Ritwik K. Niyogi, PhD

Sir Henry Wellcome Postdoctoral Fellow & Senior Research Fellow
University College London
UCL-Max Planck Centre for Computational Psychiatry and Ageing Research
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Education:

Gatsby Computational Neuroscience Unit, University College London, London, United Kingdom
PhD in Machine Learning & Theoretical Neuroscience: October, 2009-June, 2014.

Okinawa Computational Neuroscience Course (OCNC), Okinawa, Japan. June, 2012
RIKEN Brain Science Institute Summer Program: Neural Circuits from Top to Bottom, Saitama, Japan, July, 2013

Dickinson College, Carlisle, Pennsylvania, USA**.**
Bachelor of Science, *Summa Cum Laude*, August, 2005-May, 2009.
Majors**: Mathematics, Physics, Neuroscience.** Graduated with **Honors** in all three majors.

Stanford University Summer Session, 2007, Stanford, California, USA.

Technical Skills

• Python • MATLAB • C++ • Closed-loop control technologies • UNIX Shell Scripting • High Performance Computing • Git • Igor Pro • Mathematica • Maple • XPPAUT • Arduino Microcontrollers • LabVIEW • Inquisit • Microsoft Office (Word, Office, PowerPoint) • Windows • Linux • Laboratory Interfacing • Electronics hardware • Electrophysiology • Optogenetics • *in vivo* Calcium imaging • Apparatus development for animal testing

Leadership

• Recruited, led, managed and mentored a team of 7 students to execute projects at the intersection of AI and neuroscience • Raised project funding and organized a council of advisers across AI, Data Science, Neuroscience, Drug Discovery, Healthcare and Business • Helped set up laboratory and led the development of computing infrastructure, Johns Hopkins University • Founded and organized Uncertainty Club journal club, UCL.

Research Experience

- Sir Henry Wellcome Postdoctoral Fellow/ Senior Research Fellow
  January 2019-October 2019

UCL-Max Planck Centre for Computational Psychiatry
University College London
London, UK

Supervisor: ***Dr. Robb Rutledge*** / Mentor: ***Prof. Nathaniel Daw* (Princeton University)**
  ▪ *Novel diagnostics for clinical depression & Parkinson's disease using AI and Econometrics.*
  - Longitudinally tracking individuals (healthy and patient populations), performing gamified Reinforcement Learning tasks on smartphone apps, clustering them based on computational parameters, and identifying early-on when at-risk healthy individuals are likely to become clinically depressed.
  - Combining Reinforcement Learning, Bayesian modeling and Data Science on >1000 individuals.

- Sir Henry Wellcome Postdoctoral Fellow
  October 2018-December 2018

Department of Experimental Psychology
University of Oxford
Oxford, UK

Supervisor: *Dr. Mark Walton* / Mentor: *Prof. Nathaniel Daw* **(Princeton University)**
- ▪ *Developed a novel, Reinforcement Learning model of vigor-anergia* that links (i) behavioral data from human Parkinsonian and depressed patients, and (ii) cellular, pharmacological, electrochemical and behavioral data from animal neuroscience experiments.
- • Trained in Bayesian and Deep Learning techniques, for building a scalable version of the RL model.

- • Sir Henry Wellcome Postdoctoral Fellow
November 2017-September 2018

Department of Psychiatry, UNC Neuroscience Center
University of North Carolina at Chapel Hill,
Chapel Hill, NC, USA

Supervisor: *Prof Garret Stuber* / Mentor: *Prof. Nathaniel Daw* **(Princeton University)**
- ▪ *Neuro-inspired AI:* Tracked neural activity to understand what are the algorithms, architectures and representations enabling animals to learn quickly, flexibly and adaptively across tasks, from scratch.
- • Developed, coded in C++ & implemented a novel assay of vigor and reward learning in animals. ***Tested causal hypotheses from RL models by manipulating neural activity in closed-loop.*** Collected, analyzed and quantified using Reinforcement Learning models behavioral and neural data.
- • Recruited and supervised students to execute AI-neuroscience projects in under 3 months.
- • Learned 2photon imaging and single-cell transcriptomics, analyzed data from >1000 neurons.

- • Sir Henry Wellcome Postdoctoral Fellow
October 2014-October 2017

Department of Neuroscience & Brain Science Institute
Johns Hopkins University School of Medicine, Baltimore, MD, USA

Supervisor: *Dr. Jeremiah Cohen* / Mentor: *Prof. Nathaniel Daw* **(Princeton University)**
- ▪ *Neuro-inspired AI and AI-inspired neuroscience:* Combining *theory, machine learning, data science and experiments* to investigate *real-time* cost-benefit decision-making, and learning under uncertainty.
- • Developed, coded in C++ and tested novel, Reinforcement Learning-driven animal assay of vigor.
- • Developed and implemented Bayesian and Reinforcement Learning models of behavioral and neural data for Neuro-Inspired AI: *vigor-anergia*, *structure learning*, *meta-learning* and *uncertainty estimation*.
- • Munged and wrangled, statistically analyzed and modeled electrophysiological and quantitative behavioral data from animal experiments using Reinforcement Learning and Bayesian State-Space Models.
- • Recruited and mentored 7 students—who won awards for this research: to execute Neuro-AI projects.

- • PhD Student
April 2010-October 2014

Gatsby Computational Neuroscience Unit
University College London, London, UK

Adviser/Supervisor: *Prof Peter Dayan* (Gatsby Computational Neuroscience Unit)
- ▪ PhD Thesis: *What to do, when to do it, how long to do it for: a normative, microscopic approach to the labour-leisure tradeoff.* **Examiners: Dr. David Silver (UCL/ Google Deepmind) and Prof Matthew Botvinick (Princeton/ Google Deepmind)**
- • **Developed the *normative microscopic approach***: a novel, Reinforcement Learning-based theoretical framework for *real-time* cost-benefit decision-making, which predicts what a human or animal *should do, at each moment in time*.
- • Applied my real-time framework to the economic problem of the labor-leisure tradeoff, mathematically linking to and superseding prevalent quantifications from behavioral psychology and economics.
- • Analyzed and modeled the real-time behavior of animals using Bayesian and RL approaches.
- • Led and managed AI-neuroscience collaborative projects across institutes in UK and Canada.
- • Research project with Dr. David Silver: *Off-policy Multi-Agent Reinforcement Learning with temporally extended actions*.

- Summer Research Assistant
  June-August 2009
  June-August 2008

  Neuroscience for Cognitive Control Laboratory
  Center for the Study of Brain, Mind and Behavior
  (CSBMB) Princeton University, Princeton, NJ, USA

Advisers: **Prof Jonathan D. Cohen** (Psychology, Neuroscience) and **Prof Philip J. Holmes** (Program in Applied and Computational Mathematics, Mechanical and Aerospace Engineering)

- *Investigating the source of sub-optimality in human decision-making* in a simple Two-Alternative Forced Choice (TAFC) task. <u>Supervisor</u>: *Dr. Patrick Simen, Dr. Angela Yu, Prof Jonathan D. Cohen, Dr. Fuat Balci.*
- Designed, collected, statistically analyzed and modeled data from decision-making experiments.
- Investigating human performance in Deadlined decision making tasks. Supervisor: *Dr. Angela Yu, Prof Jonathan D. Cohen.*
- *Mathematical analyses of Leaky Competing Accumulator (LCA)* dynamical systems models. Supervisor: *Prof Philip J. Holmes.*

- Research Assistant
  June-August 2007

  McClelland laboratory Center for Mind, Brain and
  Computation (MBC) Department of Psychology
  Stanford University, Stanford, CA, USA

Adviser/Supervisor: **Prof James L.(Jay) McClelland** (Psychology)
- *Investigating the Neurodynamics of Decision Making.*
- Extended a neural network model of sensory decision-making by incorporating the effect of time-varying reward biases. Performed regression and statistical analyses of data against model predictions.

- Research Assistant
  June-August 2006
  September 2006-January 2007 (offsite).

  Clinical Cognitive Neuroscience Laboratory
  Western Psychiatric Institute and Clinic, University of
  Pittsburgh Medical Center, Pittsburgh, PA, USA

Adviser/Supervisor: **Prof. Raymond Cho** (Psychiatry)
- *Investigating the generalizability and task specificity of Cognitive Control in task-switching using Parallel Distributed Processing (PDP) / Neural Network models.*

- Student Researcher
  September 2005-December 2007

  Unconscious Semantic Cognition Laboratory
  Department of Psychology
  Dickinson College, Carlisle, PA, USA

Supervisor/Adviser: **Prof Richard L. Abrams** (Psychology)
- *Investigating Unconscious Cognition.*

- Honors Researcher
  August 2008-May 2009

  Non-Linear Lattice Dynamics Laboratory
  Department of Physics
  Dickinson College, Carlisle, PA, USA

Adviser/Supervisor: **Prof Lars Q. English** (Physics)
- Thesis: *Synchronization and Hebbian Learning in a Network of Coupled Neural Phase Oscillators.*

- Honors Researcher
  August 2008-May 2009

Department of Mathematics
Dickinson College, Carlisle, PA, USA

Supervisor: ***Dr. Kong-Fatt Wong-Lin*** (Program in Applied and Computational Mathematics, Princeton University). Adviser: Prof John MacCormick (Computer Science)
  - Thesis: *Dynamical Effects of Non-Linearities and Time-Varying Gain Modulation in Neurally Plausible Network Models of Perceptual Decision-Making* Tasks.

- Honors Researcher
  January-May 2009

Program in Neuroscience
Dickinson College, Carlisle, PA, USA

Supervisor: ***Dr. Patrick Simen*** (Program in Applied and Computational Mathematics, Princeton University). Adviser: Prof Anthony Pires (Biology, Program in Neuroscience)
  - Thesis: *The Source of Suboptimality in Human Performance on Two-Alternative Forced Choice Motion-Discrimination Decision-Making Tasks.*

Fellowships

- **Sir Henry Wellcome Postdoctoral Fellowship**, **GBP 250,000.**
- Gatsby Research Studentship, 2009-2014, Gatsby Computational Neuroscience Unit.
- Galkin Undergraduate Summer Research Fellowship (2006), Brain Science Program, Brown University.

Honors and Awards
- **Best Talk Award, Society for Neuroeconomics, 2013**
- Faculty of Life Sciences award, UCL, 2013
- Brains for Brains Young Researchers' Computational Neuroscience Award, Bernstein Computational Neuroscience Association, 2010 (*award plus travel grant to visit computational neuroscience institutes in Germany).*
- Phi Beta Kappa (*PBK)*, 2009.
- Summa Cum Laude, Dickinson College, 2009.
- Honors in Mathematics, Neuroscience and Physics, Dickinson College, 2009.
- Delaplaine McDaniel Prize, 2007 (*GPA dependent, awarded to a single member of the sophomore class*).
- Member of Pi Mu Epsilon ($\Pi M E$), the National Mathematics Honors Society.
- Member of Alpha Lambda Delta ($A \Lambda \Delta$) **–** the National Freshman Honor Society (*GPA>3.5*).
- Invited for membership, Omicron Delta Kappa ($O \Delta K$), Upsilon Circle, (*top 35% of class*).
- John Dickinson Scholarship—for excellence in Academics in High School and College.
- John Montgomery Scholarship—for excellence in Academics in College.
- Dean's List, Fall 2005-2008 (*GPA>3.7*).
- Carolyn Soward Student Researcher in Mathematics (August 2006-May 2009).

Manuscripts in preparation

1) Nair, A., **Niyogi, R.K.**, Tabrizi, S., Rees, G., & Rutledge, R.B. *How fast should I go? Sensitivity to opportunity costs of time predicts vigour and apathy*, in preparation.

2) **Niyogi, R.K.**, Solomon R.B, Breton Y-A, Conover, K., Shizgal, P. & Dayan, P. *The utility of leisure*, in preparation.

3) **Niyogi, R.K,** & Dayan, P. *Fatigue and satiation: implications for the labour-leisure tradeoff,* in preparation.

4) **Niyogi, R.K,** Breton Y-A, Conover, K., Shizgal, P. & Dayan, P. *The value of information of value*, in preparation.

Peer Reviewed Journal Publications

1) Ahilan, S., Solomon, R., Breton Y-A, Conover, K., **Niyogi, R.K.**, Shizgal P., Dayan, P. *Forgetful inference in a sophisticated world model,* (accepted, PLoS Computational Biology, BioArxiv 2018)

2) **Niyogi, R.K,** Shizgal, P. & Dayan, P. *Some work and some play: microscopic and macroscopic approaches to labor and leisure*, PLoS Computational Biology 10(12): e1003894 (2014)

3) **Niyogi, R.K.**, Breton Y-A, Solomon R.B, Conover, K., Shizgal, P. & Dayan, P. *Optimal indolence: how long to work and how long to play,* Journal of the Royal Society Interface,11, 969 (2013)

4) **Niyogi, R.K.** & Wong-Lin, K-F, *Dynamic excitatory and inhibitory gain modulation can produce flexible, robust and optimal decision-making*, PLoS Computational Biology, 9(6):e1003099, (2013)

5) Balci, F., Simen, P., **Niyogi, R.**, Saxe, A., Hughes, J.A., Holmes, P., & Cohen, J.D. *Acquisition of decision making criteria: accuracy ultimately loses the competition with reward rate*, Attention Perception Psychophysics, 73(2), 640-657 (2011)

6) **Niyogi, R.K.** & English, L.Q. *Learning-rate-dependent clustering and self-development in a network of coupled phase oscillators*, Physics Review E, 80, 066213 (2009)

Conference Proceeding

- Nair, A*., **Niyogi, R.K.***, Tabrizi, S., Rees, G., & Rutledge, R.B. *Vigour as a diagnostic of apathy: sensitivity to opportunity costs of time predicts action latencies*, Reinforcement Learning and Decision Making (RLDM), 2019, Montreal, QC.

- Bari, B.A., Grossman, C., **Niyogi, R.K.**, Cohen, J.Y. *Action-outcome encoding in dorsomedial prefrontal cortex.* Society for Neuroscience, Washington DC, 2017.

- Ahilan, S., Solomon, R., Conover, K., **Niyogi, R.K.**, Shizgal P., Dayan, P. *Observing the observer observing: forgetful world modelling in a self-stimulation task.* Reinforcement Learning and Decision Making (RLDM), 2017, Ann Arbor, MI; Computational and Systems Neuroscience (Cosyne), 2017, Salt Lake City, UT.

- Guez, A., **Niyogi, R.**, Bach, D., Dolan, R. & Dayan, P. *A normative theory of approach-avoidance conflicts during dynamic foraging in humans.* Reinforcement Learning and Decision Making (RLDM), 2013, Princeton, NJ.

- **Niyogi, R.K.**, Breton, Y.A, Solomon, R.B., Conover, K., Shizgal, P., & Dayan, P. *Some work and some play:* a normative, microscopic approach to allocating time between work & leisure*. Computational and Systems Neuroscience (Cosyne), 2013, Salt Lake City, UT.

- **Niyogi, R.K.**, Breton, Y.A., Conover, K., Solomon, R.B., Shizgal, P., & Dayan, P. *Semi-Markov models of the molecular psychophysics of brain stimulation reward.* Computational and Systems Neuroscience (Cosyne), 2012, Salt Lake City, UT.
  Also presented at Federation of European Neurosciences (FENS), 2012, Barcelona, Spain.

- **Niyogi, R.K.**, & Wong-Lin, K-F. *Time-varying gain modulation on neural circuit dynamics and performance in perceptual decisions.* Computational and Systems Neuroscience (Cosyne), 2010, Salt Lake City, UT.

- **Niyogi, R.**, & Wong-Lin, K-F. *Dynamical Effects of Non-Linearities and Time-Varying Gain Modulation in Neurally Plausible Network Models of Perceptual Decision-Making.* Sigma Xi Student Research Symposium, 2009, Saint Joseph's University, Philadelphia, PA.

- **Niyogi, R.**, & English, L.Q. *Synchronization and Hebbian Learning in a Network of Coupled Neural Phase Oscillators.* Sigma Xi Student Research Symposium, 2009, Saint Joseph's University, Philadelphia, PA.

- **Niyogi, R.**, Gleichgerrcht, E., & Abrams, R.L. *How Smart is the Unconscious? Exploring the Limits of Unconscious Cognition through the Two-Word Challenge.* 4th Annual Undergraduate Science Research Symposium, 2007, Ursinus College, Collegeville, PA.

- Abrams, R.L., Stull, S., Rockman, L., **Niyogi, R.**, & Fisher, F. *Unconscious processing of visually masked words by second-and third-grade children.* Eastern Psychological Association (EPA) Conference, 2007, Philadelphia, PA.

- Abrams, R.L., Ilieva, I., Niblock, A., **Niyogi, R.**, & Shainheit, C. *Unconscious Semantic Priming in the Absence of Partial Awareness.* Eastern Psychological Association (EPA) Conference, 2006, Baltimore, MD. (This research was subsequently reported in the paper: Abrams, R.L., & Grinspan, J. (2007). Unconscious priming in the absence of partial awareness, *Consciousness and Cognition, 16*(4), 942-953; my contribution is acknowledged in an Authors' Note)

Talks

- Icahn School of Medicine at Mount Sinai, July 2018.
- Brown University, July 2018.
- Columbia University, September, 2017.
- Janelia Research Campus, September, 2017.
- University of North Carolina, Chapel Hill, September, 2017.
- UCSF, July 2017.
- Emotion Club, Wellcome Trust Centre for Neuroimaging, UCL, May 2014.
- Brain Conference: Controlling Neurons, Circuits and Behaviour, Rungstedgaard, Denmark, April 2014 **[awarded special fellowship for theoretical neuroscience (all expenses paid)].**
- Society for Neuroeconomics, Lausanne, Switzerland, September 2013 **[won Best Talk Award].**
- Gatsby Unit-Columbia University-Hebrew University Jerusalem Tri-Centre Meeting, June 2013.
- Princeton University, March 2013.
- Center for Neuroeconomics, NYU, March 2013.
- Harvard University, March, 2013.
- *Invited to speak at Computational and Systems Neuroscience (CoSyNe) 2014 workshop: Information sampling in behavioral optimization (Bruno Averbeck, Robert C. Wilson, Matthew R. Nassar organizers); declined owing to insufficient travel funds.*

Colloquia
- All College Senior Research Symposium: "Synchronization and Hebbian Learning in a Network of Coupled Neural Phase Oscillators", April, 2009, Dickinson College, PA.
- Math/CS Chat: "The Neurodynamics of Decision Making", November, 2007, Dickinson College, Carlisle, PA.
- Math/CS Chat: "Investigating Conflict Monitoring and Cognitive Control using Parallel Distributed Processing models", November, 2006, Dickinson College, Carlisle, PA.

Membership in Professional Organizations
- Member, Society for Neuroscience.
- Member, Society for Neuroeconomics.
- Student Member, Cognitive Science Society (2007).
- Associate Member, Eastern Psychological Association (2005-2009).
- Attended the Annual Meeting of the Sloan-Swartz Centers for Theoretical Neuroscience, Princeton, NJ, July, 2008.

Teaching Experience
- **Teaching Assistant**, Theoretical Neuroscience, **Gatsby Unit, October-December 2010.**
- **Teaching Assistant**, Calculus I and II, **Dickinson College, January 2007-May 2009.**
- **Teaching Assistant**, Workshop Physics-I, **Dickinson College, August 2006-December 2006.**
- **Mathematics Tutor,** Calculus, **Dickinson College, August 2006-May 2009.**

Relevant Coursework

AI, Machine Learning & Data Science: • Approximate Inference and Learning in Probabilistic Models (Gatsby Unit: 2018 and 2009) • Probabilistic and Unsupervised Learning (Gatsby Unit Machine Learning course) • Advanced Reinforcement Learning (David Silver UCL course, 2012) • Theoretical and Computational Neuroscience • Machine Learning • Probability & Statistics • Linear Algebra • Calculus • Numerical Methods • Operations Research • Discrete Mathematics • Ordinary Differential Equations • Chaotic Dynamical Systems

Mathematics: • Topology • Real Analysis • Algebraic Structures

Physics: • Thermodynamics and Statistical Mechanics • Dynamics and Chaos • Vibrations, Waves & Optics • Energy & Structure (Quantum Chemistry) • Introduction to Relativistic & Quantum Physics • Energy & Environmental Physics

Neuroscience, Cognitive Science and Biology: • Neurobiology • Physiology • Research Methods in Biological Psychology • Biology of Behavior • Organic Chemistry and Synthesis & Reactivity • Population Genetics & Evolution • Brain and Behavior • Senior Seminar in Cognitive Psychology • Perception Memory and Thought