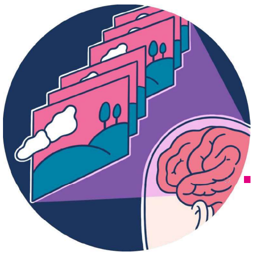
Moonshot Research and Development Program Goal 1 Kanai Project

IoB Core Technology

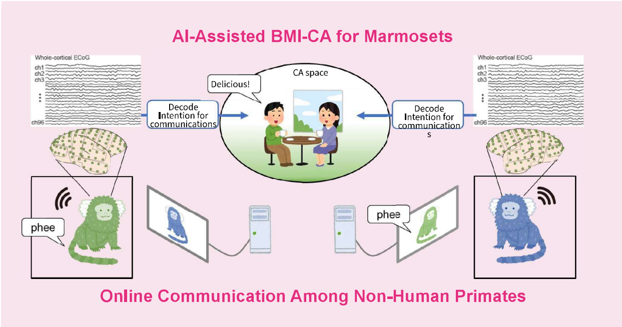


Core Technology for Intent Communication

Misako Komatsu, Ph.D., Specially Appointed Associate Professor, Institute of Integrated Research, Institute of Science Tokyo

Overview

Komatsu Group develops an intent-communication environment for animals and seeks key features required for intention decoding by applying AI to invasive, non-invasive, and contact-free signals in an integrated manner. Through recording signals ranging from highly informative invasive neural activity to fully contactless modalities, we can systematically evaluate the required level of invasiveness for a given application. The project provides the core IoB technologies toward realizing a cybernetic avatar with brain–machine interface capabilities (BMI-CA).



Shaping the future of primate research

~Large-Scale Neural Dynamics in Freely Behaving Primates~

Komatsu Group is developing invasive brain–machine interfaces (BMIs) using nonhuman primates, common marmosets. In particular, we focus on decoding contents of thoughts and intentions, and on delivering the information directly into the brain.

Traditionally, primate neuroscience requires restraining the animal during neural recording, which limits the observation of natural behavior and restricts the duration of experiments. We were the first in the world to successfully record large-scale neural activity across the entire lateral hemisphere of freely moving marmosets (Fig. A). This breakthrough enables long-term, high-resolution recording of neural activity during natural movements and vocal communication between marmosets. Acquiring high-precision neural data at large scale is a fundamental technological component for all BMI development.

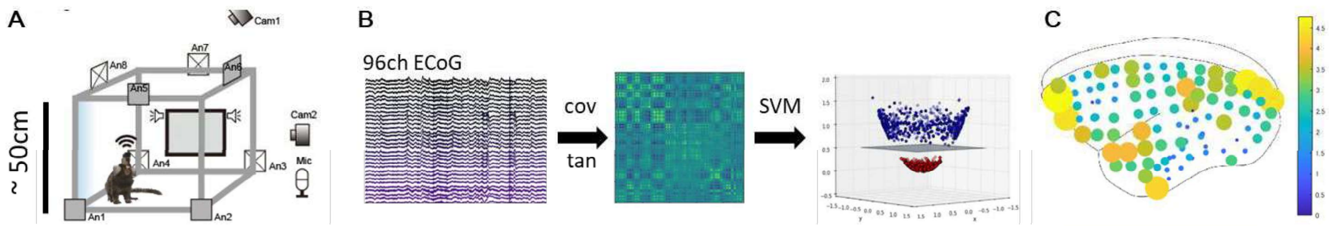
Beyond BMI research, primate models are essential for understanding advanced human brain functions—such as empathy, consciousness, and language—as well as the mechanisms underlying psychiatric disorders. In recently, ethical concerns have reduced primate research in Europe and the United States. However, our newly developed technology for large-scale neural recording in freely behaving marmosets imposes minimal burden on the animals and is poised to become a new standard in future primate neuroscience.

Higher brain areas contribute to decoding multimodal intentions

BMIs are expected to help people who are unable to move their bodies due to illness or injury operate prosthetic limbs or communicate their thoughts when speech is impaired. However, current BMIs often handle only limited types of actions. To broaden their applications, BMIs must accurately decode multiple modalities of intention, such as those related to movement and vocalization.

Using our large-scale neural recording technology in marmosets, we captured extensive brain activity during natural vocal communication and spontaneous movement. At the same time, we recorded behavior with cameras and vocalizations with microphones, and collaborated with the Sasai Group to develop a decoder which predict body movements and vocal call types from preceeding neural activity. We found that higher-order cortical regions, known as association areas, play a key role in decoding both future movements and vocalizations. This suggests that the brain may process motor and vocal intentions in overlapping regions, and that such intentions can be extracted directly from neural activity.

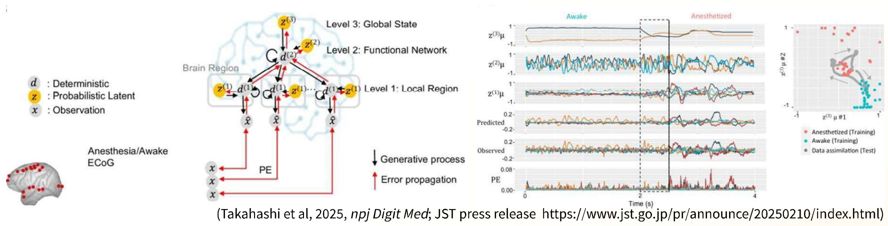
These findings represent an important step toward more advanced BMIs. If multiple intentions could be decoded simultaneously from brain activity, individuals who have difficulty moving or speaking could use prosthetic limbs more naturally and communicate their thoughts more freely.



A) Wireless cortical-wide ECoG system for free-moving primates B) Decoder architecture C) Cortical association areas contribute to multimodal decoding. (Komatsu et al, 2023, *Proc 10th Int BCI Meeting*)

Digital Twin Brain Simulator

We are developing methods to estimate brain network structure from cortical electrophysiological signals and to simulate neural activity based on these estimates. In a collaborative study with Dr. Yuichi Yamashita (National Center of Neurology and Psychiatry) under Moonshot Goal 3, we created a new digital twin brain simulator that performs real-time simulations of cortical activity in nonhuman primates.



(Takahashi et al, 2025, *npj Digit Med*; JST press release https://www.jst.go.jp/pr/announce/20250210/index.html)

This simulator models latent neural states across multiple hierarchical levels of the brain and generates high-precision virtual cortical signals. Moreover, by using data assimilation techniques—updating latent-state estimates in real time based on prediction–observation discrepancies—it provides simulations that continuously reflect the brain's current functional state.

Using this model, we demonstrated the feasibility of conducting virtual drug-effect simulations and estimating functional neural networks underlying ECoG signals. These results highlight the potential of digital twin brain technologies for both basic neuroscience and brain–machine interface applications.

This research, which aims to elucidate individual-specific mechanisms of neural information processing in real time, holds strong potential for future applications in personalized medicine. Looking ahead, we plan to develop comprehensive models that integrate multiple sensory modalities—including exteroceptive signals (e.g., vision and audition), interoceptive signals (e.g., cardiac and respiratory sensations), and proprioceptive signals (e.g., joint position and muscle sense)—in addition to brain activity. By doing so, we aim to reproduce the altered information-processing dynamics characteristic of psychiatric and neurological disorders in a unified and biologically grounded manner.

Future Prospects

We have found that a single device can predict multiple intentions, offering a clue toward a next-generation BMI based on a new concept. By accumulating more data, we aim to develop a BMI that enables diverse intention-driven behaviors with electrodes placed in only part of the brain.

Misako Komatsu, Ph.D.

Specially Appointed Associate Professor, Institute of Integrated Research, Institute of Science Tokyo

After completing her B.S. in Physics at Tokyo Metropolitan University, she obtained her Ph.D. in Science from Tokyo Institute of Technology. She subsequently worked as a Research Associate and Researcher at RIKEN, where she conducted studies using neural networks and electrophysiology. She is currently a Specially Appointed Associate Professor at the Institute of Innovative Research, Institute of Science Tokyo. She has developed large-scale cortical ECoG recording techniques in marmosets and aims to elucidate large-scale information processing mechanisms in the primate brain.

Internet of Brains