Binxu Wang

Professional Website: scholar.harvard.edu/binxuw/home
Mobile: (+1)314-224-0648 | E-mail: binxu_wang@hms.harvard.edu
Github, Google Scholar, Semantic Scholar, ORCID

Research interest: NeuroAI, Visual Neuroscience, Interpretability, Generative Models

EDUCATION

Research Fellow, Kempner Institute for the Study of Natural and Artificial Intelligence, Harvard University, US Oct 2023- Now

Ph.D. in Neuroscience, **Washington University in St Louis** Sep 2018- Sep 2023

GPA: 3.87/4.0
Moved to HMS in 2021 with thesis advisor Carlos R. Ponce

Visiting Graduate Student† in Neurobiology, **Harvard Medical School,** US Sep 2021- Sep 2023

Dissertation: Charting the Landscape of Ventral Stream Neural Code on Generative Image Manifolds
Advisor**:** *Carlos R. Ponce*
Committee: *Timothy Holy (chair), Gaia Tavoni, Gabriel Kreiman, Dennis Barbour*

Brains, Minds & Machines Summer Course, Woods Hole Aug 2021

BSc in Physics, **Peking University**, Beijing, China Sep 2013- July 2018

Major GPA: 3.78/4.0 (top 12% in Department of Physics)

PUBLICATIONS

†: *Equal contribution.* §: *Corresponding author*

Preprints & Under review

Wang, B.§, Pehlevan C. (2025), An Analytical Theory of Spectral Bias in the Learning Dynamics of Diffusion Models, *under review.*

Wang, B.§, Shang, J., Sompolinsky, H., (2024), How do diffusion models learn and generalize on abstract rules for reasoning?, *under review.*

Wang, B., and Ponce, C.R.., (2024), Neural Dynamics of Object Manifold Alignment in the Ventral Stream, *under review.*

Wang, B.§, and Vastola, J.J., (2023), Diffusion Models Generate Images Like Painters: an Analytical Theory of Outline First, Details Later, arxiv: 2303.02490

Peer Reviewed

Wang, B.§, and Vastola, J.J., (2024), The Unreasonable Effectiveness of Gaussian Score Approximation for Diffusion Models and its Applications, *TMLR*

Wang, B.§**,** Shang, J., Sompolinsky, H., (2024), Diverse capability and scaling of diffusion and auto-regressive models when learning abstract rules, *Workshop on System-2 Reasoning at Scale in NeurIPS*

Wang, B.§**,** and Vastola, J.J., (2023), The Hidden Linear Structure in Score-Based Models and its Application, *Workshop on Diffusion Models in NeurIPS 2023*

Kuntala C., Sharma D., Ponce, C. R., and **Wang, B.**§ (2023), Understanding Learning Dynamics of Neural Representations via Feature Visualization at Scale, in *UniReps Workshop: Unifying Representations in Neural Models, in NeurIPS 2023*

Wang, B., and Ponce, C. R., (2022), On the Level Sets and Invariance of Neural Tuning Landscapes, *Proceedings of the 1st NeurIPS Workshop on Symmetry and Geometry in Neural Representations, PMLR 197:278-300*

Wang, B., and Ponce, C. R., (2022), Tuning Landscapes of the Ventral Stream, *Cell Reports*

Wang, B., and Ponce, C. R., (2022), High-performance Evolutionary Algorithms for Online Neuron Control, *Genetic and Evolutionary Computation Conference*
(Nominated for **Best Paper Award** in Real World Application Track)

Rose, O., Johnson, J., **Wang, B.,** and Ponce, C. R., (2021), Visual prototypes of the ventral stream are attuned to complexity and gaze behavior, *Nature Communications*

Wang, B., Mayo, D., Deza, A., Barbu, A., Conwell, C., (2021), On the use of Cortical Magnification and Saccades as Biological Proxies for Data Augmentation. *SVRHM Workshop @ NeurIPS*

Wang, B., Ponce, C. R., (2021), A Geometric Analysis of Deep Generative Image Models and Its Applications. *International Conference on Learning Representations* (*ICLR*)

Shao, Y†., **Wang, B.†,** Sornborger, A. T., Tao, L., (2019), A mechanism for synaptic copy between neural circuits. *Neural Computation*, 31(10)

Xiao, Z.†, **Wang, B.†,** Sornborger, A.T., Tao, L., (2018) Mutual Information and Information Gating in Synfire Chains, *Entropy,* 20(2), 102

Conference Posters

Wang B†, Shang J†, Sompolinsky H., (2024), Do diffusion models generalize on abstract rules for reasoning?, poster at 2024 Conference on Cognitive Computational Neuroscience

Wang, B., Ponce, C. R., (2022), Factorized convolution models for interpreting neuron-guided images synthesis, poster at 2022 Conference on Cognitive Computational Neuroscience

Wang, B., Ponce, C. R., (2021), Climb High and Gaze Far: mapping tuning landscapes of the ventral stream via image optimization and manipulation, poster at *Bernstein Conference 2021*

Shao, Y., **Wang, B.**, Andrew, T., Tao, Louis, (2018), A mechanism for synaptic copy between neural circuits, poster at *Society for Neuroscience*

FELLOWSHIP AND AWARDS

2023-26 The Kempner Research Fellowship, Harvard University, Kempner Institute for the Study of Natural and Artificial Intelligence.

2025 Top reviewer award of *International Conference on Machine Learning* (ICML 2025).

2022-23 Quan Predoctoral Fellowship in Neurobiology, Harvard University.

2022 Best paper award nomination (Real World Application track), in *Genetic and Evolutionary Computation Conference* 2022.

2021 Fujitsu Laboratories Fellowship for Brains, Minds and Machines Summer Course, Massachusetts Institute of Technology

2019-21 Cognitive, Computational, and Systems Neuroscience Pathway Traineeship in Washington University

2018 Excellent Graduate in the City（市级优秀毕业生）
(*Highest Honor for Graduates in Peking University*)

2016-17 Peking University Merit Student Award

2014-15 Peking University Academic Excellence Award

2015-17 Peking University Physics Department WeiMingXueZi Scholarship（未名学子奖学金）

2014-16 Peking University Guanghua Scholarship（光华奖学金）

(*Both scholarships are merit-based, awarded for academic excellence*)

INVITED TALKS

2025 VSS 2025 Workshop: *Model Optimized Stimuli: more than just pretty pictures*
"Feature accentuation as a stringent test of model-brain alignment"
https://youtu.be/f3SFQpZ6yOg

2025 VSS 2025 Nanosymposium.
"Factorized convolution models for interpreting neuron-guided images synthesis"
https://youtu.be/Z8pdzfLP-vA

2025 Washington University in St Louis, Special Seminar.
"The Geometry of Ventral Stream Neuronal Tuning and Its Alignment with Generative Image Manifolds" *https://youtu.be/cCeidmUYzck*

2025 Yale University, CNC Lab.
"The Geometry of Ventral Stream Neuronal Tuning and Its Alignment with Generative Image Manifolds"

2024 SfN 2024 Nanosymposium.
"Factorized convolution models for interpreting neuron-guided images synthesis"

2024 Cold Spring Harbor Laboratory, NAISYS 2024.
"Dynamic Alignment of Ventral Stream Tuning with Generative Manifold"

2024 Caltech, Neuro-ML Reading Group.
"Dynamic Alignment of Ventral Stream Tuning with Generative Manifold"

2024 LMU-Harvard Young Scientist Forum.
"Dynamic Alignment of Ventral Stream Tuning with Generative Manifold"

2023 SfN 2023 Nanosymposium.
"Probing the Dynamic Alignment of Ventral Stream Tuning with Object vs Pattern Manifold"

2023 Timothy Buschman Lab, Princeton Neuroscience Institute.

2023 Nikolaus Kriegeskorte Lab, Columbia University.

2023 Kempner Institute for the Study of Natural and Artificial Intelligence
"The Geometry of Creativity: Understanding Generative Models in Brains and Machines"
https://youtu.be/w3rsTcXKzZo

2022 Hang Zhang Lab, Psychology Department at Peking University,
"Tuning Landscapes of the Ventral Stream"

2022 Demba Ba Lab, Engineering School at Harvard University,
"Geometry of Natural Image Manifold and Tuning Landscapes of the Ventral Stream"

2022 LMU-Harvard Young Scientist Forum,
"Investigating Tuning Landscapes of the Ventral Stream with Generative Models"

2022 GECCO 2022,
"High-performance Evolutionary Algorithms for Online Neuron Control"
https://youtu.be/IksDG84seng

2021 AI Time organization (virtual),
"The Geometry of Deep Generative Image Models and Its Applications."
https://youtu.be/IksDG84seng

2021 CCN 2021 GAC panel discussion
"What constitutes understanding of ventral pathway function?" https://youtu.be/v8dyIk0pEaY

TEACHING & MENTORING

2025 Mentored three undergrad students for their summer research (*Hannah Kim*, *Emma Finn*, *Nafisa Anmul*), Kempner Institute, Harvard University

2023 Mentored an undergrad student (*Chandana Kuntala*) for summer research in Ponce lab, Harvard University

- Guiding her through coding analysis, towards publishing a workshop paper in NeurIPS 2023

2022-23 Organizer for Machine Learning from Scratch workshop series, in Harvard University

- Prepared and held lectures and coding tutorials on Fundamentals of Diffusion Model, Building Stable Diffusion from Scratch, Understanding Transformers from Attention to LLM.

2023 Lecturer in Computational and Cognitive Neuroscience Summer School, Cold Spring Harbor Asia.

- Gave a lecture and tutorial on Diffusion Generative Models

2023 Lecturer in Neuromatch Academy, Deep Learning Summer School.

- Gave a lecture on Diffusion Generative Model and prepared coding exercise for the students.

2023 Teaching fellow for NEURO140/240 Biological and Artificial Intelligence, in Harvard University

- Helped 10 to 20 students develop their individual research projects on topics related to NeuroAI, including RL, LLM, representation learning, interpretability of neural networks etc.

2021 Teaching fellow for NEURO120 Introduction to Computational Neuroscience, in Harvard University

- Prepared material and held a one-hour review section each week, covering topics from: LNP model, H-H-model, Hebbian learning, dynamic system analysis, visual system and reinforcement learning.

2020 Teaching assistant for BIO5648 Coding and Statistical Thinking in the Neurosciences, in Washington University in St Louis

- Helped develop course material and homework from scratch for the first iteration. Gave a lecture on the application of bootstrapping methods in neuroscience.

SERVICE

Journal article review:

Nature Neuroscience; PLOS Computational Biology; Cognitive Neural Dynamics.

Conference article review:

ICLR, ICML, NeurIPS, AAAI; NeurIPS workshops on SVRHM, Diffusion, NeurReps, UniReps, AMHM; Cognitive Computational Neuroscience (CCN).

SKILLS

Computational Skills

- Proficient in Python and Matlab, strong skills in data analysis, statistical learning, and deep learning.
- Proficient in PyTorch and in the development and evaluation of models of biological visual neurons, visualization and interpretation of generative adversarial models (GANs), diffusion models, convolutional neural networks, transformers, and biologically inspired self-supervised learning systems.
- Strong aptitude with TensorFlow and Keras frameworks for building and training Floodfill networks for Electron Microscopy 3D Image Segmentation, 2D tissue classification.
- Fluent in Julia, R for image processing, statistical analysis, and model fitting tasks.
- Experience with Linux systems and HPC cluster parallel computing.

Coursework

- **Mathematics**: Methods of Mathematical Physics (Complex function and PDE); Mathematical Statistics; Nonlinear Dynamics for Physicists; Topology; Differential Geometry; Nonlinear Dynamic System.
- **Physics:** General Relativity; Quantum Field Theory; Gauge Field Theory.
- **Computation**: Optimization Algorithms for Big Data Analysis; Deep Learning: Algorithm and Application; Computer Vision; Advances in Computer Vision; Introduction to Artificial Intelligence; Computational Sensorimotor Learning (MIT 6.484); Advanced Natural Language Processing (MIT 6.8610); Probabilistic models for neural data (Harvard Neuro 316QC)

Experimental Skills

- Four years of experience with *in vivo* multi-electrode array recording on awake monkey.
- Skills in behavioral task designs for non-human primates.
- Light-sheet microscopy (volumetric imaging) for transparent samples.
- zTree human behavior task design.

RESEARCH EXPERIENCE

2023-25 Postdoc research fellow in Kempner Institute (Harvard University)

- Leveraged feature accentuation to interpret and control neural activities in macaques visual cortices, and using them as a benchmark to compare the causal alignment of vision backbones to the brain (collaborating with Talia Konkle and Margaret Livingstone lab)
- Developed analytical theory of linear diffusion model and characterized their learning dynamics and spectral bias. (collaborating with Cengiz Pehlevan lab)
- Derived a Gaussian linear approximation of score-based models that explains diverse empirical phenomena and utilized the corresponding analytical solution to accelerate diffusion sampling. (collaborating with John Vastola)
- Developed recurrent neural circuit models with star-shape continuous attractors, drawing inspirations from diffusion models. (collaborating with Haim Sompolinsky lab)
- Studied the rule learning and reasoning capabilities of a diverse family of modern generative models (GPT, Diffusion, Mamba etc.) on the Raven's progression matrix task, highlighted their diverse learning behavior, learned representation and inductive biases, prompting further comparison to human subjects. (collaborating with Haim Sompolinsky lab)

2018-23 Thesis work in Dr. **Carlos Ponce** lab (Harvard Medical School / Washington University)

- Developed and validated a novel gradient-free optimization algorithm to control neuronal responses through stimulus synthesis.
- Investigated the geometric structure of the image manifold created by GANs. Investigated how neurons in V1, V4, and inferotemporal cortex are tuned on different image manifolds represented by different image generators, using electrophysiology experiments.
- Analyzed level-set geometry of the tuning maps for visual neurons and CNN units.
- Developed closed-loop systems to control population neural activity with synthetic stimuli.
- Developed modeling pipelines based on tensor factorization and CNNs to interpret visual selectivity of neurons.

2019 Research rotation in Dr. **Timothy Holy** lab (Washington University)

- Learned to use lab-built light-sheet microscopes (Object-Coupled Planar Imaging) to do calcium imaging on larval zebrafish forebrain. Learned image processing pipeline in Julia, then used data to parcellate the fish forebrain by functional connectivity.

2019 Research rotation in Dr. **Joshua Morgan** lab (Washington University)

- Debugged and successfully trained Google's *Flood Field Network* from scratch to segment and trace neuronal morphology in electron microscopic volumes of lateral geniculate nuclei and retina. This project led to a massive acceleration of the lab's workflow.

2017 Summer internship in Dr. **Alex Reyes** lab (NYU Center for Neural Science)

- Developed a novel optimization algorithm to extract post-synaptic potentials from whole-cell recordings. Applied the method towards *in vivo* recordings of mice auditory cortex to understand the input structure to cortical cells. I then used the extracted post-synaptic waveform to understand the population coding structure of the inputs into the target cell.

2017 Collaboration with Dr. **Shiming Tang** (Peking University)

- Conducted computational analysis and modeling of population neural response to static images in macaque primary visual cortex (two-photon imaging data). The analysis focused on the topological similarity of the population neural responses and the input stimuli space and found that some exotic topological manifold in the stimuli space could be recovered by dimensionality reduction of the population response space.

2016-18 Theoretical neuroscience research with Dr. **Louis Tao** (Peking University)

- Analyzed information transmission in the synchronous firing chain model and found that the optimal mutual information transmission corresponded to a bifurcation point in the dynamic system. Built a normative model of how synaptic weights could be copied using Hebbian learning rules and oscillations.

2015 Human social behavior modeling with Dr. **Xiaolin Zhou** (Peking University)

- Developed a group-level behavior task, to investigate the dynamics of compliance behavior. By manipulating the observed groupmates' behavior from each subject's perspective, we could exert social influence on their choice. We then adapted classic learning models to extract the strength of influence on behavior. We found a rate difference between the influence on selfish and altruistic behavior.