

## **Large-scale assessment of human mobility during COVID-19 outbreak**

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## **Abstract**

Social distancing is an important measure to prevent the collapse of public health systems during the COVID-19 pandemic. While some countries have managed to impose a strong control for social distancing, countries like Brazil largely depend on the population's cooperation. Therefore, it is very necessary to monitor human mobility to detect whether social distancing policies are being implemented and to adjust them in places where the population is not adhering to these. By using cell phone data of millions of people, we were able to assess the population mobility in Brazil's biggest city, São Paulo. Our analysis revealed the reduction in the circulation of people in most neighborhoods after social distancing policies began. We also showed the dispersion of people by tracking the visits of people to the GRU airport and the visit locations of the same people after they left the airport. Over the course of a few days, it was possible to detect over 70,000 visits across Brazil, with distances greater than 2,000 km from the GRU airport. We hope that data when collected in real time can be useful to stem the progress of the COVID-19 epidemic, or at least to help "flatten the curve".

## **Introduction**

The coronavirus (SARS-CoV-2) that causes COVID-19 is highly contagious and has infected over 300,000 people worldwide till March 2020. Social distancing, isolation and quarantine, and community containment [1] are important measures to prevent the collapse of public health systems during the pandemic. While some countries have managed to impose a strong control for social distancing, countries like Brazil largely depend on the population's cooperation. Therefore, it is very necessary to monitor human mobility to detect whether social distancing policies are being implemented and to adjust them in places where the population is not adhering to these.

We collaborated with In Loco company to investigate the mobility pattern of people in Brazil's largest and most populous city, São Paulo. In Loco has more than 60 million cell phones in its database and records more than 1.8 billion visits at physical locations every month. Although no civil information is collected, such as name or social security number, in deference to users' privacy concerns, In

Loco can detect, through anonymous tracking, the most likely home location of a device and devices' locations across the country.

São Paulo is the Brazilian city where the first COVID-19 case was detected and has the largest concentration of cases. Its more than 12 million inhabitants live in nearly 100 neighborhoods spread over an area of 1,521 square kilometers [2]. Among these inhabitants, over 4 million use mobile applications associated with In Loco.

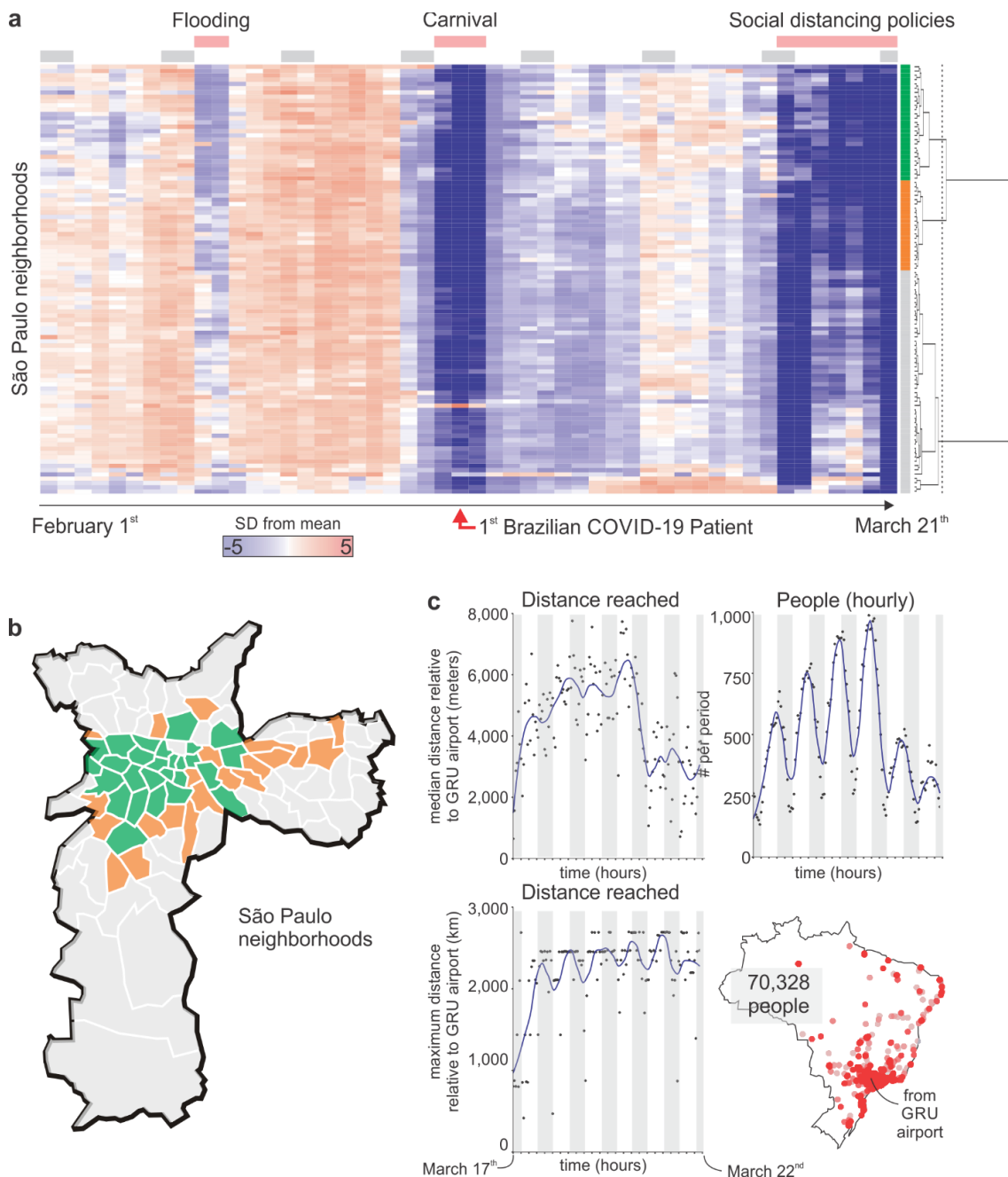
## **Results and discussion**

To assess population mobility, we analyzed the number of residents and daily visitors (who do not live in the neighborhood) in each neighborhood in São Paulo between February 1<sup>st</sup> and March 21<sup>st</sup>, 2020. Overall, the circulation of people decreased during a flood in the city on February 10<sup>th</sup> and during the carnival (February 24<sup>th</sup> to 26<sup>th</sup>) (Figure 1a). When social distancing policies began to be implemented, there was a reduction in the circulation of people in most neighborhoods (Figure 1a). The most central neighborhoods in São Paulo were those that received the least visitors during the time of social distancing (Figure 1b). There are several possible explanations for this, including biases on smartphone usage and the differences in neighborhood sizes.

Air travel has contributed to the spread of several past epidemics, including SARS-CoV (2002), MERS-CoV (2012), and the H1N1 pandemic (2009). By international air traveling, infected individuals, with or without symptoms, may initiate or contribute to viral spread to other countries [3]. Thus, we chose Guarulhos international airport (GRU airport) in São Paulo to assess the dispersion of people around the city and in the country. We tracked the visits of people to the GRU airport and the visit locations of the same people after they left the airport. Over the course of a few days (March 17<sup>th</sup> to 22<sup>nd</sup>), it was possible to detect over 70,000 visits across Brazil, with distances greater than 2,000 km from the GRU airport (Figure 1c).

In addition to monitoring social distancing policies, data collected by smartphone devices can be of great value for epidemiological models that make projections

about the number of infected cases. We hope that data when collected in real time can be useful to stem the progress of the COVID-19 epidemic, or at least to help “flatten the curve” [4, 5].



**Figure 1. Mobility of Brazilians during the COVID-19 epidemic. a.** Concentration of people by neighborhoods in São Paulo. Lines represent neighborhoods and columns represent days. The colors represent the number of residents and visitors in each neighborhood normalized by z-score for the day of the week (excluding carnival and the social distancing period). Red means more people in the neighborhood and blue means less. Weekends are represented by

gray rectangles. Red rectangles above the heat map show the days that the floods took place in São Paulo, the carnival and the implementation of social distancing measures. The red arrow represents the day the first patient with COVID-19 was diagnosed in Brazil. The neighborhoods were grouped according to the changes in the number of people along the days (Manhattan distance and ward.D clustering). The 3 resulting clusters are indicated by different colors. **b.** Map of São Paulo neighborhoods colored by clusters in item **a.** **c.** Visits from people who went to GRU airport and their spread across the country. The upper left plot shows the median distances of visits relative to GRU airport (Y-axis) over each hour (X-axis). The upper right plot shows the number of visits in total (Y-axis) over each hour (X-axis). The lower left plot shows the maximum straightline distance between the visit and the GRU airport (Y-axis) over each hour (X-axis). The hours between 6pm and 6am are marked by gray rectangles. The blue line was obtained with loess smoothing method (span=0.2). The map on the lower right shows the places visited (red dots) after passengers left the GRU airport. The total number of visits is indicated.

**Declaration of Interest:** LQ, JLM, AF, and GB work for In Loco company.

**Ethical Approval:** Not applicable as we collected anonymous data.

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### **Author contributions**

All authors performed analyses, and wrote the manuscript.

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