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Idiosyncratic and systematic experienced isolation in urban networks

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Extended Abstract

Human mobility defines urban systems, which require the transfer of goods and ideas to grow and evolve their economies. Here we develop an understanding of the way that urban spatial structure biases mobility in cities. A growing body of work identifies regularities in the way people move around cities, with interesting implications for the structure of the city, which maps onto our demands for different kinds of mobility [1, 2]. Many studies also point out that we sort ourselves into groups and these divisions manifest in the places we visit [3, 4]. A current research frontier involves building an understanding of how this "homophily" is systematic—the product of urban spatial structure—and which is idiosyncratic to whims and preferences. To advance it, we construct spatial interaction networks in London from mobile phone data and measure experienced isolation, the degree to which individuals of one group will interact with individuals of another during daily life. We explore how variation in human behaviours and urban affordances could influence experienced isolation in London. To do this, we use modelling and permutation to observe how isolation changes under different scenarios, finding that existing mobility is much more homophilous than what would be expected according to predictions derive by machine learning. Although observed and permuted networks are far from perfect integration, a more dispersed "collection of villages" distribution of amenities would be more segregated—though travel distance would be reduced.

We first use kernel methods reduce the data to unique visits and identify functionally coherent units of the city (economic corridors of contiguous activity) selecting local maxima in the kernel density function representing all visits across London (Fig. 1A). We test various bandwidths σ, or the resolution in metres of the kernel, finding that the number of activity centres stabilises near 300 at 200m and below (Fig. 1B), suggesting that this approximates the true number of mass gathering places in London. Another interesting property of this bandwidth is that it is the point which the flow of people between regions is best described by the gravity equation. We take these mass gathering places as destinations and construct origins from imputed home locations, aggregated to H3 cells ($10^5 m^2$).

We measure experienced isolation by looking at the "diversity" of economic corridors and the "exposure" of neighbourhoods. The first answers, how diverse are the visitors to an area? While the second answers, how diverse are the areas that people from this neighbourhood visit? Assuming all visitors in an hour interact with each other, diversity is measured as ratio of interactions in a cell between people of different groups to all interactions in that cell. To determine these groups, we use an existing classification scheme to divide each home neighbourhood into 8 categories, ranging from "urban elites" to "immigrant enclave" [5]. Exposure is dependent on recasting and reweighting the diversity at destinations to origins. We then opt for machine learning to estimate magnitude of flows between areas, using a random forest to predict flows between origin and distance. The calibrated model accounts for half the variation in the data. The predicted value is the degree to which mobility is systematic—expected given amenity, distance and population—and the error is that which is idiosyncratic. We resample the errors

(idiosyncratic) and combine with predictions (systematic) to generate new weights on the network. Our results show that residents in London could reallocate existing travel in a manner that holds distance constant while visiting more diverse areas: the permuted mixing distribution is more mixed than the observed one (Fig. 1C). The strong relationship between permuted and observed (Fig. 1D) suggests that mixing is at least in part a product of urban spatial structure, as captured by the gravity model.

To understand how the structure dictates our mobility, we then construct a series of kernel density estimations of points of interest at different bandwidths, which has the effect of producing more (higher σ) or less (lower σ) dispersed clusters. Resampling the points of interest from these distributions creates counterfactual cities where amenities are more or less diffuse, including a city with a maximum entropy distribution and no structure. This allows us to substitute the counterfactual points of interest into our model of mobility. We obtain a curve relating distance to mixing: as amenities become distributed throughout the city, the travel distance decreases while mixing decreases. This is because London is demographically segregated, so when needs are met locally, people no longer mix. The relationship is not monotonic, however, and London as it exists is both high-mixing, low-travelling compared to counterfactual cities. We also we shuffle the amenity column in our table to create a city with same concentration of amenities distributed at random; this permutation has both the highest distances travelled and the lowest mixing, suggesting the existing structure of the city is efficient.

Our results suggest that decreasing activity in business districts, which serve as hubs for mixing our model, will increase experienced isolation. Our main contributions are a method for understanding mixing, using counterfactual human behaviors and counterfactual urban affordances, as well as a new metric to compute such mixing that corrects for heterogeneity in mobility data. We also add to a growing body of literature [6] which identifies the need for better strategies to improve mixing as cities change under remote work.

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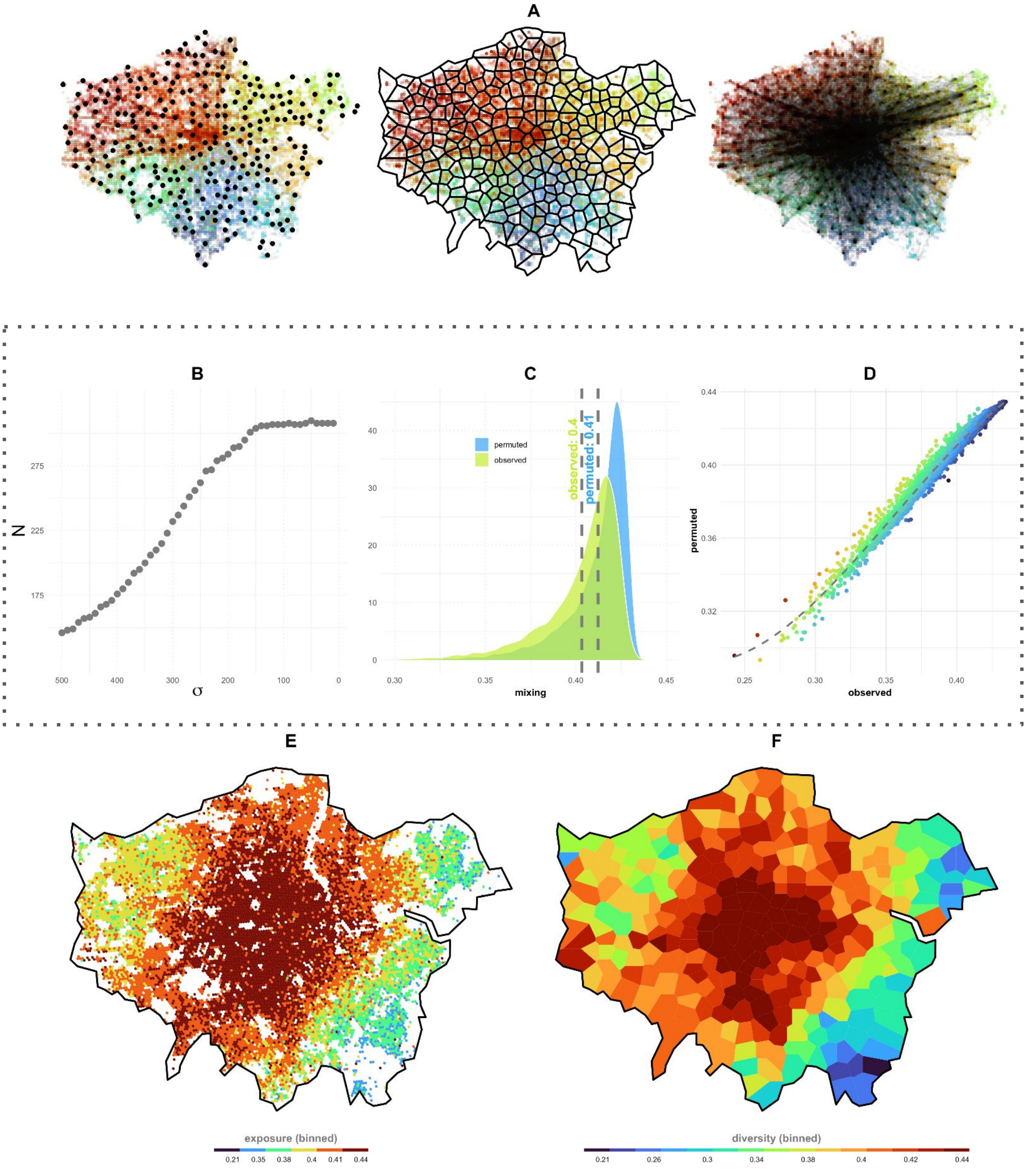

Figure 1: **A** Illustrating our process for moving from visits, coloured by home neighbourhood, to local maxima in the distribution, Voronoi tessellations of them, and then a network of interactions between neighbourhoods and this economic clusters. **B** Convergence of clusters as we change the bandwidth. **C** Permuted and observed exposure distributions as well as **D** the relationship between them, suggesting much but not all is the product of systematic biases. Maps of **E** exposure to diversity by neighbourhood and **F** diversity of cluster.