Review of: "Mobility network reveals the impact of spatial vaccination heterogeneity on COVID-19"

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Potential competing interests: The author(s) declared that no potential competing interests exist.

Thank you for the invitation to review “Mobility network reveals the impact of spatial vaccination heterogeneity on COVID-19”. The study proposed vaccine uptake resemble social processes in which the effects of hubs (the assumption that high mobility areas disproportionately impact case count) and homophily (the assumption that vaccination rates are similar among geo-socially connected locations) impact heterogeneity on epidemic outbreaks. The team applied simulations on synthetic networks to show that homophily exacerbates outbreaks (clustered network) and hubs attenuates them (centralized network). The team also applied simulations on real-life US human mobility data, and vaccination distribution rates inferred from Census Block Groups (CBGs) via Bayesian deep-learning, and census data during COVID-19, the simulation estimates that at least 9.3% of the COVID-19 infections were explained by the homophily effect while the urban-rural divide (a type of hypothesized hub effect) reduced cases of infection. Using the estimated cases infected when vaccinating at random locations as a baseline (and three other baseline policies: uniform targeting, targeting the least vaccinated CBGs, and targeting the most central CBGs), the team contributed to generating a surrogate-assisted gradient-based optimization algorithm to find the optimal vaccination strategy (accurate location targeting), whereby increasing vaccination rates by 1% reduces 9.5% of the cases, which reduces cases by 3 times more than the uniform targeting. This strategy was able to identify where vaccination should be implemented 8 months later (Jan 2022) with 87% overlap of CBGs from July 2021, and 80.1% of these CBGs still overlap with those targeted by the “most-central” baseline policy when added on a hub effect.

A few methodological questions that are of personal interest:

1. The concept of mobility networks is an unfamiliar term to the generally interested audience. In addition to the description of how mobility networks are constructed on page 7/35, “The nationwide mobility network is constructed based on mobile phone users' home census block group (CBG) and the points of interest (POIs) they visit on an hourly basis.” In order to familiarize the audience to the notion of mobility networks and how they are applied, suggest to provide a description on how mobility networks have been applied in estimating network effects poverty and inequality in the introduction.
2. How does this study account for different transmission dynamics, reinfection rates, and existing vaccination rates, and vaccine efficacy for July 1, 2022? If the conclusion that the optimization algorithm were resilient to time sensitivity based on the assumption of perfect vaccine efficacy and no reinfection, explanations for the conclusion should be elevated from supplementary information to the main document.

3. On page 26/35, the evaluation of the robustness of the simulation results requires more justification citing additional literature/experiments.
4. The decision to construct 4 hypothetical vaccination distribution modes “reverse, exchange, shuffle, order” is plausible, however, are there concerns related to how conclusions are drawn on infection rate reduction, where large networks evolve differently from smaller networks, especially when given the assumption that all 10,000 CBGs uniformly have a population of 10,000 each, and there there are only 10,000 POIs spread out in 100 clusters?
5. What are the advantages of using SEIR over SEIAR? From an implementation perspective, it is helpful to elaborate on how this algorithm can be enhanced (e.g., what situations may enhance the algorithm's best policy), and note that migratory concerns were not considered and results not generalizable to situations in which international migratory activity, border restrictions and lockdowns are not in effect.
6. Any real-world examples to support your conclusion? In North America, public health practitioners may recall debates on addressing equity and prioritization of vaccine administration to senior homes, frontline healthcare workers, and areas that are underserved and rural. In China, government prioritized works in public transportation, metropolitan areas with large labour mobility, and workers with the most exposure to customers. Do we see any substantive evidence that at comparable vaccination rates, Chinese had less infection than North America?

Thank you for the invitation to review a very novel experiment, it was a pleasurable and insightful read.