Model sets minimum restrictions needed to control COVID-19 given vaccination rate

July 7 2021, by Mary L. Martialay

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If only 60% of Americans were vaccinated against COVID-19, two-thirds of people currently wearing face masks and half of those staying at home must stay the course to keep the disease in check, according to a

new model that establishes the relationship between non-pharmaceutical interventions (NPI), vaccination rates, and the disease. But with a 70% vaccination rate, we could eliminate all those measures with the same result.

The model, available on the open access preprint website *medRxiv*, draws on control theory, used to optimize engineered systems from washing machines to spaceships. Using publicly available data tracking the disease, vaccination rates, and social distancing and hygiene measures, it is able to predict the minimal non-pharmaceutical intervention needed to control COVID-19 in 381 metropolitan statistical areas—cities and their surrounding communities—across the country.

"Now that we have the vaccine, we're all asking, 'what should we do?' Our methodology helps estimate how different areas of the country, with different vaccine levels, can relax non-pharmaceutical interventions while still maintaining COVID at a manageable level," said Jianxi Gao, an assistant professor of computer science at Rensselaer Polytechnic Institute and co-corresponding author on the research. "We hope this approach will help policy makers across the country safely relax restrictions in their area."

By establishing the equation between the disease, vaccine, and other measures, the model makes it possible to predict other aspects of the relationship. For example, the researchers found that, although they collected data on eight non-pharmaceutical interventions, the model could represent the dynamics of the disease with only three: face masks, staying at home, and testing.

The model is also able to predict the duration of the diseases at different vaccination levels. With overall vaccination in the U.S. currently at 45%, the model predicts the disease could be eliminated in some areas within three months.

Overall, the research team said the model demonstrates the need for a cautious return to pre-pandemic behavior, bolstered by high vaccination levels.

"We see that we can stop the disease very fast if everyone moves quickly to get the vaccine," said Lu Zhong, a doctoral candidate in the lab of co-corresponding author Mamadou Diagne, a Rensselaer assistant professor of mechanical, aerospace and nuclear engineering. "But unless 60% of people are fully vaccinated, the interventions should not be reduced very quickly, especially face-mask wearing. If the interventions are reduced very quickly, it could induce another surge."

Control theory establishes the relationship between the inputs and outputs of a system. The movement of a car, for example, can be predicted based on inputs to the steering wheel, gas, and brake.

Mapping the inputs in a social system is not a simple matter, but the team hypothesized that levels of vaccination and NPIs could serve as the inputs. The team modified the existing Susceptible-Infectious-Recovered-Deceased model, which is used by epidemiologists to predict the spread of disease, using real-world data on vaccination rates, NPIs, and the number of people infected, recovered, and killed by COVID-19 in each community.

"The SIRD model captures the spread of disease. But we want to know, how do you control that spread?" said Diagne. "What we do is to build a feedback loop, where we design the input signals and fine-tune impacts of those inputs so that the output exactly matches the number of infections, deaths, and recoveries happening in the U.S. And with that, we can change the inputs, relaxing the interventions, and predicting how it will affect the disease."

Diagne, Gao, and Zhong were joined in the research on "Vaccination

and three non-pharmaceutical interventions determine the end of COVID-19 at 381 metropolitan statistical areas in the US" by Qi Wang at Northeastern University.

More information: Lu Zhong et al, Vaccination and three non-pharmaceutical interventions determine the end of COVID-19 at 381 metropolitan statistical areas in the US, *medRxiv* (2021). DOI: 10.1101/2021.05.18.21257362

Provided by Rensselaer Polytechnic Institute