Embodied Cognitive Science Unit

Assistant Professor Tom Froese

(From left to right) Mark James, Finda Putri, Leonardo Zapata, Tom Froese, Brian Morrissey, Kaori Yamashiro, Georgii Karelin, Ani Grigoryan, Stephen Estelle, Kazuma Takada, Natalya Weber
(From top to bottom) Chen Lam Loh, Ivan Shpurov, Shannon Hayashi, Iga Adamska, Tae Morrissey.

Abstract

The scientific mission of Dr. Froese's Embodied Cognitive Science Unit (ECSU) is to develop a comprehensive theoretical framework with which to understand the multi-scalar complexities of the human mind. This broad scope is essential given that even relatively simple examples of intelligent action, such as a handshake, inevitably reach across bodily, mental, social, and cultural domains of investigation.

1. Staff

- Dr. Sebastien LERIQUE, Postdoc
- Dr. Mark JAMES, Postdoc
- Dr. Andres G. MEJIA RAMON, Postdoc
- Dr. Finda Dwi PUTRI, Postdoc
- Dr. Leonardo ZAPATA FONSECA, Postdoc
- Brian MORRISSEY, Technician
- Stephen ESTELLE, Technician
- Rai SATO, Technician
- Natalia KOSHKINA, Research Assistant
- Tae MORRISSEY, Technician

- Ivan SHPUROV, OIST Ph.D. Student
- Chen Lam LOH, OIST Ph.D. Student
- Natalya WEBER, OIST Ph.D. Student
- Shannon HAYASHI, OIST Ph.D. Student
- Kazuma TAKADA, OIST Doctoral Candidate
- Georgii KARELIN, OIST Doctoral Candidate
- Mats-Helge STRONMBERG, Research Intern Student
- Aisha BELHADI, Research Intern Student
- Hinako IREI, Research Intern Student
- Kaori YAMASHIRO, Research Unit Administrator

2. Collaborations

2.1 EEG-based stratification of patients with depression

- Description: ECSU is collaborating with Dr. Tomáš Páleníček and his PhD student Marek Nikolič in the context of their ongoing prospective study of the efficacy of psychedelic therapy for treating depression, specifically psilocybin. The aim is to test whether levels of neural entropy of EEG resting state recordings can be used for stratifying patients according to the severity of their depression. The ambition is to develop a method that can help to identify those patients with atypically low levels of neural entropy who are most likely to benefit from undergoing psychedelic therapy. The implementation of this analysis is ongoing in collaboration with Dr. Pedro Mediano from Imperial College.
- Type of collaboration: Joint research
- Researchers:
    - Dr. Tomas Palenicek, National Institute of Mental Health, Czech Republic
    - Marek Nikolic, National Institute of Mental Health, Czech Republic

2.2 fMRI-based stratification of patients with depression

- Description:

  With Dr. Taro Suwa, we are planning to analyze a dataset consisting of 90 fMRI resting state recordings of patients with depression that were taken before and after three types of treatment, including electroconvulsive therapy (ECT), cognitive behavior therapy, and conventional antidepressant medication. We are also considering using ECSU's mobile EEG systems to record patients resting state activity before and after ECT sessions. In line with irruption theory, the aim is to test whether patients exhibit more neural entropy after compared to before their treatment. The method for this analysis is being developed in collaboration with Dr. Pedro Mediano from Imperial College.

  With Dr. Masanori Isobe and his PhD candidate Momoka Taniguchi, we are planning to conduct a pilot perceptual crossing experiment with adolescents suffering from anorexia in interaction with neurotypical partners. The aim is to investigate whether these pairs exhibit altered social interaction dynamics, and whether the patients show atypical sensitivity to social contingency. We expect the perceptual crossing experiment to reveal these alterations because anorexia is characterized by an unusually elevated concern

for how one's body is perceived by others, which is a concern that is also raised by cooperative solutions to the task of mutual recognition during the perceptual crossing experiment.

- Type of collaboration: Joint research
- Researchers:
    - Dr. Taro Suwa, Kyoto University Hospital, Japan
    - Dr. Masanori Isobe, Kyoto University Hospital, Japan
    - Momoka Taniguchi, Kyoto University Hospital, Japan

2.3 Social contingency without social cues in infant-caretaker interaction

- Description: ECSU is collaborating with Dr. Sho Tsuji's Baby Lab at the International Research Center for Neurointelligence (IRCN) of the University of Tokyo on perceptual crossing experiments for pre-verbal infants. The guiding motivation is to disentangle the factors that could cause real-time social interaction between infants and their caretakers to enhance infant language learning. A prevalent confound in the literature is the presence of both social cues and social contingency in the social interaction condition, which leaves it unclear whether either one or both are contributing to the outcomes. The perceptual crossing experiment being developed by ECSU is generally suitable for the purpose of clarification, as it provides participants the possibility of responding to social contingency in the strict absence of pre-given social cues.

  However, for making it usable with pre-verbal infants the perceptual crossing setup had to be significantly modified to make it more intuitive: the haptic interface was replaced by an interface combining eye-tracking with visual feedback on a screen. Initial studies demonstrated the feasibility of this vision-based perceptual crossing setup for studying interaction between infants and adults. Analyses of the results of the first studies are ongoing, and preliminary results indicate that infants are indeed sensitive to the social contingency of the adult's eye-movement driven visual stimuli. The next step is to test whether infants' sensitivity to visual social contingency facilitates social learning, such as the acquisition of an artificial language.

- Type of collaboration: Joint research
- Researchers:
    - Dr. Sho Tsuji, University of Tokyo, Japan

2.4 Qualitative analysis of user experience in mediated social interaction

- Description: ECSU is collaborating with Prof. Dr. Johannes Wagemann, an expert in phenomenology and qualitative methods, and has completed a full perceptual crossing experiment at his institution with healthy young adults. One aim of this study is for Prof. Dr. Wagemann to conduct a systematic qualitative analysis of participants' subjective experience of task performance. This corpus of subjective

reports that was collected looks promising, and is expected to provide a much richer perspective on participants' social experience than the Likert scales used in the current ECSU-PCE dataset.

A second aim is to test whether any preexisting social bonds of a pair of participants will predispose them to better performance because of an enhanced sensitivity to each other's social contingency. In the ECSU-PCE dataset special care was taking that the pairs of participants remain anonymous to each other until the end of the experiment. In this new behavioral experiment the extent of social familiarity was explicitly recorded, making it possible to assess how social relationships shape social interaction.

- Type of collaboration: Joint research
- Researchers:
    - Dr. Johannes Wagemann, Alanus University of Arts and Social Sciences, Germany

2.5 Quantitative analysis of the dyadic level in social interaction

- Description: ECSU is collaborating with Dr. Iwin Leenen from UNAM's Faculty of Psychology to develop a sophisticated statistical model of the various kinds of data that are collected in perceptual crossing experiments. The aim is to use hierarchical Bayesian models to identify the factors that most contribute to variability in the subjectively reported clarity of social awareness. The current focus is to expand the existing model so as to include variables derived from recordings of EEG, ECG, EDA, and respiratory dynamics.
- Type of collaboration: Joint research
- Researchers:
    - Dr. Iwin Leenen, UMAN, Mexico

2.6 Complex systems approach to the origins of social complexity

- Description: ECSU is collaborating with Prof. Charles Stanish, Executive Director of the Institute for the Advanced Study of Culture and the Environment. Prof. Stanish is expert on ancient South American civilizations, with a special focus on the region around Lake Titicaca, a high-altitude lake in the Andes mountains extending into Peru and Bolivia. The aim is to evaluate to what extent the self-optimization model can help to explain the prehistoric settlement patterns and political consolidation in the Lake Titicaca Basin.

  Of particular note is the long-term and highly conserved tradition of monumental ceremonial sites characterized by their sunken court architecture, which eventually proliferated in the Basin. This likely constituted a ritually integrated region-wide social network. However, the prevalence and importance of these sunken courts sites declined in subsequent centuries, as the region's social complexity became consolidated to unprecedented extent at one ceremonial site, namely Tiwanaku.

  Previous modeling work of this emergence of state-level social complexity has focused on the possible mechanism of culture evolution, which would assume a primarily competitive process between settlements.

In contrast, the self-optimization model proposes that synchronized ritual resets across a regional social network, centered on the sunken court sites, could have unleashed novel network-level capacities, including the spontaneous generalization toward unprecedented forms of more global social coordination. Ideally, archaeological evidence and field work should be able to arbitrate between these two abstract models of the region's transition from stateless to state-level social complexity.

- Type of collaboration: Joint research
- Researchers:
    - Prof. Charles Stanish, University of South Florida, USA

3. Activities and Findings

The novelity of ECSU's approach lies in its broad style of interdisciplinary research:

- Firstly, theoretical contributions are evaluated in terms of the extent to which they facilitate research across domains, rather than whether they come from the humanities or natural sciences.
- Second, although primarily theory-driven, ECSU integrates its theory development into its own lines of computer-, lab-, and field-based work.
- Third, the empirical studies tend to draw on custom-built, high-resolution research platforms, which are often designed in a tight engineering prototyping cycle.
- Fourth, and most importantly, an epistemic stance of "diversity in unity" is cultivated to facilitate interdisciplinary integration: care must be taken when studying cross-boundary interactions, such as mind-body, self-other, and self-collective.

A breakthrough discovery by ECSU has been that approaches to eliminating these boundaries can be productively replaced by an acceptance of the uncertainty resulting from the irreducibility inherent in such cross-boundary relations, which is amenable to quantification. Future cognitive science could quantitatively test if its long-standing anomalies, as epitomized by the hard problem of consciousness, may actually be indications of an irreducible diversity intrinsic to human nature.

ECSU is leading the way with the development of "irruption theory" and its application to classic problems across scales:

(1) the problem of mental causation (individual agency),

(2) the problem of other minds (specifically the "we"), and

(3) the problem of collective action (society).

4. Publications

4.1 Journals

Peer-reviewed Papers

1. **Sangati, E.,** Lobo, L., **Estelle, S.,** Sangati, F., Tavassoli, S., & **Froese, T.** (2023). Uncovering the Role of Intention in Active and Passive Perception. PROCEEDINGS OF THE ANNUAL MEETING OF THE COGNITIVE SCIENCE SOCIETY, 45: 663 – 670, https://escholarship.org/uc/item/6wj762mq

2. **Takada, K**., Kumasaki, N., **Froese, T.**, Shibata, K., Nishida, J., & Kasahara, S. (2023). ShadowClones: an Interface to Maintain a Multiple Sense of Body-space Coordination in Multiple Visual Perspectives. doi: 10.1145/3582700.3582706
3. **Froese, T.**, **Weber, N.**, **Shpurov, I.**, & Ikegami, T. (2023). From autopoiesis to self-optimization: Toward an enactive model of biological regulation. Biosystems, 230, 104959. DOI: 10.1016/j.biosystems.2023.104959
4. Munson, J. L., Scholnick, J., **Mejía Ramón, A. G.,** & Paiz Aragón, L. (in press). Beyond House Size: Alternative Estimates of Wealth Inequality in the Ancient Maya Lowlands. ANCIENT MESOAMERICA. doi: 10.31235/osf.io/kwe8m
5. **Froese, T.** (2023). Irruption Theory: A Novel Conceptualization of the Enactive Account of Motivated Activity. ENTROPY 25(5): 748 doi: 10.3390/e25050748
6. Sheets, P. D., & **Mejía Ramón, A. G.** (in press). Following the Silencio Processional Path Eastward. VÍNCULOS: REVISTA DE ANTROPOLOGÍA DEL MUSEO NACIONAL DE COSTA RICA.
7. Froese, R., Coro, G., Palomares, M. L. D., Bailly, N., Scotti, M., **Froese, T.**, Garilao, C., & Pauly, D. (2023). A simple framework for the exploration of functional biodiversity. CYBIUM, 47(3): 271-286. doi: 10.26028/CYBIUM/2023-003
8. **James M. M.** & Leader J. F. (2023) Do digital hugs work? Re-embodying our social lives online with digital tact. FRONTEIRS IN PSYCHOLOGY 14:910174. doi: 10.3389/fpsyg.2023.910174

Other Papers

1. **Mejía Ramón, A. G.** (2023). La Transición Neolítica en el Sur de Centramérica. SOCARXIV. doi: 10.31235/osf.io/jhxcr
2. **Froese, T.**, & **Sykes, J.** (2023). La pragmatique, l'inscription corporelle, et l'efficacité de l'expérience vécue: évaluer les principes fondamentaux de la neurophénoménologie Varélienne. PSYARXIV. doi: 10.31234/osf.io/gkxbz
3. **Mejía Ramón, A. G.** (2023). Efficient Functions for Energetic Least-Cost Analysis over Land and Water in the lbmech package for R. BIORXIV. doi: 10.1101/2023.07.09.548254

4.2 Oral and Poster Presentations

1. **Froese T**. *Mindscapes*. Culture, AI, and Human Minds Workshop, Australia, March 12, 2024.
2. **Froese T**. *The enactive account of motivated activity and the hard problem of efficacy (HPE): Artificial life meets the physics of life*, ALIFE 2023, City Name, Hokkaido, Japan, July 28, 2023.
3. **Froese T**. *Making mind matter: Introducing irruption theory*, 1st Symposium on the Philosophy of Computing, Mexico, December 4-8, 2023.
4. **Froese T**. *Making Mind Matter,* ComCo2023, Germany, October 10, 2023.
5. **Froese T**. *Doing More with Less: Social cognition beyond the brain*, 4th Summer School on Social HRI, Poland, September 19, 2023.
6. **Froese T**. *Why does cognition feel effortless?*, Proceedings of International Symposium on Predictive Brain and Cognitive Feelings, Tokyo, Japan, July 1, 2023.
7. **Froese T**. *Irruption Theory of Consciousness*, Workshop on Synchrony in the Brain: Time, Consciousness, and Life, Spain, May 27, 2023.

8. **Froese T**. **Mejía Ramón, Andrés G**. *The Dawn of Mesoamerica*, Special Exhibition Ancient Mexico, Japan, July 20, 2023.
9. **Froese T**. *Irruption Theory*, Sussex COGS Research Seminar, UK, June 27 2023.
10. **Froese T**. *Using Irresolvable Tensions to Drive System Self-Optimization*, Morpho Talks, UK, June 24, 2023.
11. **Weber, N.** On the Use of Associative Memory in Hopfield Networks Designed to Solve Propositional Satisfiability Problems, 2023 IEEE SSCI conference, Mexico, December 8, 2023.
12. **Karelin G.** *Complexity from simple form: 3D-printed aperiodic monotiles and Cheerios effect*, CCS 2023, October 18, 2023.
13. **Putri F,** Leonardo Zapata-Fonseca, Sébastien Lerique, Stephen Estelle, Shannon Hayashi, Tae Morrissey, Tom Froese, *Behavioural and Brain Activity Features during Perceptual Crossing Interaction Between Two Individuals,* IHSRC 2023 Tokyo, Japan, August 11, 2023.
14. Toshihiro AJIOKA, Futa MAEDA, Kirty TSUJITA, Jinsuke MORITA, **Kazuma TAKADA**, Ryoichi ANDO, Midori KAWAGUCHI, Kouta MINAMIZAWA. *Investigation of daily life design with robotic avatars through fieldwork and proposals for future applications,* SIG TX Tokyo, Japan, November 13, 2023
15. **Takada K.** *Investigating the Influence of Preemptively Driven Interfaces on the Sense of Agency*, Young Perceptionists' Seminar 2023, September 4-5, 2023.
16. **Takada K.** *Introduction to Cognitive Ecology*, *Elucidating life from an ecological perspective. "Self" Mechanisms are Diversified by Computer,* The 71st Annual Meeting of the Ecological Society of Japan, March 2024.
17. **James M.** *Applying insights from embodied cognitive science to the design of health behaviours*, Chinese Academy of Science, China, November 30, 2023.
18. **James M.** *Laying down a path to thrive in*, University of Edinburgh, May 22, 2023.

5. Intellectual Property Rights and Other Specific Achievements

Nothing to report

6. Meetings and Events

6.1 ECogS 2023: What is Well-being? Comparative Perspectives

- Date: November 13-17, 2023
- Venue: OIST Sydney Brenner Lecture Hall
- Speaker:
  Dr. Daniel Hutto (University of Wollongong
  Dr. Elizabeth Torres (Rutgers University)
  Dr. Guillaume Dumas (University of Montreal)
  Dr. Reiko Mazuka (Riken Center for Brain Science)
  Dr. Tetsushi Nonaka (Kobe University)
  Dr. Tomoko Isomura (Nagoya University)
  Dr. Jessica Munson (Lycoming College)
  Dr. Ines Hipolito (Macquarie University)

Dr. Mark Miller (Monash University)

Dr. Chritian Schütz (University of British Columbia)

Dr. Kris Nielsen (Victoria University of Wellington)

Dr. Katsunori Miyahara (Hokkaido University)

6.2 Extending the Scientific Study of Consciousness by an Empirical-Introspective Method

- Date: April 3, 2023
- Venue: C700, OIST Campus
- Speaker:
    - Dr. Johannes Wagemann (Alanus University)

6.3 Enactive Psychiatry and the integration problem: beyond dyadic interactions

- Date: June 8, 2023
- Venue: C209, OIST Campus
- Speaker:
    - Mads J Dengso (University of Wollongong)

6.4 Scaffolded emotions

- Date: December 13, 2023
- Venue: C209, OIST Campus
- Speaker:
    - Dr. Giovanna Colombetti (University of Exeter)

6.5 Wayshaping Workshop

- Date: March 21, 2024
- Venue: C740, OIST Campus
- Participants:
    - Dr. Jules Yim (Cynefin Company and The Cynefin Centre)
    - Dr. Mushfiqa Jamaluddin (Futurist and Coach)
    - Dr. Nicolas Gravel (Freie University Berlin)
    - Dr. Aisha Belhadi (Manama Medical Centre)
    - Marek Nikolic (National Mental Health Institute)

7. Other

Nothing to report.