Gecia Bravo-Hermsdorff

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I design principled statistical tools and learning algorithms for structured data, such as graphs, and for problems in causal inference, model selection, and private learning.

Education

Princeton University
Princeton, NJ, USA

PhD in Quantitative & Computational Neuroscience *(link)* *2020*

- *Dissertation*: "Quantifying human priors over abstract relational structures"
- *Selected courses (hyperlinked):* Random graphs and networks, Mathematical physics, Natural algorithms, Theory of deep learning, Complex analysis, Statistical learning and nonparametric estimation, Machine learning & pattern recognition, Optimal learning, Abstract algebra, Computational complexity, Statistical optimization and reinforcement learning, Stochastic processes on graphs

École Normale Supérieure (ENS Ulm)
Paris, France

Research Master in Cognitive Sciences and Neuroscience *(link)* *2011*

- *Dissertation*: "Neural basis of self-contingency detection in 5-month-old babies"

Diplôme de l'ENS *(link)* *2011*

- Admitted via the "International Selection in Science" *(link)*
- Three-year multidisciplinary program, coursework included: Computational neuroscience, Cognitive science, Decision theory, Biophysics, Logic, Mathematics, Statistics, Modeling, Ecology and evolutionary biology, Philosophy of science, Theoretical chemistry

Bachelor of Science *(link)* *2009*

Employment

School of Informatics - University of Edinburgh
Edinburgh, Scotland, UK

Research Fellow *Oct 2024 - now*

Dept of Statistical Science - University College London
London, UK

Research Fellow *2022 - 2024*

- Causal Graphical Models for Relational Data ($\geq$ Oct 2023, with Kayvan Sadeghi):
  Systematically categorizing the conditional independence structures induced by natural models of growing random networks, analyzing their asymptotic distributions, and characterizing the relevant notions of intervention.
- Extrapolating Interventions ($\leq$ Oct 2023, with Ricardo Silva):
  Using our framework of *interventional factor graphs*, we show when and how data collected under different interventions can be used to characterize the outcome of (unseen) combinations of interventions *(link)*.
  Currently working on principled methods for causal-effect estimation using *imperfect instrumental variables (link)*.

Google Research - Algorithms and Theory
US (remote) and London, UK

AI Resident *2020 – 2022*

- Privacy: Leading author on a paper proposing a class of data collection protocols that offer anonymity to users without the need for a fully-trusted central entity *(link)*.
- Geometric Deep Learning: Developed and implemented (in TensorFlow) a permutation and rotation equivariant neural network architecture for analyzing images of cells from drug discovery experiments, with the aim of identifying compounds that are likely to be effective against the dormant phase of the parasite responsible for Malaria.
- Graphs: Implemented (production code in C++) a method for scalable computation of graph cumulants with up to 3 edges [G&B-H 2020 *(link)*], with the aim of detecting atypical patterns of information propagation in social networks.
- Entropy: Developed private and communication efficient algorithms for estimating entropies (work published at NeurIPS, 2022). Implemented the algorithm from [Jian et al 2015 *(link)*] for computing entropy in the sparse data regime (production code in C++).

Publications

Bounding Causal Effects with Leaky Instruments. *(link)*
DS Watson, J Penn, LM Gunderson, G Bravo-Hermsdorff, A Mastouri & R Silva. *UAI, 2024* *(code)*

The Graph Pencil Method: Mapping Subgraph Densities to Stochastic Block Models. *(link)*
LM Gunderson, G Bravo-Hermsdorff & P Orbanz. *NeurIPS, 2023* *(poster)*

Intervention Generalization: A View from Factor Graph Models. *(link)*
G Bravo-Hermsdorff, DS Watson, J Yu, J Zeitler & R Silva. *NeurIPS, 2023* *(code, poster)*

Quantifying Network Similarity using Graph Cumulants. *(link)*
G Bravo-Hermsdorff*, LM Gunderson*, PA Maugis & CE Priebe.
Journal of Machine Learning Research (JMLR), 24(187):1-27, 2023 *(poster)*

Quantifying Human Priors over Social and Navigation Networks. *(link)*
G Bravo-Hermsdorff. *ICML, 2023* *(demo, poster)*

Private and Communication-Efficient Algorithms for Entropy Estimation. *(link)*
G Bravo-Hermsdorff, R Busa-Fekete, M Ghavamzadeh, A Muños Medina & U Syed. *NeurIPS, 2022* *(video)*

Statistical Anonymity: Quantifying Reidentification Risks Without Reidentifying Users. *(link)*
G Bravo-Hermsdorff, R Busa-Fekete, LM Gunderson, A Muños Medina & U Syed. *arXiv, 2022*

Introducing Graph Cumulants: What is the Variance of your Social Network? *(link)*
LM Gunderson* & G Bravo-Hermsdorff*. *arXiv, 2020* *(video, code)*

Quantifying Human Priors over Abstract Relational Structures. *(link)*
G Bravo-Hermsdorff. *Ph.D. dissertation, Princeton University, 2020* *(slides, demos)*

A Unifying Framework for Spectrum-Preserving Graph Sparsification and Coarsening. *(link)*
G Bravo-Hermsdorff* & LM Gunderson*. *NeurIPS, 2019* *(video, demos, code, poster)*

Gender and Collaboration Patterns in a Temporal Scientific Authorship Network. *(link)*
G Bravo-Hermsdorff, V Felso, E Ray, LM Gunderson, ME Helander, J Maria & Y Niv.
Applied Network Science, 4(1), 2019 *(dataset)*

Modeling the Hemodynamic Response Function for Prediction Errors in the Ventral Striatum. *(link)*
G Bravo-Hermsdorff & Y Niv. *bioRxiv, Cold Spring Harbor Laboratory, 2019*

Quantifying Humans' Priors over Graphical Representations of Tasks. *(link)*
G Bravo-Hermsdorff, TD Pereira & Y Niv.
Unifying Themes in Complex Systems IX. ICCS, Springer Proceedings in Complexity, 281–290, 2018

**denotes equal contribution*

Teaching

Probability and Statistics II STAT0005 (University College London) *(link)* *Fall 2023*

- Last mandatory course for bachelors and masters students in the Statistical Science Department, lectures given by Kayvan Sadeghi. Topics included: transformation of random variables, relations between standard distributions, statistical estimation, consistency, method of moments, Bayesian inference, conjugate priors, asymptotic guarantees.
- I held three one-hour tutorial sessions per week covering the students' homework and questions.

BioMath Bootcamp (Princeton University) *(link)* *Summer 2016*

- Month-long training in mathematical and computational tools for incoming PhD students in the computational neuroscience and computational biology programs, organized by Carlos Brody.
- I lectured for the probability module, and held afternoon sessions for exercises in: programming (Python), linear algebra, ordinary differential equations (ODEs), nonlinear dynamical systems, probability, Fourier transforms, convolutions, and signal processing.

Introduction to cognitive neuroscience (Princeton University) *(link)* *Spring 2015*

- I held three one-hour sessions per week discussing relevant journal publications, and helped construct and grade the exams.

Lab for introduction to experimental psychology (Princeton University) *Fall 2014*

- I held a weekly three-hour lab session with introductory lectures and exercises in: statistical analysis, MRI, EGG, psychophysics, experimental design, programming, computational modeling, and game theory.

Awards and fellowships

- Top reviewer award for Learning on Graphs (LoG) Conference (prize of $1,500) *2023*
- Google AI residency NYC (Algorithms and Theory branch) *2020—2022*
  Competitive position for exploring research at Google
- Independent research grant ($5,000) *2019*
  Funding awarded by the Princeton Cognitive Science Department to selected research proposals
- Scholarship for Lake Como School of Advanced Studies in Complex Networks *May, 2016*
- Cognitive Science Graduate Fellowship *2016—2017*
- Scholarship for Brains, Minds and Machines summer school *August, 2015*
- Scholarship for SAMSI Bayesian Nonparametrics workshop *July, 2015*
- Princeton PhD Fellowship *2013—2019*
- École Normale Supérieure (ENS Ulm) "International Selection in Science" *2008*
- Scholarship by the Lions Club to study French literature in France *Summer, 2006*
- Brazilian CNPq "scientific initiation" scholarship *2006—2008*
- Entrance exam for Biomedical Sciences degree at the Universidade Federal do Rio de Janeiro *2006*
  Top Brazilian undergraduate program in biomedical sciences, completed 2 of 4 years before moving to France
- 99th percentile at the Exame Nacional de Ensino Médio (ENEM) *2005*
  Nationwide exam for Brazilian students after high school
- Travel awards for conferences and workshops:
  Eurandom Workshop on Graph Laplacians, Multivariate Extremes and Algebraic Statistics *(link)* *TU Eindhoven, Netherlands, 2024*
  Foundations of Quantum Computing (FQC2024) Workshop *(link)* *Royal Holloway, University of London, 2024*
  YES Causal Inference Workshop *(link)* *Eurandom, Eindhoven University of Technology, 2023*
  Neural Information Processing Systems (NeurIPS) Scholar Award, *2022*
  Neural Information Processing Systems (NeurIPS) Scholar Award, *2019*
  International Conference on Complex Systems (ICCS), *2018*
  NeurIPS Women in Machine Learning, *2018*
  Society for Industrial and Applied Mathematics (SIAM) Annual Meeting, *2018*
  Multidisciplinary Conference in Reinforcement Learning and Decision Making (RLDM), *2017*
  NeurIPS Women in Machine Learning, *2017*
  International Conference on Mathematical Neuroscience (ICMNS), *2017*
  Multidisciplinary Conference in Reinforcement Learning and Decision Making (RLDM), *2015*
  Austin Memory & Learning Conference, *2015*

Languages

- **Human:** (Brazilian) Portuguese *(native),* English & French *(fluent),* Spanish *(basic)*
- **Computer:** Python & MATLAB *(fluent),* Mathematica, Qiskit, C++ & R *(functional),* Javascript & HTML *(basic)*

Summer schools

Machine Learning Summer School (MLSS) *(link, my video ~9min)* — *Summer 2020*
Max Planck Institute for Intelligent Systems — *Tübingen, Germany (virtual)*

Complex networks: theory, methods, and applications *(link)* — *May 2016*
Lake Como School of Advanced Studies — *Lake Como, Italy*

Brains, Minds and Machines (BMM) Summer Course *(link)* — *August 2015*
MIT Center for Brains, Minds and Machines — *Woods Hole, MA, USA*

Bayesian Nonparametrics: Synergies between Statistics, Prob and Math *(link)* — *June 2015*
Statistical and Applied Mathematical Sciences Institute (SAMSI) — *Durham, NC, USA*

Computational and Cognitive Neurobiology Summer School *(link)* — *July 2010*
Cold Spring Harbor Laboratory Asia — *Suzhou, China*

Academic service and activities

Science outreach

Volunteer teacher for the In2STEM-In2ScienceUK outreach initiative *(link)* — *London, August 2024*

- Designed and taught three 2-hour classes to nine high-school students:
  The mathematics of card magic tricks — based on the wonderful book "Magical Mathematics" by Diaconis and Graham *(link)*;
  Optimal betting — derive the Kelly criterion *(link)* using hands-on simulations and a story about exploiting a broken arcade game;
  The mathematics of cooperation — a friendly introduction to evolutionary game theory using as entry point the classical work by Axelrod on tournaments of the repeated Prisoner's Dilemma game *(link)*.
- Our placement (which was hosted by Alex Watson) was picked as "host of the week" thanks to nominations from our students *(link)*.

Volunteer at the Princeton Neuroscience Fair — *Princeton, March 2018*

- Event with fun neuroscience demonstrations for 4th grade of low-income households from the Christina Seix Academy.

Science outreach volunteer at STEMCivics Charter School — *Ewing, NJ, April 2017*

- I performed a demonstration of a cerebellar illusion using glasses that distort ones aim as they throw a ball.

Pedagogy training

- One day workshop by the Alda Center for Communicating Science *(link)*. — *Princeton, October 2018*

Mentoring

Graduate

- Jordan Penn — *PhD student at King's University College* — *Winter 2023–now*
  I am helping supervise his project on analyzing phase transitions in dynamical network models.
- Emma Graham (now PhD student at Dartmouth) — *Master's student at UCL Center for Artificial Intelligence* — *Summer 2023*
  I helped supervise her MSc thesis project on using Voronoi diagrams to study catastrophic forgetting in reinforcement learning.

Undergraduate

- Cristian Andronic — *Computer science major at Princeton University* — *2016*
  I proposed and supervised a project to build a navigation App to collect data for modeling naturalistic human mobility.
- Daniel J. Wilson (now PhD student at University of Toronto) — *Volunteer intern at Princeton Neuroscience Institute (PNI)* — *2015*
  I proposed and supervised a project involving coding a contextual bandit task in MTurk *(link)* to model human representation learning.
- Caitlyn Cap and Olamilekan Sule — *Summer interns at the Botvinick lab on PNI* — *2014*

Invited workshops

Graph Laplacians, Multivariate Extremes and Algebraic Statistics *(link)* — *Eurandom, Nov 2024*

Foundations of Quantum Computing (FQC2024) Workshop *(link)* — *Royal Holloway, University of London, August 2024*

Networks and Time Meeting II *(link)* — *Northeastern University London, April 2024*

YES Causal Inference workshop *(link)* — *Eurandom, Eindhoven University of Technology, March 2023*

Hackathons

Weekend-long MIT Quantum Hackathon (iQuHack) *(link)* — *Remote, Feb 2024*

- I worked on the IonQ challenge to reverse-engineer quantum circuits *(link)*.

Day-long biohackathon by PrecisionLife and ME Research UK *(link)* — *UCL, Feb 2024*

- Exploratory analysis of a large database of single nucleotide polymorphisms (SNPs) correlated with Myalgic Encephalomyelitis (ME).

Week-long PNI-Intel Hackathon on multivariate analysis of fMRI data — *Princeton, Jan 2017*

Reviewer

Journals

- Network Science *(2024)*; IEEE Transactions on Signal Processing *(2024)*; Scandinavian Journal of Statistics *(2023)*; Socio-Economic Planning Sciences *(2019)*; Trends in Cognitive Sciences *(2017)*

Conferences

- Learning on Graphs Conference (LoG) *(2024, 2023)*; International Conference on Machine Learning (ICML) *(2023, 2022)*; TheWebConf2023; Conference on Neural Information Processing Systems (NeurIPS) *(2022)*; WHMD *2021* NeurIPS workshop; NeurIPS Women in Machine Learning *(2017, 2018)*

Other research experiences

PhD candidate at the Niv lab *(link)* — *Princeton University, 2014 – 2019*

- I developed methods to efficiently quantify human priors over relational data by exploiting the relevant underlying symmetry *(link)*.

PhD research rotation at the Botvinick lab — *Princeton University, 2013 – 2014*

Research scholar in neuroeconomics at the Montague lab *(link)* — *Virginia Tech, 2011–2013*

- I developed and validated computational models to explain human behavioral data from various neuroeconomic experiments, such as, multi-armed bandit tasks and the repeated ultimatum game. *Advisors*: Read Montague and Terry Lohrenz

Master's student at the Cognitive Science and Psycholinguistic lab *(link)* — *ENS Ulm, Paris, 2011*

- Researched the neural substrates of self-contingency detection in babies using functional near-infrared spectroscopy (fNIRS). I designed, coded, and built the experimental apparatus, and recorded and analyzed data from 61 babies. *Advisor*: Emmanuel Dupoux

Research internship at Caltech Emotion and Social Cognition lab *(link)* — *Caltech, Pasadena, Spring 2010*

- I designed and carried out behavioral experiments to analyze whether humans express values learned via Pavlovian conditioning in an unrelated task without their conscious awareness. *Advisors*: Naotsugu Tsuchiya and Ralph Adolphs

Research internship at the Development and Neuropharmacology lab *(link)* — *Collège de France, Paris, 2009*

- Researched the molecular mechanisms involved in the emergence of cellular territories during the morphogenesis of the neural tube. *Advisors*: Elizabeth Di Lullo and Alain Prochiantz

Undergraduate student at the Physiology of Cognition lab *(link)* — *UFRJ, Brazil, 2007-2008*

- Studied the physiology of the visual system in monkeys (using intracranial recordings) and humans (using EEG). *Advisor*: Mário Fiorani

Research internship at the Institute of Neurobiology Alfred Fessard *(link)* — *CNRS, Gif-sur-Yvette, Summer 2007*

- Researched the development of the neural crest by grafting quail and chick embryos *in ovo*. *Advisors*: Sophie Creuzet

Selected talks

- What is the variance (and skew, kurtosis, etc) of a network?
  Graph cumulants for network analysis
  Networks Seminar Series, Mathematical Institute, University of Oxford, Dec 2024
- Stochastic graph reduction via combinatorial invariants
  Eurandom Workshop on Graph Laplacians, Multivariate Extremes and Algebraic Statistics, Eindhoven, Nov 2024
- Principled Processing of Relational Data
  University of Southampton, School of Mathematics, July 2024
- What is the variance (and skew, kurtosis, etc) of a network?
  University of Bristol, School of Mathematics, June 2024
- What is the variance (and skew, kurtosis, etc) of a network?
  Introducing graph cumulants for network analysis
  University of Warwick, Department of Computer Science, May 2024
- A taxonomy of causal models for growing networks
  Northeastern University London Meeting on Networks and Time II, April 2024 *(link)*
- Cumulants for networks
  Algebraic and Combinatorial Perspectives in the Mathematical Sciences (ACPMS) Seminar, Online, 2022 *(link)*
- Graph cumulants: What is the variance of your social network?
  Learning with Graphs Summit (Google), 2022
- Graph cumulants: What is the variance of your social network?
  Graph Mining Meeting (Google), 2021
- Statistical anonymity: Quantifying reidentification risk without reidentifying users.
  Chrome Privacy Budget Meeting, 2021
- Using graph cumulants to detect atypical patterns of information spread in social networks.
  MML Eng Meeting (Google), 2021
- Entropy estimation of high-dimensional sparse datasets.
  Chrome Privacy Budget Meeting, 2021
- Graph reduction by edge deletion and edge contraction.
  International Conference on Complex Systems (ICCS), Cambridge, MA, 2018
- Quantifying people's priors over graphical representations of tasks.
  International Conference on Complex Systems (ICCS), Cambridge, MA, 2018
- Graph reduction by edge deletion and edge contraction.
  SIAM Workshop on Network Science (SIAMNS18), Portland, Oregon, 2018
- Assessing decision-making in patients with insula lesion using various neuroeconomic tasks.
  Regional Conference in Neuroeconomics at the Duke Center for Interdisciplinary Decision Sciences, 2016

Three selected publications

Quantifying Network Similarity using Graph Cumulants. *(link)*
G Bravo-Hermsdorff*, LM Gunderson*, PA Maugis & CE Priebe.
Journal of Machine Learning Research (JMLR), 24(187):1-27, 2023 *(video, code, poster)*

A Unifying Framework for Spectrum-Preserving Graph Sparsification and Coarsening. *(link)*
G Bravo-Hermsdorff* & LM Gunderson*. *NeurIPS, 2019* *(video, demos, code, poster)*

Quantifying Human Priors over Social and Navigation Networks. *(link)*
G Bravo-Hermsdorff. *ICML, 2023* *(demo, poster)*