IAN BALLARD
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TRAINING AND EDUCATION

Postdoctoral Scholar, University of California, Berkeley
Start date: April, 2018
Mentor: Mark D'Esposito

PhD in Neuroscience, Stanford University, Stanford, CA
Degree conferral date: April 5th 2018
PhD Mentors: Samuel McClure (Primary) and Anthony Wagner (Secondary)
Dissertation Committee: Russ Poldrack, Bill Newsome, Noah Goodman

B.S., Duke University, Durham, NC
Graduated with Distinction, Summa Cum Laude, GPA: 3.93, May 2011
Major: Individualized Curriculum: Theoretical Neuroscience

PUBLICATIONS

First Authored

- **Ballard, I.C.**, Miller, E., Piantadosi, S.T., Goodman, N., McClure, S.M. (2017) Beyond Reward Prediction Errors: Human Striatum Represents Rule Values During Categorization Learning. Cerebral Cortex.
- **Ballard, I.C**., Kim, B., Liatsis, A., Aydogan, G., Cohen, J.D., McClure, S.M. (2017) More is meaningful: The magnitude effect in intertemporal choice depends on self-control. Psychological Science.
- **Ballard, I.C.**, Hennigan, K., McClure, S.M. (2017) Mere Exposure: Preference for Novel Drinks Reflected in Human Ventral Tegmental Area. Journal of Cognitive Neuroscience. In Press.
- Murty, V.P*., **Ballard, I.C*.**, Adcock, R.A. (2016). Hippocampus and Prefrontal Cortex Predict Distinct Timescales of Activation in the Human Ventral Tegmental Area. Cerebral Cortex.
- **Ballard, I.C.***, Murty, V.P.*, Carter R.M., MacInnes J.J., Huettel S.A., Adcock R.A. (2011). Dorsolateral prefrontal cortex drives mesolimbic dopaminergic regions to initiate motivated behavior. Journal of Neuroscience, 31(28):10340-6.

Co-Authored

- Murty V.P., **Ballard, I.C**., Macduffie, K., Krebs, R.M., Adcock, R.A. (2014) Hippocampal Networks Habituate as Novelty Accumulates. Learning and Memory, 20 (4), 229-235.
- Samanez-Larkin, G.R., Mata, R., Radu, P.T., **Ballard, I.C**., Carstensen, L.L., McClure, S.M. (2011). Age differences in striatal delay sensitivity during intertemporal choice in healthy adults. Frontiers in Neuroscience, 5, 126.

Submitted and In-Prep Manuscripts

- **Ballard, I.C.**, Wagner, A.D., McClure, S.M. Hippocampal Pattern Separation Supports Reinforcement Learning.
- **Ballard, I.C.**, McClure, S.M. Joint Modeling of Choice and Reaction Times Improves Parameter Identifiability in Reinforcement Learning Models.
- **Ballard, I.C.**, Aydogan, G., Kim, B.K., McClure, S.M. Causal Evidence for the Dependence of the Magnitude Effect on Dorsolateral Prefrontal Cortex.

- Aydogan, G., Amand, J.S., **Ballard, I.C.**, Bickel, W.K., McClure, S.M. The Force of Habit: Repeated Decisions Reduces Framing Effects and Lateral Prefrontal Involvement in Choice.
- Diehl, M., Steele, V., Lempert, L., Parr, A., **Ballard, I.C.**, Smith, D. Toward an Integrative Perspective on the Neural Mechanisms Underlying Persistent Maladaptive Behaviors

RESEARCH EXPERIENCE

- **Learning:** I studied how reinforcement learning algorithms map onto the brain. I focused on the representation of state space by the hippocampus and oribitofrontal cortex, as well as the representation of value in the striatum.
- **Decisions:** I helped to map the neural systems that underlie decisions between rewards available at different times in the future. Currently, I am leading a project at Arizona State University about how repeated financial decisions become habits.
- **Dopamine:** Dopamine is a remarkable neurotransmitter that signals the difference between expectations and outcomes and influences physiology throughout the forebrain. I have studied the functional neuroanatomy of this system and its connection to motivation, learning and memory, and the formation of preferences.

EXTRACURRICULAR RESEARCH INTERESTS

- **Imaging:** I successfully led an effort to implement and test research scanning protocols at a clinical scanner at Banner Health in Phoenix, Arizona.
- **Behavioral Modeling:** I tested and shared techniques for modeling behavior, including a novel method for integrating reaction time with choice data in order to fit reinforcement learning models.
- **Statistical Methods:** I implemented an analysis pipeline for imaging data at my advisor's new lab at Arizona State University. In addition, I trained new lab members on important statistical techniques and challenges for our field.

FUNDING

- Stanford Center for Mind, Brain and Computation Graduate Training Fellowship (2013)
- National Science Foundation Graduate Research Fellowship Program (NSF GRFP) (2012)
- Duke University Scholars, full tuition and expenses academic scholarship (2007-2011)

HONORS AND AWARDS

- Travel Award for Computational Cognitive Neuroscience Conference, NYC (2017)
- Travel Award for Persistent Maladaptive Behaviors: Why We Make Bad Choices (2016)
- Reinforcement Learning and Decision Making Travel Fellowship (2015)
- Kavli Travel Award, Neuroeconomics Annual Conference (2013)
- Phi Beta Kappa

TEACHING

- The Nervous System, Teaching Assistant, First-Year Curriculum, Stanford University School of Medicine (2014-2018)
- Learning and Memory, Teaching Assistant, Department of Psychology, Stanford University (2016)
- Developmental Psychology, Teaching Assistant, Department of Psychology, Stanford University (2014)

ORAL PRESENTATIONS

- **Ian Ballard**. Hippocampal Pattern Separation Supports Reinforcement Learning. Computational Cognitive Neuroscience Conference, September 2017.
- **Ian Ballard**. More is meaningful: The magnitude effect in intertemporal choice depends on self-control. Talk. Interdisciplinary Symposium on Decision Neuroscience, June 2017.

- **Ian Ballard.** Human Stratum Represents Bayesian Surprise, Not Reward Prediction Error, in Categorization Learning. Poster Spotlight. Society for Neuroeconomics Annual Meeting, August 2016.
- **Ian Ballard**. Human Reinforcement Learning over Latent Sensory Features. Nanosymposium Talk, Society for Neuroscience Annual Meeting, October 2015.

SPECIALIZED TRAINING

- Kavli Summer Institute in Cognitive Neuroscience (2016)
- Neuroeconomics Society Summer School (2015)

GRADUATE-LEVEL COURSEWORK

- Computer Science: Probabilistic Graphical Models, Machine Learning, Artificial Intelligence, High-Level Vision
- Math: Algebraic Topology, Nonlinear Dynamics
- Psychology: Computational models of cognition: the probabilistic approach, Current debates in learning and memory
- Neuroscience: The nervous system, Current issues in aging, Neurobiology of disease

RELEVANT UNDERGRADUATE COURSEWORK

- Calculus, Liner Algebra, Probability, Differential Equations, Theoretical Neuroscience Independent Study, Behavioral Economics, Program Design and Analysis, Learning and Cognition, Functional Neuroimaging, Fundamentals of Neuroscience, Biological Basis of Behavior

AD-HOC REVIEWER

- Current Biology
- Cerebral Cortex
- Brain Imaging and Behavior

POSTERS

- **Ian Ballard**, Sam McClure. Beyond Reward Prediction Errors: Human Striatum Represents Rule Values During Categorization Learning. Cosyne Computational Systems Neuroscience Conference. February, 2017.
- **Ian Ballard**, Sam McClure. Society for Neuroscience Annual Meeting, November 2016. URL: http://jabstracts.org/iancballard/beyond-reward-prediction-errors-human-striatum-represents-rule-values-during-categorization-learning/
- **Ian Ballard**, Sam McClure. Human Reinforcement Learning over Latent Sensory Features. Bay Area Memory Meeting, August 2015.
- **Ian Ballard**, Sam McClure. Human Reinforcement Learning over Latent Sensory Features. Reinforcement Learning and Decision Making Biannual Conference, June 2015.
- **Ian Ballard**, Bokyung Kim, Sam McClure. A TMS Study of lateral prefrontal cortex function in intertemporal choice. Washington, D.C. Society for Neuroscience Annual Meeting, November 2014.
- **Ian Ballard**. Mesolimbic Activity Tracks Preference Change in the Mere Exposure Effect. Lausanne, Switzerland Neuroeconomics Society Conference. September, 2013.
- **Ian Ballard**. Mesolimbic Activity Tracks Preference Change in the Mere Exposure Effect. San Francisco, Ca. Bay Area Memory Meeting. August, 2013.
- **Ian Ballard**, Vishnu Murty, R. Alison Adcock. Hippocampal Novelty Responses Show Distinct Relationships with Event-Related and Baseline VTA Variability. New Orleans, Louisiana. Society for Neuroscience Annual Meeting. October, 2012.
- **Ian Ballard**, Vishnu Murty, Ruth M. Krebs, Kate MacDuffie, R. Alison Adcock. Novelty Habituation in the Human Hippocampus. Senior Thesis. April 2011.

- **Ian Ballard**, Anthony Liatsis, Sebastien Houde, Samuel McClure. A General Model of Temporal Discounting Based on Two Value Systems. San Diego, California. Society for Neuroscience Annual Meeting. November 2010.
- **Ian Ballard**, Vishnu Murty, Jeff MacInnes, R. McKell Carter, Scott Huettel, R. Alison Adcock. Network Dynamics of the Mesolimbic Dopamine System During Human Reward Anticipation: A DCM Study. Montreal, Canada. Cognitive Neuroscience Society Annual Meeting. April 20p10.