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

Current Work

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

Faculty Sponsor: Dr. Manish Saggar

Description: The main goal is to develop new computational methods for characterizing neural dynamics that bring new theoretical and empirical insights into the functional organization of the brain. First, I developed a dynamic mean-field model of the brain and show how structural properties at different scales contribute synergistically to the complexity of the whole-brain dynamics (**Zhang** & Saggar, *submitted*). Using this model, I created simulated neural dynamics and BOLD signals with intentionally induced phase transitions; and a computational method was developed to recover the ground-truth transition map from simulated data, integrating a range of techinques from computational topology/geometry (**Zhang**, Chowdhury, & Saggar, *in prep*-a, 2019, SfN). I am currently applying the method to real neuroimaging data recorded from healthy adults and patients with psychiatric disorders, to investigate the difference across populations and individuals in the dynamic organization of the brain.

Doctoral Research

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

Mentors: Drs. Emmanuelle Tognoli & J. A. Scott Kelso

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

Dissertation Description: This dissertation presents a series of research aiming to uncover the dynamic principles underlying coordination patterns formed among multiple interacting agents. 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 subsequently 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).

Earlier Experience

Santa Fe Institute **Santa Fe, NM**
Complex Systems Summer School Projects *2013*
"Simulation of Evolutionary Dynamics and Fitness Landscapes" (with Bruno Pace and Tom Carter); "Unfolding History: Classification and analysis of written history as a complex system, using Wikipedia editing data of networks of historical events" (with D. Massad, E. Omodei, C. Strohecker, Y. Xu, J. Garland and L. F. Seoane).

Center for functional Neuroimaging (CfN), University of Pennsylvania **Philadelphia, PA**
Research Coordinator *2012-2013*
Coordinated fMRI studies on risk taking behavior in healthy adults and adults with cocaine or nicotine addiction (supervised by Drs. Hengyi Rao and John Detre).

Department of Criminology, University of Pennsylvania **Philadelphia, PA**
Master Program Research *2012*
"The role of internet in shaping traditional crime with data from Federal Uniform Crime Report" (supervised by Dr. John Roman).

Jerry Lee Center of Criminology, University of Pennsylvania **Philadelphia, PA**
Research Assistant *2011-2012*
Health, Brains and Behavior Study: the etiology and treatment of conduct disorder, aggression, and psychopathy in 11-12 year old children from the community in Philadelphia (supervised by Dr. Adrian Raine).

Department of Clinical Pharmacology, Peking University **Beijing, China**
Bachelor Thesis *2011*
"A meta-analysis of 59 clinical studies on Ginkgo Biloba leaves injection's effect on Coronary Heart Disease in Chinese population" (supervised by Hengyi Yang).

Department of Psychology & Neuroscience Research Institute, Peking University **Beijing, China**
Research Assistant *2008-2011*
Assisted in data collection and management for human experiments on social cognition and decision making (supervised by Drs. Liqing Zhang and Xiaolin Zhou); assisted in rodent experiments on the neural changes underlying cocaine addiction and withdraw (supervised by Dr. Cailian Cui).

Teaching

Stanford University **California, U.S.**
NVIDIA Deep Learning Institute (DLI) 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 other academic institutes.

Stanford University, Brain Dynamics Lab **California, U.S.**
Instructor *2019–Present*
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".

Publications

Zhang, **M**., & Saggar, M. (*submitted*). Complexity of resting 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. (*under minor revision*). Coordination dynamics: A foundation for understanding social behavior.

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: Characterizing transitions in simulated neural dynamics using topological data analysis.

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**., 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, Cincinnati, Ohio [Now virtual due to COVID-19])

Zhang, **M**., Kalies, W. D., Kelso, J. A. S., & Tognoli, E. (2020, March 30). *Topological portraits of multiscale coordination dynamics.* Retrieved from `https://crowdcast.io/e/neuromatch/8` (the Neuromatch Conference)

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

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**., 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)

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:
Cognitive Processing, Cognitive Systems Research, Biological Cybernetics*, International Journal of Psychophysiology*, PLoS*, Physics of Life Reviews*, Psychological Science*, Journal of Neuroscience Research*. (* assisting Dr. J. A. Scott Kelso)

Mentees

- Rafi Ayub (graduate student, Bio-engineering, Stanford University) *2019–Present*
  advise him on fitting neuroimaging data using nonlinear dynamic models of the brain, 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.

Computational and Other Technical Skills

My expertise in Scientific Computing is accumulated over the years, addressing real computational challenges encountered in my empirical and theoretical research. These challenges are highly diverse and demand me to develop and integrate a broad range of skills, from soldering 2mm capacitors to Applied Mathematics, to push forward innovative scientific projects.

- **Parallel Computing:** CUDA C/C++ (for acceleration based on 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.
- **HPC Cluster:** slurm, shell scripting.
- **Primary Languages for Data Analysis:** MATLAB, C/C++, Python
- **Open & Closed Loop Data Acquisition:** I have designed and built complex experimental apparatus and software where real-timeness is essential and a closed loop component is present (e.g. **Zhang** et al., 2018, *in prep*-c; Stefanescu et al., *in prep*-d). Due to the innovative nature of these experimental paradigms, proprietary hardware is either not flexibility enough to carry out all desired experimental manipulations or do so with unacceptable latency. To build satisfactory experimental equipment, I developed a system of skills surrounding open hardware, which involved electrical engineering of sensors (design printed circuit boards, build surface mount devices), programming micro-controllers (Arduino), and interfacing them with a central software (usually in a PC, written in C/C++).
- **Applied Mathematics & Numerical Methods:** Computation involved in my empirical and theoretical research rely heavily on an understanding of the mathematics underlying the problems and their numerical solutions. By training and by practice, I have developed expertise in numerical solutions of 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; see presentations on Turing patterns and Brusselator dynamics), and stochastic differential equations (**Zhang** & Saggar, *submitted*; **Zhang** et al., *in prep*-a, 2019, SfN); and complementarily, in characterizing such numerical solutions, as well as dynamic patterns in real data, using applied topology/geometry (**Zhang** et al., 2020, *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
- **Founding Member 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)

May 18, 2020