Eric B. Knudsen, PhD

knudcns.org

Helen Wills Neuroscience Institute
University of California, Berkeley
210G Barker Hall
Berkeley, CA 94720
Phone: (605)-695-9131
eric.knudsen@berkeley.edu

Research Interests

Understanding how the brain generates internal representations of the world (**cognitive maps**) to enable **adaptive decision making**. Using engineering principles to bring cutting-edge methodologies, including single trial population **decoding** and **closed-loop manipulation** of cognitive variables through high-throughput neurophysiology to dissect the cellular origins of cognitive maps. Developing the tools to **reliably and bidirectionally modulate the neural computations** underlying cognitive processes for neurotherapeutics in patient populations with severe mental health disorders.

Education

Drexel University March 2013
Ph.D. Biomedical Engineering
Thesis: *Encoding of Interval Time within the Rat Hindlimb Sensorimotor Cortex: the Effects of Temporal Context, Brain-Machine Interface Control, and the Impact of Spinal Cord Injury*

South Dakota State University June 2006
B.S. Electrical Engineering

Research Experience

Postdoctoral Scientist, University of California, Berkeley 2014-present
Helen Wills Neuroscience Institute
Advisor: Joni Wallis

- Provided first direct neurophysiological evidence of the encoding of a cognitive map for reward in the primate hippocampus (Knudsen and Wallis, 2021, *Cell)*

- Identified the causal nature between the interaction of orbitofrontal cortex and the hippocampus underlying adaptive decision making through closed-loop manipulation of theta oscillations (Knudsen and Wallis, 2020, *Neuron*)
- Developed computer-aided techniques for large-scale acute neurophysiology in the awake, behaving primate (Knudsen et al. 2019, *IEEE*)
- Performed rapid-iteration open-loop stimulation experiments as part of DARPA SUBNETs initiative (2014-2016)

*This work resulted in publications in **Neuron** and **Cell**, an upcoming review in **Nature Reviews Neuroscience**, and several more publications in preparation investigating hippocampal replay during reward learning, the fast and slow components of value-based decision making, and how task state information in the hippocampus affects value-based processing in orbitofrontal cortex.*

Postdoctoral Researcher, Drexel University, Philadelphia 2013-2014

School of Biomedical Engineering

- Developed preliminary analyses on neural responses to postural adaptation

This one year postdoc was devoted to finishing graduate work and developing a new behavioral task for brain-machine interface in the rodent and resulted in several publications.

Graduate Student, Drexel University, Philadelphia 2006-2013

School of Biomedical Engineering

Advisor: Karen Moxon

- Showed that combined rehabilitation strategies foster enhanced cortical reorganization following spinal cord injury
- Demonstrated encoding of subject time estimates in rat sensorimotor cortex, which are subsequently altered by brain-machine interface training
- Decoded hindlimb movements for the restoration of movements after spinal cord injury

This work led to four principal author publications and nine additional publications. Work was funded by a Drexel Neuroengineering Fellowship, an R01, and the Shriners Hospital for Children.

Research Skills

Animal models Non-human primate, rodent

Aseptic Technique Cranial implants and explants for acute and chronic electrophysiology, craniotomy, dura mater scraping, implant maintenance

Experiment Techniques Large-scale neurophysiology, closed loop stimulation, pupilometry, psychophysics, instrumentation and task design, rapid prototyping, structural MRI.

Research Grants

Contributions to Ongoing Funded Research

R01-MH117763: *Frontostriatal Rhythms Underlying Reinforcement Learning* 2018-present
Principal Investigator: Joni Wallis, PhD
University of California, Berkeley
*Role: **Contributor**. My work on the role of orbitofrontal cortex theta oscillations in reinforcement learning were the basis for this award. I provided preliminary data and contributed to the grant with Dr. Wallis.*

R01-MH121448: *Hippocampal-Orbitofrontal Interactions and Reward Learning* 2019-present
Principal Investigator: Joni Wallis, PhD
University of California, Berkeley
*Role: **Contributor**. My work on the interactions between orbitofrontal cortex and hippocampus were the basis for this award. I provided preliminary data and contributed to the grant with Dr. Wallis.*

R01-NS116623: *Large-Scale Recordings in Primate Prefrontal Cortex: Mechanisms of Value and Attention.*
Principal Investigators: Tirin Moore, PhD, Krishna Shenoy, PhD, Joni Wallis, PhD.
Stanford University, University of California, Berkeley
*Role: **Contributor**. My closed-loop stimulation work and acute recording platform were part of the basis of the Wallis lab portion of the grant. I provided data.*

Contributions to Prior Funded Research

R21-DA041791: *The Unlearning of Stimulus-Outcome Associations Through Intracortical Microstimulation.* 2016-2017
Principal Investigator: Joni Wallis, PhD
University of California, Berkeley
*Role. **Co-writer**. My work on microstimulation in orbitofrontal cortex and large-scale neurophysiology were the basis for this award. I provided preliminary data and co-wrote the grant with Dr. Wallis.*

Publications

2021

Knudsen, EB, and Wallis, JD. Taking stock of value in orbitofronal cortex. *Nature Reviews Neuroscience*, in preparation.

Balewski, ZZ, **Knudsen, EB**, and Wallis, JD. Fast and slow contributions to decision making. In preparation.

Knudsen, EB, and Wallis, JD. Huct a map of an abstract value space. *Cell* 184(18), 4640-4650.e10. https://doi.org/10.1016/j.cell.2021.07.010

2020

Knudsen, EB, and Wallis, JD. Closed-Loop Theta Stimulation in the Orbitofrontal Cortex Prevents Reward-Based Learning. *Neuron* 106, 537–547.e4 https://doi.org/10.1016/j.neuron.2020.02.003

2019

Knudsen, EB, Balewski, ZZ, and Wallis, JD. Model-based approaches for targeted neurophysiology in the behaving non-human primate. *9th International IEEE EMBS Conference On Neural Engineering*, San Francisco, CA. https://doi.org/10.1109/NER.2019.8716968

2017

Moxon, KA, and **Knudsen, EB**. Restoration of hindlimb movements after complete spinal cord injury using brain-controlled functional electrical stimulation. *Front. Neurosci*. https://doi.org/10.3389/fnins.2017.00715

2016

Foffani, G, Shumsky J, **Knudsen, EB**, Ganzer, PD, and Moxon, KA. Interactive effects between exercise and serotonergic pharmacotherapy on cortical reorganization after spinal cord injury. *Neurorehabil. Neural Repair* 30(5): 479-489. https://doi.org/10.1177%2F1545968315600523

2014

Knudsen, EB, Powers, MP, and Moxon, KA. Dissociating movement from movement timing in the rat primary motor cortex. *Journal of Neuroscience* 34(47): 15576-15586. https://doi.org/10.1523/JNEUROSCI.1816-14.2014

2013

Ganzer, PD, Moxon, KA, **Knudsen, EB**, and Shumsky, JS. Serotonergic pharmacotherapy promotes cortical reorganization after spinal cord injury. *Exp. Neurol.* 241: 84-94. https://doi.org/10.1016/j.expneurol.2012.12.004

Granziano, A, Foffani, G, **Knudsen, EB**, Shumsky, JS, and Moxon, KA. Passive exercise of the hindlimbs after complete thoracic transection of the spinal cord promotes cortical reorganization. *PLoS One* 8(1). https://doi.org/10.1371/journal.pone.0054350

2012

Dougherty, JB, Goodman, JM, **Knudsen, EB,** and Moxon, KA. Controlled Unilateral Isometric Force Generated by Epidural Spinal Cord Stimulation in the Rat Hindlimb. IEEE Transactions on Neural Systems and Rehabilitation Engineering. 20(4): 549-556. https://doi.org/10.1109/tnsre.2012.2190424

Knudsen, EB, Flint, RD, and Moxon, KA. Encoding of temporal intervals in the rat hindlimb sensorimotor cortex. *Frontiers in Systems Neuroscience* 6(67). https://doi.org/10.3389/fnsys.2012.00067

Manohar, A, Flint, RD, **Knudsen, EB**, and Moxon, KA. Decoding hindlimb movement for a brain machine interface to restore function after a complete spinal transection. *PLoS One* 7(12) https://doi.org/10.1371/journal.pone.0052173

2011

Dougherty, JB, **Knudsen, EB,** Goodman, JM, and Moxon, KA. Response mapping for epidural spinal stimulation for the restoration of controlled hindlimb movement after spinal cord injury. *Proceedings of the Fifth IEEE-EMBS Conference on Neural Engineering*, Cancun Mexico.

Kao, T, Shumsky, JS, **Knudsen, EB**, Murray, M, and KA Moxon. Functional role of exercise-induced cortical organization of sensorimotor cortex after spinal transection. *Journal of Neurophysiology* 106(6), 2662-2674. https://doi.org/10.1152/jn.01017.2010

Manohar, A, Flint, RD, **Knudsen, EB**, and Moxon, KA. Role of Neuronal Plasticity after Spinal Cord Injury for Neurorobotic Control. *Proceedings of the Fifth IEEE-EMBS Conference on Neural Engineering*, Cancun, Mexico.

Knudsen, EB, Moxon, KA, Sturgis, EB, and Shumsky, JS. Skilled hindlimb reaching task in rats as a platform for a brain-machine interface to restore motor function after complete spinal cord injury, *Proceedings of the 33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Boston MA.

Teaching Experience

Guest lecture, Berkeley City College Fall 2020
Course: Child Growth & Development
Responsibilties: Invited to teach one lecture on the neuroscience of child development. Developed and delivered a 50-minute lecture.

Lecturer, Drexel University Winter 2014
Course: Neural Engineering I
Responsibilities: Taught class for entire term. Developed and delivered 13 hour-long lectures, created dry-lab assignments for course work, and wrote, administered, and graded quizzes, midterm and final exams. Students performed an end-of-term computation project based on their own interests. 30 students.

Team Advisor, Drexel University 2013-2014
Course: Senior Design I-III
Responsibilities: Guided a group of three senior biomedical engineering undergraduate students in the design and development of a fully-implantable, programmable spinal cord stimulator to restore functional movements following spinal cord injury. Students gained experience in biomedical circuit design, microfabrication, and spinal cord anatomy and physiology.

Graduate Teaching Assistant, **Drexel University** 2010-2011
Course: Neural Engineering I

Responsibilities: Ran laboratory curriculum and discussion of electrophysiological principles. Used software (Matlab, Yale's NEURON) to perform simulations of single neurons and networks of spiking neurons.

Graduate Teaching Assistant, Drexel University 2008
Course: Senior Design
Responsibilities: Provided front-line help for all senior design groups. 12 teams of 3-4 students.

Mentoring Experience

Mentor for Celia Ford, University of California, Berkeley 2018-present
Current status: Graduate student in the Wallis lab, UC Berkeley

Mentor for Zuzana Baleweski, University of California, Berkeley 2017-present
Current status: Graduate student in the Wallis lab, UC Berkeley

Mentor for Mauricio Rangel-Gomez, PhD, University of California, Berkeley 2015-2017
Current status: Program Manager at NIMH

Mentor for Nathaniel Bridges, PhD, Drexel University graduate student 2012-2014
Current status: Air Force Research Laboratory

Mentor for Marissa Powers, PhD, Drexel University graduate student 2010-2014
Current status: Solutions Architect at Intel Corporation

Mentor for Carl Beringer, Drexel University undergraduate student 2012-2014
Current status: Graduate student in the Gaunt lab, University of Pittsburgh

Mentor for James Goodman, PhD, Drexel University undergraduate 2010-2012
Current status: Postdoctoral Scientist at University of Gottingen

Other Undergraduate Mentees: Shoyra Ghai (UC Berkeley), Erik Donovan *(Drexel),* Elliott Berkowitz-Sturgis *(Drexel)*

Service & Outreach

Ad Hoc Reviewer 2015-present
Frontiers in Computational Neuroscience, IEEE Engineering in Medicine and Biology Society

Professional Societies
Society for Neuroscience, member 2009-present
Institute of Electrical and Electronics Engineers, member 2004-present

Journal Club 2018-present

Founder. Lead weekly discussions with Wallis lab members on the latest primary neuroscience research

Judge, Drexel University Research Day 2013

Presentations

Invited Talks

1. "Getting lost in thought? How the hippocampus maps the unseen world in our heads." Popping the Science Bubble via the Berkeley Public Library. Berkeley, CA October 19, 2021.
2. "Learning in abstract value spaces." Wellcome Centre for Integrative Neuroimaging via World Wide Neuro platform. Oxford University, Oxford, GB. July 22, 2020.
3. "Learning in abstract value spaces". Robert Knight Lab. Berkeley, CA. June 17, 2020.
4. "Orbitofrontal cortex synchronizes with hippocampus to enable reward-based learning." UC Berkeley Neuroscience Retreat. Richmond, CA. October 6, 2018.
5. "Orbitofrontal Theta and Reinforcement Learning." Center for Neural Engineering and Prostheses Annual Retreat. Berkeley, CA. December 7, 2017.
6. "Large-Scale Frontal Lobe Neurophysiology in the Behavior Non-human Primate." 7th Annual Plexon Neurophysiology and Behavior Workshop. Dallas, TX, April 11-14, 2016.

Oral Presentations

7. "Mapping the unseen: traversing cognitive spaces." Behavioral and Systems Neuroscience Area Retreat. Berkeley, CA. May 4, 2021.
8. "Monkey Hippocampus as a Value Map." Cortex Club. Berkeley, CA. December 5, 2019.
9. "Hippocampal contributions to value learning in the primate". Behavioral and Systems Neuroscience Area Retreat. Berkeley, CA. May 8, 2019.
10. "Keeping up in a Changing World: How OFC-Hippocampal Interactions Enable Reward-Based Learning." Cortex Club. Berkeley, CA. December 5, 2018.
11. "OFC-hippocampal interactions underlying reinforcement learning." Behavioral and Systems Neuroscience Area Retreat. Berkeley, CA. May 3, 2018.
12. "OFC-hippocampal interactions underlying reinforcement learning." Cortex Club. Berkeley, CA. February 7, 2018.
13. "Characterizing Subjective Value Learning in OFC." Behavioral and Systems Neuroscience Area Retreat. Berkeley, CA. May 3, 2017.

Poster Presentations

1. **Knudsen, EB**, and Wallis, JD (2021). Replay events in primate hippocampal neurons encoding an abstract cognitive map. Society for Neuroscience, Chicago.

2. Balewski, ZZ, **Knudsen, EB**, and Wallis, JD (2021). Fast decision representation in caudate nucleus dur value-based choices. Society for Neuroscience, Chicago.

3. **Knudsen, EB**, and Wallis, JD (2019). A value map in primate hippocampus during reward-based learning. Society for Neuroscience, Chicago. SfN No. 084.12.

4. **Knudsen, EB**, and Wallis, JD (2019). Closed-loop theta stimulation in orbitofrontal cortex prevents reinforcement learning. RLDM, Montreal, QB. Poster 80. rldm.org

5. **Knudsen, EB**, and Wallis, JD (2018). Orbitofrontal-hippocampal interactions underlying reinforcement learning. Society for Neuroscience, San Diego. SfN No. 325.12.

6. **Knudsen, EB**, and Wallis, JD (2017). Orbitofrontal theta critical for reinforcement learning in non-human primates. Society for Neuroscience, Washington D.C. SfN No. 205.06.

7. **Knudsen, EB**, and Wallis, JD (2016). Biasing decision-making through stimulus-outcome specific microstimulation of orbitofrontal cortex. Society for Neuroscience, San Diego. SfN No. 354.22.

8. **Knudsen, EB**, and Wallis, JD (2014). Modifying subjective value using intracortical microstimulation: a reinforcement learning approach. DARPA SUBNETs Event 2014, Washington D.C.

9. **Knudsen, EB**, Powers, ME, and Moxon, KA (2013). BMI control of the hindlimb after complete spinal transection: the encoding of movement-related temporal intervals. Society for Neuroscience, San Diego. SfN No. 374.17.2013.

10. Ganzer, PD, Moxon, KA, **Knudsen, EB**, and Shumsky, JS (2012). 5-HT pharmacotherapy promotes cortical reorganization that is correlated to improvements in behavioral outcome after spinal cord injury. Society for Neuroscience, New Orleans. SfN No. 787.09.

11. **Knudsen, EB**, Flint RD, and Moxon KA (2012). Effect of behavioral training on the encoding of temporal intervals in the rat hindlimb sensorimotor cortex. Society for Neuroscience, New Orleans, SfN No. 809.07.

12. **Knudsen, EB**, Moxon, KA, Dugan, EA, Flint RD, Shumsky JS (2009). Combined rehabilitative therapies following spinal cord injury induce cortical reorganization. Society for Neuroscience, Chicago. SfN No. 657.8.