Adam J. Calhoun

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Personal Data
Date of Birth: July 8, 1984.
Gender: Male.

Education and Research Experience

- Postdoctoral Fellow, Advisor: Mala Murthy — 2014 - Present
  Princeton University, Princeton Neuroscience Institute

- Ph.D. Neuroscience, Advisors: Dr. Tatyana O. Sharpee, Dr. Sreekanth Chalasani — 2007 - 2014
  University of California – San Diego, Department of Neuroscience.

- Master of Mathematics, Advisor: Dr. James Mitchell — 2004 - 2007
  University of St. Andrews, School of Mathematics.
  First Class with Honours
  Dissertation title: Universal equations on the full transformation monoid

Awards and Fellowships

- Simons Foundation Postdoctoral Fellowship — 2017 – 2020
- T32 Training Grant — 2015 – 2017
- Jesse and Caryl Philips Foundation — 2012
- Institute for Neural Computation Fellowship — 2012
- National Science Foundation Graduate Research Fellowship — 2009 - 2012

Publications

1. **Calhoun AJ**, Pillow JW, Murthy M. Unsupervised identification of the internal states that shape natural behavior. *Nature Neuroscience* (in press), 2019.

2. **Calhoun AJ**, Murthy M. Quantifying behavior to solve sensorimotor transformations: advances in worms and flies. *Current Opinion in Neurobiology*, 46, 90-98 (2017).

3. Stern DL, Clemens J, Coen P, **Calhoun AJ**, Hogenesch JB, Arthur BJ, Murthy M. Experimental and statistical reevaulation provides no evidence for Drosophila courtship song rhythms. *Proceedings of the National Academy of Sciences*, 201707471 (2017).

4. **Calhoun AJ**, Hayden BY. The foraging brain. *Current Opinion in Behavioral Science*, 5, 24-31 (2015).

5. **Calhoun AJ**, Pokala N, Fitzpatrick JAJ, Sharpee TO, Chalasani SH. Neural mechanisms for evaluating environmental variability in *Caenorhabditis elegans*. *Neuron*, 86 (2), 428-441 (2015).

6. **Calhoun AJ**, Chalasani SH, Sharpee TO. Maximally informative foraging by *Caenorhabditis elegans*. *eLife* 3, e04220 (2014).

7. Sharpee TO, **Calhoun AJ**, Chalasani SH. Information theory of adaptation in neurons, behavior and mood, *Current Opinion Neurobiology*, 25, 47-53 (2014).

8. Reinagel P, Mankin E, **Calhoun A**. Speed and accuracy in a visual motion discrimination task as performed by rats, *arXiv*, 1206.0311 [q-bio.NC] (2012).

9. Nandy D, **Calhoun A**, Windschitl J, Canfield RC, Linton MG. A new technique for measuring the twist of photospheric active regions without recourse to the force-free-field equation: reconfirming the hemispheric helicity trend, *Bulletin of the American Astronomical Society*, Vol 39, 128 (2007).

Contributions to science

1. *New methods for behavioral quantification:* Do animals always respond to the same sensory input in the same way? To investigate this, I have used the dynamic social interactions of *Drosophila melanogaster*. Previous work has shown that, during courtship, males pattern their songs using sensory cues that are arriving on fast timescales (tens to hundreds of milliseconds) from their partner. However, this left a large portion of the variance in behavior unexplained. During my postdoc in the lab of Mala Murthy at Princeton University, I hypothesized that the internal state of the nervous system could be changing over time so that the sensory cues that were being used, and the timescales over which they were being integrated, were different in each state (as opposed to one relationship used across all of courtship). I collaborated with Jonathan Pillow to **develop an unsupervised computational method to identify these internal states purely from behavioral data. My model uncovers three states underlying this behavior**, and is able to predict most of the moment-to-moment variation in natural song patterning decisions. **These behavioral states correspond to different sensorimotor strategies**, each of which is characterized by unique relationships between sensory inputs and song outputs. Using the model on experimental manipulations of neural circuitry, I show that a pair of neurons previously thought to be command neurons for song production are sufficient to drive switching between states. This illustrates that not only can we identify nervous system-relevant states from behavioral data alone, but also how **careful quantification of behavioral states can provide insight into the function of neural circuits that we would not have otherwise understood**.
    a. **Calhoun AJ**, Pillow JW, Murthy M. Unsupervised identification of the internal states that shape natural behavior. *Nature Neuroscience* (in press), 2019.
    b. **Calhoun AJ**, Murthy M. Quantifying behavior to solve sensorimotor transformations: advances in worms and flies. *Current Opinion in Neurobiology*, 46, 90-98 (2017).
    c. **Calhoun AJ**, Pokala N, Fitzpatrick JAJ, Sharpee TO, Chalasani SH. Neural mechanisms for evaluating environmental variability in *Caenorhabditis elegans*. *Neuron*, 86 (2), 428-441 (2015).

2. *'Spontaneous' switching between behavioral states:* Why does an animal spontaneously switch between different behaviors or behavioral states in the absence of new stimuli? Working with Tatyana Sharpee during my PhD, I focused on a foraging behavior (Calhoun, 2015) in *C. elegans* where an animal switches spontaneously between a local search behavioral state (searching a small area) and global search state (searching a large area). **I developed an information theoretic model that unified the two types of search (local and global) and described how long the animals should spend in one state before switching to the other** (Calhoun, 2014). The theory made several predictions, chief among them that the time animals should spend in one state was determined by how food was distributed about its environment prior to search. I tested these predictions in the lab of Sreekanth Chalasani (Calhoun, 2015) where I used statistical tools to predict the relationship between the animal's experience prior to search and its future behavior, showing that much of the perceived randomness in the behavior was in fact a result of prior experience that was not observable without

careful quantification of sensory experience. **I bridged molecular, cellular, and systems analysis to identify a small neural circuit that is needed for the behavior, identified the neurons which were releasing and receiving dopamine, and found a role for CREB in the network**. I also identified the computations that the sensory neurons were performing to detect variability in food using calcium imaging.

a. **Calhoun AJ**, Chalasani SH, Sharpee TO. Maximally informative foraging by *Caenorhabditis elegans*. *eLife* 3, e04220 (2014).
b. **Calhoun AJ**, Pokala N, Fitzpatrick JAJ, Sharpee TO, Chalasani SH. Neural mechanisms for evaluating environmental variability in *Caenorhabditis elegans*. *Neuron*, 86 (2), 428-441 (2015).
c. **Calhoun AJ**, Hayden BY. The foraging brain. *Current Opinion in Behavioral Science*, 5, 24-31 (2015).

Invited talks

1. Identifying the internal states that shape sensorimotor integration during natural behavior. *Cosyne workshop on Quantifying Social Behaviors*, 2019.

2. Quantitative methods to identify behavioral states. University of Washington Institute for Neuroengineering seminar series, February 2019.

3. Quantifying behavior to solve sensorimotor transformations. NeuroNex workshop on Statistical Neuroscience, 2019.

4. Internal States Shape Sensorimotor Dynamics. Janelia Research Campus, *Theoretical Neuroscience Seminar Series*, September 2018.

5. A circuit for learning about variability over long timescales. *Cosyne workshop on Information Sampling in Behavioral Optimization*, 2014.

Meeting presentations

1. A circuit for learning about environmental variability in *Caenorhabditis elegans*. Selected talk. *CSHL – Circuits* (2014).

2. Predicting song structure from social context. Selected talk. *Society for Neuroscience Nanosymposium: Neuroethology of Auditory Communication* (2017).

3. Estimating Behavioral State. Workshop organizer and speaker. Cosyne Workshop: *Automated Tools for High-Dimensional Neurobehavioral Analysis* (2017).

4. MANIFOLDS. Workshop organizer and speaker. Cosyne Workshop: *Manifold-splaining: what the theorist said to the experimentalist* (2018).

5. Estimating behavioral state for sensorimotor transformations. Selected talk. *Champalimaud Research Symposium: Quantitative approaches to Behaviour and Neural Systems* (2018).

6. How can we measure and model the dynamics of interacting minds? Cross-collaboration breakout organizer and speaker: *Cognitive Computational Neuroscience* (2019).

7. Unsupervised identification of the internal states that shape natural behavior. Selected talk. *Neurobiology of Drosophila* (2019).

Posters presented at Cosyne 2013, 2014, 2017, 2019, SFN 2011, 2012, 2013, Sloan-Swartz 2013, Worm Meeting 2011, 2013, CSHL Circuits 2013, 2014, 2018, BRAIN Initiative 2018.

Service

- Organizing Committee, Cosyne 2020, Publicity Chair
- Reviewer, PLoS Computational Biology, eLife, Cognitive Affective and Behavioral Neuroscience, Journal of Philosophy, EJAM
- Conference Reviewer, Cosyne
- Guest editor, PLoS Computational Biology

Teaching

- Guest lecturer, NEU282 “Analytical methods for computational neuroscientists” (Spring 2014)
- Guest lecturer, NEU282 “Analytical methods for computational neuroscientists” (Spring 2012)
- Teaching assistant, PHYS 221A “Nonlinear dynamics” Fall 2009