Science You Can Use

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Dear Science: I hear all kinds of dates about when I will be able to be vaccinated for COVID-19. Why is there so much uncertainty? -- Buck R.

Dear Buck: Various health experts say that we will have to vaccinate about 75% of the US population before we can have high confidence that vaccination will bring the pandemic under control. This level of control is informally called "herd immunity". (There will still be a few new COVID cases even when herd immunity is achieved.) So suppose that the objective of the US vaccination program is to vaccinate 75% of the US population (let's call that 75% the "target population") in the next six months.

There is significant uncertainty in each of a long list of activities that have to be completed, in a specific order, to achieve herd immunity in six months (or in any other specific time period). The chance of all these activities being completed in six months is small. To see this, let's list the activities that have to be completed, then estimate how likely it is these activities can be completed during the time of interest.

What activities must be completed to get the vaccine injected in the target population? Once developed, tested for safety and effectiveness, and approved for use, the vaccine, *in sufficient quantity to vaccinate the target population in six months*, must be:

1. manufactured, packaged, and stored at the manufacturer's site, then
2. shipped to the vaccination-administration centers (such as pharmacies and doctors' offices), then
3. stored at the vaccine-administration centers, then
4. scheduled for injection at the vaccine-administration centers, then
5. injected by qualified healthcare personnel at the vaccine-administration centers

How likely is it that all these activities can be completed in a given time? Each step described above can succeed or fail in ways that are specific to those individual steps. Suppose we have the following estimated chances ("probability") of success at each step, where the number on the left corresponds to the number of the step in the list above, the number on right is the chance of success on that step, and the time period of interest is six months:

1. 0.9 (manufactured, packaged, and stored at manufacturer's site)
2. 0.99 (shipped to the vaccine-administration centers)
3. 0.9 (stored at the vaccine-administration centers)
4. 0.8 (scheduled for injection at the vaccine-administration centers)
5. 0.7 (injected by qualified personnel)

The chance that the vaccine will be injected in all of the target population is calculated by multiplying all of the individual-step-level chances together. Thus the overall chance of succeeding, in this example, is 0.9 x 0.99 x 0.9 x 0.8 x 0.7 = 0.45, or only about one chance in two.

Several of the individual-step chance-values in the example are likely to be too optimistic. That means the chance that all of them will succeed in six months is even lower than 0.45 (45%). For example, as of 25 January 2021, it appears that the vaccine manufacturers have produced only about half the number of vaccine doses required to keep the pipeline filled. (There is some chance that this problem can be reduced in the next three months as additional vaccine supplies become available.) In addition, many vaccination sites can't inject fast enough to keep up with the demand even when they have the vaccine on hand, because most states have only about half of the qualified healthcare personnel required to achieve herd immunity in six months.

Some states have made more progress the activities listed above than other states have. As part of "scheduling injections", for example, various healthcare providers in New Mexico have lists that specify the order in which individuals who sign up will be vaccinated at specific vaccination-centers, provided the vaccine is available at those centers; other states, such as Kansas, do not have injection schedules that are nearly as specific as New Mexico's.

You can experiment with the example above by changing the chance-values for individual steps. (All chance-values must be between 0 and 1 inclusive). Those experiments will convince you that given plausible estimates of the chances of success for each step, the total set of activities required to get the vaccine to the entire target population has a relatively low chance of succeeding in six months. Considerations like these have led several healthcare experts to suggest it is likely it will be January 2022 before we have vaccinated 75% of the US population.

For information about getting your vaccination, contact your healthcare provider. For further information about reasoning about chance, see John F. Symons, *Formal Reasoning: A Guide to Critical Thinking*, Kendall Hunt Publishing Company, 2017, especially Chapter 9.

Jack Horner is a systems engineer. *Clancey Maloney made several valuable suggestions about earlier drafts of this column.*