

# Jacob M. Graving

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## Research Interests

Machine learning, self-supervised learning, Bayesian statistical inference, deep learning, causal inference, probabilistic models

## Experience

2020–present

### Research Scientist

Advanced Research Technology Unit  
Max Planck Institute of Animal Behavior

- Head of a central machine learning research group focused on developing advanced, general-purpose methods for the measurement and analysis of animal behavior in laboratory and field environments using computer vision, deep learning, and modern statistical methods, such as Bayesian causal inference.

## Education

2021

### Dr.rer.nat., Biology (0,0 “summa cum laude”)

Department of Collective Behaviour, Max Planck Institute of Animal Behavior  
Department of Biology, University of Konstanz

Centre for the Advanced Study Collective Behaviour, University of Konstanz

International Max Planck Research School (IMPRS) for Organismal Biology

- Thesis: “Deep Learning and Computer Vision Methods for Measuring and Modeling Animal Behavior” <http://nbn-resolving.de/urn:nbn:de:bsz:352-2-dgcbudqch6ix8>
- Supervisor: Iain Couzin

2015

### M.Sc., Biology

Department of Biological Sciences, Bowling Green State University

- Focus: Ethology, Neuroscience

2013

### B.Sc., Biology

Department of Biological Sciences, Bowling Green State University

## Relevant Publications

In Prep

**Graving, J.M.**, Heins, C., Couzin, I.D. Variational Divergence Estimation as a Unifying Framework for Contrastive Representation Learning. Code: <https://github.com/jgraving/selfsne>

- Developed a generalist self-supervised deep learning model that unifies much of the contrastive learning literature into a single model class.

In Review

Bath, D.E., **Graving, J.M.**, Walter, T., Sridhar, V.H., Vizcaíno, J.P., Couzin, I.D. Collective detection and processing of distributed information by fish schools. In revision for Current Biology. Code: [https://github.com/jgraving/bayesian\\_beta\\_regression](https://github.com/jgraving/bayesian_beta_regression)

- Collaborated with researchers from multiple disciplines to test the collective intelligence of large schools of fish using computer vision, deep learning, and Bayesian inference
- Developed and applied a generative Bayesian statistical model using JAX, Numpyro, and Tensorflow Probability to analyze an extremely large and complex time series data set (approx. 3 billion observations across 400+ experimental conditions)

2023 Koger, B., Deshpande, A., Kerby, J.T., **Graving, J.M.**, Costelloe, B. R., Couzin, I.D. Quantifying the movement, behaviour and environmental context of group-living animals using drones and computer vision (2023). Journal of Animal Ecology. doi:10.1111/1365-2656.13904 Code: <https://github.com/benkoger/overhead-video-worked-examples>

- Helped develop a data collection pipeline using state-of-the-art deep learning and computer vision algorithms combined with aerial drone imaging to measure detailed behavioral data from groups of individuals, and synchronously reconstruct accurate 3D models of the natural environment

2020 Li, L., Nagy, M., **Graving, J.M.**, Bak-Coleman, J., Guangming X., Couzin, I.D. (2020). Vortex phase matching as a strategy for schooling in robots and in fish. Nature Communications 11, 5408 <https://doi.org/10.1038/s41467-020-19086-0>

- Collaborated with researchers from multiple disciplines to test theoretical predictions from robotic experiments for how schooling fish collectively optimize their swim patterns to maximize energy savings in flow environments
- Measured and analyzed detailed body posture data of schooling fish using computer vision and deep learning, as well as mechanistic and statistical models of behavior to show that fish adopt optimal swimming patterns

2019 **Graving, J.M.**, Chae, D., Naik, H., Li, L., Koger, B., Costelloe, B.R., Couzin, I.D. (2019). DeepPoseKit, a software toolkit for fast and robust animal pose estimation using deep learning. eLife, 8. <https://doi.org/10.7554/elife.47994> bioRxiv: <https://doi.org/10.1101/620245> Code: <https://github.com/jgraving/deepposekit>  
Press: Quanta Magazine, Nature Methods, Nature News & Views, eLife Science Digests

- Led the development of a general-purpose few-shot deep learning toolkit for measuring the body posture of animals using TensorFlow (<https://youtu.be/hCa2zaoUWwh> ; <https://youtu.be/dSjaphoGHAY>).
- Supervised Daniel Chae, a visiting Bachelor's student from Princeton University, to develop a keypoint annotation GUI and custom data augmentation methods

## Teaching

2023 **Konstanz School of Collective Behavior, University of Konstanz**

- Led a “Probabilistic Machine Learning” workshop introducing concepts and practical examples from information theory, Bayesian inference, and causal inference to 30+ international PhD students. <https://www.exc.uni-konstanz.de/kscb/>

2022 **Deep Learning Workshop, Max Planck Institute of Animal Behavior**

- Led a practical workshop introducing deep learning concepts and PyTorch to 15 participants.
- Co-organized a practical workshop on “Quantifying Behavior with Machine Learning” with 27 participants

2019 **ASAB 2019 Summer Conference, University of Konstanz**

- Led a seminar on “Machine Learning in the Behavioral Sciences” with over 400 participants
- Co-organized a practical workshop on “Quantifying Behavior with Machine Learning” with 27 participants

2016–2020 **University of Konstanz, Department of Biology**

- Co-organized an intensive research course for Master's students on the collective animal behavior research
- Served as project advisor for 5 Master's students
- Led lectures and workshops on the topics of “Measuring Animal Behavior with Computer Vision”, “Analyzing Behavioral Data”, and “Introduction to Programming in Python”

## Skills

*Languages:*

Python

*Applications:*

Bayesian inference, causal inference, statistical analysis, data visualization, machine learning, deep learning, computer vision, and image processing

*Libraries:*

JAX, Numpyro, Stan, TensorFlow, PyTorch, scikit-learn, OpenCV

## References

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