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

Academic Degrees

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*

Other Programs

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

Research Positions

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

Advisor: Flavio Fröhlich, Ph.D.

Description: continue to develop computational techniques for characterizing and modeling complex brain dynamics. The goal is to combine animal and human data to better understand multiscale rhythmic coordination in the brain.

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

Faculty Sponsor: Manish Saggar, Ph.D.

Description: develop computational techniques for analyzing and mechanistically modeling complex brain dynamics. I developed an innovative method for computing brain dynamic landscapes combining neuroimaging data and biophysical network modeling (Zhang & Saggar, 2020). The landscape-based analysis better predicts human functional connectivity than traditional numerical simulations. A computational topology/geometry method was further developed to reconstruct the network of state transitions within the dynamic landscape from simulated and real neural dynamics (Zhang, Chowdhury, & Saggar, *in prep*-a, 2019, SfN). The methods are being applied to patient neuroimaging 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; **Zhang**, Kelso, & Tognoli, *in prep*-b) and a methodological component (**Zhang**, Kalies, Kelso, & Tognoli, 2020). First, I designed a new experimental paradigm to study rhythmic coordination between eight people where individuals' movement frequency and network connectivity were fully manipulable (see techniques involved); this led to the discovery of various forms of coordination and transitions at dyadic, group, and ensemble levels in a human experiment (**Zhang** et al., 2018). Based on this experiment, I developed a mathematical model (**Zhang** et al., 2019) that captured 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. A preliminary theory was proposed for classifying complex metastable patterns based on their topological types (**Zhang** et al., *in prep*-b; **Zhang**, 2018, Section 3.2.6). Further, a computational tool was developed for detecting transitions between such complex metastable patterns in real data, leveraging existing tools from computational algebraic topology (**Zhang** et al., 2020).

Other Projects: I conducted a separate line of research on social coordination by studying human emotional responses (**Zhang**, Dumas, Kelso, & Tognoli, 2016) and neural activities (**Zhang**, Kelso, & Tognoli, *in prep*-c; Stefanescu et al., *in prep*-d) during dyadic interaction with a socially capable Virtual Partner. The Virtual Partner's behavior is driven by a system of differential equations, allowing parametric manipulation of its "sociality" and "competitiveness"—this paradigm is named the "Human Dynamic Clamp" (Dumas, Lefebvre, **Zhang**, Tognoli, & Kelso, 2018).

Publications

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.**, Chowdhury, S., & Saggar, M. (*in prep*-a). The topology of time: transition networks in simulated and real neural dynamics.

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

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

Stefanescu, R. A., **Zhang**, **M.**, Fuchs, A., Steinberg, F. L., Tognoli, E., & Kelso, J. A. S. (*in prep*-d). From self to other: Transactions of agency in social coordination.

Invited Talks

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

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

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

Stanford University   **California, U.S.**
NVIDIA Deep Learning Institute (DLI) Certified Instructor & University Ambassador   *2019–2021*

Teach workshops on "the Fundamentals of Accelerated Computing with CUDA C/C++" at Stanford University (hosted by Stanford Research Computing Center) and other academic institutes.

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, 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

Among all the undergraduate and graduate students (∼10) that I have mentored or trained, 80% are persons of color, including 50% black and Latino students, 50% female students. Below are a few primary mentees:

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

- Joshua Child (graduate student, Political Sciences, Florida Atlantic University)   *2018*

advised him for his Directed Independent Study on oscillator models of economic inequality.

○ Nadine Akin (postgraduate student, Biological Sciences, Florida Atlantic University)   *2017-2018*
advised her on the analysis of dynamical behavioral data from a social coordination experiment.

○ Ananda Chowdhury (undergraduate student, Engineering, Florida Atlantic University)   *2015-2016*
advised him on signal processing, and analysis of multiagent interaction data.

○ Daniela Herrera (undergraduate student, Neuroscience, Florida Atlantic University)   *2015-2016*
advised her on 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; used in **Zhang** et al. 2019), and computational geometry (∼150x acceleration; used in **Zhang** et al. *in prep*-a and **Zhang** et al. 2019, SfN). 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, *in prep*-c; Stefanescu et al., *in prep*-d). 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, 2016, *in prep*-c; Stefanescu et al., *in prep*-d), partial differential equations (in particular, weak solutions of pattern formation problems with irregular or moving boundaries, using finite element method), stochastic differential equations (**Zhang** & Saggar, 2020; **Zhang** et al., *in prep*-a, 2019, SfN), algebraic topology (**Zhang** et al., 2020, SfN), and computational geometry (**Zhang** et al., *in prep*-a, 2019, SfN).

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)

March 22, 2021