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[GeoHealth]

Supporting Information for

Optimizing spatial allocation of COVID-19 vaccine by agent-based spatiotemporal simulations

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Contents

Introduction

This supporting information includes texts and figures complementary to the main text. This includes a full description of SEIR model, a detailed simulation process about parameter *k* (how many people an agent would encounter in one day, or the average numbers of contact), and a figure about the estimation result of parameter *k*.

Text S1: SEIR Model

SEIR is a classic compartmental model in epidemiology which divides the population into: susceptible individuals (*S*), exposed individuals (*E*), infectious individuals (*I*), and recovered individuals (*R*). The total population size is denoted as *N (N=S+E+I+R)*. The model is described by the following system of ordinary differential equations (*Eq. 1*):

$$\begin{cases} \frac{dS}{dt} = -\frac{\beta IS}{N} \\ \frac{dE}{dt} = \frac{\beta IS}{N} - \alpha E \\ \frac{dI}{dt} = \alpha \mathrm{E} - \gamma \mathrm{I} \\ \frac{dR}{dt} = \gamma \mathrm{I} \end{cases} \tag{1}$$

Susceptible individuals are originally healthy people. They become infected by being in contact with the infectious individuals and enter the latent compartment with the effective contact transmission rate β (i.e. the contact that will result in an infection). Individuals in the latent period progress to the infectious compartment at a transfer rate α (the inverse of the latent period， D_e). Infectious individuals get recovered at a recovery rate γ (the inverse of the infectious period， D_i). Meanwhile, the effective contact transmission rate β can be expressed roughly as $k * \theta$, where k is the average number of contacts per day, and θ is the probability of be infected per contact. Therefore, *Eq. 1* can be also express as follows (*Eq. 2*):

$$\begin{cases} \frac{dS}{dt} = -\frac{k\theta IS}{N} \\ \frac{dE}{dt} = \frac{k\theta IS}{N} - \frac{1}{D_e} E \\ \frac{dI}{dt} = \frac{1}{D_e} E - \frac{1}{D_i} I \\ \frac{dR}{dt} = \frac{1}{D_i} I \end{cases} \tag{2}$$

The average number of contacts per day k, the probability of be infected per contact θ, latent period D_e and infectious period D_i are important parameters for SEIR.

Text S2: Parameter k (the average numbers of contact)

We use another agent-based model to simulate how many people an agent would encounter in one day. The simulation is implemented using the mobile phone trajectory data from the 8146 users. The simulation reproduces these users' actual mobility and encountering process in a day (28-Dec-2016). Based on the simulation, the number of encounters that an agent meets can be observed. The average number of encounters per agent estimates parameter k. The detailed simulation process is as follows.

Firstly, all of agents were distributed in grids randomly. Each agent followed its own trajectory to move among grids hourly from 7 a.m. to 10 p.m. Agents appearing in the same grid at the same time are regarded as encountering. An agent moved to a location in an hour, and the number of encounters that the agent met was recorded. An agent's movement continued hour by hour and the number of encounters per agent was accumulated until the end of the day (10 p.m.). The average number of encounters of all agents is exactly the simulated value of parameter k. The simulation repeated 100 times to get 100 simulated k values. These 100 values are shown in *Figure S1*. Obviously, the mean value of k is $29.45(\pm 0.2)$, which means the average number of encounters per day for an agent is about 30 agents.

Figure S1: Parameter k

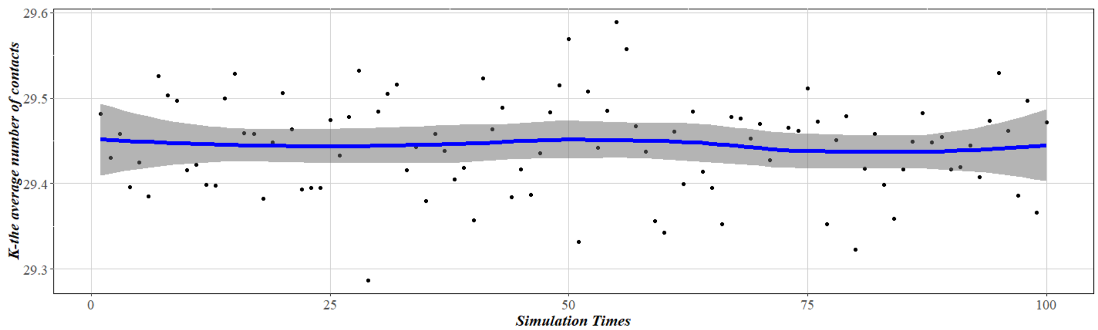

Figure S1. Parameter k; Parameter k was estimated through multi-agent-based simulation with the same mobile phone trajectory data; The simulation procedure was repeated 100 times.