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Modeling behaviors that spread disease

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Whether it's a cough or a handshake, one point of contact by an infected individual may be all it takes to spark an epidemic. The same can also be true for cultural traits related to a disease. Stanford theoretical biologists have developed a new mathematical model that investigates how a health-related behavior or idea that is transmitted between people can harm

public health.

When these "cultural pathogens"—such as anti-vaccination sentiments, aversion to wearing a face mask, or preferences for ineffective folk medicines—spread through a populace, they can promote the spread of diseases, according to the model developed by Stanford biologist Noah Rosenberg and his team.

The research, conducted pre-COVID-19 and published in May in the journal Evolutionary Human Sciences, has received a Stanford grant to further explore how the coupling of cultural behavior and disease might specifically relate to the coronavirus.

"A well-known difficulty in mathematical modeling of infectious disease is the unpredictability of human behavior," said Rosenberg. "But we can classify different possible behaviors and put them into a mathematical model that can analyze different possible outcomes."

The model population

Rosenberg said the idea for the study came from observations of harmful folk medicines and cultural practices, such as bloodletting practiced by physicians, or the use of arsenic, lead and mercury in traditional Indian medicine. The choice to turn to harmful treatments is a sentiment that spreads among practitioners and patients but often exacerbates disease conditions.

To couple the transmission of disease with the transmission of a sentiment, the researchers used what's called an S-I-R model, which divides populations into groups, or "compartments"—namely those who are susceptible, infected and recovered. "The S-I-R model with one dimension for behavior and one dimension for disease is among the simplest ways to understand how the behavioral dynamics affect the

disease dynamics," said Rosenberg.

In the case of modeling anti-vaccination sentiment as a transmissible preference, this would mean susceptible individuals are undecided about vaccines; infected individuals are those who have the anti-vaccination sentiment; and recovered individuals are pro-vaccine and not susceptible to anti-vaccination sentiment.

There could realistically be a broad spectrum of feelings associated with any particular sentiment, but simplifying the model provides a clearer connection to disease dynamics. For example, individuals who are pro-vaccine could change their minds in the real world, but the model assumes they cannot (as if they have already been vaccinated as a result of their sentiments and cannot undo the action).

"We want these kinds of models to have some realism, but the more complicated we make them, the harder it is to fully understand all the potential behaviors that could emerge," said Rosenberg. "The goal is to understand how phenomena affect each other, rather than to make projections. We see clearly in the model how anti-vaccination sentiment can promote spread of the disease for which the vaccine is being applied."

A cultured virus

The study was designed with a disease like measles in mind, for which the majority of the population has already been vaccinated. The model shows how the dynamics of anti-vaccination sentiments can allow even seemingly controlled diseases to experience new outbreaks—a consideration that may become important with regard to the current pandemic.

For public health communication and resources, Rosenberg said, it is

useful to consider the cost and benefit of transitioning each of the S-I-R groups toward a more desirable compartment. Costs in terms of time and resources, and benefits in reducing infections, will differ with interventions such as attempts to stop transmission of anti-vaccination sentiment and to transition those who are anti-vaccination or undecided to pro-vaccination, as well as to vaccinate those who are pro-vaccination.

A COVID connection?

While the research predates the pandemic, the scientists have received a Stanford RISE grant to further explore how the findings could apply to COVID-19. According to Rosenberg, aversion to wearing a face mask fits the model's definition of a cultural pathogen. But anti-vaccination sentiment may also become a significant factor for COVID-19 once an effective vaccine has been developed. The model can be adapted to explore how future resurgences could occur if the behaviors associated with anti-vaccination sentiments persist.

"As the pandemic has progressed, it has become clear that combining a cultural evolution framework with an epidemic dynamics framework has something to offer," Rosenberg said.

More information: Rohan S. Mehta et al. Modeling anti-vaccine sentiment as a cultural pathogen, *Evolutionary Human Sciences* (2020). DOI: 10.1017/ehs.2020.17

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