New models show how human behavior influences pandemic trends

February 6 2024, by Jordi Shelton

Navid Ghaffarzadegan, associate professor in the Grado Department of Industrial and Systems Engineering, developed a COVID-19 in Universities model that helped university officials at Virginia Tech and beyond make research-based policy decisions. Now, his research is focused on the impacts of human behavior in COVID-19 mortality rates. Credit: Lee Friesland for Virginia Tech

Nearly four years after the first case of COVID-19 reached the United States, researchers want to learn more about what impacted varying rates of the virus' outbreak and spread. One question in particular piqued the interest of a team of researchers across the country: Why were there such varied COVID-19 death rates across the world, even though implemented policies were not that different?

"A pandemic emerges from a complex system of human interactions, and a big part of systems engineering is learning how to develop models of complex systems so we can make better decisions," said Navid Ghaffarzadegan, associate professor in the Grado Department of Industrial and Systems Engineering.

"This was a major puzzle during the first two years of the pandemic because we were dealing with the same virus, governments were implementing similar policies, people of different countries on average were doing the same thing, but still death rates varied greatly across different countries. In some countries, people were dying 100 times more than in other countries. We wanted to know, 'Why was this happening?'"

The answer is as simple as it is complex: Human behavior. This unpredictable yet crucial piece of the puzzle is one that was often missing from COVID-19 forecasting models. Ghaffarzadegan collaborated with a team of researchers across engineering, science, and health disciplines to dive deeper.

"One of the shortcomings of previous modeling was the lack of modeling change in human behavior. People are not passive. They see risk around them and change their actions. It can be difficult to predict how people might behave in the future, so traditionally, researchers neglect modeling this component," Ghaffarzadegan said. "What we are doing now is modeling human behavior during an epidemic and adding

that human responsiveness and behavioral component."

Using responsiveness as a jumping-off point, Ghaffarzadegan and his team created mathematical models that examine aspects of human behavior that affect responsiveness, such as risk perception and adherence to preventive measures. They uncovered that how seriously and quickly people assess risks and threats is key to understanding why similar policies resulted in such different outcomes. Their paper featuring these findings was published in *Health Affairs* in December 2023.

Unlocking the code to COVID-19 forecasting

Solving complex COVID-19-related puzzles using modeling is nothing new for Ghaffarzadegan and his research team. Since 2020, their research on modeling infectious diseases has informed decisions at Virginia Tech and beyond. In 2021, Ghaffarzadegan's COVID-19 in Universities model helped university officials make decisions about mitigating the risk of COVID-19. While models are not always perfect representations of how people react, they are helpful tools for understanding a complex system, and for decision-making and forecasting.

"Modeling is just a way of representing relationships in the world," said Tse Yang Lim, who led the study and is a postdoctoral research fellow at the Center for Communicable Disease Dynamics at the Harvard T.H. Chan School of Public Health. "We use mathematical equations to understand causality by observing phenomena, estimating variables, and getting data. We then use that data to ground the model, so when it comes to COVID, we can ask questions like how many people are going to get infected, how many people are going to die over a certain time period, and so on."

Lim added, "We can then use data from the real world about the number of infections and deaths being reported in different countries over different time periods, etc., to estimate how people are going to behave."

The team's models are developed by collecting data on individual and group actions and constructing algorithms that capture the underlying patterns beneath these behaviors. By forecasting potential outcomes, these models enable public health officials to make optimal decisions to keep people safe.

"Often when we ask a question like how COVID spreads, there'll be a lot of values, data, and numbers that go into those equations. It can be very complicated. We deliberately used a simple model over a more sophisticated one for this research so that we could distill the core idea: When there's an outbreak and COVID numbers rise, people reduce their contacts. They take more precautions, but there's a delay because it takes time for those numbers to be reported," said Lim.

"As the number of deaths increases, the rate at which people come into contact with each other and therefore potentially spread the disease is going to decrease as people take more precautions. But how quickly will they decrease their contact with each other? That's going to depend on this behavioral parameter of responsiveness."

Understanding this relationship is what the research team is working on now. Ultimately, when deaths rise, data shows people eventually change their behavior, even if they didn't follow the guidelines initially or were resistant to making major changes in daily life.

"For us to know how people might react to future epidemics or pandemics, we have to collect information about how humans react to different situations," said Ghaffarzadegan. "For example, what might cause us to choose to wear a mask or not? What might lead people to end

their quarantine early due to adherence fatigue? When misinformation spreads, how does that affect decision-making? In a nutshell our research deals with coupling models of human behavior with models of epidemics."

COVID-related decision-making four years later

Though restrictions have eased, COVID-19 still continues to circulate. In fact, COVID-19 cases are currently on the rise, and many communities are experiencing rates of disease similar to winter 2022. Ghaffarzadegan said we can expect COVID-19 to remain circulating.

"COVID-19 has become a new normal and a regular part of our lives. We can expect new variants of the virus, and ups and downs in cases and hospitalizations in the years to come, especially seasonal patterns that rise with colder temperatures. Adjusting our lifestyles with these patterns is crucial," Ghaffarzadegan said.

Modeling and forecasting COVID-19 will continue to be an important tool used by policy makers and individuals to help people make better decisions about preventing current and future disease spread.

"Now is the time for reflection and learning, and in this we can offer new theories of what makes some communities more successful than others when it comes to dealing with pandemics," Ghaffarzadegan said. "Scientists are actively developing new medicines, and as a society, we're adapting to this new normal with hope for a healthier future."

More information: Tse Yang Lim et al, Why Similar Policies Resulted In Different COVID-19 Outcomes: How Responsiveness And Culture Influenced Mortality Rates, *Health Affairs* (2023). DOI: 10.1377/hlthaff.2023.00713

Provided by Virginia Tech