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How to Explain the Relation Between Different Empirical Covid-19 Self-Isolation Periods

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Abstract

Empirical data implies that, to avoid infecting others, an asymptomatic career of Covid-19 should self-isolate for a period of 10 days, a patient who experiences symptoms for 20 days, and a person who was in contact with a Covid-19 patient should self-isolate for 14 days. In this paper, we use Laplace's Principle of Insufficient Reason to provide a simple explanation for the relation between these three self-isolation periods.

1 Formulation of the Problem

Empirical data. Based on the empirical data, the US Center for Disease Control and Prevention (CDC) provides the following recommendations for self-isolation [2]:

- a person who tested positive for Covid-19 but did not have any symptoms should self-isolate for 10 days;
- a person who had symptoms should self-isolate for 20 days after the symptoms appear;
- a person who was in contact with a Covid-19 patient should self-isolate for 14 days.

These periods were selected because, according to the empirical data:

- any shorter self-isolation would lead to an unnecessary risk of infecting others, and
- any longer self-isolation is unnecessary: it does not decrease the risk of infecting others.

Natural question. A natural question is: how can we explain these empirical conclusions?

What we do in this paper. In this paper, we provide a partial explanation of these conclusions. To be more precise, we do not explain the actual self-isolation periods, but we do explain the relation between these three periods.

2 How to Explain the Relation between Symptomatic and Asymptomatic Self-Isolation Periods

Idea. From the commonsense viewpoint, a person who had symptoms – and who, thus, experienced a more serious effect of the diseases – has to be isolated for a longer time than a person who did not have any symptoms – and whose exposure to the virus was thus less serious.

Let us formalize this idea. Let us take, as a given, that a person who had symptoms has to be self-isolated for $T_s = 20$ days, after which contacts with this person are no longer dangerous to others. What will then be the needed self-isolation time T_a for an asymptomatic person?

The only thing we know – based on the above idea – is that the desired value T_a should be smaller that T_s. In other words, the only information about T_a that we can deduce from the above idea is that T_a should belong to the interval $[0, T_s)$.

How can we extract a specific number from this information?

Let Us Use Laplace's Principle of Insufficient Reason. Situations when we have several alternatives, and we do not now which alternatives are more probable and which are less probable are ubiquitous. To assign reasonable probabilities in such situations, the 18/19 century mathematician Pierre-Simon Laplace proposed a reasonable idea:

- if we do not have any reason to assume that some alternatives are more probable and some are less probable,
- a reasonable idea to assign equal probabilities to all these alternatives.

This principle was later developed into a general approach to assigning probability known as *Maximum Entropy approach*; see, e.g., [1].

In particular, for the case when possible values form an interval, we assign equal probability to all the values from this interval, i.e., we consider a uniform distribution on this interval.

So what value T_a should we select? With equal probability, the desired value can be equal to all possible values from this interval. In a situation in which we have a finite number of possible values $T_1, \ldots, T_n$, we can describe this situation as having n equally possible approximate equations:

$$T_a \approx T_1;$$

$$T_a \approx T_2;$$

$$\ldots$$

$$T_a \approx T_n.$$

We can combine these 1-D approximate equalities into a single multi-D approximate equality:

$$(T_a, T_a, \ldots, T_a) \approx (T_1, T_2, \ldots, T_n).$$

It is reasonable to select a value for which the corresponding multi-D vectors are the closest possible, i.e., for which the distance

$$d((T_a, T_a, \ldots, T_a), (T_1, T_2, \ldots, T_n)) = \sqrt{\sum_{i=1}^{n} (T_a - T_i)^2}$$

is the smallest. This distance is the smallest when its square

$$d^2 = \sum_{i=1}^{n} (T_a - T_i)^2$$

is the smallest possible. Differentiating the expression for d^2 with respect to T_a and equating the derivative to 0, we conclude that

$$T_a = \frac{T_1 + T_2 + \ldots + T_n}{n},$$

i.e., that the adequate selection of T_a is the mean value of T_i.

For the uniform distribution on an interval, the mean value is the midpoint of this interval. In particular, for the interval $[0, T_s)$, the midpoint is $T_a = \frac{T_s}{2}$, i.e., for $T_s = 20$, exactly $T_a = 10$ days.

So, the relation between asymptomatic and symptomatic self-isolation periods is indeed explained.

3 How to Explain the Relation between Symptomatic, Asymptomatic, and Contact-Related Self-Isolation Periods

Idea. In case of a contact, we do not know how many viruses we got:

- we could get a lot, or
- we could get a few.

So, from the commonsense viewpoint, in this situation of uncertainty, the required self-isolation period should be:

- shorter than the period T_s when we know that there was a large number of viruses, but
- longer than the period T_a when we know that was a significantly smaller number of viruses.

In other words, from the commonsense viewpoint, all we know about the contact-related self-isolation period T_c is that it should be:

- greater than T_a but
- smaller that T_s,

i.e., that the period T_c should be located in the interval (T_a, T_s).

Let us transform this idea into an exact value for T_c. Similar to the analysis presented in the previous section, it is reasonable to assign equal probability to all the values from the interval (T_a, T_s), i.e., to select a uniform distribution on this interval.

Again, similarly to the analysis presented in the previous section, it is reasonable to select a value which is equal to the mean value of this distribution, i.e., to the midpoint

$$T_c \approx \frac{T_a + T_c}{2}$$

of this interval.

For $T_a = 10$ and $T_s = 20$, we get

$$T_c \approx \frac{10 + 20}{2} = 15,$$

which is indeed very close to the recommended period of 14 days.

Actually, the empirical data are not so accurate to distinguish between 14 and 15 days, so we can conclude that this period is explained as well.

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