Epidemic Control under Exploration and Return Dichotomy

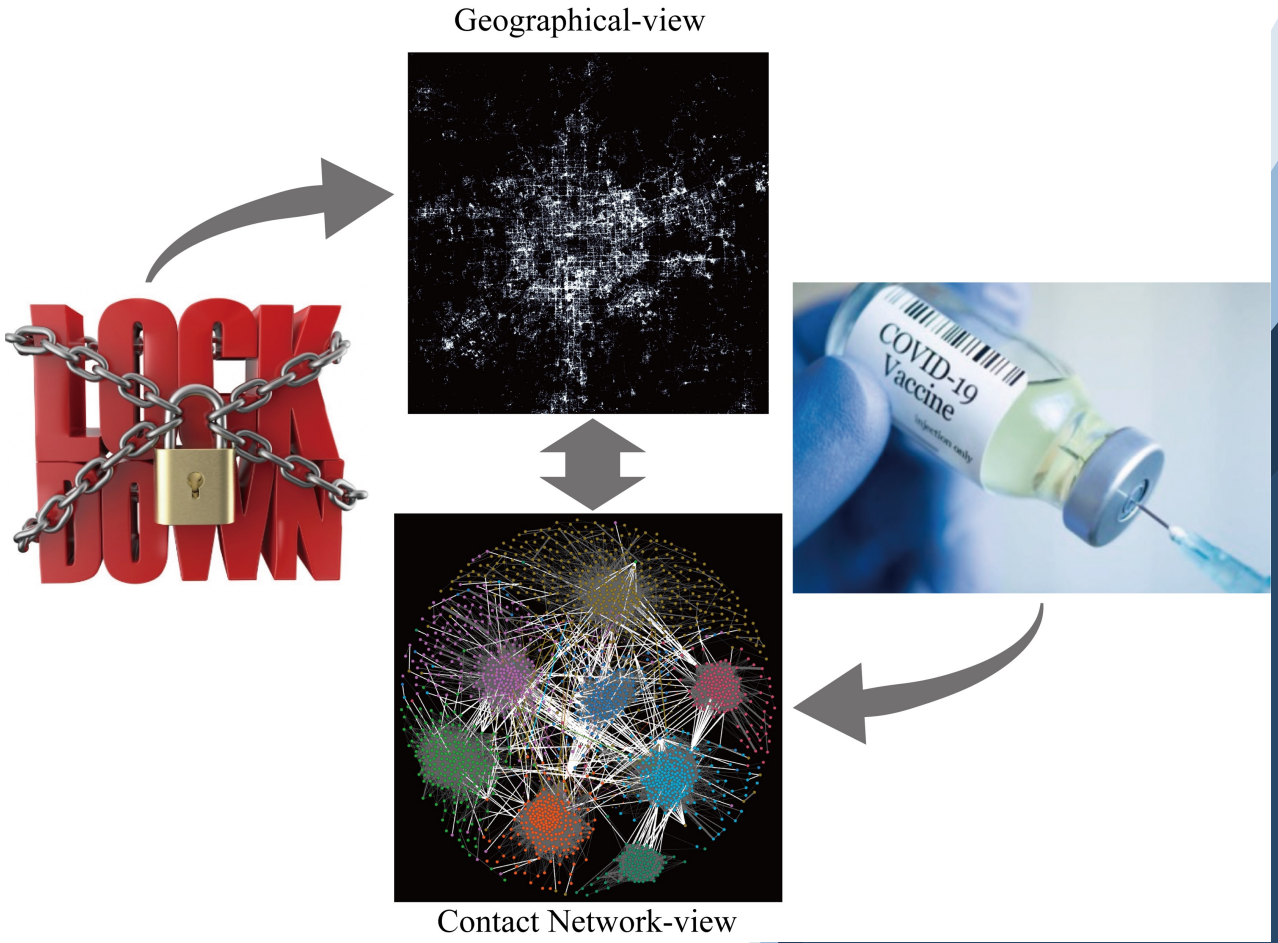
Erzhuo Shao

Limits of pharmaceutical interventions & non-pharmaceutical interventions

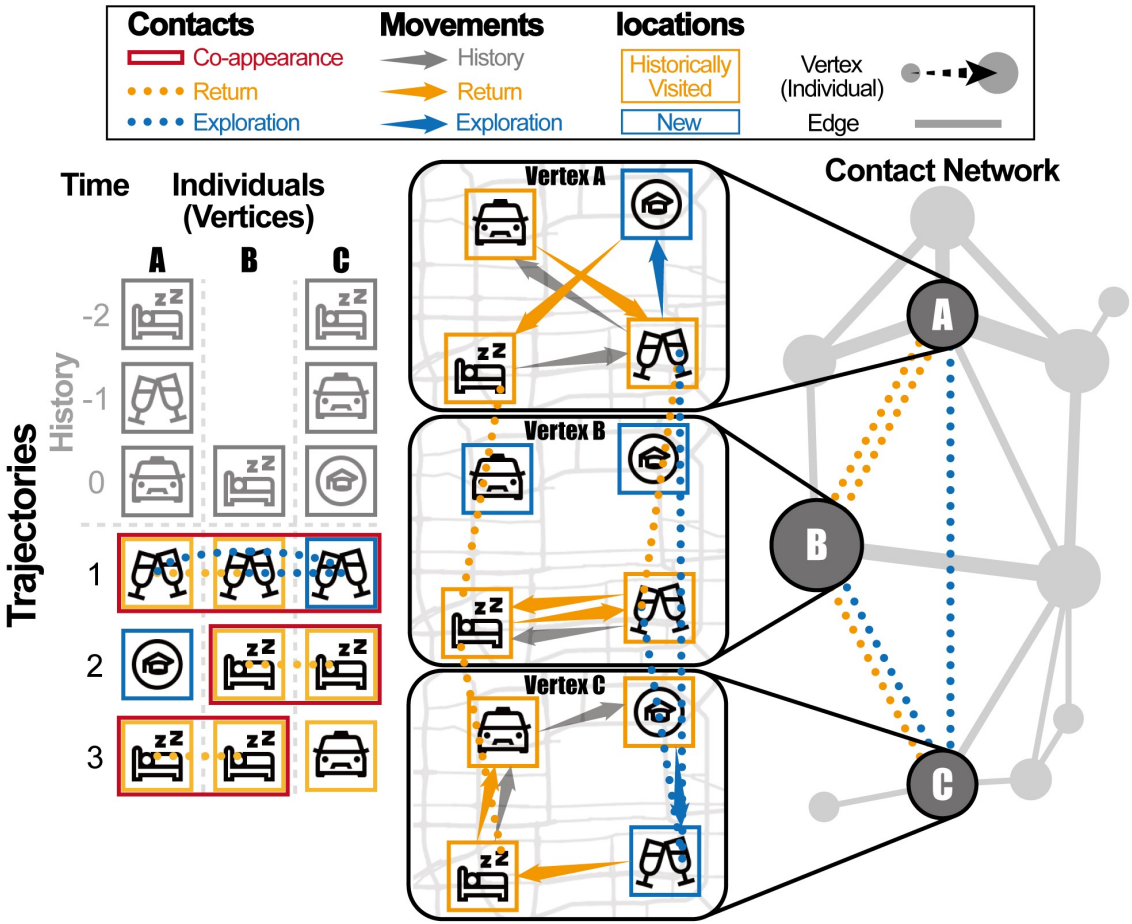
- **Targets**

A. Propose an NPI-PI combined epidemic containment approach with limited social cost by analyzing the interaction between movements restriction and vaccination.

B. Provide explanations for our findings by analyzing the correlation of population movement (geographical-view) and their contact network (complex network-view).



CONTENTS



Construct Agent-based Contact Network

- Dataset:

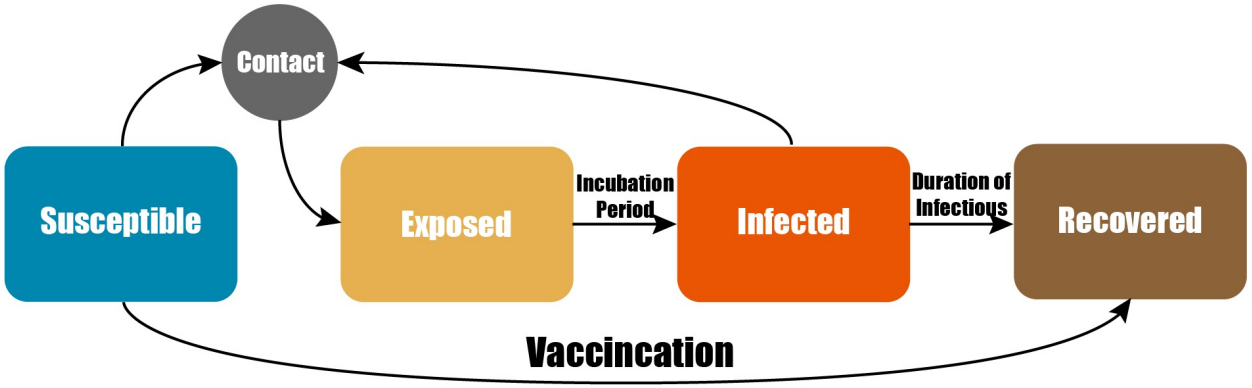
City	Population	Movements
Beijing	208,204	52,699,911
Shanghai	222,990	39,721,698
Shenzhen	232,392	40,735,530

- Historical Trajectories: 1 Week
- Future Trajectories: Remaining 3 Weeks
- Temporal Resolution: 1 Hour
- Spatial Resolution: 50m x 50m

/01

Agent-based SEIR Model

- $P(S \rightarrow E) = 1 - (1 - \beta)^k$
- $P(E \rightarrow I) = \frac{1}{d_L}, d_L = 6.4\ days(Average\ Incubation\ Period)$
- $P(I \rightarrow R) = \frac{1}{d_I}, d_I = 3\ days(Average\ Duration\ of\ Infectious)$
- $\beta: Transmission\ Rate = \frac{R_0}{N * d_I}, R_0 = 2.5, N = Average\ Degree$
- $k: Contact\ Number$



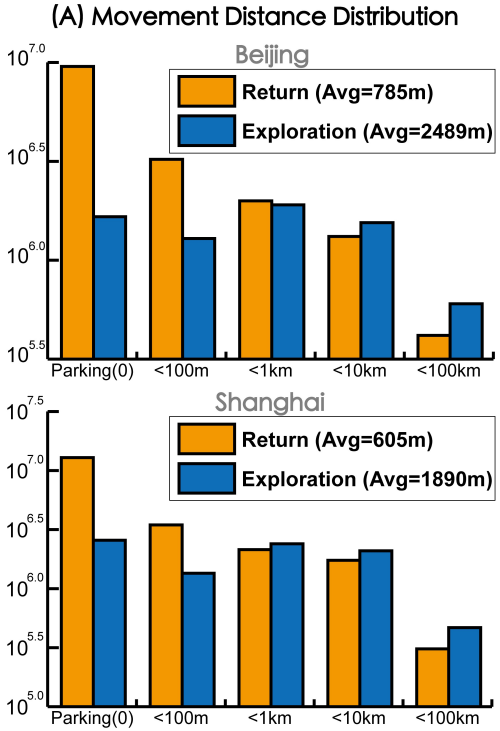
/02

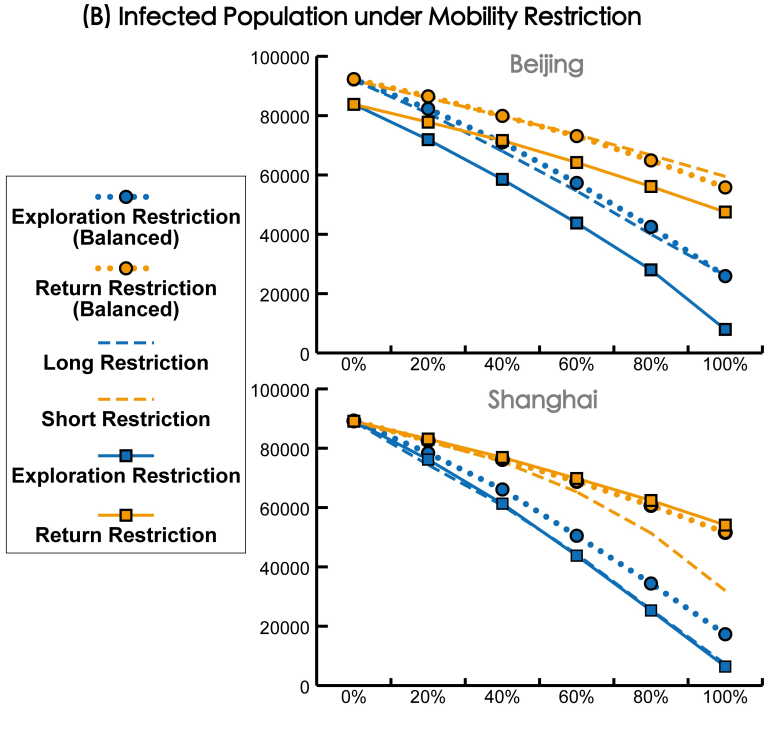
Effect of Exploration Restriction Policy

- **Observations**

A. Exploration Movements' distance is much longer than Return movements.

B. Exploration Restriction Policy is much more effective than return restriction. Long movements is also more effective than short movement (a potential explanation). However, after balancing removed exploration/return movements. Exploration restriction is still more effective. That shows exploration/return dichotomy is independent effect from long/short dichotomy.



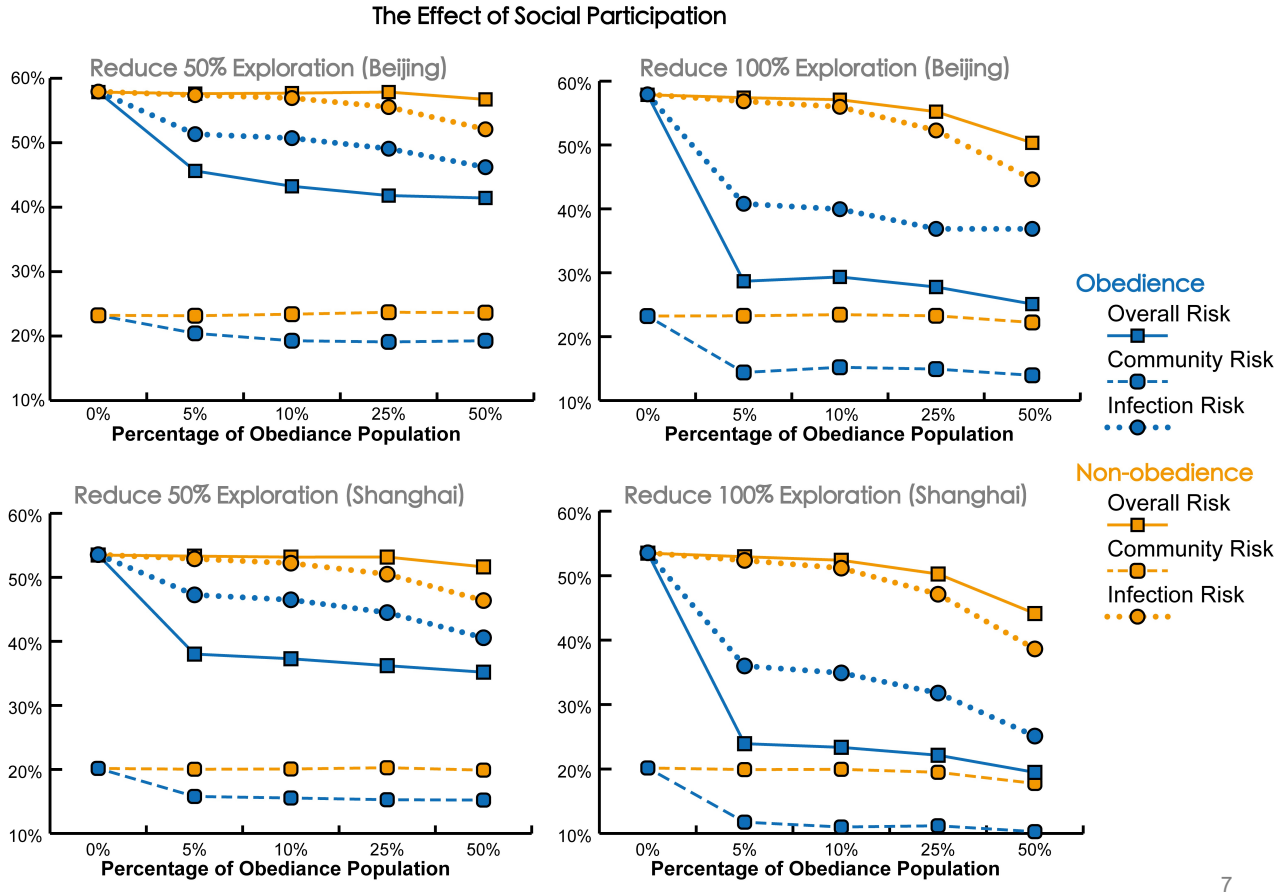


The Impact of Social Participation

- **Observations**

Compared with Non-obedience population, the overall risk, community risk, infection risk are significantly reduced (blue curves are always much lower than orange).

- **Overall risk:** expectation of following infection from a infected population.
- **Community risk:** expectation of following internal (same community) infection from a infected population.
- **Infected risk:** Probability of infection in a group of people (obedience/non-obedience).



The Performance of Exploration Restriction Policy

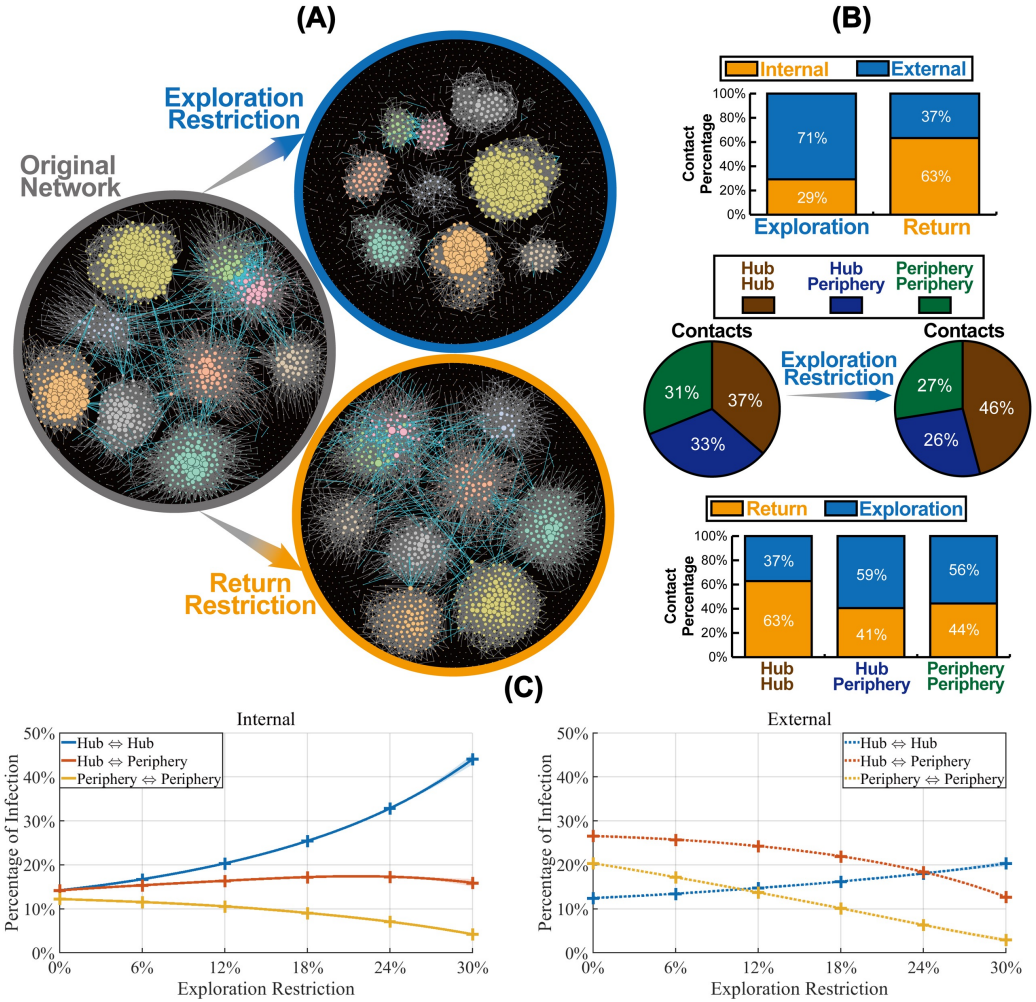
- **Observations**

A. Exploration restriction would significantly reduce the connection across communities, while return restriction will reduce the hub in communities.

B. **1)** External connection are mainly constructed by Exploration Movements. **2)** Exploration restriction will improve the significance of hub-hub connection. **3)** Hub-hub connections are mainly constructed by return movements. That makes them less affected by exploration restriction and be improved by exploration restriction.

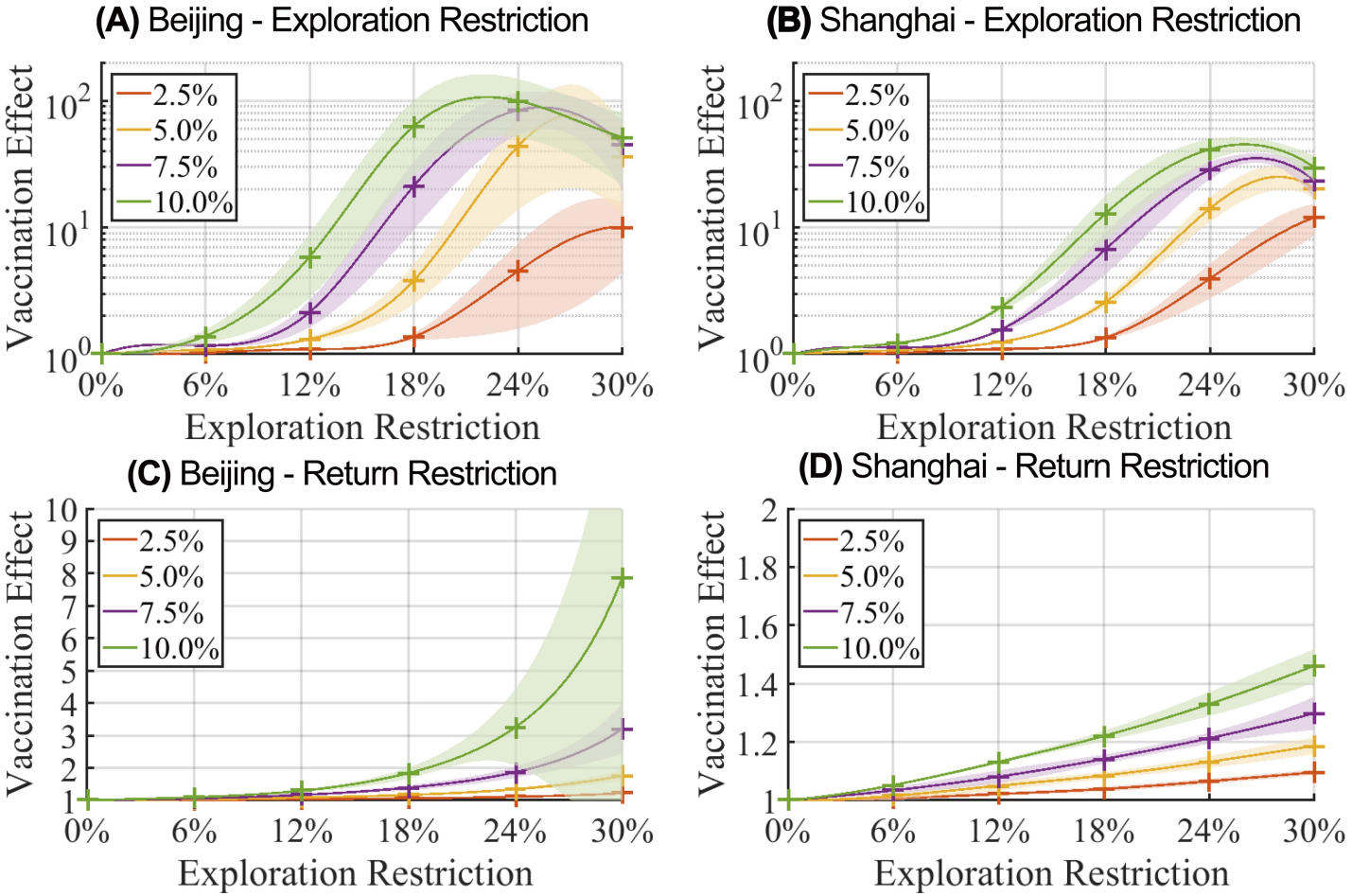
C. The statistics of infection, which is categorized into 6 categories (hub-hub/hub-periphery/periphery-periphery × internal/external). Results shows that the infection between hub-hub vertices will dominate the whole network under exploration restriction.

- **hub/periphery: top 20% degree / last 80% degree**
- **Internal/external:** For any contact or edge, its 2 endpoints are in **same/different** community.



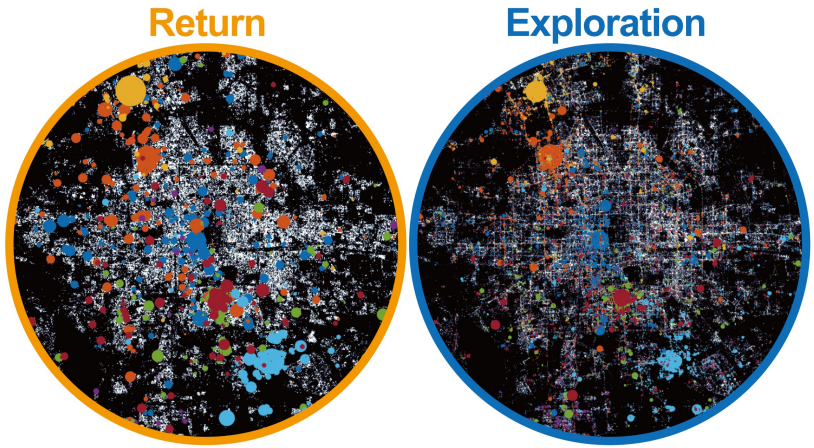
The Amplification of Vaccination under Exploration Restriction

- Relative Effectiveness of Vaccination, defined as: $E_{1+1>2} = (I_r/I_{r,v})/(I/I_v)$, also designated as 1+1>2 effect
- I represents the infected population, r and v represent mobility restriction and vaccination.
- Experiments in Beijing and Shanghai shows exploration restriction will significantly reinforce the relative effect of hub-prioritized vaccination, while this effect is much less significant under return restriction.

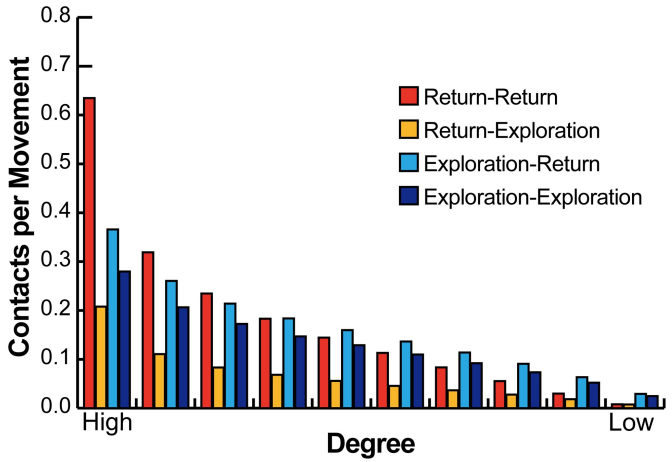


The Origin of Community Structure and Hub/Periphery Dichotomy

(A) The Clustering of Return Movements



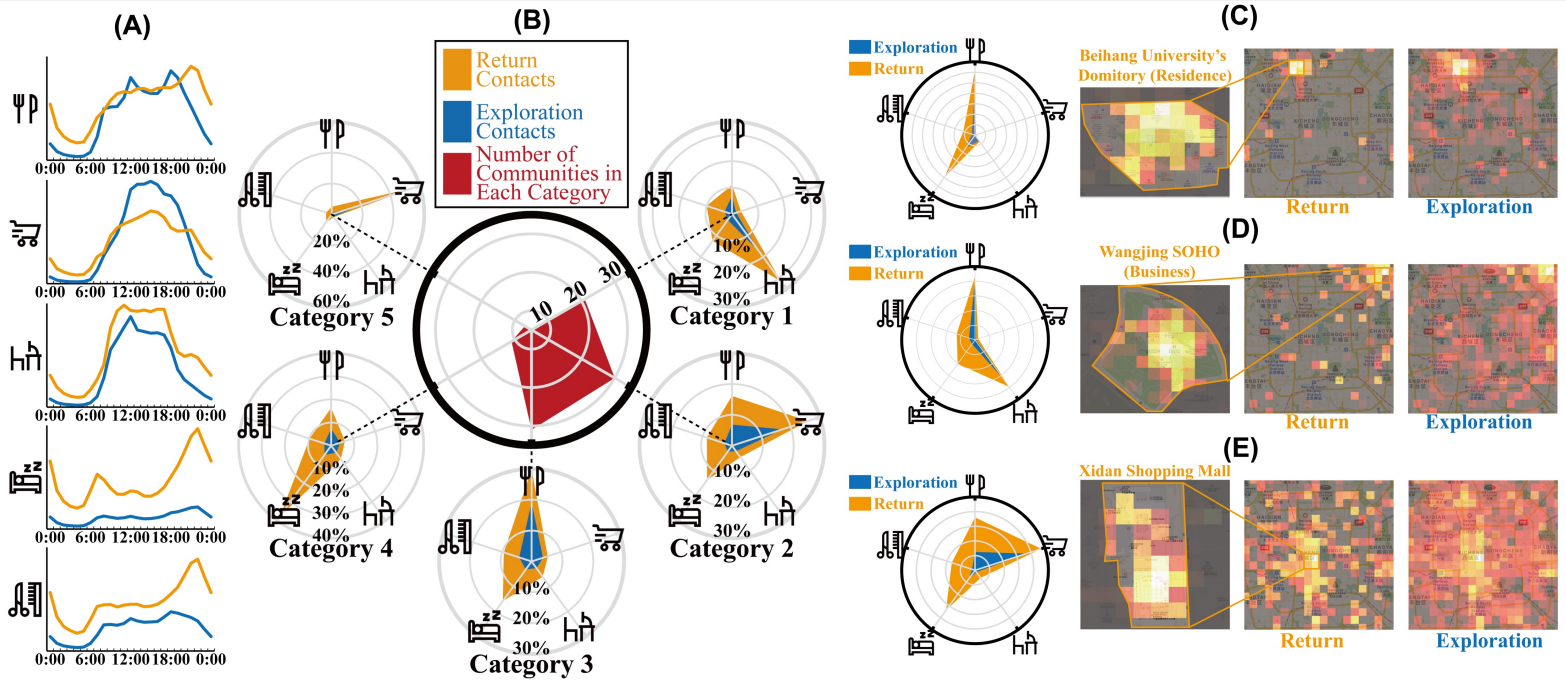
(B) The Concentration of Hub's Return.



A. Compared with exploration, return movements is more concentrated, the clustering of return movements create dense connections among groups of vertices and forms communities in contact network

B. The return movements of hub vertices is especially concentrated and effective to generate contacts among them. That shows the concentration of return movements is the origin of hub/periphery dichotomy.

Case Studies



A. Most contacts are generated in 5 categories of locations, including, **Restaurant**, **Shopping**, **Business**, **Residence**, and **Life Services.**

B. Figure shows the motif of contact in communities. We employ kNN to cluster communities by the distribution of their contacts.

C. Case studies of 3 typical communities in Beijing city.