Understanding urban resilience through behavioral data

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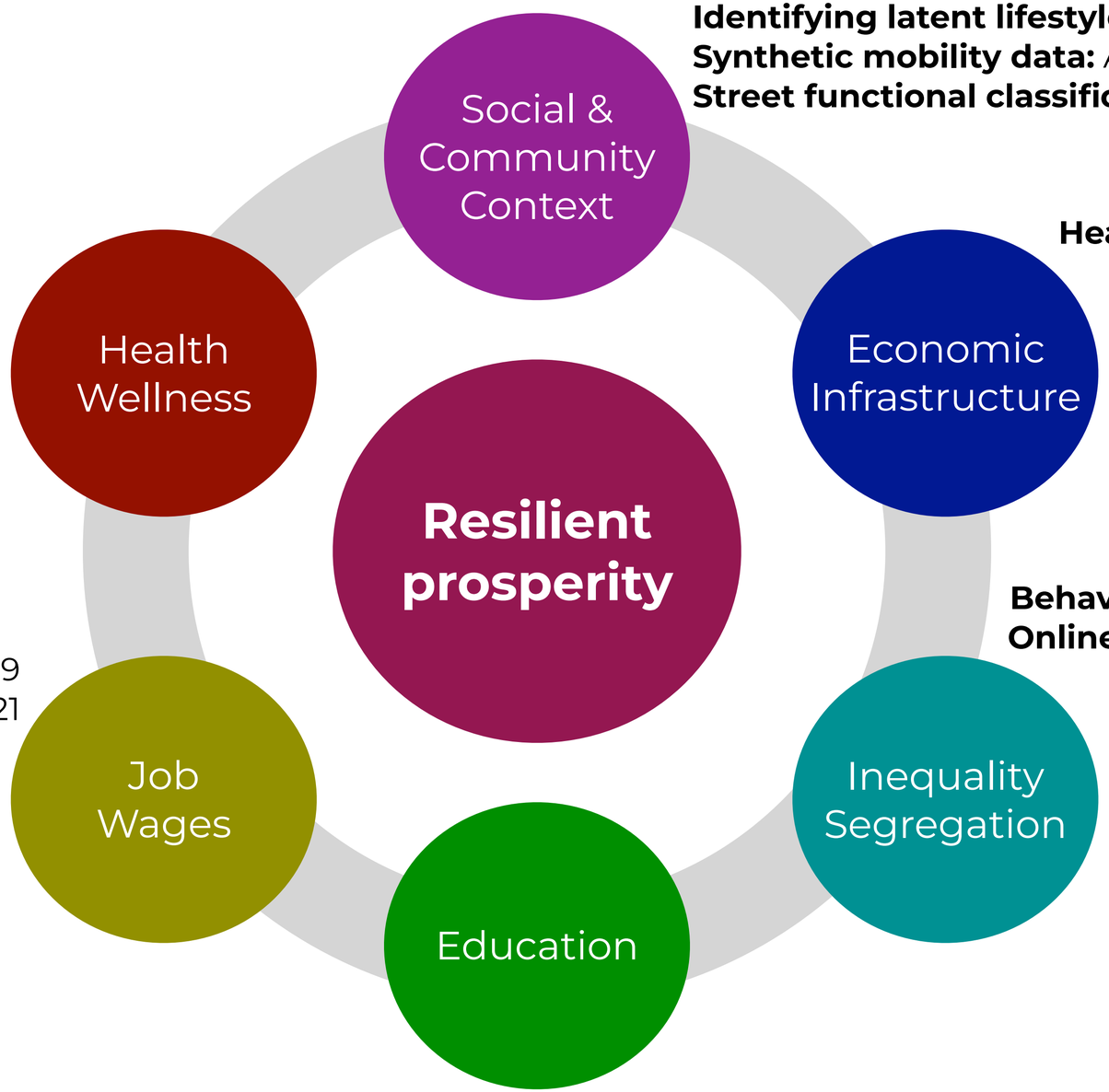
NetSci-X ’23 Buenos Aires

Resilience of complex social systems to global challenges through behavioral data

Identifying latent lifestyles: arxiv 2022
Synthetic mobility data: ACM-ACM/SIGAPP 2022
Street functional classification: EPJ Data Science 2022

COVID-19: PNAS 2022
Nat. Human Behavior 2020
Physical Activity: Nat. Comms 2021
Healthy Food: MedRxiv 2022, 2021

Health-economy tradeoff: arXiv 2022



Behavioral segregation: Nat. Comms. 2021
Online-offline segregation: EPJ Data 2020
Effect of urban changes: arxiv 2022
Impact of COVID-19: arxiv 2022

Impact of automation: PNAS 2019
Universal resilience: Nat. Comms. 2021

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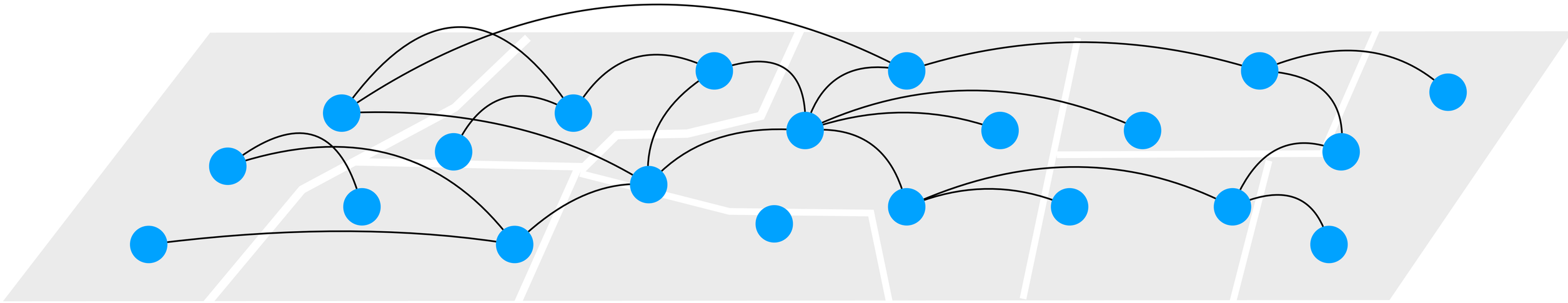
Resilience of complex social systems to global challenges through behavioral data

Social networks shape our society/urban areas



“Communities, where social capital is high and diverse, are healthier, wealthier, happier, and feel stronger bonds to their neighbors and their communities in general.” Institute for Social Capital, 2020

“Economic connectedness is the best predictor of social mobility” Chetty et al., Nature 2022

“Communities with more social capital are less affected and recover faster from natural disasters” Aldrich et al., 2014

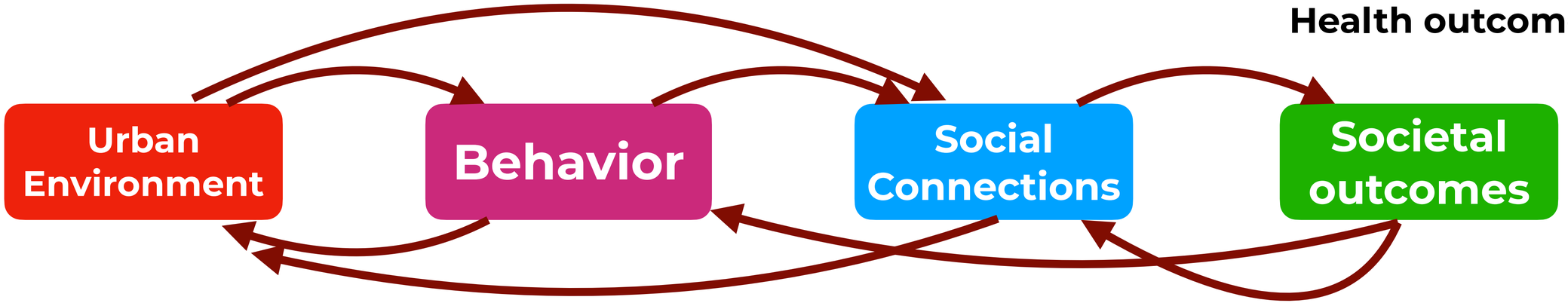
“The city is not a tree”

Infrastructure
Amenities
Weather
Pollution

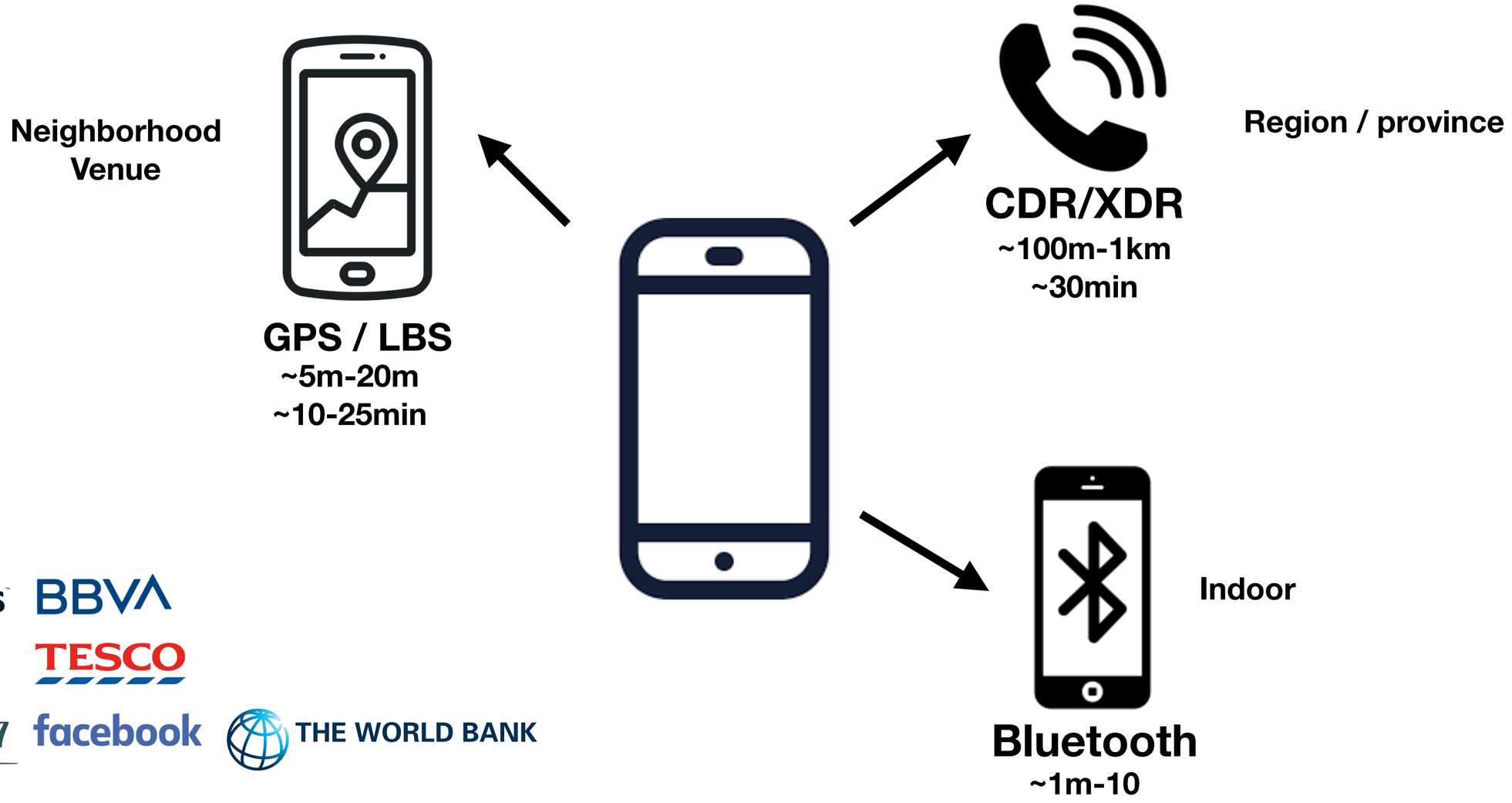
Mobility
Online/offline
Lifestyles

Encounters
Interactions
Groups

Inequality / Segregation
Pandemics
Disaster resilience
Innovation
Economic growth
Health outcomes



Mobile phone data to understand human behavior



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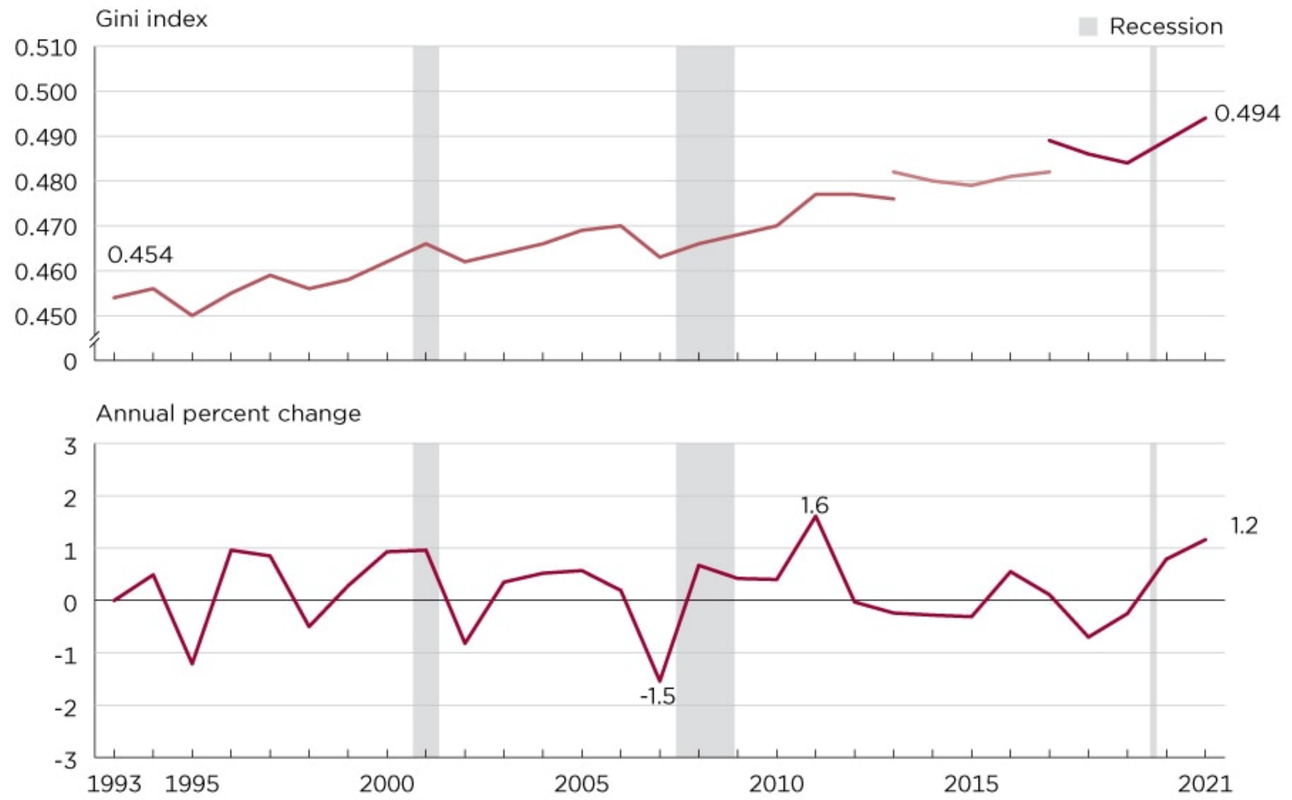
Inequality / segregation

Income inequality is rising in our societies

Figure 1.

Money Income Gini Index and Annual Percent Change: 1993 to 2021

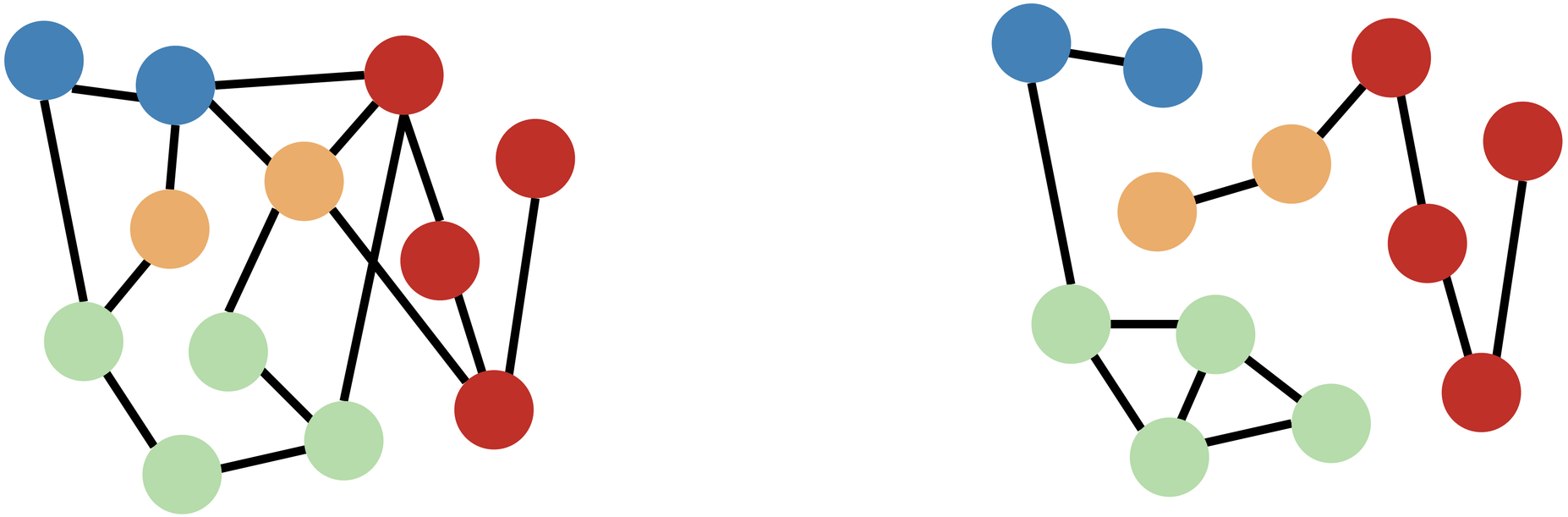


Notes: The data for 2017 and beyond reflect the implementation of an updated processing system. The data for 2013 and beyond reflect the implementation of the redesigned income questions. The data points are placed at the midpoints of the year. Refer to the "Income in the United States: 2021" report for more information on the Gini Index, <www.census.gov/library/publications/2022/demo/p60-276.html>. Information on confidentiality protection, sampling error, nonsampling error, and definitions is available at <https://www2.census.gov/programs-surveys/cps/techdocs/cpsmar22.pdf>.

Source: U.S. Census Bureau, Current Population Survey, 1994 to 2022 Annual Social and Economic Supplements (CPS ASEC).

Social capital inequality

Economic segregation in social networks



“Communities, where social capital is high and diverse, are healthier, wealthier, happier, and feel stronger bonds to their neighbors and their communities in general.”

Institute for Social Capital, 2020

“Economic connectedness is the best predictor of social (income) mobility”

Chetty et al., Nature 2022

The cost of economic isolation (segregation)

Cities with high segregation…
Higher homicide rates
Slower economic growth
Less innovation over time
Less resilient after natural disasters

Areas highly segregated…
Live 10/15 year less
Fewer years of secondary education
Small social (upper) mobility

Behavior

Around

75%

of the people we encounter/interact live more than

15 km

away

Average

distance travelled

by users to a given place is

9.5 km


If we are segregated
where
&
why
is it happening?

WHERE

How unequal are places in our cities?

Economic inequality isn't just limited to neighborhoods. The restaurants, stores, work, and other places we visit in cities are all unequal in their own way.

The Atlas of Inequality shows the income inequality of people who visit different places in US metro areas. It uses aggregated anonymous location data from digital devices to estimate people's incomes and where they spend their time.

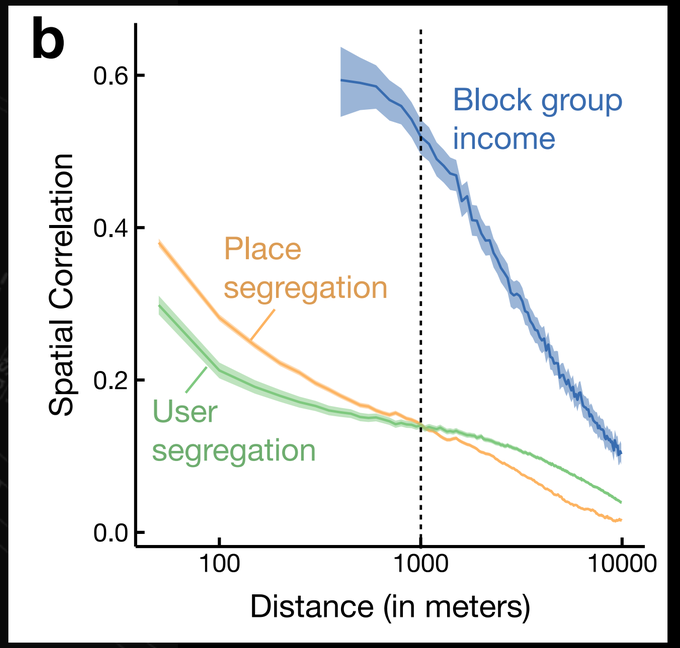
Using that data, we've made our own place inequality metric to capture how unequal the incomes of visitors to each place are. Economic inequality isn't just limited to neighborhoods, it's part of the places you visit every day.

Moro, E., Calacci, D., Dong, X. & Pentland, A. **Mobility patterns are associated with experienced income segregation in large US cities.** Nature Communications 12, 4633 (2021).

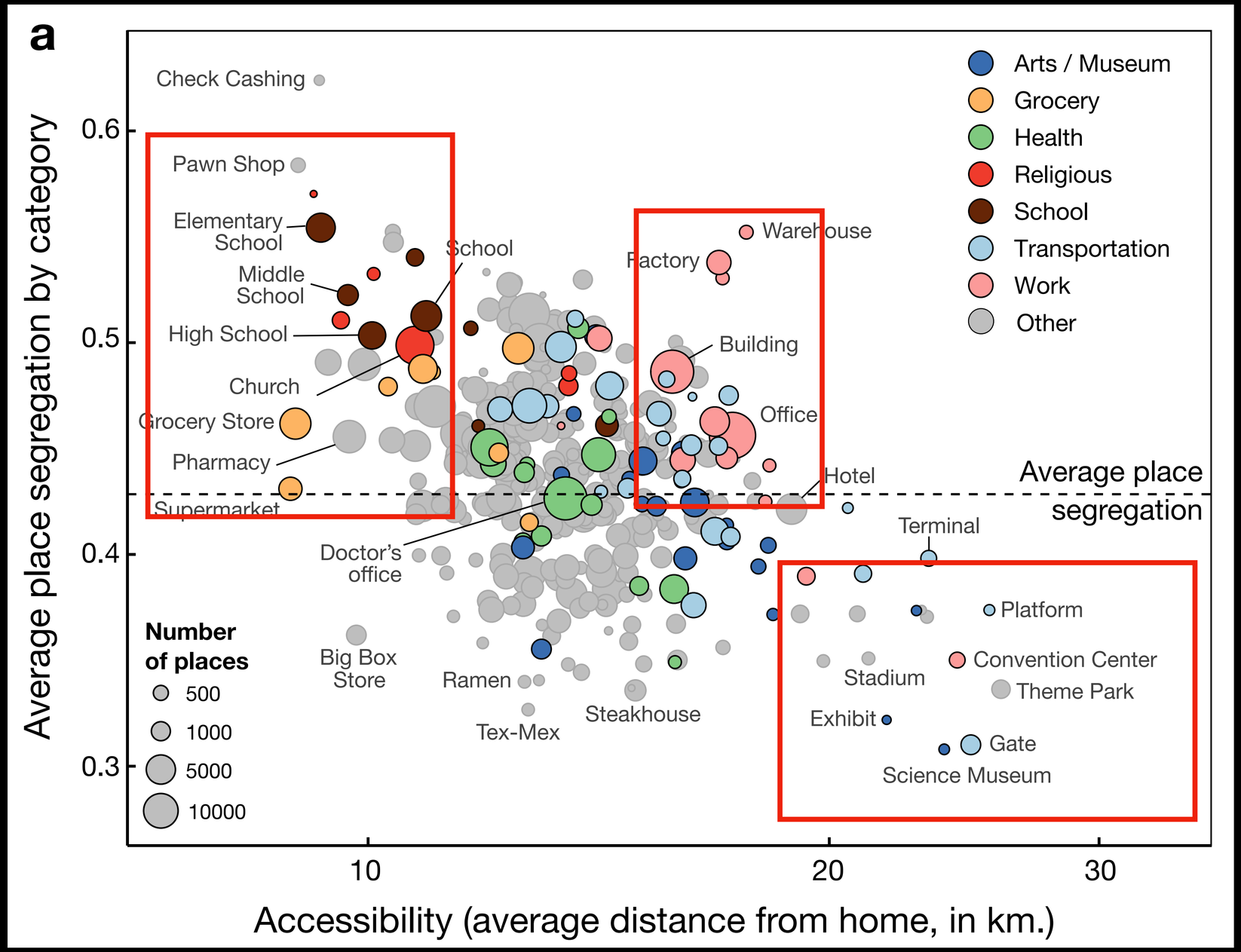
inequality.media.mit.edu

Segregation happens at high spatial resolution

- Even across the street (~25m) we can find places with different segregation



Segregation happens at places, not census areas



Impact of a single place on inequality

Prudential Center (Mall)

Oct 2016 | **Nov 2016** | **2016-11-29** | **Dec 2016** | **Jan 2017**

Inequality in the area
Before

-15%

(relative to the city)

Inequality in the area
Before

-25%

(relative to the city)

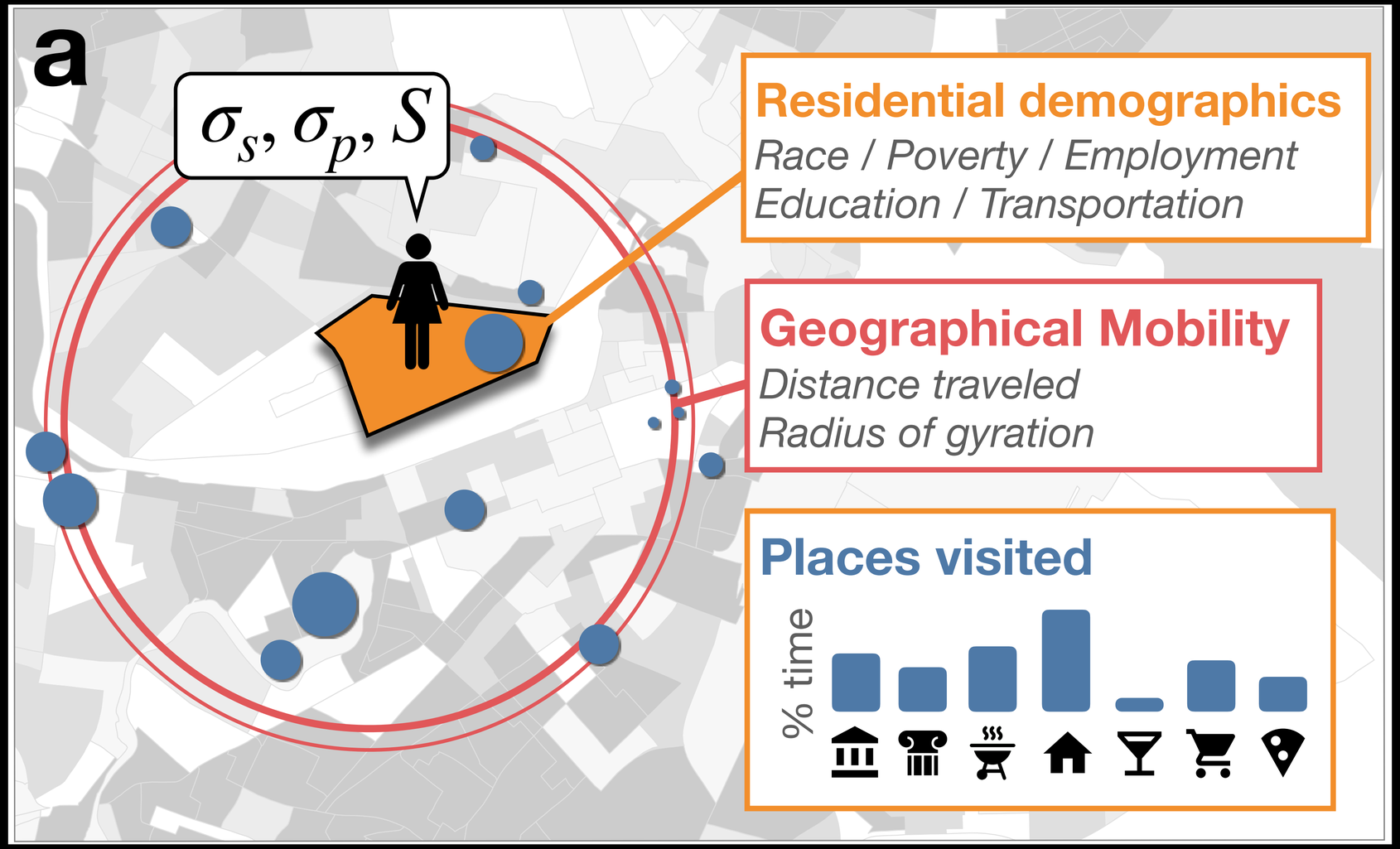
WHY

How do you measure *user inequality*?

- Using the same metric, we can calculate user inequality (homophily in the contact network)

What explains social and place exploration?

$$S_i \sim \{R_i\} + \{M_i\} + \{P_i\}$$



How much of our segregation depends on where we live?

$$S_i \sim \{R_i\} + \{M_i\} + \{P_i\} \quad N = 1.1 Million \quad R^2 = 0.435(S_i)$$

S_i

$\{M_i\} + \{P_i\}$
Behavior
55%

- Choices (Venues visited) **45%**
- Mobility patterns **10%**

$\{R_i\}$
Residential
45%

- Income / Poverty **10%**
- Education **7%**
- Region **10%**
- Other **18%**

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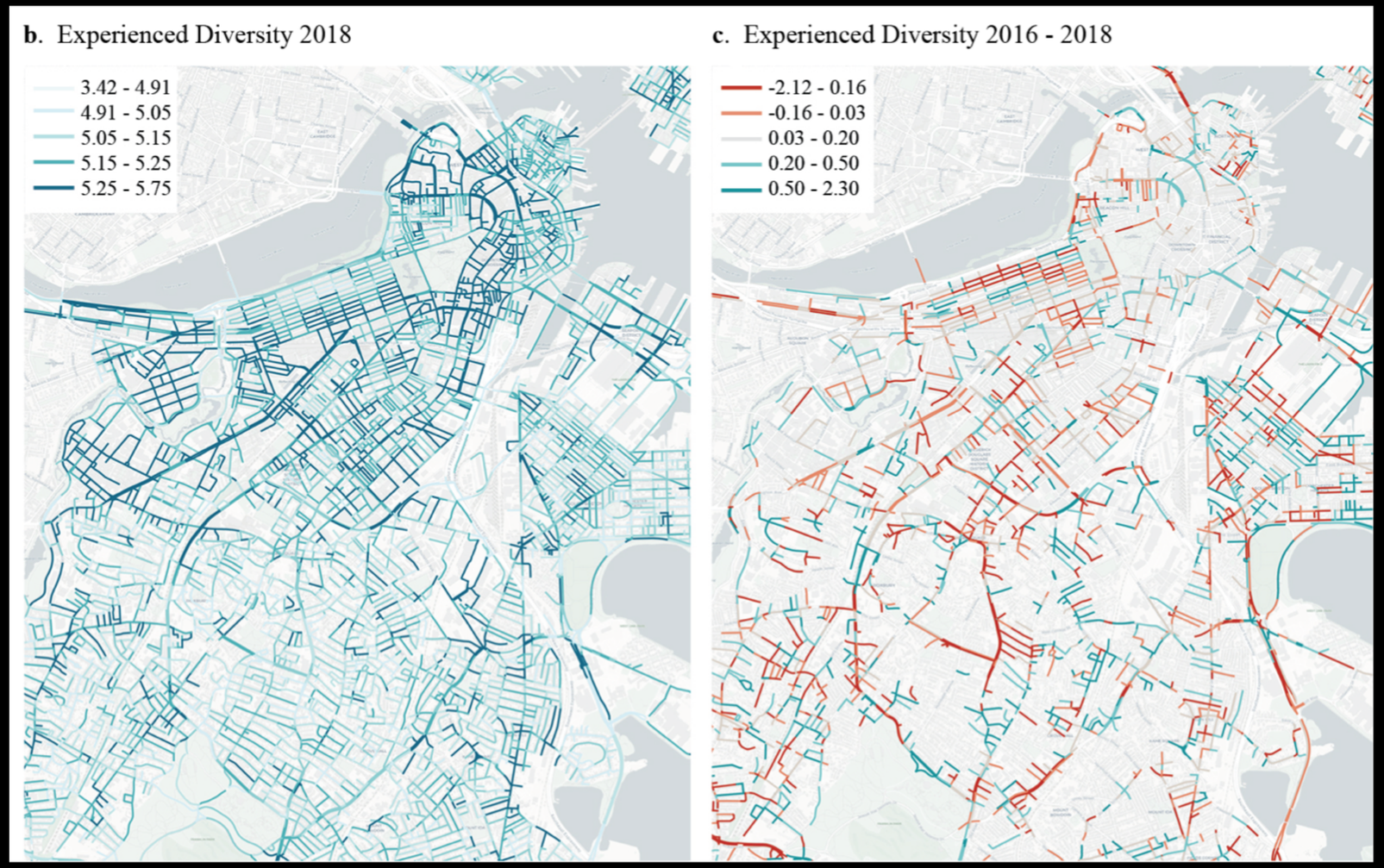
Changes on inequality in areas with time

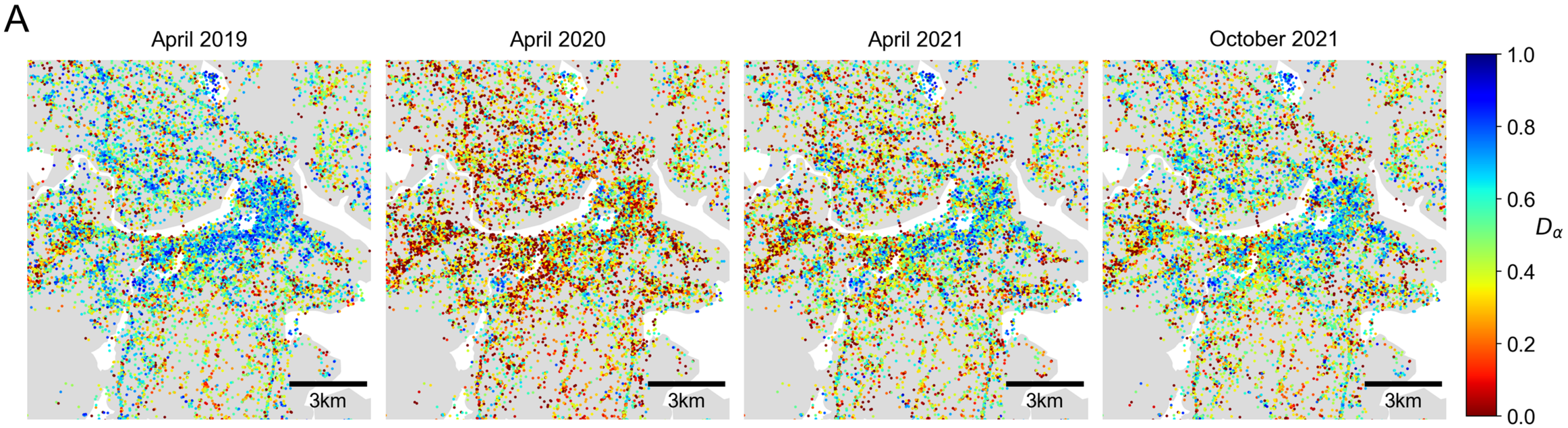


Fan, Zhuangyuan, Tianyu Su, Maoran Sun, Ariel Noyman, Fan Zhang, Alex Sandy Pentland, and Esteban Moro. "Diversity beyond density: experienced social mixing of urban streets." arXiv preprint arXiv:2209.07041 (2022).

Segregation decreased in areas that attracted more educated people and more food business

The new (more segregated) normal

- After 2 years, levels of mobility have recovered to 2019 levels.
- But profound changes in our behavior (work-from-home, less traveling, fewer food outings) have changed forever the social fabric of our cities. We are ~15% more segregated by income in our cities than before the pandemic.

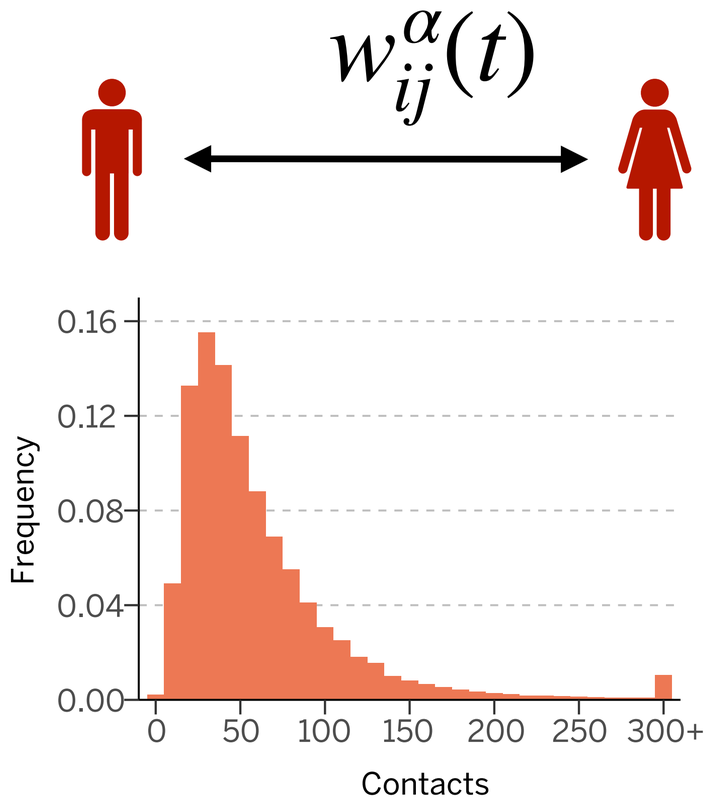


Yabe, T. et al. Behavioral adaptation to the new normal worsened income diversity in urban encounters, arXiv (2022)

Epidemics

Contact matrices at high resolution

- Using the high-resolution mobility data and sociodemographic data from the Boston area we can construct the contact networks
- We can estimate the probability that two agents are in contact (by day t, by place α, ...)



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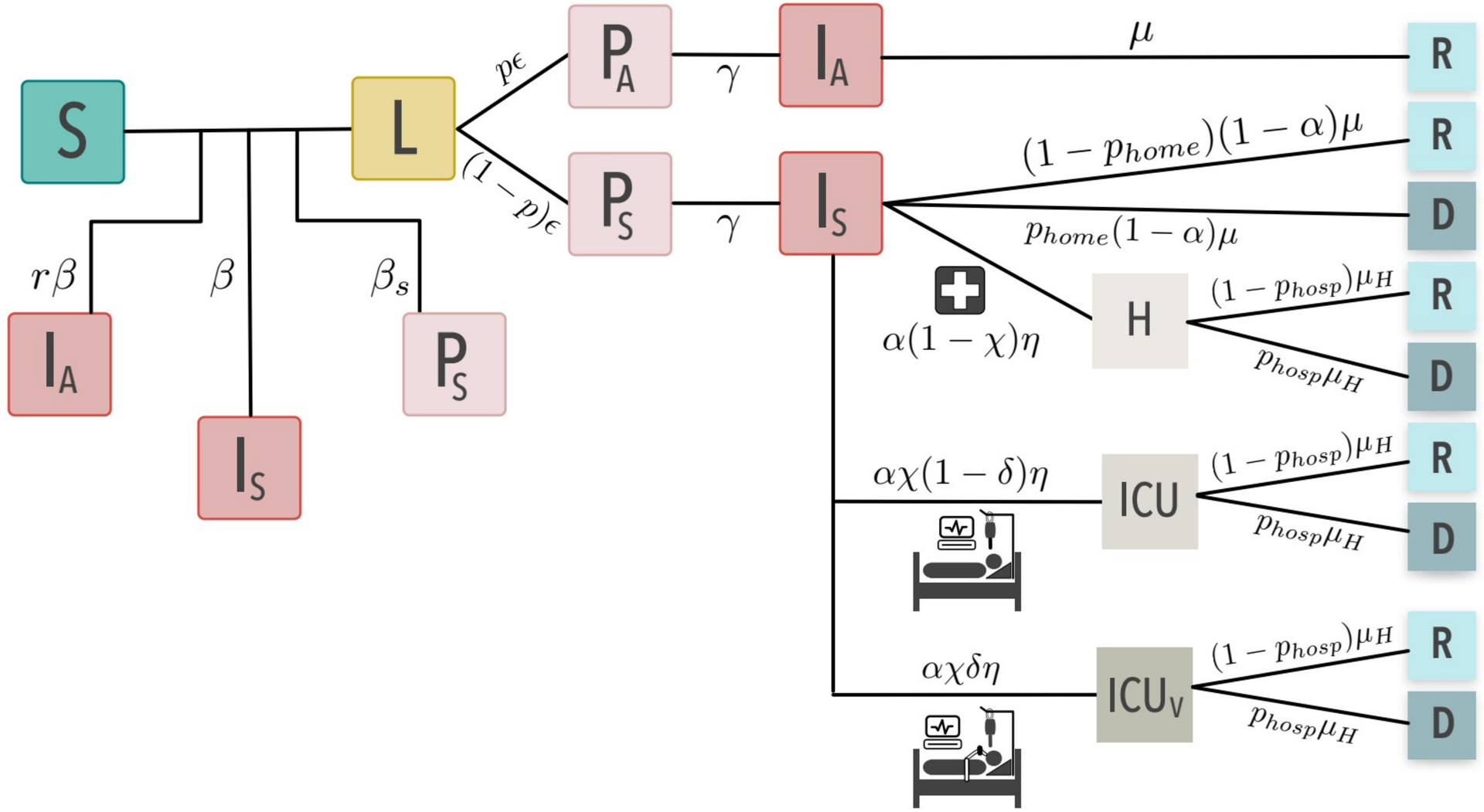
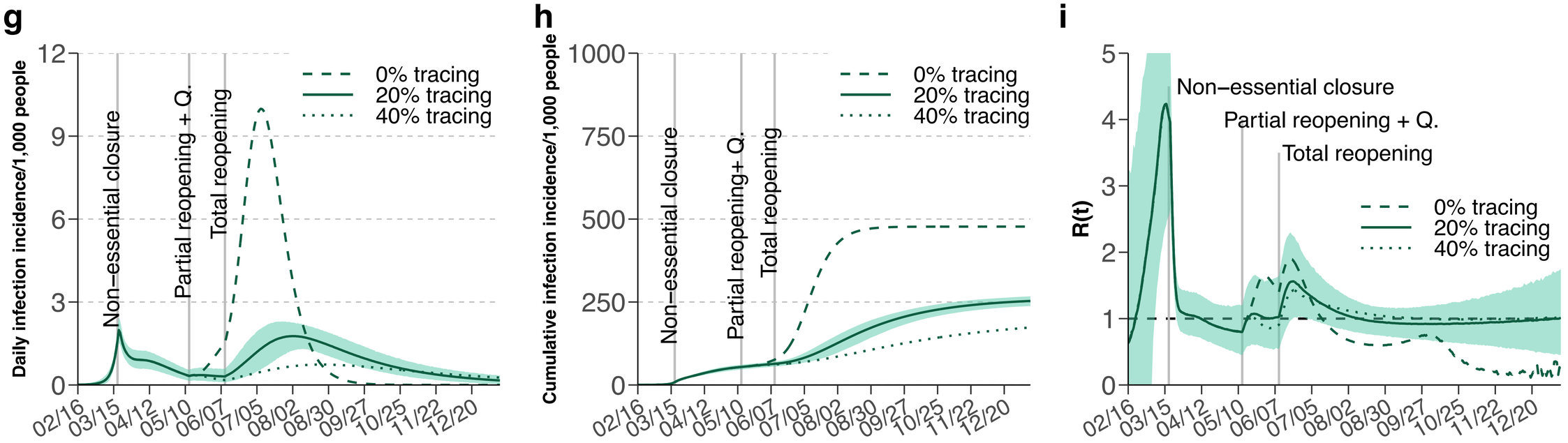
Agent-based epidemic simulations



Modelling the impact of testing, contact tracing and household quarantine on second waves of COVID19



Aleta, A. et al. Modelling the impact of testing, contact tracing and household quarantine on second waves of COVID-19.
Nat Hum Behav 4, 964–971 (2020).

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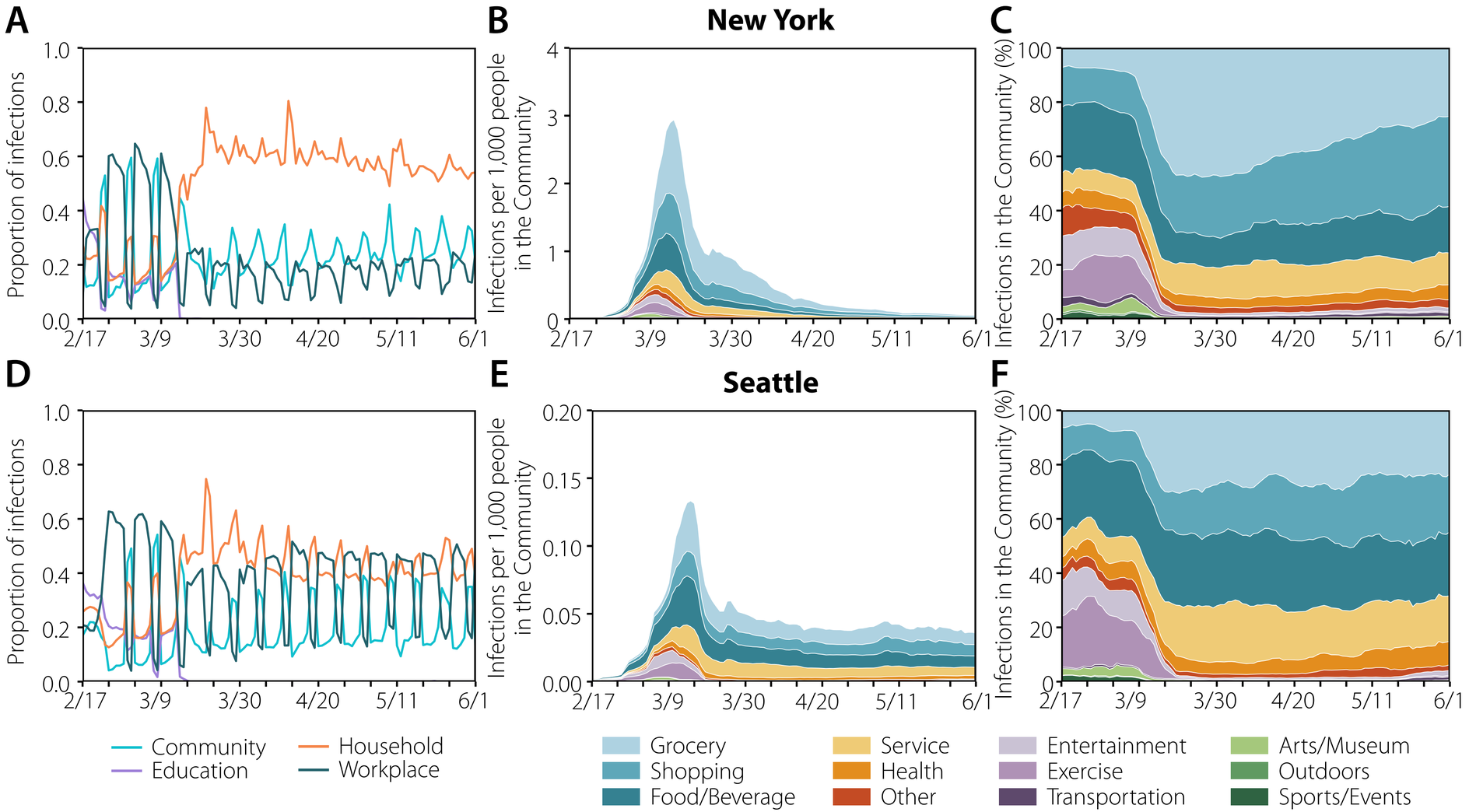
Where, who, when transmission (and super-spreading) events happen



Alberto Aleta, David Martín-Corral, Ana Pastore y Piontti, Marco Ajelli, Maria Litvinova, Matteo Chinazzi , Natalie E. Dean , M. Elizabeth Halloran , Ira M. Longini, Jr. , Stefano Merler, Alex Pentland, Alessandro Vespignani Yamir Moreno & Esteban Moro. *PNAS* 2022

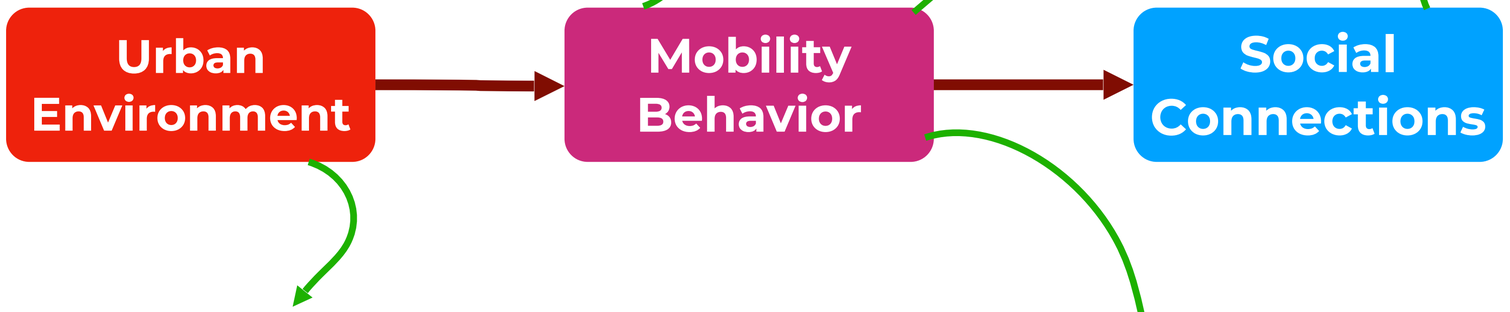
Outlook

Data quality and privacy-preserving methods

Synthetic data: using deep learning methods to low-embed large-scale mobility data. Debiasing mobility data using statistical and small survey datasets (**NSF**). https://arxiv.org/abs/2209.12095 https://dl.acm.org/doi/abs/10.1145/3477314.3507230

Environmental-behavioral inequality

Some groups are more exposed to pollution event when they move away from home.



Epidemics

- Mobility data can be used to manage better social distancing policies, **Nature Human Behavior 2020.**
- Human behavior is as important as physical locations in determining the pathways of transmission in epidemics. **(PNAS 2022)**

Mobile food environments

70% of fast food is consumed > 10km away from home. Better interventions should consider behavioral rather than home deserts. https://doi.org/10.1101/2022.09.20.22280128

Public health

The second pandemic: social distancing changed physical activity behavior in our cities **(Nature Communications 2021)**

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Cuebiq/Spectus
MasterCard
Carto
Ferrovial
BBVA

Queen's University Belfast
Ruth Hunter
Leandro García

USC
Kayla de la Haye
Abigail Horn

Thanks!

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