The different effects of non-pharmaceutical interventions in epidemic models based on networks versus mixing matrices

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Mathematical models are one of the key tools to combat epidemics of emerging diseases. As the recent COVID-19 pandemic has shown, it is essential to properly model human contact patterns to truly understand the epidemic dynamics. The classical approach is based on mixing matrices that encode the number of interactions between certain groups of the population, being age-mixing matrices the most common of them. More recently, the use of networks has sparked a plethora of discoveries in the field of mathematical epidemiology. Despite their differences, it is generally possible to reproduce the same results with both approaches as long as one properly calibrates them. However, once this had been done, if one introduces non-pharmaceutical interventions aimed at reducing the number of contacts in the population one might get very different outcomes.

In this work, we first build multiplex contact networks using highly detailed sociodemographic data representing the interactions of individuals in schools, workplaces, households, and the general community. Then, we derive the age-mixing matrices that would encode exactly the same set of human interactions from these networks. We implement a classical SIR model, as well as a model for influenza and for COVID-19, using each of these approaches, and calibrate them to yield the same results under a baseline scenario. We aim to understand what would each model predict when a certain intervention is put in place.

In particular, we mimic the closure of schools, workplaces, and the reduction of contacts in the community that has been observed during the COVID-19 pandemic, and study how stringent they have to be to control an outbreak. Our results show that when interactions are encoded in networks, the models predict that a milder intervention is enough to stop an outbreak in comparison to the approach with age-mixing matrices (see figure 1). This has very important policy implications given that the large majority of models that have been used during the COVID-19 pandemic are based on approaches akin to the age-mixing matrix one. However, we acknowledge that building such networks is a very complex process that requires a large amount of data, and the models build on networks are not free from caveats. As such, we also explore the strengths and weaknesses of each approach and give some recommendations regarding the strength of the claims that can be done with one approach or the other.

Keywords: *compartmental models; network epidemiology; multilayer networks*

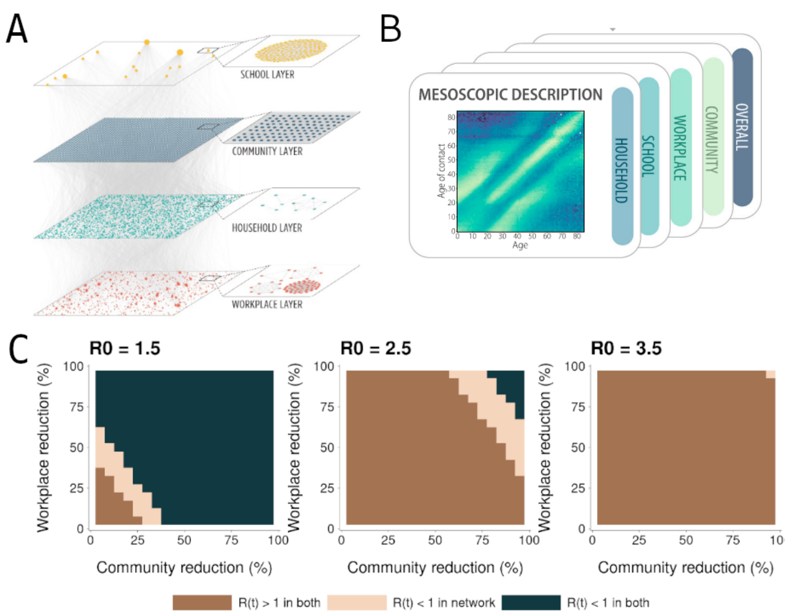

Figure 1: **Modeling non-pharmaceutical interventions**. A: multilayer network representing the daily social interactions in a large population of individuals. B: age-mixing matrices extracted from the aggregation of contacts in each layer. C: Effect of interventions on the spreading of an outbreak. In both models, we implement a SIR model with a recovery period of 2.8 days and explore three values of R_0: 1.5, 2.5 and 3.5. We reduce the number of interactions in the workplace and community layers, and explore the value of $R(t)$ after the intervention. If contacts are modeled using networks, milder interventions can get an outbreak under control in comparison to models based on mixing matrices.