

R&D item

1. Interpreting mental states through brain and autonomic nerves

Progress until FY2023

1. Outline of the project

In our R&D Item 1, we develop **technologies to interpret our mental states through brain and autonomic nervous activities**. That will broaden our ways of non-verbal communication.

The primary task of our R&D Item 1 is to instantiate **sensing technologies worthy of use in everyday communication**. For instance, fMRI offers rich information yet is costly and time-consuming; polygraphs are handy yet are far from precise in decoding one’s mental state. Interpretation of one’s mental state through electroencephalography (EEG) has yet to be established.

Here, our R&D Item 1 aims to develop **precise and**



Rich, but expensive



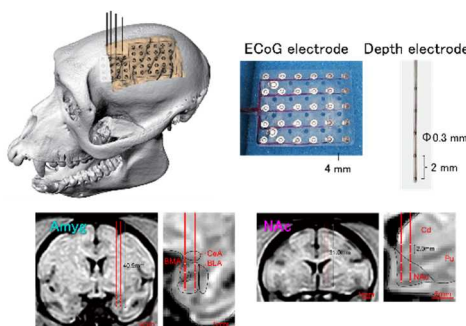
Handy, but inaccurate

multi-dimensional mind sensing based on brain and autonomic nervous activities combined with behavioral data. Our goal is to offer a reliable mind-interpretation method suitable for everyday use.

2. Outcome so far

1. Established a method for simultaneously recording both depth and surface EEG signals in monkeys

2. Clarified the importance of the interaction between the vagus nerve and brain activity in maintaining mental states
3. Constructed a machine learning model to distinguish aversive states
4. Discovered novel EEG characteristics associated with autism tendencies

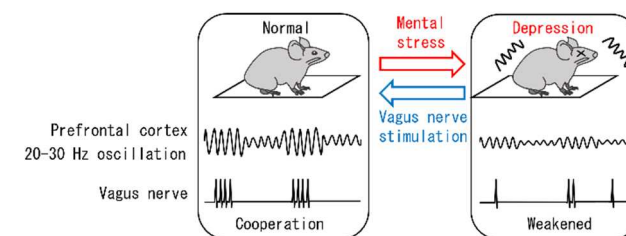


Outcome 1 — illustrative summary

Image provided by Prof. Ken-Ichiro Tsutsui (Tohoku U)

Outcome 1: We established a method for simultaneously recording brain activity from deep and surface areas in monkeys. Utilizing this approach, we are identifying the brain regions where mental states manifest in activity and advancing the establishment of basic principles for reading mental states from brain activity.

Outcome 2: We found that the vagus nerve, which transmits information from the organs to the brain, interacts with brain activity to shape normal emotions. This is a significant discovery for understanding mental states such as stress and anxiety.



Outcome 2 — illustrative summary

Source: <https://www.tohoku.ac.jp/japanese/2024/01/press20240110-02-stress.html>

Outcome 3: We constructed a machine learning model to differentiate between the states of mice (normal or aversive) based on brain activity recorded from both deep and surface regions of the brain.

Outcome 4: We discovered novel frequency characteristics of EEG, derived from the analysis of EEG data obtained from humans during rest, which serve as new indicators related to autism tendencies.

So far, we are conducting researches to unravel the relationship between neuronal activities and one’s mental state by combining animal and human experiments.

3. Future plans

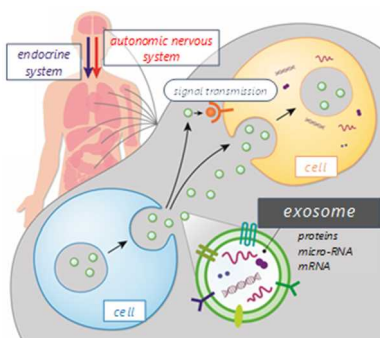
Based on these animal/human researches, our R&D Item 1 will further develop sensing technologies to interpret human mental states reliably. We also plan to combine these findings with our R&D Item 2 (exosomes) to offer a multi-dimensional interpretation of one’s mental state. (Tohoku U: K.I. Tsutsui, T. Sasaki & NIPS: K. Kitajo)

2. Interpreting mental states through exosomes

Progress until FY2023

1. Outline of the project

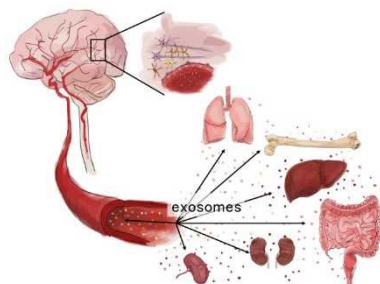
In R&D item 2, we develop **technologies to evaluate our mental states through exosomes in our body fluid**. Information of mental states will be provided to Jizai-hon-yaku-ki system, and used to optimize the quality of communication aids.



The endocrine and autonomic nerve systems link our physical and mental states. Exosomes are believed to play an additional role in this body-mind relationship.

Our body fluid (like saliva and blood) contains small particles, **exosomes**, produced in cells of various organs. One of their functions is to manage metabolic waste. But they also have another interesting role — intercellular communication. Increasing attention has been paid to this function of exosomes, as they might work as biomarkers of bodily and neurodegenerative diseases.

It is pointed out that the uptake of exosomes into the brain is connected to (changes in) the state of the brain. However, **little is known about the relationship between one's exosomes and mental state**.



- 30–150 nm
- Every cell produces exosomes
- Approx. $<10^{12}$ in 1 mL plasma
- Waste management and intercellular communication

Illustrative summary of exosomes

Source: https://www.rcast.u-tokyo.ac.jp/ja/research/people/staff-hoshino_ayuko.html

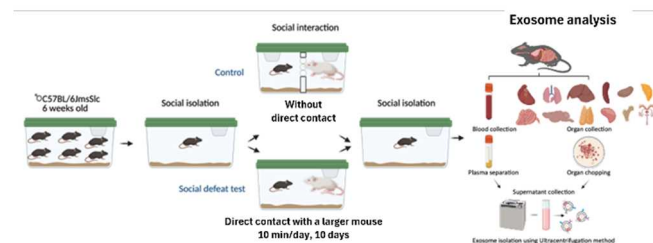
Our R&D item 2 aims to unravel the interactions of the brain and other organs mediated by exosomes through biochemical examinations and AI-based data analysis.

2. Outcome so far

1. Suggested the possibility of significant changes in exosome composition due to social stress
2. Discovered differences in exosomes between individuals with ASD and Neurotypical Individuals
3. Successfully distinguished between individuals with ASD and neurotypical individuals based on exosome protein composition

Outcome 1: Using mice, we discovered that blood exosomes undergo dynamic changes in response to social stress. Particularly noteworthy is the increased production of exosomes from the brain. This finding holds significant promise as a clue to explore the relationship between exosomes and mental state.

Outcome 2: We compared the molecular (microRNA)



Outcome 1 — illustrative summary

Image provided by Prof. Ayuko Hoshino (U Tokyo)

composition of plasma exosomes between individuals with ASD and neurotypical individuals. We identified eight significantly different molecules between the two groups, raising expectations for their potential use as biomarkers.

Outcome 3: We compared the protein composition of the exosomes from individuals with ASD and neurotypical individuals. We found differences in complement molecules related to the immune system, and through machine learning of the results, we could distinguish between the two groups.

We are advancing basic research to unravel the interactions between exosomes and brain function.

3. Future plans

Our R&D item 2 will further investigate the interactions of brain and other organs mediated by exosomes.

Furthermore, we aim to develop technology to interpret mental states multidimensionally by integrating information from exosomes with brain activity and other physiological signals (R&D Item 1).

(U Tokyo: A. Hoshino, A. Nasiri Kenari)

3. Functions of Jizai Hon-yaku-ki

Progress until FY2023

1. Outline of the project

In R&D Item 3, we aim to develop *Jizai Hon-yaku-ki* itself and, specifically, its **key functions necessary to support our everyday interactions**.

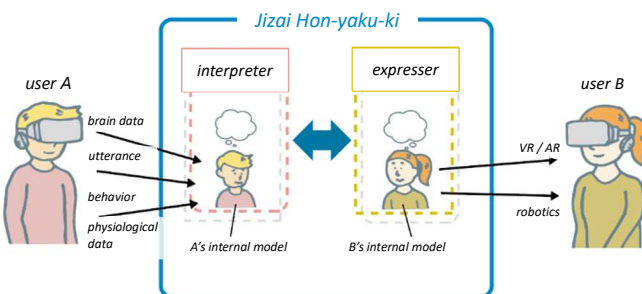


Illustration of *Jizai Hon-yaku-ki* (when A speaks to B)

Jizai Hon-yaku-ki consists of two components: an **interpreter** “reads” the user’s mental state and an **expresser** “conveys” it to another user.

The primary task of this R&D Item is to develop the two parts with **sensitivity to the diversity of contexts and our personalities**, so that *Jizai Hon-yaku-ki* can assist our mundane communication.

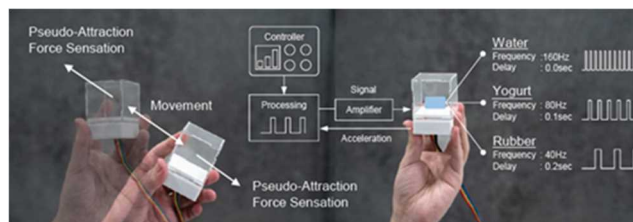
2. Outcome so far

1. Developed tactile feedback devices to create various textures
2. Developed a system to share visual perspectives with

others

3. Developed a computational model to infer emotional states from speech
4. Verified the importance of facial information from speakers for understanding unclear speech
5. Devised a method to evaluate the naturalness of conversations

Outcome 1: We have developed a new device that allows for the manipulation of various vibration parameters to create a sensation similar to the movement of materials felt at the fingertips. This device can serve as a foundational technology for tactile interaction with others and communication assistance. Currently, we are preparing to conduct user experience evaluations targeting individuals with developmental disabilities as part of R&D Item 4.



Outcome 1 — tactile feedback device with adjustable texture sensation

Image provided by Prof. Masahiko Inami (U Tokyo)

Outcome 2: We have developed a system using head-mounted displays that enables users to experience viewing things from others’ perspectives. Sharing perspectives can serve as a useful function for communication support. Currently, we are verifying when shared perspectives, such as viewing the same object as others or synchronizing with



Outcome 2 — sharing the perspective of others

Image provided by Asst. Prof. Hiroto Saito (U Tokyo)

heartbeats, affect the user's emotional state.

Outcome 3: We have developed a model to estimate emotions from voice and found synchronized emotional changes between infants and caregivers using their voice, aiding interpretation device development for diverse users.

Outcome 4: We have found that listening to unclear speech while observing the speaker's face allows for more accurate comprehension. This finding is valuable for developing devices aimed at better understanding others' words.

Outcome 5: We have devised a new method using large-scale language models (GPT) to assess conversation continuity. This is valuable for developing interpretation devices, reflecting diverse personalities and contexts.

3. Future plans

We will continue developing an interpreter and an expresser that are sensitive to contexts and personalities.

In parallel, we attempt to develop a proof-of-concept product of *Jizai Hon-yaku-ki* by incorporating the findings from the other five R&D Items.

(U Tokyo: Y. Nagai, M. Inami, H. Saito,

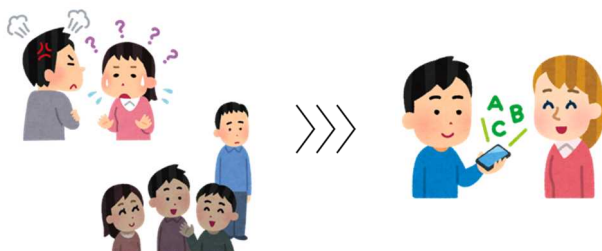
Tokyo Metropolitan U: F. Homae, Tohoku U: M. Hariyama)

4 / 5. Social implementation of Jizai Hon-yaku-ki (neurodiversity / education)

Progress until FY2023

1. Outline of the project

In R&D items 4 and 5, we analyze and solve problems in Jizai Hon-yaku-ki implemented in the following two contexts. R&D item 4 focuses on using Jizai Hon-yaku-ki as **supported communication, especially involving people with developmental conditions**. While our R&D project is not dedicated specifically to disabled people, it may have the social benefit of improving our communication while respecting neurodiversity.



Communication problems can be alleviated by Jizai Hon-yaku-ki.

R&D item 5 addresses **classroom use of Jizai Hon-yaku-ki for education**. Along with the MEXT initiative to install up-to-date devices for students to utilize in their study, our R&D item 5 aims at providing proof-of-concept cases of educational application.

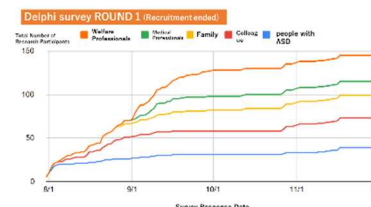
Close engagement with the relevant parties (like those with developmental conditions, their supporters, children, and teachers) is necessary from the very beginning of our R&D. The common task of these two R&D items is to incorporate their viewpoints to make Jizai Hon-yaku-ki useful to

them.

2. Outcome so far

1. Conducted a Delphi survey to deliver stakeholders' voices to researchers and developers
2. Acquisition of EEG/behavior data from individuals with developmental disabilities

Outcome 1: We collected opinions on communication difficulties and ideas for features and functions to be included in the devices from stakeholders and those around them. The issues were classified into four categories, and the ideas were organized accordingly. In addition to the need to understand others, the need to "understand one's own internal state (mind and body)" was also identified. By sharing and discussing these needs with the research and development team, we are considering which features and functions should be prioritized for inclusion in the "Jizai Hon-yaku-ki."



Communication Difficulties Between People with ASD and Neurotypical Individuals in the Workplace

1. Difficulties in Interpersonal Relationships
 - 1.1 Accessibility of Communication Forms
 - 1.2 Discrimination, Prejudice, and Misunderstanding
 - 1.3 Trauma and Transference
2. Difficulties Due to Sensory Sensitivities
3. Emotional and Physical Difficulties
 - 3.1 Managing Emotions and Health
 - 3.2 Self-Understanding, Excessive Self-Blame, and Excessive Demand for Accommodation
4. Difficulties in Job Performance
 - 4.1 Easily Surprised by Unexpected Situations
 - 4.2 Difficulty Grasping a Big Picture
 - 4.3 Inability to Meet Deadlines
 - 4.4 Challenges with Multitasking and Automation

Ideas for Elements/Functions into Jizai Translation Device Corresponding to Theme Analysis (Partial List)

1. Difficulties in Interpersonal Relationships
 - Providing model answers for words and emotions
 - Analyzing facial expressions and words (speech reading, lip reading, facial expression analysis)
 - Transcribing speech to text
2. Difficulties Due to Sensory Sensitivities
 - Fostering a workplace culture through appropriate education and training to enhance understanding of minorities, including neurodiverse individuals, etc.
3. Emotional and Physical Difficulties
 - Adjusting auditory sensitivity, etc.
 - Displaying physical stress levels
 - Monitoring physical and brain states, etc.
4. Difficulties in Job Performance
 - Monitoring physical and brain states, etc.
 - Supporting verbalization of thoughts and organization of thinking, etc.

Outcome 1 — summary of interim Delphi survey results

Outcome 2: Using the system we have developed that simultaneously records EEG and behavioral data from multiple perspectives with minimal burden, we have measured various physiological and behavioral data from individuals with developmental disabilities. In addition to scalp EEG, we are recording electromyograms (EMG), electrocardiograms (ECG), respiration, and video recordings of behavioral data during developmental psychological assessments. This allows for a more comprehensive analysis of the users' brain activity during interpersonal communication.

So far, we are engaging with potential users — especially those with developmental conditions — in various ways to lead our R&D better.



Outcome 2 — measurement scene of physiological data (64ch EEG and autonomic indicators)

3. Future plans

We continue the ongoing engagement with users in every stage of our R&D, from basic research to trial and assessment of the products.

Our R&D project also plans to build partnerships with educational sectors to proceed to trial implementations of Jizai Hon-yaku-ki for educational use. (Tokyo U: S. Kumagaya, Showa U: M. Nakamura, Tohoku U: K.I. Tsutsui)

6. Ethical, legal, and social issues (ELSI) involved in Jizai Hon-yaku-ki

Progress until FY2023

1. Outline of the project

In R&D Item 6, we **analyze the ethical, legal, and social issues (ELSI) involved in this R&D project** to make Jizai Hon-yaku-ki socially acceptable.



Privacy issues may be salient in Jizai Hon-yaku-ki.



Protecting participants is our utmost priority.

Since Jizai Hon-yaku-ki builds on emerging biology and neuroscience, it may cause various ethical concerns regarding **privacy** and **unfamiliar forms of communication**. Also, our highest priority is to protect the rights of participants in our R&D. Jizai Hon-yaku-ki should reduce — rather than worsen — **discrimination against people with developmental conditions**.

The primary task of our R&D Item 6 is to investigate these potential issues from theoretical and practical standpoints. This sub-project also aims to provide future-oriented insights into neurodiversity and (supported) communication.

2. Outcome so far

1. ELSI Review Meeting with External Experts
2. Exchanged opinions and hearing and analyzing concerns with scholars
3. Deliberation on the nature and method of Jizai Hon-yaku-ki and the current status of related international regulatory frameworks

Outcome 1: In March 2023, an ELSI review meeting was held in Sendai. We invited Dr. Saeko Aketani (Tokyo U), who specializes in risk management related to conflicts of interest and research and practice of data utilization, and Dr. Ei-

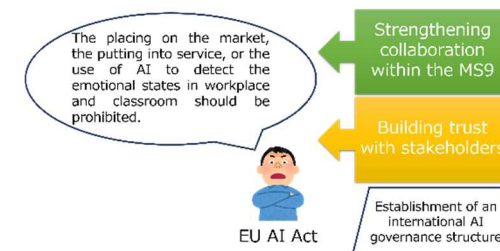


Outcome 1 — The first ELSI review meeting

Source: <https://jizai2050.org/inside-story/870>

suke Nakazawa (Tokyo U), who specializes in bioethics. They engaged in in-depth discussions on various scenarios for the use of Jizai Hon-yaku-ki. The meeting revealed the need for further deliberation to implement Jizai Hon-yaku-ki, and we are planning a next ELSI review meeting.

Outcome 2: At the project meetings held in September 2023 and March 2024, we discussed with scholars. Following research presentations at these meetings, we analyzed



Outcome 3 — Current status of international regulations related to Jizai Hon-yaku-ki and our response

concerns and issues related to ELSI and shared them with scholars. Furthermore, we presented and shared this content at the Goal 9 overall meeting.

Outcome 3: We have recognized that it is crucial to establish a framework whereby users can autonomously assess the purchase, usage, benefits, and risks of implementing Jizai Hon-yaku-ki. Furthermore, examining the current state of international regulations, there are significant concerns regarding the regulations on research based on the EU's AI Act. These insights have been documented and shared within the research team.

3. Future plans

We go on with the ongoing collaboration between scholars from various academic disciplines to achieve consensus on important ELSI on our R&D project.

Our R&D Item 6 is broadening further the scope of issues addressed. We also have a plan to compile a recommendation/opinion document, or a “guidebook,” to address various ELSI-related problems attributed to Jizai Hon-yaku-ki and communication aids in general.
(Tohoku U: N. Osumi, S. Hara)