

# Digital cities and COVID-19: modeling the impact of non-pharmaceutical interventions

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## Keywords

Non-pharmaceutical intervention, synthetic population, multilayer networks, agent-based models

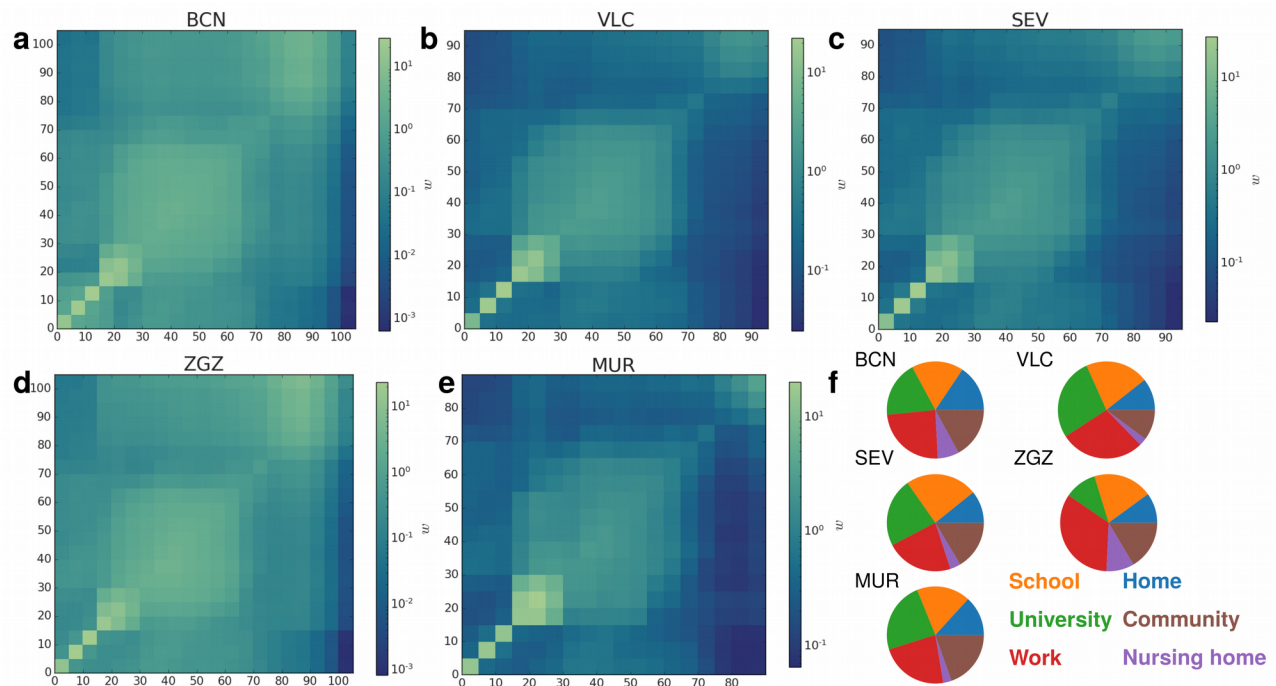
## Abstract

After a general lockdown that controlled the first wave (finishing on June 2020) of the COVID-19 outbreak in Spain [1], there were multiple non-pharmaceutical interventions at different geographical levels, from neighbourhoods to autonomous regions. This diversity of interventions and the different implementation dates hindered the characterization of their impacts in the outcome of the second wave (from June to December 2020), both in number of infections and number of deaths.

In order to quantify these impacts, we performed an exhaustive data gathering from multiple sources, extracting relevant features that allowed inferring social interactions described by six connectivity layers, in the context of the multilayer network formalism [2]. Specifically, we considered different layers representing the interactions in households, schools, working places, universities, nursing homes and community (Fig. 1). These multilayer networks, together with the available metadata (age and sex), enabled the creation of five synthetic cities (Barcelona, Valencia, Sevilla, Zaragoza, Murcia), where we modeled the first and second waves of the spread of COVID-19 inside the cities.

After calibrating our models with empirical data, we simulated new scenarios where we modified or omitted the interventions that were taken in the real scenario. The comparison between these counterfactuals and reality allowed us to quantify the impact of the most relevant non-pharmaceutical interventions, as well as made it possible to contrast responses, real and possible, in different locations.

## Figure



**Figure 1.** a-e, Inferred contact matrices by age for a, Barcelona (BCN), b, Valencia (VLC), c, Sevilla (SEV), d, Zaragoza (ZGZ), and e, Murcia (MUR). Rows and columns represent the population of specific ages, and weights  $w$  represent the expected number of contacts for an individual from a specific row with individuals from each column. f, Fraction of links in each of the connectivity layers.

## References

- [1] Eguíluz, V. M., Fernández-Gracia, J., Rodríguez, J. P., Pericàs, J. M., & Melián, C. (2020). Risk of secondary infection waves of COVID-19 in an insular region: the case of the Balearic Islands, Spain. *Frontiers in Medicine*, 7, 563455.
- [2] Aleta, A., & Moreno, Y. (2019). Multilayer networks in a nutshell. *Annual Review of Condensed Matter Physics*, 10, 45-62.