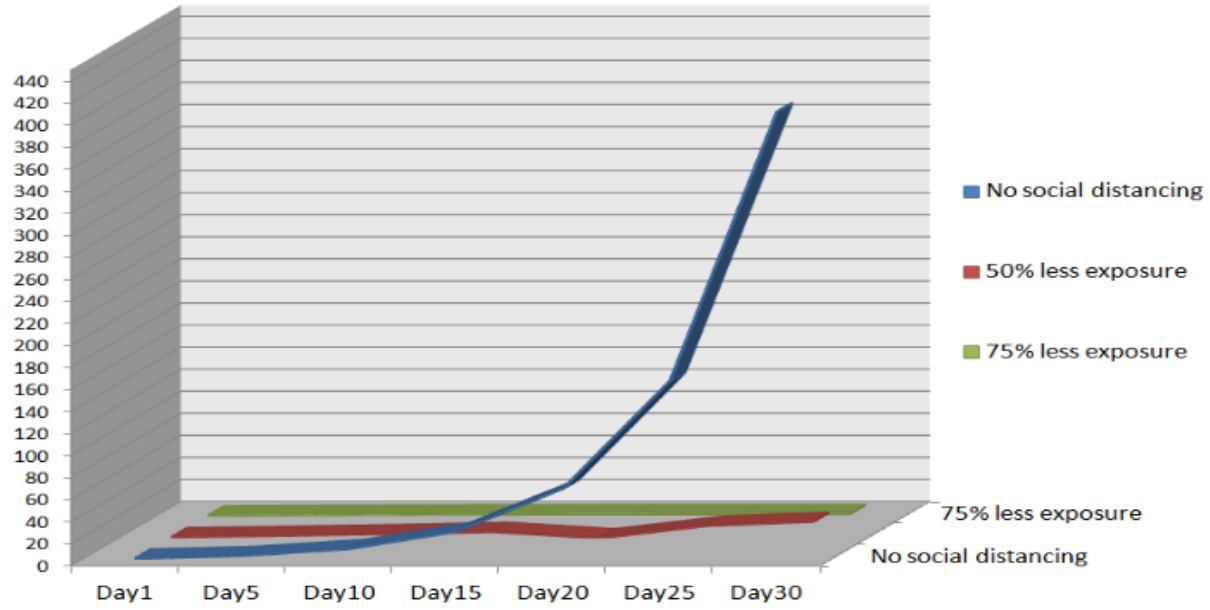
$$R_0 = (Number\ of\ close\ associations) * (Probability\ of\ passing\ on\ the\ virus) * 5$$

$$R_0 = 1.25 * 10\% * 5$$

$$R_0 = 0.625$$

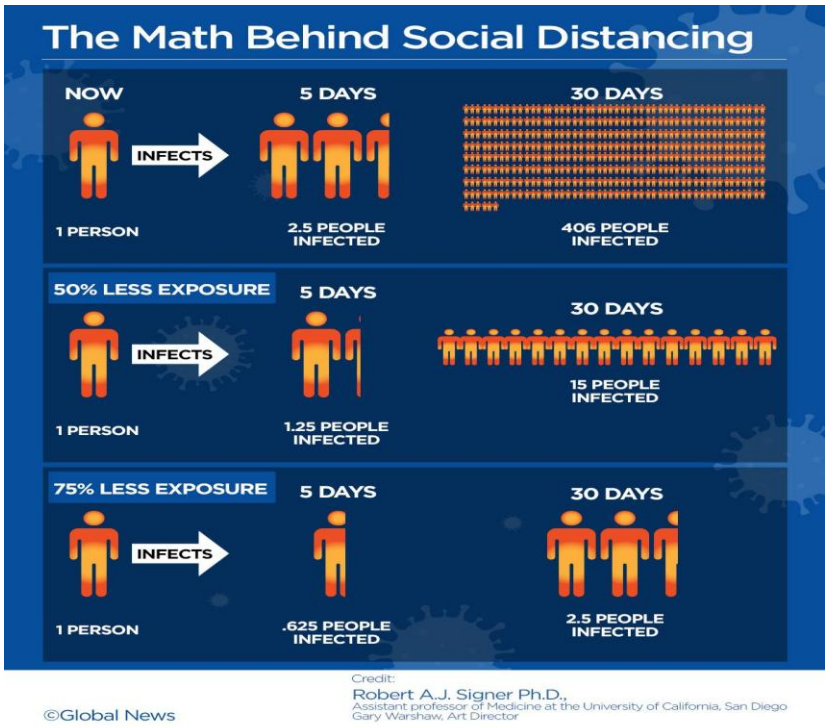
This indicates that a single infected person will pass on the disease to 0.625 healthy individuals in 5 days.

As a matter of fact, it can be observed that the transmission chain will eventually end. In the practical scenario, a person can't actually infect 0.625 people. An infected individual will infect zero people, one person, or more than one person. There is also a good chance of an infected person not passing on the virus, i.e., infecting zero people, and hence this way the transmission will end.



Number of people infected by a single person

Condition	Day1	Day5	Day10	Day15	Day20	Day25	Day30
No social distancing	1	3.5	9.75	25.38	64.44	162.06	406.13
50% less exposure	1	2.25	3.81	5.77	8.2	11.25	15.06
75% less exposure	1	1.63	2.02	2.27	2.42	2.52	2.57



CONCLUSION

It will take at least a year-if not two or more-for the development of a successful and effective vaccine. The most promising of therapies identified until now also have limited benefits at best. As a result of which social distancing strategies have now become the core of national policies of the countries which have started lifting up the curbs. Until we get an in-depth knowledge of the virus and effective measures of controlling the spread, physical distancing is here to stay.

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