Report of Proceedings and Recommendations from the Workshop on Privacy and Ethics in Pandemic Data Collection and Processing

January 17 – 20, 2023

Sponsored by the Center for Mobility Analysis for Pandemic Prevention Strategies and the Institute for Computational and Experimental Research in Mathematics at Brown University

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Overview and Leadership

In January of 2023, over 50 experts in the field(s) of public health, epidemiology, simulation modeling, cryptography, and bioethics came together in Providence, Rhode Island for the first in a series of workshops sponsored by the Center for Mobility Analysis for Pandemic Prevention Strategies (MAPPS) at Brown University. The goal(s) of the January 2023 workshop were to:

i. Develop a state-of-the-art approach to collect and analyze human mobility and social mixing data that can inform real-time pandemic responses while balancing benefits, risks and harms.

ii. Develop a protocol for the MAPPING@Brown exercise; and

iii. Identify and initiate new collaborations that can support an application in response to the U.S. National Science Foundation (NSF) Predictive Intelligence for Pandemic Prevention (PIPP) Phase II Center Grants solicitation.

Workshop Steering Committee

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Workshop Website: https://mapps-brown.github.io/workshop2023/

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I. Introduction

Workshop context and motivation

(Adapted from opening plenary presentation by Mark Lurie)

The Center for Mobility Analysis for Pandemic Prevention Strategies (MAPPS) was recently funded at Brown University through a National Science Foundation Predicting and Preventing Pandemics (PIPP) Phase I award (Award Abstract # 2154941), with the goal of answering the grand challenge:

> **How can we best measure and use human mobility and population mixing data to inform real-time pandemic responses across a range of pathogens and under conditions of uncertainty while balancing benefits, risks and harms?**

With a focus on understanding the role of human migration and social interaction in the dispersion of infectious diseases, the Center aims to:

- catalog existing information and make it publicly accessible to researchers,
- generate new data on migration and social mobility,
- develop technology to measure social interaction, and
- use the resultant data to model disease dynamics.

Collecting and analyzing high-resolution data on individual mobility and social mixing raises fundamental ethical questions related to privacy, individual autonomy, consent, and the distribution of power in society. The core motivating challenge of this workshop was to balance those concerns with the data needs determined by public health researchers and policy makers to be integral to decision-making in emergency scenarios.

Workshop structure and target deliverables

The four-day workshop ran from January 17th – 20th, 2023 and included five keynote speakers, three state of the science presentations, five small-group breakout sessions, and one panel discussion with MAPPS investigators. [See Appendix 1 for the full Workshop Agenda; See Appendix 2 for a list of all Workshop Attendees]. The workshop aimed to build on collective knowledge and deliver the following outcomes:

- **Data:** Prioritized list of data needs for measuring movement and social mixing during the MAPPING@Brown study.
- **Privacy and ethics:** Concrete approaches to managing the ethical issues that arise from collecting, managing, analyzing, and sharing mobility and social mixing data.
- **Technical execution:** Outline of the technical approaches to use and share potentially sensitive data responsibly.
- **Modeling:** Proposed MAPPING@Brown modeling and simulation scenarios that might enable us to, predict, prevent, and mitigate future pandemics.

- **Data Sharing:** Identification of techniques for using multi-party computation to securely analyze mobility and social mixing datasets from multiple institutions or mobile devices at once.

II. Workshop Day 1 (January 17, 2023)

State of the Science presentations

Network Epidemiology - **Samuel V. Scarpino**, Northeastern University

Session chair: Jeremy Goldhaber-Fiebert

Key Message(s): Effectively responding to future outbreaks and preventing future pandemics will require collecting real-time, high-resolution data on human mobility and interaction.

A. Hyperlocal information can improve and appropriately target outbreak responses. Crucial to estimate overdispersion in the distribution of secondary cases produced by infected individuals: epidemics sustained by superspreading events are fragile and prone to extinction.

B. Avoid unintended consequences in which policies aimed at curbing transmission may actually increase it (e.g., closing places of worship in one county may inadvertently result in larger gatherings at places of worship in the next county over, where there are no such restrictions).

Privacy for Pandemics: An Introduction to Differential Privacy (DP) for Human Mobility and Interaction Data - **Katrina Ligett**, Hebrew University

Session chair: Jeremy Goldhaber-Fiebert

Key Message(s): We must grapple with an inherent trade-off between statistical accuracy and privacy preservation.

A. The outputs from each analysis conducted on a dataset spend a "privacy budget", in the sense that each published output reveals information about the underlying dataset that could, in principle, be used to identify individuals who contributed to the dataset.

B. Accumulating even seemingly benign data, such as aggregate statistics, creates privacy concerns. Privacy harms add up with each query we make into the data.

C. Domain experts must specify which research questions are most important (i.e., justify higher spending of the privacy budget) and relay this information to those implementing privacy-preserving algorithms.

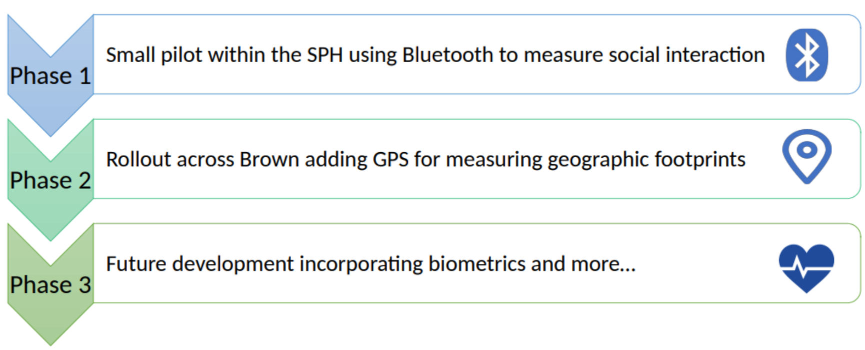
Introduction to MAPPING@Brown

The MAPPING@Brown exercise is a proof-of-concept study that the MAPPS team will be conducting among students, faculty, and staff of the Brown University community, with the aim of mapping individuals' location and proximity to other community members using a smartphone app. The main goals of the exercise are to:

- Measure the social and physical contact network at Brown University
- Use the social network data to populate flexible and realistic mathematical models of disease transmission
    - Intervention assessment: Explore transmission dynamics under different scenarios of social mixing and mobility
- Simulation exercise
    - Introduce a virtual pathogen with specific epidemiological characteristics into the network and observe spread through the network
    - Identify points of intervention/changes in social mixing that would be effective at elimination or containment of the virtual pathogen

A feasibility study, currently planned for the Fall 2023 academic semester, will focus on the Brown University School of Public Health at 121 South Main Street. In Phase 2, the full study will be extended to the entire Brown community, incorporating measurements of geographic movement and, possibly, biometric data. Phase 3 will be potentially implemented outside of Brown as proposed in our NSF PIPP Phase II Center Grant application.

Timeline: MAPPING@Brown



<u>Preliminary qualitative data</u> from focus groups with n=28 Brown-affiliated faculty, students and staff generally indicated positive attitude towards and support for the MAPPING@Brown exercise. Key concerns related to who would have access and ownership of the personal data collected during the exercise, how these data would be used in the future, and the risk of data re-identification.

In persona simulation of epidemics [Presenters: Thomas Trikalinos and Jason Gantenberg, Brown University] during the MAPPING@Brown exercise will aim to (1) reduce assumptions about how the patterning of human interactions arises and (2) observe humans' interactions. To achieve this, MAPPING@Brown will need to record:

(1) Absolute location of each person over time (preferred), and/or

(2) Pairwise distances between persons over time (e.g., as inferred from device Bluetooth received signal strength or other data).

Outstanding challenges: Defining data required to measure network features (in real-time and post hoc); developing contact definitions for multiple disease types.

Smartphone application development [Presenters: Guixing Wei and Kimani Toussaint, Brown University] will facilitate the production of data during registration and location tracing. During Phase 1 of MAPPING@Brown, tracing data will rely primarily on Bluetooth technology. During Phase 2, tracing data may integrate global positioning system (GPS) data. A future Phase 3 will seek to also integrate biometric data. Auxiliary data (e.g., passive data from existing Wi-Fi modules) may be collected in each phase.

Outstanding challenges: Device capacities and limitations; Battery life; iPhone/Android implementations; Transmitting data to MAPPS servers securely.

Breakout Session 1 – Data needs for MAPPING@Brown

Guiding question(s): What data would we ideally like to collect in the MAPPING@Brown exercise, including the specific variables and the frequency and resolution required?

Science Lead(s): Lurie, Trikalinos

Key takeaways:

- Relational data (person-to-person and person-to-place), environmental data, and basic demographic data are most important for Phase 1 (School of Public Health feasibility study) of MAPPING@Brown.
- Only the minimum essential data should be ascertained during Phase 1. All other data points should be reserved for Phase 2 and/or Phase 3 while protections against specific data privacy threats have been established. The data points discussed during Breakout Session 1 are summarized in Appendix 3.

III. Workshop Day 2 (January 18, 2023)

Keynote presentations

Privacy and Synthetic Data - **Adam Smith**, Boston University

Session chair: Anna Lysyanskaya

Key Message(s): We must grapple with an inherent trade-off between statistical accuracy and privacy preservation.

A. The publication of too many "too accurate" statistics can reveal individual information. And threats like reconstruction attacks, membership attacks, and memorization are increasingly advancing.

B. The more we want our data to tell us, the more noise will be introduced into a given synthetic data set.

C. Using differential privacy (DP) synthetic data algorithms efficiently and effectively requires that we (1) clearly define the minimum statistics we want to preserve from the original data, and (2) ensure some available validation check is in place.

Differentially Private Analysis of Graphs and Social Networks - **Sofya Raskhodnikova**, Boston University

Session chair: Wilmot James

Key Message(s): Privacy concerns are inherent in all social network graph data.

A. Relations between nodes in an unlabeled social (or other) network graph can be used to deduce the identities of individual nodes.

B. It is possible for researchers to obtain interesting graph statistics in a DP manner. Some examples include the number of edges, counts of small subgraphs (e.g., triangles), degree distribution, number of connected components, correlation between node attributes, and network attributes.

C. Node-private algorithms offer one way of facilitating more precise analysis of social networks while simultaneously privatizing graphical network data.

Key concerns and principles for large-scale data collections and surveillance - **Julia Netter**, Brown University

Session chair: Wilmot James

Key Message(s): Maintaining data privacy has instrumental value for both the individual and their collective network.

A. In the digital sphere it is particularly difficult (1) to grasp the scope of the personal data one is revealing and (2) to conceive of the different ways a party may act maliciously using that information.

B. Potential threats to the privacy of large-scale data collection and surveillance can vary by time and degree of impact.

C. Mechanisms for mitigating privacy threats will require weighing the shorter versus longer term potential harms, as well as the material and immaterial potential harms.

Breakout Session 2 – Privacy and data collection in the context of MAPPING@Brown

Guiding question(s): Which of the data required for public health research in the context of MAPPING@Brown is privacy sensitive, and how can we minimize the collection of such data without compromising research goals?

Science Lead(s): Lurie, Netter

Key Takeaways: Much of the potentially collected data (Appendix 1) do not pose privacy threats on their own but can be used to identify an individual when combined with other data.

- There are privacy risks involved in solely collecting and storing data, as well as utilizing those data for modeling and other activities.
- There are no sensitive and non-sensitive data from a differential privacy perspective. Thinking of data as sensitive vs. non-sensitive may not be the most useful framing. Rather, we should think of all data as potentially sensitive and potentially identifiable and develop our data collection tools accordingly.
- Techniques for mitigating privacy threats can include coarsening the data, geo-fencing, and using an overall data minimization approach- especially for Phase 1.

Breakout Session 3 – Differential Privacy in the context of MAPPING@Brown

Guiding objective(s): Outline high-level guidance to ensure that the MAPPS project uses the appropriate technical approaches to respect the personal privacy of people whose data it collects and uses.

Science Lead(s): Lurie, Lysyanskaya

Key Takeaways:

- For very precise statistics (e.g., number of contacts per day), we already have the tools to generate them in a differentially private manner. For less precise statistics, there remain questions and opportunities for how best to apply differential privacy algorithms, missing data techniques, and other approaches to improve privacy while maximizing data accuracy.
- Considering the pragmatics of the missing data, some current methods for dealing with missing data could help or be included in differential privacy techniques.
- There are temporal aspects to consider in terms of differential privatization – there is not much research surrounding DP in graphs from continual release models.

IV. Workshop Day 3 (January 19, 2023)

Keynote presentations

Forecasting epidemiological patterns using multi-scale semi-mechanistic models – **Gerardo Chowell-Puente**, Georgia State University

Session chair: George Mohler

Key Message(s): Understanding the mechanisms driving variable, non-exponential patterns in epidemics is necessary to accurately forecast future outbreaks.

- Real epidemics exhibit variable epidemic growth scaling due to mode(s) of transmission, reactive behavior changes, spatial effects, and individual-level heterogeneity in susceptibility and infectiousness.
- Ensemble sub-epidemic models can capture complex transmission dynamics, including fluctuations in epidemic waves over time.
- Sub-epidemic modeling frameworks have been shown to outperform similar infectious disease models (e.g., ARIMA models of COVID-19 in the USA) and hold potential for forecasting other biological and social growth processes.

Some advances in and use scenarios for practical MPC and ZK – **Vladimir Kolesnikov**, Georgia Institute of Technology

Session chair: Anna Lysyanskaya

Key Message(s): Multi-party computation (MPC) can be used to compute on data from multiple sources (e.g., on multiple servers) without revealing private information to other collaborating machines.

- Zero-knowledge proofs (ZKP) are a special case of MPC.
- ZKPs allow one party to convince another party that a given computation or output is true without revealing any identifiable information.
- Computational and financial tradeoffs must be considered when determining the potential benefits of applying ZKPs for data privacy.

State of the Science presentation

Multiparty computation - **Peihan Miao**, Brown University

Session chair: Anna Lysyanskaya

Key Message(s): Nascent cryptographic tools can enable secure computation on joint datasets in a privacy-preserving way.

- Secure multi-party computation (MPC) can enable multiple parties (e.g., via secret sharing, two-server secure aggregation) to perform a computation for output generation without disclosing any individual's inputs.

- In extreme cases, an individual's identity could be inferred from MPC outputs. There is potential to pair MPC with differential privacy techniques to further reduce privacy threats.

Breakout Session 4 – Design of the MAPPING@Brown epidemic simulation and evaluation of statistical network analysis methods

Guiding objective(s): Define how the data collected from MAPPING@Brown will be incorporated into epidemic simulations and studies that evaluate how well common network generating algorithms recreate the observed network.

Science Lead(s): Trikalinos, Gantenberg

Key Takeaways:

- Epidemic simulation scenarios based on MAPPING@Brown data could choose to rely on graphical networks, locational data, or contact matrix data. Graphical network data have the potential to answer questions related to space/location that contact matrices cannot.
- Analytical methods for network analysis could include simulating the MAPPS network data using semi-mechanistic models, Exponential Random Graph Models, classic ensemble models, or an ensemble of ERGMs. Any simulation(s) should be guided by policy-relevant hypotheses.
- We will explore the value in using summary statistics from data passively collected at Brown for simulations, with an eye towards data minimization during Phase 1.

Breakout Session 5 – Multi-party computation (MPC) for analyzing human mobility data

Guiding objective(s): Identify techniques for the MAPPS project to use with datasets belonging to different individuals and organizations in a way that doesn't require that the full data sets be shared.

Key Takeaways:

- MPC protocols that utilize two servers for secret sharing and computation of MAPPS data have the potential to increase data sharing efficiency and will be favorable from an IRB perspective.
- MAPPS data can be used to improve our understanding and measurement of networks in multiple ways, such as measuring how long individuals have been in contact with specific fomites or whether there are associations between proximity to specific locations (e.g., bathrooms) and pathogen spread.
- For computation of MAPPING@Brown data, sensitive data could be protected by certificate of confidentiality or MPC protocols. For relational data that are recorded via beacons, we can reject during computation all data for MAC addresses that have not consented to study participation.

V. Workshop Day 4 (January 20, 2023)

Synthesis

On the last day of the workshop, key points and outstanding questions from each Breakout Session were synthesized and presented to attendees. MAPPS PIs participated in a panel discussion. Emerging questions and key considerations from the panel included the following:

- For Phase I MAPPING@Brown, the project should consult with advisory groups to integrate community perspectives/preferences within the project protocol and get ahead of potential privacy concerns from the Brown SPH community.
- For all MAPPING@Brown phases, cost considerations should also guide data collection approaches (e.g., what number of beacons per space are financially feasible).
- MAPPS may want to collaborate with urban design scientists to systematically look at the impact of place/environment on human behaviors and decision-making.
- MAPPS should engage decision-makers (e.g., St. Louis COVID modelers, local public health departments) as to…
    - What data do they wish they had to manage and prepare for pandemic outbreak?
    - What is their capacity for managing and analyzing the data?
- What are the wider implications and future potential uses of the App?
    - Connecting with individuals who are highly isolated
    - Informing responses to data being collected in real-time (e.g., if there is an emerging hot spot)
    - Phase 3 biometric data (heart rate, blood sugar, temperature, sweat, mobility) could be useful in long-term care facilities / home health / nursing homes
    - Queuing systems (e.g., in amusement parks)

Next Steps

- The MAPPS team will reach out to interested collaborators to involve them in Phase I and Phase II planning, as well as the upcoming NSF PIPPS application.
- The MAPPS team will circulate a list of potential manuscripts to interested collaborators/co-authors.
- The MAPPS team will develop targeted outreach and educational materials for Brown SPH and finalize the Smartphone application in preparation for MAPPING@Brown Phase I. All data collection protocols and human subjects materials will be developed in accordance with Brown IRB requirements and the National Science Foundation Code of Federal Regulations 45 CFR 690.101-124. MAPPING@Brown Phase I will begin in the Fall of 2023 with a semester-long data collection period.

Appendix 1. Workshop Agenda

Workshop Day 1 (January 17, 2023)

Time	Agenda
8:30	Registration, Coffee, and Tea
9:00	Welcome from Brendan Hassett (Director, ICERM)
9:15	Opening Plenary: *Introduction to the Center for Mobility Analysis for Pandemic Prevention Strategies* by Mark Lurie
9:45	Participant introductions in small groups
10:00	Morning break with refreshments
10:30	State of the science: *Modeling epidemics with network data* by Samuel Scarpino with session chair Jeremy Goldhaber-Fiebert
11:15	State of the science: *Privacy and epidemic modeling* by Katrina Ligett with session chair Jeremy Goldhaber-Fiebert
12:00	Lunch
1:30	Session: *Introduction to MAPPING@Brown and breakout sessions* by Peyton Luiz, Thomas Trikalinos, Jason Gantenberg, Guixing Wei, and Kimani Toussaint with session chair Mark Lurie
2:45	Afternoon break with refreshments
3:10	Breakout 1: *Data needs for MAPPING@Brown* led by Mark Lurie
4:30	Report-outs
4:50	Short direction from Mark Lurie
5:00	Adjourn; ICERM evening reception catered by Hemenway's (until 6:30 PM)

Workshop Day 2 (January 18, 2023)

Time	Agenda
8:30	Registration, Coffee, and Tea
8:55	Welcome from Megan Ranney (Deputy Dean, Brown School of Public Health)
9:15	Keynote: *Synthetic data- social mixing data* by Adam Smith with session chair Anna Lysyanskaya
10:00	Morning break with refreshments
10:30	Keynote: *Key concerns and principles for large-scale data collections and surveillance* by Julia Netter with session chair Wilmot James
11:15	Keynote: *Differential privacy in graphs* by Sofya Raskhodnikova with session chair Wilmot James
12:00	Lunch
1:00	Prep for Breakouts 2 & 3
1:15	Breakout 2: *Privacy and data collection in the context of MAPPING@Brown* led by Julia Netter
2:45	Afternoon break with refreshments
3:15	Breakout 3: *Applications of differential privacy for MAPPING@Brown* led by Anna Lysyanskaya
4:45	Report-outs
4:50	Short direction from Julia Netter
5:00	Adjourn

Workshop Day 3 (January 19, 2023)

Time	Agenda
8:30	Registration, Coffee, and Tea
9:00	Introductory remarks and Breakout 4 prep by Thomas Trikalinos
9:15	Keynote: *A survey of modeling approaches that use social mixing data* by Gerardo Chowell-Puente with session chair George Mohler
10:00	Morning break with refreshments
10:30	Breakout 4: *Design of the MAPPING@Brown epidemic simulation and evaluation of statistical network analysis methods* led by Thomas Trikalinos and Jason Gantenberg
12:00	Lunch
1:00	Introductory remarks and Breakout 5 prep by Anna Lysyanskaya
1:15	State of the science: *Multiparty computation* by Peihan Miao with session chair Anna Lysyanskaya
2:00	Keynote: *Efficient and scalable multiparty computation* by Vladimir Kolesnikov with session chair Anna Lysyanskaya
2:45	Afternoon break with refreshments
3:15	Breakout 5: *Multiparty computation for analyzing MAPPING@Brown mobility data* led by Anna Lysyanskaya
4:45	Report-outs
4:50	Short direction from Anna Lysyanskaya
5:00	Adjourn
6:30	MAPPS dinner Waterman Grille, 4 Richmond Square, Providence

Workshop Day 4 (January 20, 2023)

Note: 9:30 a.m. program start

Time	Agenda
9:00	Registration, Coffee, and Tea
9:30	Summary of breakout findings by Jason Gantenberg, Thomas Trikalinos, and Aditya Khanna
10:00	Flipped panel led by MAPPS research team
10:45	Morning break with refreshments
11:00	Closing discussion led by Betsy Stubblefield Loucks
12:00	Lunch
1:00	Adjourn

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Appendix 3. Breakout Session Output: Key Data for MAPPS

Data Type	Variables
Geographic	• GPS coordinates • Travel distances • Phone brightness (to indicate inside/outside location) • Geocircles, and once someone enters the geocircle, it sends a signal back that the device has entered this location
Environmental	• Phone brightness (to indicate inside/outside location) • Room occupancy • Within room density • Prevalence of pathogen mitigation activities (UV lights, air filters, air exchange) • Outside weather • Strength of Wi-Fi connection • Temperature • CO2 monitor • Interior layout data of SPH and other Brown buildings (Only select variables important for Phase 3)
Relational	• Contact characteristics (with person and place): type, duration, frequency • Room occupancy over time (affects distances between people) • Within room density (affect distances between people) • Understanding from where and to where people are going; type of activities occurring in each room • Place a beacon in a given location that acts as an additional person contact (this can reduce the need for geospatial data) • Battery life (i.e., if battery is dead this is a way to tell whether we are missing relational data) (Only select variables, or estimates of these variables, might be required for Phase 3)
Personal	• Demographics (should be collected for all invited participants, i.e., those who enroll and those who decline to participate in the study) • Biometric data (temp, heart rate, oximeter, skin sweating) • Personality intake • Co-occurring conditions; respiratory conditions; vaccination status • Lifestyle • Health literacy • Occupation; year of school (e.g., freshman) • Type of activities being engaged in (work and leisure) • Individual behaviors: masked vs. unmasked • Phone brightness (to indicate inside/outside location) • Is someone currently sick? (biometrics/self-report) (Demographic data more important for Phase 2 than for Phase 1)