Mengsen Zhang | Curriculum Vitae

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"If there is a 'secret of life', it is here we must look for it, among the causes which bring about the arrangement of innumerable separate processes into a single harmonious living organism."

— C. H. Waddington

Education

Florida Atlantic University	**Florida, U.S.**
Ph.D. Complex Systems and Brain Sciences	*2013–2018*
University of Pennsylvania	**Pennsylvania, U.S.**
M.S. Criminology	*2011–2012*
Peking University	**Beijing, China**
B.S. Psychology & B.S. Pharmaceutical Sciences	*2007–2011*

Special Program

Santa Fe Institute	**New Mexico, U.S.**
Complex Systems Summer School	*2013*

Research

University of North Carolina at Chapel Hill (UNC-CH)   **North Carolina, U.S.**
Post-Doc Research Associate   *2021–present*

Advisor: Flavio Fröhlich, Ph.D.

Description: develop new computational and experimental techniques for understanding multiscale brain dynamics in animals, humans, and clinical populations; use optogenetics and non-invasive brain stimulation (e.g., transcranial alternating current stimulation) to understand the causal role of brain oscillations in organizing macroscopic network dynamics and microscopic neuronal spiking, and to develop treatment for psychiatric disorders (e.g., auditory hallucinations in schizophrenia).

Stanford University   **California, U.S.**
Postdoctoral Scholar   *2019–2021*

Faculty Sponsor: Manish Saggar, Ph.D.

Description: developed new computational techniques for modeling complex brain dynamics in two main directions. Both combine nonlinear dynamic modeling and geometric/topological analysis. Direction 1: model global brain dynamics using high-dimensional biophysical network models that are highly multistable, and found the global layout of critical points better predicts human brain functional connectivity (fMRI) than conventional local approaches. Direction 2: developed a data-driven method to recover attractors and phase transitions from simulated and human fMRI time series, which is validated with theoretical ground truth computed from a nonlinear dynamic model of the brain. The methods are currently being applied to patient data.

Florida Atlantic University   **Florida, U.S.**
Graduate Student   *2013–2018*

Mentors: Emmanuelle Tognoli, Ph.D. & J. A. Scott Kelso, Ph.D.

Committee Members: Christopher Beetle, Ph.D., Armin Fuchs, Ph.D.

Dissertation Title: The Coordination Dynamics of Multiple Agents (Zhang, 2018)

Dissertation Description: My dissertation reveals the dynamic principles of biological coordination between multiple interacting processes across spatiotemporal scales. It consists of an empirical component (Zhang, Kelso, & Tognoli, 2018), a theoretical component (Zhang, Beetle, Kelso, & Tognoli, 2019) and a methodological component (Zhang, Kalies, Kelso, & Tognoli, 2020). Experiment: I designed a new paradigm to study rhythmic coordination between eight people where individuals' movement frequency and network connectivity were fully manipulable; this led to the discovery of various forms of coordination and transitions at dyadic, group, and ensemble levels in a human experiment. Theoretical modeling: a nonlinear dynamic model was developed to capture key empirical observations at all levels and unified well-known models of small- and large-scale models of biological coordination; with further numerical and mathematical analyses, I demonstrated how multistable and metastable coordination, well understood at a small scale, led to formidable complexity at larger scales. New computational method: developed a computational topology tool to detect collective transitions in multifrequency coordination in the above experiment.

Other Projects: multiple human-model hybrid experiments using the "Human Dynamic Clamp" paradigm. In these experiments, humans were coupled to a dynamical system model of themselves, where manipulating model parameters resulted in changes in emotional and neural dynamics.

Publications

Zhang, M., Force, R., Walker, C., & Fröhlich, F. (*To be submitted*). Transcranial alternating current stimulation enhances alpha power and connectivity in patients with auditory hallucination.

Zhang, M., Riddle, J., & Fröhlich, F. (*To be submitted*). Closed-loop control of bistable symptom states.

Zhang, M., Chowdhury, S., & Saggar, M. (*To be submitted*). The topology of time: transition networks in simulated and real neural dynamics.

Zhang, M., & Fröhlich, F. (*Under review*). Cell type-specific excitability probed by optogenetic stimulation depends on the phase of the alpha oscillation.

Zhang, M., Sun, Y., & Saggar, M. (*Under review*). Cross-attractor repertoire provides new perspective on structure-function relationship in the brain.

McKinley, J., Zhang, M., Wead, A., Williams, C., Tognoli, E., & Beetle, C. (2021). Third party stabilization of unstable coordination in systems of coupled oscillators. *Journal of Physics: Conference Series*, *2090*(1), 012167. doi: 10.1088/1742-6596/2090/1/012167

Zhang, M., & Saggar, M. (2020). Complexity of intrinsic brain dynamics shaped by multiscale structural constraints. *bioRxiv*. doi: 10.1101/2020.05.14.097196

Tognoli, E., Zhang, M., Fuchs, A., Beetle, C., & Kelso, J. A. S. (2020). Coordination dynamics: A foundation for understanding social behavior. *Frontiers in Human Neuroscience*, *14*, 317. doi: 10.3389/fnhum.2020.00317

Zhang, M., Kalies, W. D., Kelso, J. A. S., & Tognoli, E. (2020). Topological portraits of multiscale coordination dynamics. *Journal of Neuroscience Methods*, *339*. doi: 10.1016/j.jneumeth.2020.108672

Zhang, M., Beetle, C., Kelso, J. A. S., & Tognoli, E. (2019). Connecting empirical phenomena and theoretical

models of biological coordination across scales. *Journal of The Royal Society Interface*, *16*(157), 20190360. doi: 10.1098/rsif.2019.0360

Zhang, **M**. (2018). *The Coordination Dynamics of Multiple Agents* (Doctoral Dissertation, Florida Atlantic University). Retrieved from `https://pqdtopen.proquest.com/pubnum/10979968.html`

Zhang, **M**., Kelso, J. A. S., & Tognoli, E. (2018). Critical diversity: Divided or united states of social coordination. *PLOS ONE*, *13*(4), e0193843. doi: 10.1371/journal.pone.0193843

Tognoli, E., **Zhang**, **M**., & Kelso, J. A. S. (2018). On the nature of coordination in nature. In J. M. Delgado-García, X. Pan, R. Sánchez-Campusano, & R. Wang (Eds.), *Advances in Cognitive Neurodynamics (VI)* (pp. 375–382). Singapore: Springer. doi: 10.1007/978-981-10-8854-4_48

Dumas, G., Lefebvre, A., **Zhang**, **M**., Tognoli, E., & Kelso, J. A. S. (2018). The Human Dynamic Clamp: A probe for coordination across neural, behavioral, and social scales. In S. C. Müller, P. J. Plath, G. Radons, & A. Fuchs (Eds.), *Complexity and Synergetics* (pp. 317–332). Cham: Springer International Publishing. doi: 10.1007/978-3-319-64334-2_24

Zhang, **M**., Dumas, G., Kelso, J. A. S., & Tognoli, E. (2016). Enhanced emotional responses during social coordination with a virtual partner. *International Journal of Psychophysiology*, *104*, 33 - 43. doi: 10.1016/j.ijpsycho.2016.04.001

Zhang, **M**., Nordham, C., & Kelso, J. A. S. (2015). Deterministic versus probabilistic causality in the brain: To cut or not to cut. *Physics of Life Reviews*, *15*, 136 - 138. doi: https://doi.org/10.1016/j.plrev.2015.10.002

In Preparation

Zhang, **M**., Kelso, J. A. S., & Tognoli, E. (*in prep*-a). Simple oscillators produce complex and ordered sequences without synchronization.

Zhang, **M**., Kelso, J. A. S., & Tognoli, E. (*in prep*-b). Dynamics of EEG neuromarkers during competitive coordination between humans and a Virtual Partner.

Invited Talks

Zhang, **M**. (2022, February 12). *Computational characterization of large-scale brain dynamic landscapes and attractor transition networks.* (The fourth Data-Driven Science and AI Conference, Florida Atlantic University)

Zhang, **M**. (2021, July 7). *Transitions and their topological signatures in social and brain dynamics.* (Topological Data Analysis Seminar, Michigan State University)

Zhang, **M**. (2021, May 28). *Flexible coordination and system complexity in social and brain dynamics.* (TCCI NeuroChat, Tianqiao and Chrissy Chen Institute)

Zhang, **M**. (2021, March 26). *Dynamics meet networks: how diverse nodes and links impact functional complexity.* (Brain Networks and Behavior Lab, the Department of Psychological and Brain Sciences at Indiana University, Bloomington)

Zhang, **M**. (2020, November 18-20). *Always on the move: Fluid social coordination across scales.* (Social BRIDGES e-conference | link to recording)

Zhang, **M**. (2020, June 18). *Social coordination across spatiotemporal scales.* (Virtual NeuroSymposium, Montreal, Québec, Canada | link to recording)

Zhang, M., Kalies, W. D., Kelso, J. A. S., & Tognoli, E. (2020, June 8). *Topological portraits of multiscale coordination dynamics.* (Minisymposium: Applications and Methods in Topological Data Analysis and Machine Learning, SIAM Conference on Mathematics of Data Science, Virtual | link to recording)

Zhang, M., Kalies, W. D., Kelso, J. A. S., & Tognoli, E. (2020, March 30). *Topological portraits of multiscale coordination dynamics.* (the Neuromatch Conference | link to recording)

Zhang, M. (2019, May 14). *The Coordination Dynamics of Multiple Agents.* (Stanford Complexity Group, Stanford, California, CA | link to recording)

Zhang, M. (2017, October 19). *Identifying pattern changes in human rhythmic movement coordination with persistent homology.* (Analysis and Applications Seminar, Department of Mathematics, Florida Atlantic University, FL)

Zhang, M. (2016, September 14). *Multiagent social coordination dynamics.* (Department of Psychology, University of Miami, FL)

Selected Conference Presentations

McKinley, J., **Zhang, M.**, Wead, A., Williams, C., Tognoli, E., & Beetle, C. (2021, September 6). *Third party stabilization of unstable coordination in systems of coupled oscillators.* (Talk, The 10th International Conference on Mathematical Modeling Physical Sciences)

Zhang, M., & Saggar, M. (2020, October 26-30). *Intrinsic dynamic landscape of the brain shaped by multiscale structural constraints.* (Talk, the Neuromatch Conference 3.0 | link to recording)

Zhang, M., & Saggar, M. (2020, October 6-8). *Complexity of intrinsic brain dynamics shaped by multiscale structural constraints.* (Poster, the Brain Criticality Virtual Meeting | link to poster)

Zhang, M., Chowdhury, S., & Saggar, M. (2019, October 21). *The topology of time: Characterizing transitions in simulated neural dynamics using topological data analysis.* (Poster, Society for Neuroscience Annual Meeting, Chicago, IL)

Stefanescu, R. A., **Zhang, M.**, Fuchs, A., Steinberg, F. L., Tognoli, E., & Kelso, J. A. S. (2018, November 7). *Transaction of agency between self and other: an fMRI study of social coordination.* (Poster, Society for Neuroscience Annual Meeting, San Diego, CA)

Zhang, M., Beetle, C., Kelso, J. A. S., & Tognoli, E. (2018, July 25). *Linking the many and the few: an experimental-theoretical analysis of multiagent coordination.* (Oral presentation, the Ninth International Conference on Complex Systems, Cambridge, MA)

Kelso, J. A. S., **Zhang, M.**, & Tognoli, E. (2018, May 1–4). *Coordination laws for couples and collectives: What about the 'in-between'?* (Society of Experimental Psychologists Annual Meeting, Tucson, Arizona)

Mediano, P. A. M., Rosas, F., & **Zhang, M.** (2018, March 20). *Synergistic synchronisation in coupled oscillators.* (Poster, Conference on Analysis and Modeling of Complex Oscillatory Systems, Barcelona, Spain)

Zhang, M., Kelso, J. A. S., & Tognoli, E. (2017, November 12). *Multiagent social coordination dynamics – from experiment to model.* (Poster, Society for Neuroscience Annual Meeting, Washington, D.C.)

Zhang, M., Kelso, J. A. S., & Tognoli, E. (2017, September 18). *Multiagent coordination dynamics: the human firefly experiment.* (Oral presentation, Conference on Complex Systems, Cancun, Mexico)

Zhang, M., Kelso, J. A. S., & Tognoli, E. (2017, July 22). *A new paradigm for studying pattern generation in multiagent systems.* (Poster, Progress in Motor Control XI, Miami, Florida)

Zhang, **M.**, Dumas, G., Tognoli, E., & Kelso, J. A. S. (2016, November 14). *How social coordination emerges and changes among multiple heterogeneous agents: An experimental 'human firefly' study.* (Poster, Society for Neuroscience Annual Meeting, San Diego, CA)

Zhang, **M.**, Dumas, G., Tognoli, E., & Kelso, J. A. S. (2014, November 16). *Emotional response during human-Virtual Partner interaction.* (Poster, Society for Neuroscience Annual Meeting, Washington, D.C.)

Zhang, **M.** (2012, November 15). *Agent-Based Modeling and its potential use in developing criminology theories with interdisciplinary evidence.* (Oral presentation, the 64th Annual Meeting of the American Society of Criminology, Chicago, Illinois)

Zhang, **M.**, & Raine, A. (2011, November 17). *Psychopathic personality enhances proactive aggression in east asian females but not males.* (Poster, the 63rd Annual Meeting of the American Society of Criminology, Washington, D.C.)

Raine, A., **Zhang**, **M.**, Appelby, S., & Venables, P. H. (2011, May 20). *Early childhood risk factors for psychopathic personality in adulthood: Findings from the mauritius child health project.* (Oral presentation, 4th biennial meeting of the Society for the Scientific Study of Psychopathy, Montreal, Canada)

Teaching

NVIDIA Deep Learning Institute (DLI)   **California, U.S.**
Certified Instructor & University Ambassador   *2019–present*
Teach workshops on "the Fundamentals of Accelerated Computing with CUDA C/C++" at Stanford University (hosted by Stanford Research Computing Center) and University of North Carolina at Chapel Hill.

Stanford University, Brain Dynamics Lab   **California, U.S.**
Instructor   *2019–2020*
Teach a running series of tutorials on Nonlinear Dynamics to members of the lab.

Florida Atlantic University, College of Science   **Florida, U.S.**
Instructor   *2016*
Gave a series of lectures in the "Matlab Boot Camp" on the basics of programming, MATLAB and signal processing, for students in the College of Science.

Florida Atlantic University   **Florida, U.S.**
Teaching Assistant   *2013–2018*
Taught undergraduate courses "Psychology", "Biological Bases of Behavior", and "Comparative Animal Behavior".

Awards

- **Brain Institute Travel Award**, Florida Atlantic University.   *2016*
- **NSF Travel Award**, Society for Social Neuroscience. (ID: 1543122; PI: Dr. Stephanie Cacioppo).   *2016*
- **Graduate Fellowship of Academic Excellence**, Florida Atlantic University.   *2014*
- **1-st Year Graduate Research Award**, College of Science, Florida Atlantic University.   *2014*

Professional Membership

- Society for Industrial and Applied Mathematics (SIAM)   *2017–Present*
- Society for Neuroscience (SfN)   *2014–Present*
- American Society of Criminology (ASC)   *2011–2013*

Professional Service

Society for Industrial and Applied Mathematics – Student Chapter   **Florida Atlantic University**
Vice President   *2018-2019*

Society for Industrial and Applied Mathematics – Student Chapter   **Florida Atlantic University**
Secretary   *2017-2018*

Reviewer for journals:
PLOS Computational Biology, Frontiers in Computational Biology, Network Neuroscience, Cognitive Processing, Cognitive Systems Research, Biological Cybernetics*, International Journal of Psychophysiology*, PLoS ONE*, Physics of Life Reviews*, Psychological Science*, Journal of Neuroscience Research*. (* assisting Dr. J. A. Scott Kelso)

Reviewer for conference:
Practice & Experience in Advanced Research Computing (PEARC)

Grant reviewer for:
National Science Foundation (Perception, Action, and Cognition program).

Mentoring experience

Below is a selected list of students that I have mentored:

- Grace Ross (graduate student, Neuroscience, UNC-CH)   *2021–present*
  Electrophysiology time series analyses to study posterior visual network dynamics during visual perception in ferrets.

- Lauren Sidelinger (undergraduate student, Neuroscience/Computer Science, UNC-CH)   *2021–present*
  EEG time series analyses to study the long-term stability of resting brain dynamics.

- Mary Enloe (undergraduate student, Computer Science, UNC-CH)   *2021–present*
  Mechanical engineering for animal behavior training box.

- Preetam Tanikella (undergraduate student, Biostatistics, UNC-CH)   *2021–present*
  Electrical engineering for animal behavior training box.

- Noah Trexler (undergraduate student, Computer Science, UNC-CH)   *2021–present*
  Software engineering for animal behavior training box.

- Rafi Ayub (graduate student, Bio-engineering, Stanford University)   *2019–2020*
  Biophysical network modeling of brain dynamics, assisting Dr. Manish Saggar.

- Joshua Child (graduate student, Political Sciences, Florida Atlantic University)   *2018*
  Directed Independent Study on oscillator models of economic inequality.

- Nadine Akin (postgraduate student, Biological Sciences, Florida Atlantic University)   *2017-2018*
  Analysis of dynamical behavioral data from a social coordination experiment.

- Ananda Chowdhury (undergraduate student, Engineering, Florida Atlantic University)   *2015-2016*
  Signal processing, and analysis of multiagent interaction data.

- Daniela Herrera (undergraduate student, Neuroscience, Florida Atlantic University)   *2015-2016*
  Behavioral data acquisition for multiagent coordination experiments.

Outreach

- In 2020, I volunteered for Neuromatch 3.0 (link) as a emcee for five sessions of talks. Neuromatch 3.0 is an online unconference aiming to make neuroscience conferences more open, inclusive, and democratic.

- In 2020, I volunteered for the Neuromatch Academy (link) to help prepare lecture materials. The

Neuromatch Academy is a nonprofit online school to make computational neuroscience more inclusive and diverse.

- In 2019, I joined a nonprofit organization, Women of AI (link to website), to make programming training more accessible to women interested in data science. I coordinate activities between the organization, Stanford Research Computing Center, and NVIDIA Corporation.

- In 2016, I wrote a popular science article to explain human-machine coordination to Chinese readers, entitled "Human-human coordination vs. human-machine coordination: Does it feel the same?" (in Chinese, link to article)

Computational Techniques

- **Parallel Computing:** CUDA C/C++ for accelerated solutions using NVIDIA GPUs, frequently used with MATLAB mex-function for easy interface. Since 2014, I have employed CUDA-based parallel computing techniques for various applications, including digital signal processing (Wavelet transform, ∼100x acceleration), simulation and parameter exploration of differential equations (∼1000x acceleration, **Zhang** et al. 2019), and graph matching (∼150x acceleration, **Zhang**, Chowdhury, and Saggar *To be submitted*). Specific acceleration factors depend on the intrinsic parallelizability of the problem.

- **Open- & Closed-Loop Data Acquisition:** I have engineered complex experimental apparatuses and software for real-time and/or closed-loop recording and modulation (e.g. **Zhang** et al., 2018; **Zhang**, Kelso, & Tognoli, *in prep*-b). My work relies on innovative experimental paradigms, for which proprietary hardware often lacks flexibility or lead to unacceptable latency. To build satisfactory experimental equipment, I developed a system of techniques utilizing open hardware, involving sensor engineering, printed circuit board design, micro-controller programming, and software engineering.

- **Applied Mathematics & Numerical Methods:** My work is tightly connected to the mathematics of Nonlinear Dynamics, Topology, Geometry, and associated numeric methods. By training and by practice, I have developed expertise in ordinary differential equations (**Zhang** et al., 2019; **Zhang**, Dumas, Kelso, & Tognoli, 2016; **Zhang** et al., *in prep*-b), partial differential equations (in particular, weak solutions of pattern formation problems with irregular or moving boundaries, using finite element method), stochastic differential equations (**Zhang** et al., *To be submitted*; **Zhang** & Saggar, 2020), algebraic topology (**Zhang** et al., 2020), and computational geometry (**Zhang** et al., *To be submitted*).

Other Activities and Achievements

- **Actor/Singer** *2012*
  In the short musical "The Last Mummer", directed by Wally Zialcita, Philadelphia, PA

- **Internship** *2010-2011*
  Phase III Clinical Trial Laboratory, Pharmacy Department, Peking University Third Hospital, Beijing, China

- **Director of University Radio Station** *2008-2009*
  Peking University Health Science Center, Beijing, China

- **Co-founder and Co-director of Student Association of Psychology** *2007-2008*
  Peking University Health Science Center, Beijing, China

- **Professional Renju Player** *2005-2006*
  National Champion (2x; China), World Third (1x)

- **The Best Poet Award** *2005*
  The First Chinese Student Poetry Festival, Sichuan, China
  Three award-winning poems were later published in an anthology "Soaring Youth" (2008, People's Literature Publishing House, China)

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