

Complexity Society Lab

Brennan Klein

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March 13, 2024 || PhD Recruitment Event



Northeastern University
Network Science Institute



Complexity
Society
Lab

EAI The Institute for Experiential AI
Northeastern University



H Hutchins Center
for African &
African American
Research

VERSES

About me

- ❑ 🌵 **From:** Tucson, Arizona
- ❑ 🎓 **Education:**
 - ❑ 🧠 BA: Cognitive Science
(Swarthmore College 2014; Philadelphia, USA)
 - ❑ 🕸 PhD: Network Science
(Northeastern University 2020; Boston, USA)
- ❑ 🌐 **Current position:** Associate Research Scientist
(Northeastern University; Boston, USA)
 - ❑ 🏛 Also: Data for Justice Fellow, The Hutchins Center @Harvard
 - ❑ 🏢 Also: Senior Research Scientist, VERSES AI
- ❑ 🏠 **Lives:** Roslindale (it's great!)
- ❑ 🌟 **Passions:**
 - ❑ ⚽ Watch & play
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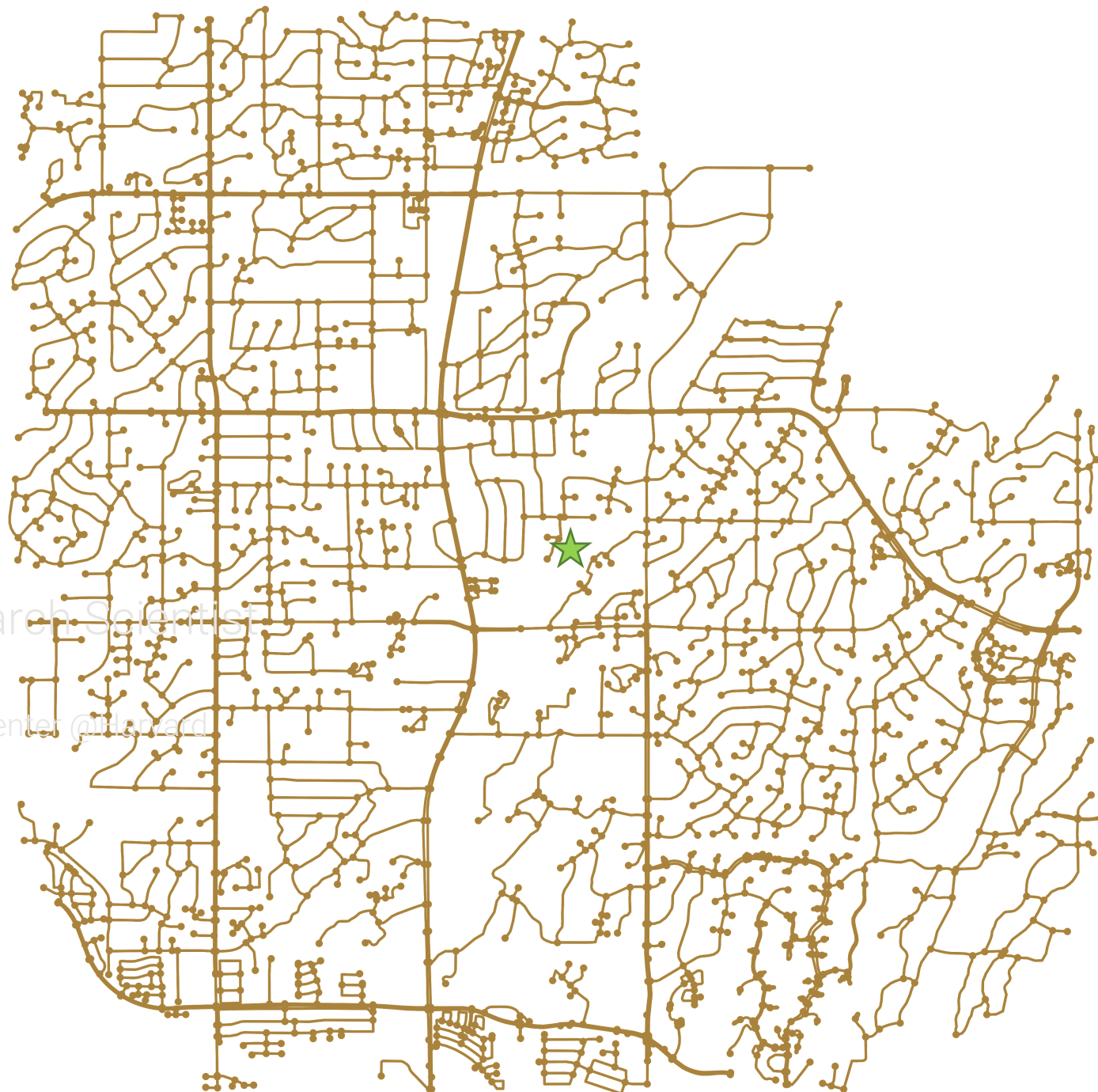
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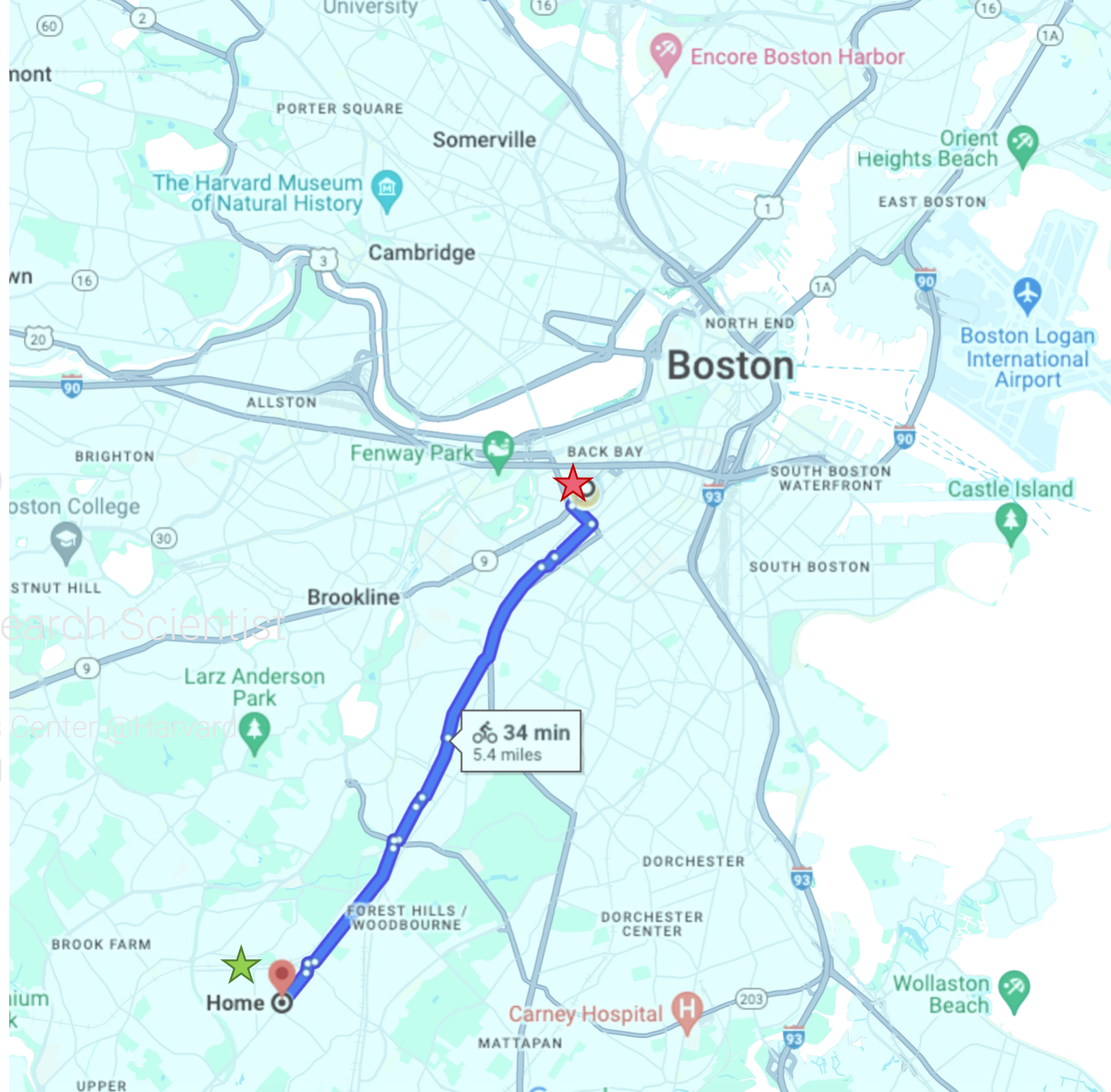
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Research Article

WILEY | Hindawi

The Emergence of Informative Higher Scales in Complex Networks

Brennan Klein^{1,2} and Erik Hoel³

communications biology

ARTICLE

<https://doi.org/10.1038/s42003-021-02867-8> OPEN

A computational exploration of resilience and evolvability of protein-protein interaction networks

Brennan Klein^{1,2,8}, Ludvig Holmér³, Keith M. Smith^{4,8}, Mackenzie M. Johnson⁵, Anshuman Swain⁶, Laura Stolp⁷, Ashley I. Teufel^{5,8,9} & April S. Kleppe^{10,11,8}

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netrd: A library for network reconstruction and graph distances

Stefan McCabe¹, Leo Torres¹, Timothy LaRock¹, Syed Arefinul Haque¹, Chia-Hung Yang¹, Harrison Hartle¹, and Brennan Klein^{1, 2}

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pympd: A Python library for active inference in discrete state spaces

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Received: 15 April 2021 | Accepted: 3 January 2022
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Methods in Ecology and Evolution

APPLICATION

Exploring noise, degeneracy and determinism in biological networks with the einet package

Brennan Klein^{1,2} | Anshuman Swain³ | Travis Byrum³ | Samuel V. Scarpino^{1,4,5,6} | William F. Fagan³

Evolution and emergence: higher order information structure in protein interactomes across the tree of life

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¹Network Science Institute, Northeastern University, Boston, MA, USA
²Laboratory for the Modeling of Biological and Socio-Technical Systems, Northeastern University, Boston, MA, USA
³Value Discovery Center, Tufts University, Medford, MA, USA
⁴Department of Biology, University of Maryland, College Park, MD, USA
⁵Department of Computer Science, Drexel University, Philadelphia, PA, USA
^{*}Corresponding author. E-mail: b.klein@northeastern.edu

PROCEEDINGS A

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Network comparison and the within-ensemble graph distance

Harrison Hartle¹, Brennan Klein^{1,2}, Stefan McCabe¹, Alexander Daniels³, Guillaume St-Onge^{4,5}, Charles Murphy^{4,5} and Laurent Hébert-Dufresne^{3,4,6}

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<https://doi.org/10.1111/2039137231222481>

Sage Journals

Perspective

Designing ecosystems of intelligence from first principles

Karl J Friston^{1,2}, Maxwell JD Ramstead^{1,2}, Alex B Kiefer^{1,3}, Alexander Tschantz¹, Christopher L Buckley^{1,4}, Mahaut Albarracín^{1,5}, Riddhi J Pitliya^{1,6}, Conor Heins^{1,7,8,9}, Brennan Klein^{1,10}, Beren Millidge^{1,11}, Dalton AR Sakthivadivel^{1,12,13,14}, Toby St Clare Smith^{1,6,15}, Magnus Koudahi^{1,16}, Safae Essafi Tremblay^{1,17}, Capm Petersen¹, Kaiser Fung¹, Jason G Fox¹, Steven Swanson¹, Dan Mapes¹, and Gabriel René¹

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News & views

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A consolidated framework for quantifying interaction dynamics

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On Bayesian mechanics: a physics of and by beliefs

Maxwell J. D. Ramstead^{1,2,1}, Dalton A. R. Sakthivadivel^{1,3,4,5,1}, Conor Heins^{1,6,7,8}, Magnus Koudahi^{1,9}, Beren Millidge^{1,10}, Lancelot Da Costa^{2,11}, Brennan Klein^{1,12} and Karl J. Friston^{1,2}

Spin Glass Systems as Collective Active Inference

Conor Heins^{1,2,3,4(ES)}, Brennan Klein^{1,6,7}, Daphne Demekas^{5,6}, Miguel Aguilera^{8,9}, and Christopher L. Buckley^{1,8,9}

An Analytical Model of Active Inference in the Iterated Prisoner's Dilemma

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communications biology

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[Open Peer Review on this article](#) OPEN

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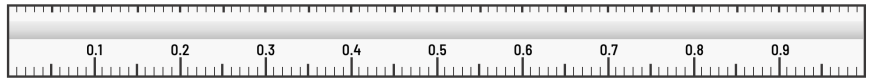
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$$D_{d,s}(G_1, G_2) = \frac{D_d(G_1, G_2)}{\langle D_d(G_{n,p}, G'_{n,p}) \rangle}$$



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Whitehead Institute for Biomedical Research, Cambridge, MA, USA
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Department of Computer Science, Brown University, Providence, RI, USA
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Complex systems

A consolidated framework for quantifying interaction dynamics

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<https://doi.org/10.1038/s41598-023-00820-4>

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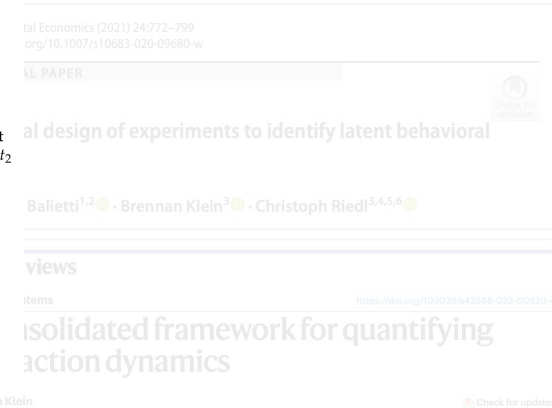
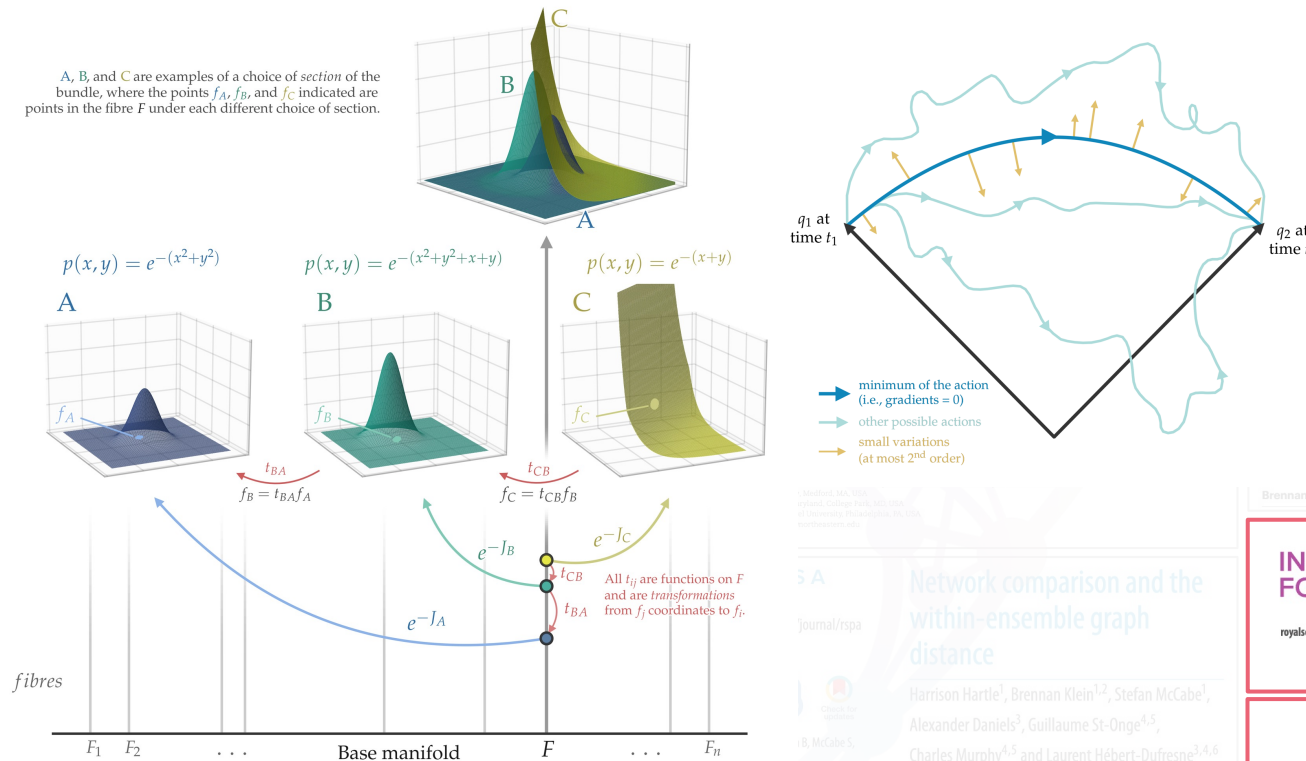
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The figure shows a heatmap of Likelihood Odds as a function of information level A (y-axis, 2 to 6) and precision π (x-axis, 0.2 to 0.8). Four callout bar charts show Likelihood Odds for three models (M1, M2, M3) at specific (A, π) points:

- Lowest Information:** $A=6.00, \pi=0.20$. M1 ≈ 0.35, M2 ≈ 0.30, M3 ≈ 0.40.
- Expert Prediction:** $A=6.00, \pi=0.50$. M1 ≈ 0.25, M2 ≈ 0.35, M3 ≈ 0.55.
- Low Information:** $A=6.00, \pi=0.80$. M1 ≈ 0.35, M2 ≈ 0.30, M3 ≈ 0.40.
- Replication:** $A=3.33, \pi=0.50$. M1 ≈ 0.65, M2 ≈ 0.15, M3 ≈ 0.25.
- Highest Information:** $A=2.00, \pi=0.50$. M1 ≈ 0.75, M2 ≈ 0.25, M3 ≈ 0.15.

Karl J. Friston^{1,2}, Maxwell J.D. Ramstead^{1,2}, Alex B. Kiefer^{1,3}, Alexander Tschantz¹, Christopher L. Buckley^{1,4}, Mahaut Albarracín^{1,5}, Riddhi J. Pitliya^{1,6}, Conor Heins^{1,7,8,9}, Brennan Klein^{1,10}, Beren Millidge^{1,11}, Dalton A.R. Sakhivadivel^{1,12,13,14}, Toby St. Clare Smith^{1,6,15}, Magnus Koudahl^{1,16}, Safae Essaiy Tremblay^{1,17}, Capm Petersen¹, Kaiser Fung¹, Jason G. Fox¹, Steven Swanson¹, Dan Mapey¹, and Gabriel René¹

Research interests: Complexity



INTERFACE FOCUS

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<https://doi.org/10.1177/26339137231222481>

Sage Journals

Perspective

Designing ecosystems of intelligence from first principles

Karl J Friston^{1,2}, Maxwell JD Ramstead^{1,2}, Alex B Kiefer^{1,3}, Alexander Tschantz¹, Christopher L Buckley^{1,4}, Mahaut Albarracin^{1,5}, Riddhi J Pitliya^{1,6}, Conor Heins^{1,7,8,9}, Brennan Klein^{1,10}, Beren Millidge^{1,11}, Dalton AR Sakhthivadivel^{1,12,13,14}, Toby St Clare Smith^{1,6,15}, Magnus Koudahi^{1,16}, Safae Essafi Tremblay^{1,17}, Capm Petersen¹, Kaiser Fung¹, Jason G Fox¹, Steven Swanson¹, Dan Mapes¹, and Gabriel René¹

Journal of Systems Management (2024) 75(1):1–12
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Research Article

WILEY | Hindawi

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communications biology

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Received: 12 April 2021 | Accepted: 3 January 2022
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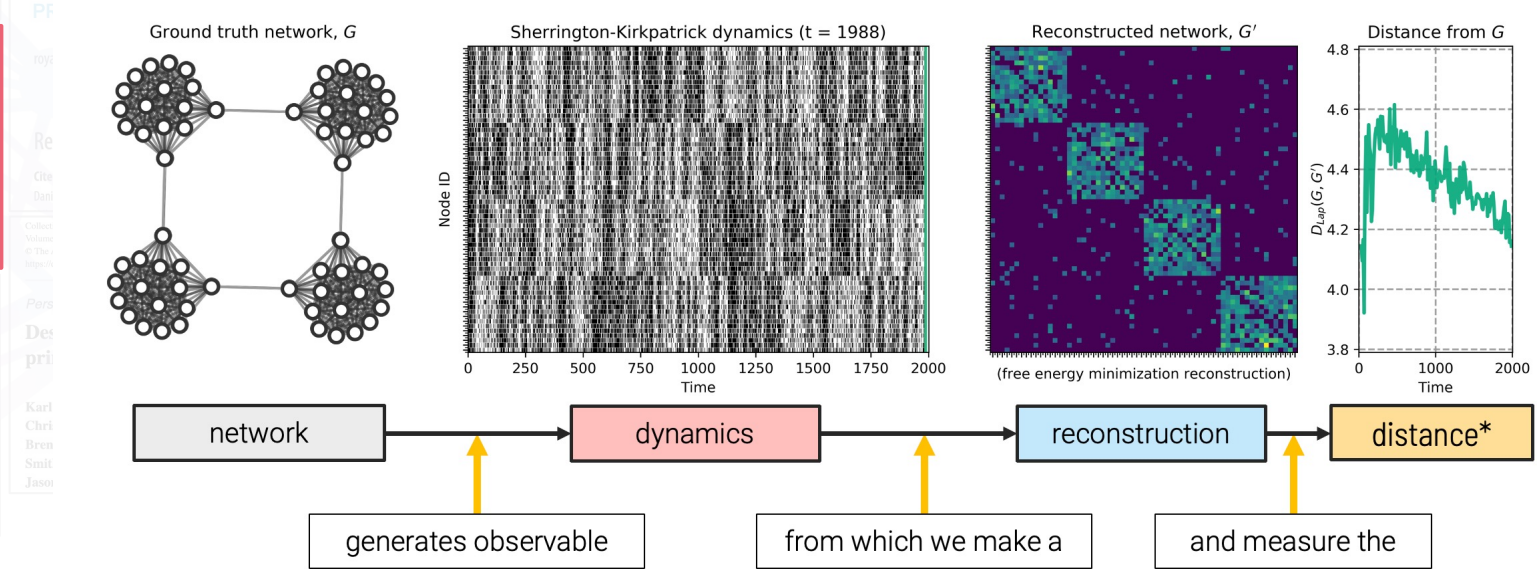
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PROCEEDINGS

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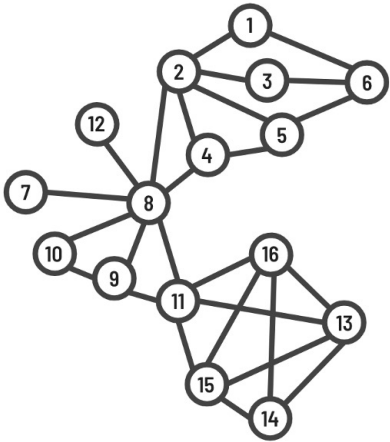
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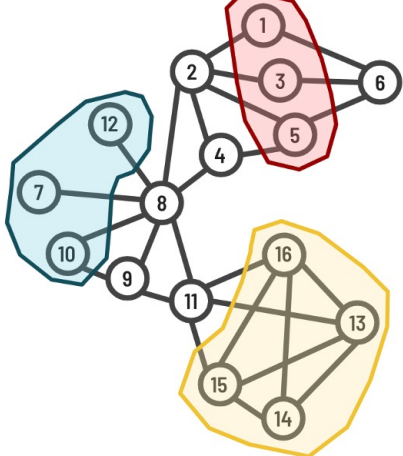
Perspective

Designing ecological principles

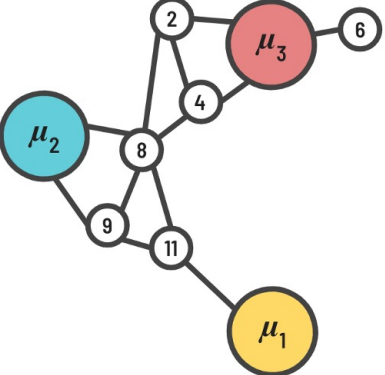
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microscale



grouping



macroscale

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netrd: A library for network reconstruction and graph distances

Stefan McCabe¹, Leo Torres¹, Timothy LaRock¹, Syed Arefinul Haque¹, Chia-Hung Yang¹, Harrison Hartle¹, and Brennan Klein^{1, 2}

JOSS The Journal of Open Source Software

pympd: A Python library for active inference in discrete state spaces

Conor Heins^{1,2,3,4*}, Beren Millidge^{4,5}, Daphne Demekas⁶, Brennan Klein^{4,7,8}, Karl Friston⁹, Iain D. Couzin^{1,2,3}, and Alexander Tschantz^{4,10,11*}

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DOI: 10.1111/2041-210X.13805

Methods in Ecology and Evolution

APPLICATION

Exploring noise, degeneracy and determinism in biological networks with the einet package

Brennan Klein^{1,2} | Anshuman Swain³ | Travis Byrum³ | Samuel V. Scarpino^{1,4,5,6} | William F. Fagan³

Evolution and emergence: higher order information structure in protein interactomes across the tree of life

Brennan Klein^{1,2*}, Erik Hoel³, Anshuman Swain⁴, Ross Griebenow⁴ and Michael Levin⁵

¹Network Science Institute, Northeastern University, Boston, MA, USA
²Laboratory for the Modeling of Biological and Socio-Technical Systems, Northeastern University, Boston, MA, USA
³Value Discovery Center, Tufts University, Medford, MA, USA
⁴Department of Biology, University of Maryland, College Park, MD, USA
⁵Department of Computer Science, Drexel University, Philadelphia, PA, USA
^{*}Corresponding author. E-mail: b.klein@northeastern.edu

PROCEEDINGS A

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Network comparison and the within-ensemble graph distance

Harrison Hartle¹, Brennan Klein^{1,2}, Stefan McCabe¹, Alexander Daniels³, Guillaume St-Onge^{4,5}, Charles Murphy^{4,5} and Laurent Hébert-Dufresne^{3,4,6}

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<https://doi.org/10.1111/2039137231222481>

Sage Journals

Perspective

Designing ecosystems of intelligence from first principles

Karl J Friston^{1,2}, Maxwell JD Ramstead^{1,2}, Alex B Kiefer^{1,3}, Alexander Tschantz¹, Christopher L Buckley^{1,4}, Mahaut Albarracín^{1,5}, Riddhi J Pitliya^{1,6}, Conor Heins^{1,7,8,9}, Brennan Klein^{1,10}, Beren Millidge^{1,11}, Dalton AR Sakthivadivel^{1,12,13,14}, Toby St Clare Smith^{1,6,15}, Magnus Koudahi^{1,16}, Safae Essafi Tremblay^{1,17}, Capm Petersen¹, Kaiser Fung¹, Jason G Fox¹, Steven Swanson¹, Dan Mapes¹, and Gabriel René¹

Experimental Economics (2021) 24:772–799
<https://doi.org/10.1007/s10683-020-09680-w>

ORIGINAL PAPER

Optimal design of experiments to identify latent behavioral types

Stefano Balietti^{1,2} · Brennan Klein³ · Christoph Riedl^{3,4,5,6}

News & views

Complex systems <https://doi.org/10.1038/s43588-023-00520-4>

A consolidated framework for quantifying interaction dynamics

Brennan Klein

INTERFACE FOCUS

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On Bayesian mechanics: a physics of and by beliefs

Maxwell J. D. Ramstead^{1,2,1}, Dalton A. R. Sakthivadivel^{1,3,4,5,1}, Conor Heins^{1,6,7,8}, Magnus Koudahi^{1,9}, Beren Millidge^{1,10}, Lancelot Da Costa^{2,11}, Brennan Klein^{1,12} and Karl J. Friston^{1,2}

Spin Glass Systems as Collective Active Inference

Conor Heins^{1,2,3,4(ES)}, Brennan Klein^{1,6,7}, Daphne Demekas^{5,6}, Miguel Aguilera^{8,9}, and Christopher L. Buckley^{1,8,9}

An Analytical Model of Active Inference in the Iterated Prisoner's Dilemma

Daphne Demekas^{1,2(ES)}, Conor Heins^{1,3,4,5}, and Brennan Klein^{1,5,6}

Research interests: Society

RESEARCH

CORONAVIRUS

The effect of human mobility and control measures on the COVID-19 epidemic in China

Moritz U. G. Kraemer^{1,2,3*}, Chia-Hung Yang⁴, Bernardo Gutierrez^{1,5}, Chieh-Hsi Wu⁶, Brennan Klein⁴, David M. Pigott⁷, Open COVID-19 Data Working Group[†], Louis du Plessis¹, Nuno R. Faria¹, Ruoran Li⁸, William P. Hanage⁹, John S. Brownstein^{2,3}, Maylis Layan¹⁰, Alessandro Vespignani^{4,11}, Huaiyu Tian¹², Christopher Dye¹, Oliver G. Pybus^{1,13*}, Samuel V. Scarpino^{4*}

RESEARCH

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PLOS DIGITAL HEALTH

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Clinical Infectious Diseases, ciac187, <https://doi.org/10.1093/cid/ciac187>

Published: 05 March 2022 Article history ▼

Article

COVID-19 amplified racial disparities in the US criminal legal system

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communications medicine

ARTICLE

<https://doi.org/10.1038/s43854-023-00253-5> OPEN

Forecasting hospital-level COVID-19 admissions using real-time mobility data

Brennan Klein^{1,2,3*}, Ana C. Zenteno^{3,4}, Daisha Joseph¹, Mohammadmehdi Zahedi^{1,4}, Michael Hu³, Martin S. Copenhaver³, Moritz U. G. Kraemer^{5,6}, Matteo Chinazzi^{1,2}, Michael Klompas^{7,8,9}, Alessandro Vespignani^{1,2}, Samuel V. Scarpino^{1,4,10,11,12} & Hojjat Salmasian^{8,12,13}

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The effect of eviction moratoria on the transmission of SARS-CoV-2

Anjalika Nande^{1,7}, Justin Sheen^{2,7}, Emma L. Walters³, Brennan Klein^{4,5}, Matteo Chinazzi^{4,5}, Andrei H. Gheorghe¹, Ben Adlam¹, Julianna Shinnick², Maria Florencia Tejada², Samuel V. Scarpino⁴, Alessandro Vespignani^{4,5}, Andrew J. Greenlee³, Daniel Schneider³, Michael Z. Levy^{2,8,9} & Alison L. Hill^{1,6,8,9}

PLOS DIGITAL HEALTH

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under review (PNAS)

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in prep.

The disparate racial impact of drug-free zone laws in the United States

Andrew Zaharia¹, Kudakwashe Mawunganidze¹, Noelle Keith¹, Christina Steele², Brein Mosely², Oghenetega Ogodo², Elizabeth Hinton^{2,6}, Brandon M. Terry², Abdul Nasser Rad¹, and Brennan Klein^{*2,7,8}

Research interests: Society

RESEARCH

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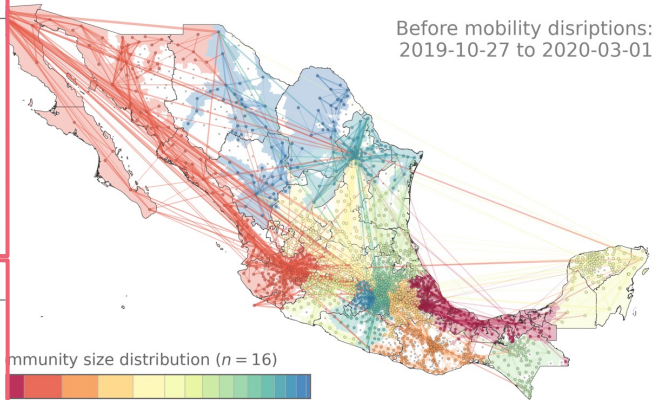
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RESEARCH

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PLOS DIGITAL HEALTH

RESEARCH ARTICLE

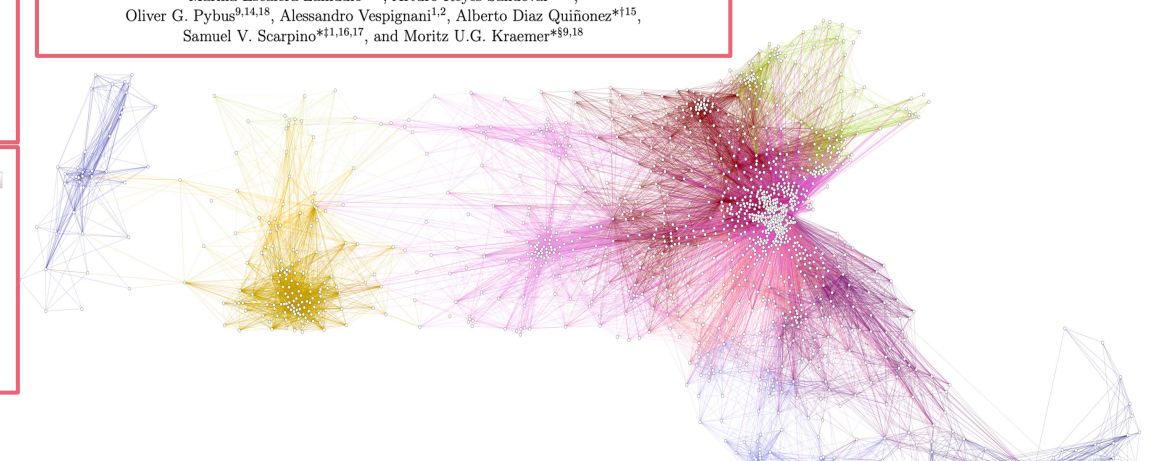
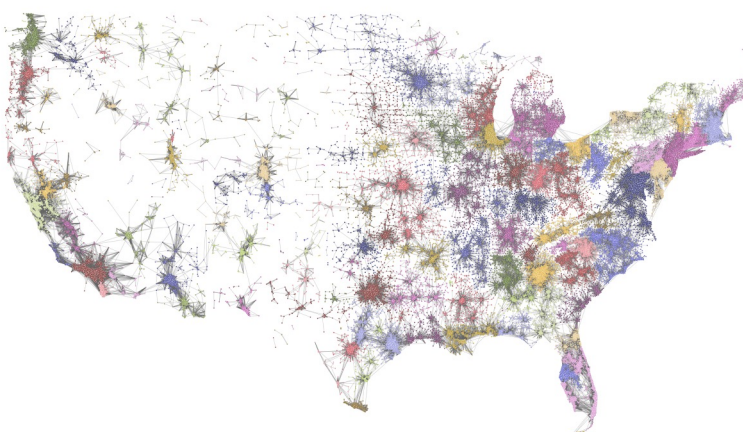
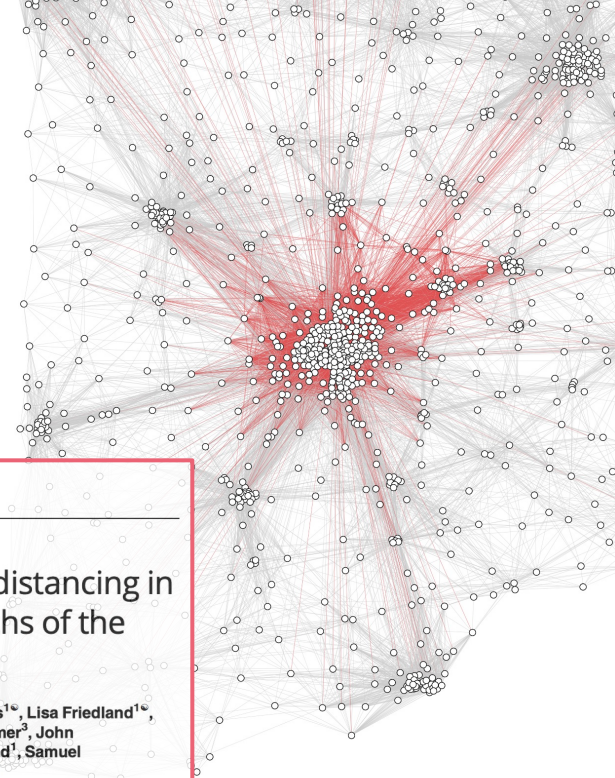
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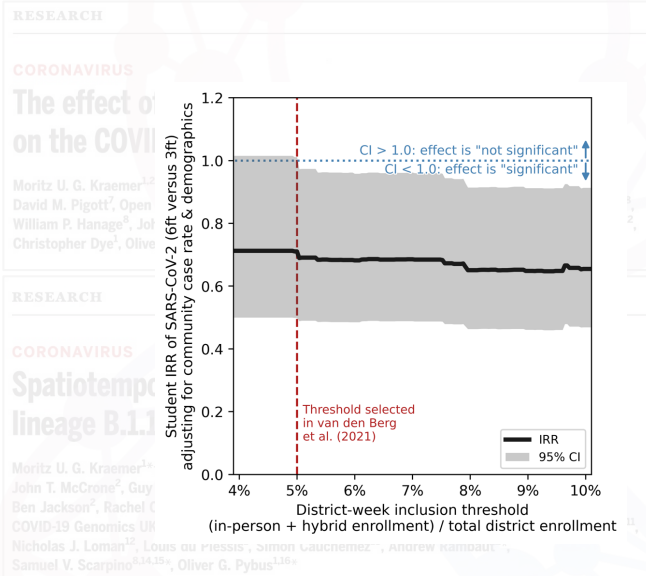
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Research interests: Society



Clinical Infectious Diseases

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Published: 05 March 2022 Article history ▼

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RESEARCH ARTICLE

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PLOS DIGITAL HEALTH

RESEARCH ARTICLE

Higher education responses to COVID-19 in the United States: Evidence for the impacts of university policy

Brennan Klein^{1,2,3,4*}, Nicholas Generous^{1,2,3,5}, Matteo Chinazzi^{1,2}, Zarana Bhadriraja^{1,4}, Rishab Gunashekar^{1,4}, Preeti Kori^{1,4}, Bodian Li^{1,5}, Stefan McCabe¹, Jon Green^{1,6}, David Lazer¹, Christopher R. Marsicano^{7,8}, Samuel V. Scarpino^{1,9,10}, Alessandro Vespignani^{1,2,*}

Article

COVID-19 amplified racial disparities in the US criminal justice system

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Article

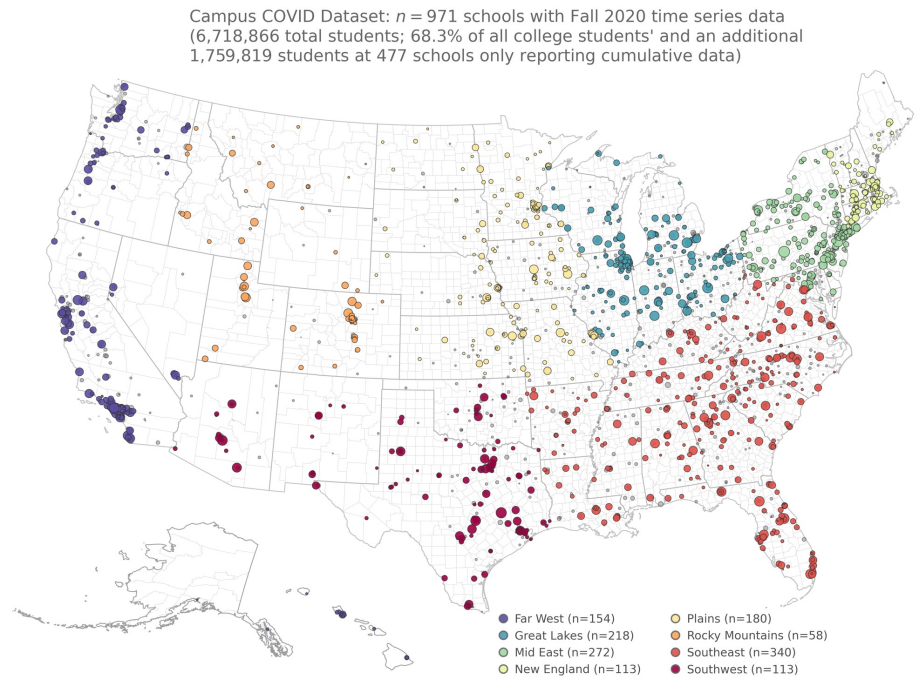
Forecasting health care demand using real-time data

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Article

The effect of physical distancing on the transmission of SARS-CoV-2

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Mexico

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RESEARCH

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PLOS DIGITAL HEALTH

RESEARCH ARTICLE

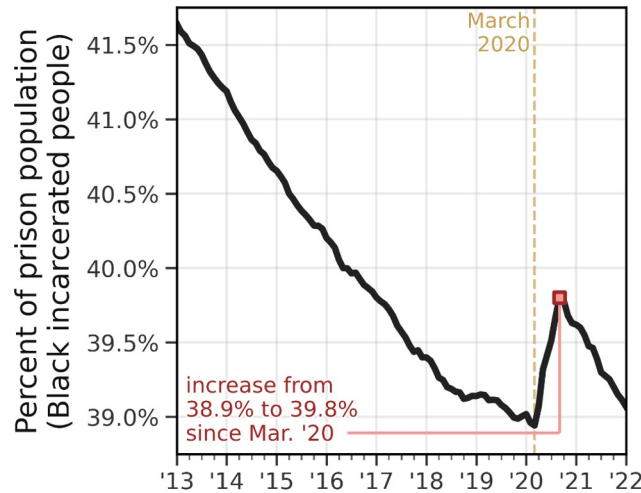
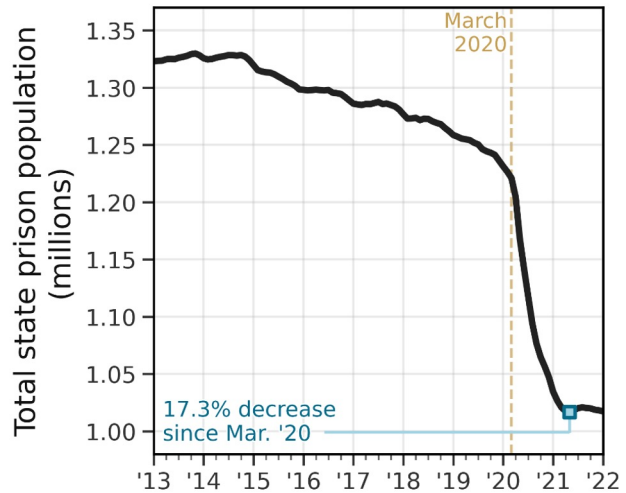
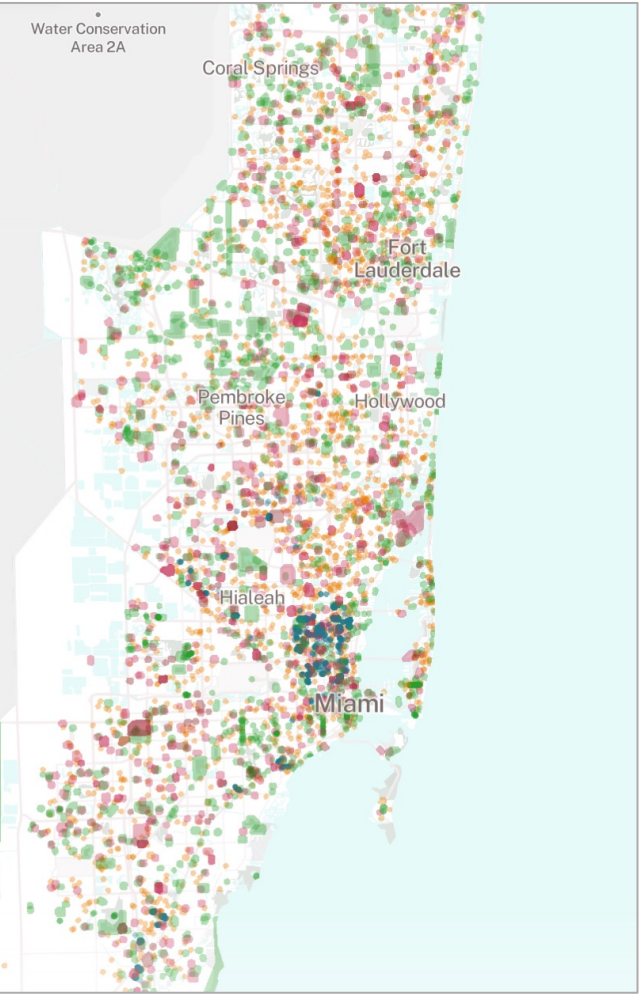
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PLOS DIGITAL HEALTH

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<https://doi.org/10.1038/s43854-023-00253-5> OPEN

Forecasting hospital-level COVID-19 admissions using real-time mobility data

Brennan Klein^{1,2,3*}, Ana C. Zenteno^{3,4}, Daisha Joseph¹, Mohammadmehdi Zahedi^{1,4}, Michael Hu³, Martin S. Copenhaver³, Moritz U. G. Kraemer^{5,6}, Matteo Chinazzi^{1,2}, Michael Klompas^{7,8,9}, Alessandro Vespignani^{1,2}, Samuel V. Scarpino^{1,4,10,11,12} & Hojjat Salmasian^{8,12,13}

ARTICLE

<https://doi.org/10.1038/s41467-021-22521-5> OPEN

The effect of eviction moratoria on the transmission of SARS-CoV-2

Anjalika Nande^{1,7}, Justin Sheen^{2,7}, Emma L. Walters³, Brennan Klein^{4,5}, Matteo Chinazzi^{4,5}, Andrei H. Gheorghe¹, Ben Adlam¹, Julianna Shinnick², Maria Florencia Tejada², Samuel V. Scarpino⁴, Alessandro Vespignani^{4,5}, Andrew J. Greenlee³, Daniel Schneider³, Michael Z. Levy^{2,8,9} & Alison L. Hill^{1,6,8,9}

PLOS DIGITAL HEALTH

RESEARCH ARTICLE

Characterizing collective physical distancing in the U.S. during the first nine months of the COVID-19 pandemic

Brennan Klein¹, Timothy LaRock¹, Stefan McCabe¹, Leo Torres¹, Lisa Friedland¹, Maciej Kos¹, Filippo Privitera², Brennan Lake², Moritz U. G. Kraemer³, John S. Brownstein^{4,5}, Richard Gonzalez⁶, David Lazer¹, Tina Eliassi-Rad¹, Samuel V. Scarpino^{1,7,8}, Alessandro Vespignani^{1,9}, Matteo Chinazzi^{1,10*}

under review (PNAS)

Spatial scales of COVID-19 transmission in Mexico

Brennan Klein^{1,2}, Harrison Hartle¹, Munik Shrestha¹, Ana Cecilia Zenteno³, David Barros Sierra Cordera⁴, José R. Nicolas-Carlock⁵, Ana I. Bento⁶, Benjamin M. Althouse^{7,8}, Bernardo Gutierrez^{9,10,11}, Marina Escalera-Zamudio^{9,11}, Arturo Reyes-Sandoval^{12,13}, Oliver G. Pybus^{9,14,15}, Alessandro Vespignani^{1,2}, Alberto Diaz Quiñonez^{*15}, Samuel V. Scarpino^{*11,16,17}, and Moritz U.G. Kraemer^{*8,9,18}

in prep.

The disparate racial impact of drug-free zone laws in the United States

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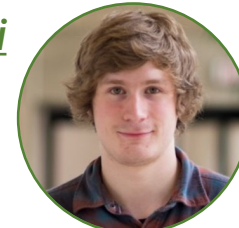


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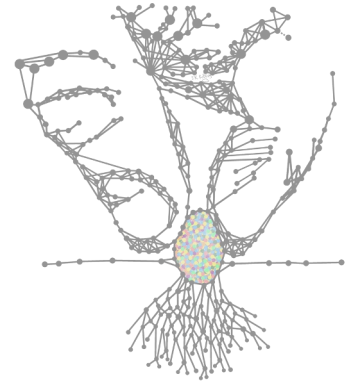
 now researcher
@ STEM AI



Conor Heins
PhD Student,
Collective Behavior

 now researcher
@ VERSES AI

Future research topics / vision



Complexity

- Higher order structure/dynamics
- Quantifying network dissimilarity & typicality
- Network science of AI
- Ranking in competition networks

Potential funding partners

- NSF “Emergent Bio” & Sloan Foundation
- RWJF Criminal Municipal Courts
- VERSES AI funded PhD positions

Society

- Drug-free zone laws
- Large-scale digitization of court transcripts
- Highly policed network neighborhoods
- Analysis of criminal municipal courts

Vera INSTITUTE OF JUSTICE

 FORWARD JUSTICE

FRRC

 **CAMPAIGN ZERO**

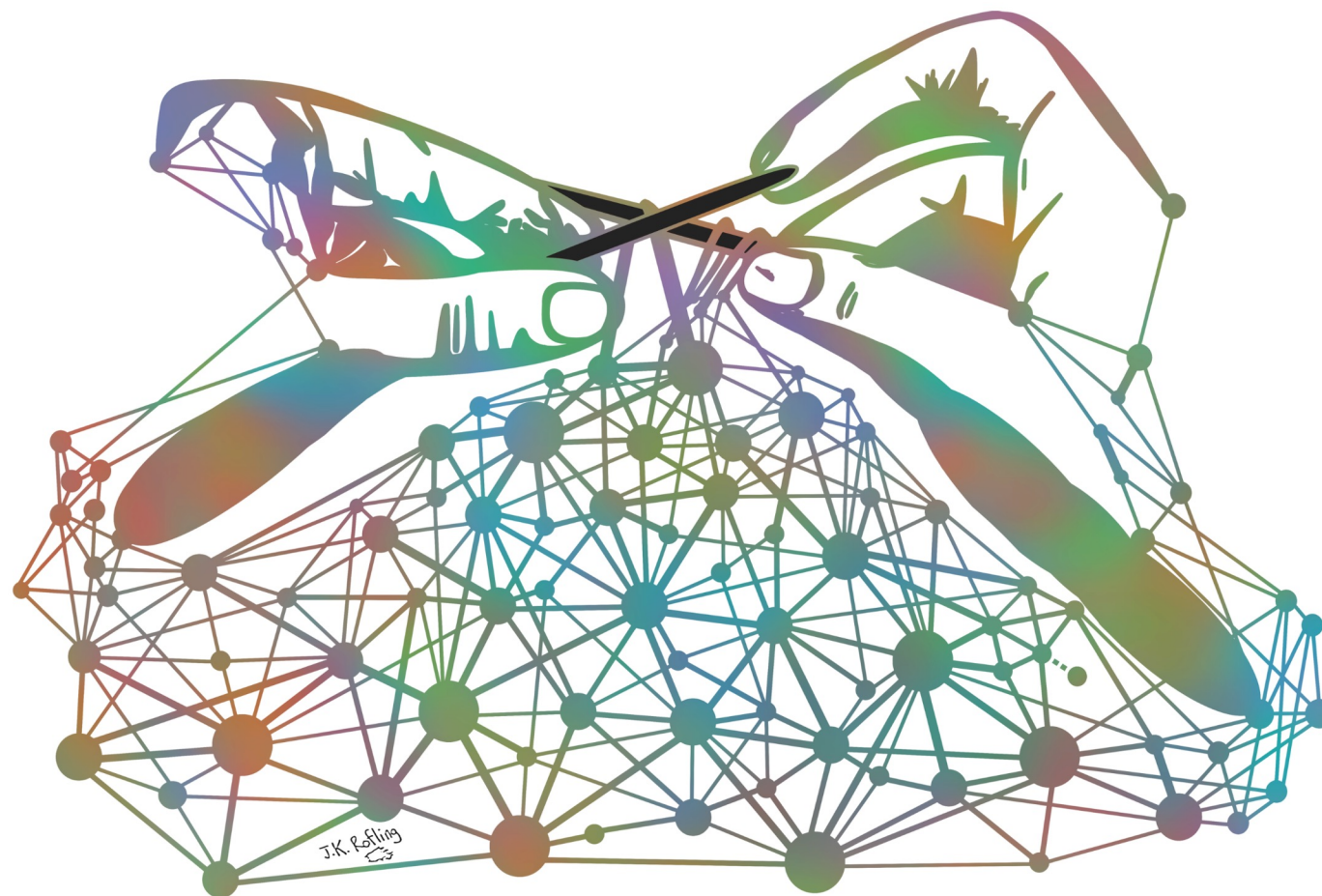
 **DATA FOR BLACK LIVES**

Questions, contact, follow-up

(Feel free to reach out!)

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Northeastern University
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Complexity
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Lab

EAI The Institute for Experiential AI
Northeastern University



HARVARD
UNIVERSITY



Hutchins Center
for African &
African American
Research

VERSES

(Bonus) Childhood street networks of a few NetSI folks

Made with OSMNX (Open Street Maps NetworkX)



Albert László Barabási — Professor — Cârța, Romania



Kate Coronges — Executive Director — Brooklyn, New York



Alessandro Vespignani — Professor — Rome, Italy



Timothy LaRock '21 — NetSI PhD student — Elizabethtown, New York



Chia-Hung Yang '21 — NetSI PhD student — Hsinchu City, Taiwan



Stefan McCabe '21 — NetSI PhD student — Alexandria, Virginia



Brennan Klein '20 — NetSI PhD student — Tucson, Arizona



Dasha Alekseeva — Budget & Project Manager — Moscow, Russia