R&D Theme

Interpreting mental states through brain and autonomic nerves

Progress until FY2022

1. Outline of the project

In our R&D Theme 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 Theme 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.

Rich, but expensive

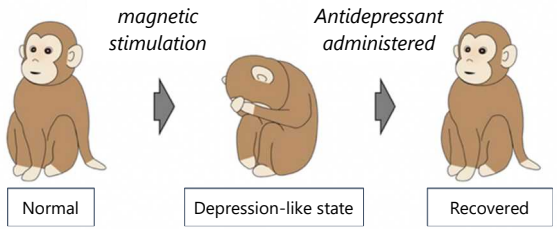
Handy, but inaccurate

Here, our R&D Theme 1 aims to develop **precise and 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. *tablished a non-human primate model of depression;*
2. *Identified brain regions related to mood regulation;*
3. *Identified the pattern of brain waves related to stress susceptibility;*
4. *Designed a simultaneous recording method of depth and scalp EEG in rodents and monkeys;*
5. *Designed a high-precision, simultaneous recording method of the human brain and autonomic nervous activities.*

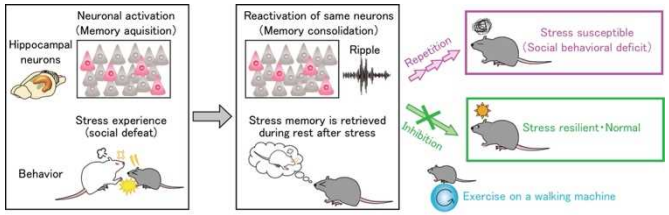
Outcome 1: We succeeded in the artificial induction of depression in monkeys by transcranial magnetic stimulation.



Outcome 1 — illustrative summary
Source: https://www.tohoku.ac.jp/japanese/2022/08/press20220804-02-brain.html

Outcome 2: We identified brain regions related to mood regulation based on this model.

Outcome 3: We found a connection between a particular form of brain waves and the onset of depression by recording and analyzing the neuronal activities of socially stressed mice.



Outcome 3 — illustrative summary
Source: https://www.tohoku.ac.jp/japanese/2023/04/press20230421-01-stress.html

Outcome 4: We established a method to simultaneously record and compare rodent brains' depth and scalp EEG. It will enable us to estimate one's depth EEG from scalp EEG, bypassing highly invasive process of direct recording of depth EEG.

Outcome 5: We established a method to simultaneously record human EEG and autonomic nervous activities (e.g., respiration, pulse, eye movements) with high precision.

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 Theme 1 will further develop sensing technologies to interpret human mental states reliably. We also plan to combine these findings with our R&D Theme 2 (exosomes) to offer a multi-dimensional interpretation of one's mental state.

(Tohoku U: K. Tsutsui, T. Sasaki & NIPS: K. Kitajo)

Development of "*Jizai Hon-yaku-ki* (At-will Translator)" connecting various minds based on brain and body functions

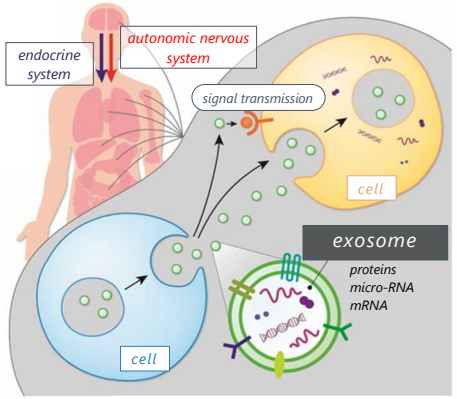
R&D Theme

Interpreting mental states through exosomes

Progress until FY2022

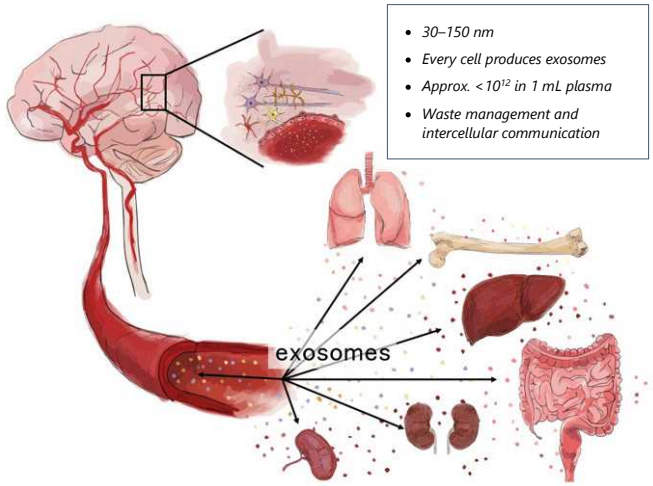
1. Outline of the project

In R&D Theme 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.



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

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**.

Here, our R&D Theme 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. *Found the difference in exosomes between ASD and non-ASD people;*
2. *Suggested the possibility of evaluating the rehabilitation effect of ASD people by exosomes.*

Outcome 1: We compared the size, number, and characteristics of exosomes taken from two groups of participants: those diagnosed with autism spectrum disorders (ASD) and those with typical development. We found that ASD participants are likely to have

- larger-sized exosomes;
- more exosomes in their blood plasma;
- exosomes with less amount of proteins

than non-ASD participants.

Outcome 2: Through proteomic analysis of exosome proteins, it was suggested that exosome could be used for the evaluation of the effect of rehabilitation in ASD people.

So far, we are conducting experiments to unravel the interactions of the brain and other organs mediated by exosomes, primarily focusing on developmental conditions like ASD.

3. Future plans

Our R&D Theme 2 will further investigate the interactions of brain and other organs mediated by exosomes. We have started the analysis of exosomes from rodents that suffered from social stress, which will unravel how negative experiences are reflected in one's exosomes.

We also plan to combine these findings with our R&D Theme 1 (neurophysiology) to offer a multi-dimensional interpretation of one's mental state.

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

国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency

Development of "*Jizai Hon-yaku-ki* (At-will Translator)" connecting various minds based on brain and body functions

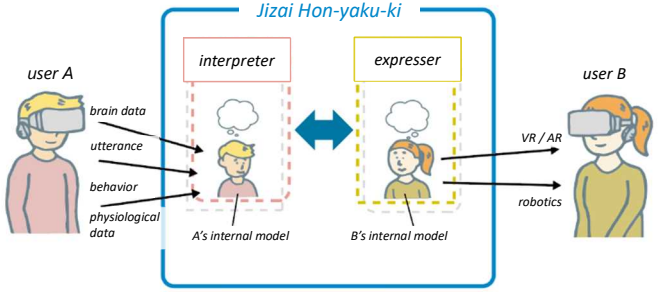
R&D Theme

Functions of *Jizai Hon-yaku-ki*

Progress until FY2022

1. Outline of the project

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



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

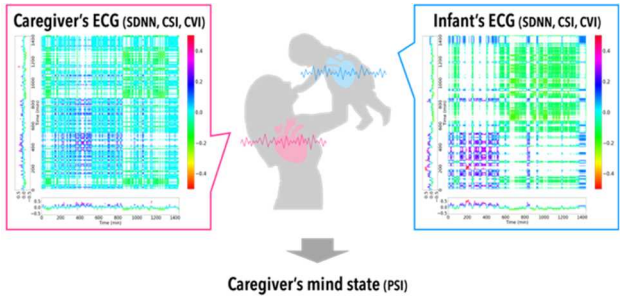
Jizai Hon-yaku-ki consists of two components: an **interpreter** "reads" the user's mental state and an **expresser** "conveys" it to another user.

The primary task of this R&D Theme 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. *Succeeded in estimating a caregiver's stress level from the caregiver's and her child's pulse rates;*
2. *Developed a warmth-presenting display that is non-contact and highly responsive;*
3. *Developed a floor interface to record room-scale human behavior;*
4. *Analyzed quantitatively the context-dependent features of our utterances.*

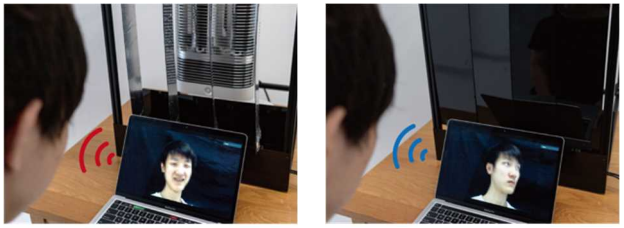
Outcome 1: We utilized the electrocardiogram (ECG) of 51 caregivers and their 3-t+o-4-year-old children. We found that one can estimate a caregiver's stress level from the caregiver's and her child's ECG. Interestingly, the physiological data from someone (a child) can improve the estimation of the mental state of another (a caregiver).



Outcome 1 — illustrative summary
Figures by Professor Yukie Nagai (UTokyo)

Outcome 2: We developed a visual display equipped with non-contact, high-responsive thermal feedback by swift control of infrared radiation. It enables one to "perceive" the interlocuter's mental state and behavior, assisting our situation-driven communication.

Outcome 3: We developed a tile-shaped interface placed on the floor with force sensors. It measures position, posture, and movement without each user wearing a device. This module helps to estimate human behaviors and related intentions that are difficult to record visually.



Outcome 2 — illustrative summary
An agent (left) feel warm when he is catching the interlocuter's eye on the display.
Source: https://doi.org/10.1145/3532721.3535569

Outcome 4: We used amplitude modulation (temporal variation in the intensity of the sound signal) to analyze phonetic changes in our utterances depending on the situations and contexts. This finding helps to develop voice outputs that reflect the user's intention and are easily understood by others.

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 Themes.

(Tokyo U: Y. Nagai, M. Inami, H. Saito
Tokyo Metropolitan U: F. Homae)

Development of "*Jizai Hon-yaku-ki* (At-will Translator)" connecting various minds based on brain and body functions

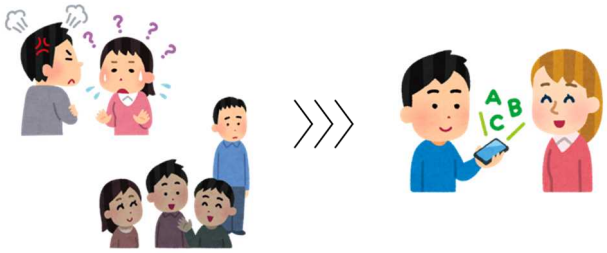
R&D Theme

Social implementation of *Jizai Hon-yaku-ki* (neurodiversity / education)

Progress until FY2022

1. Outline of the project

In R&D Themes 4 and 5, we analyze and solve problems in *Jizai Hon-yaku-ki* implemented in the following two contexts. R&D Theme 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 Theme 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 Theme 5 aims at providing proof-of-concept cases of educational application.

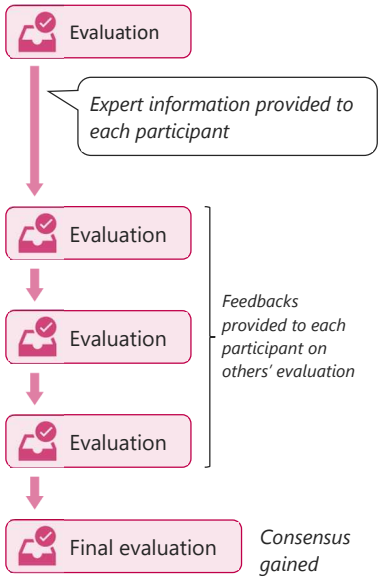
Close engagement with the relevant parties (like those with developmental conditions, their supporters, children, and teachers) is necessary from the very beginning of our R&D. The common task of these two R&D Themes is to incorporate their viewpoints to make *Jizai Hon-yaku-ki* useful to them.

2. Outcome so far

1. *Designed a method of user-led research to incorporate ASD people's perspectives;*
2. *Established a user-friendly, real-time EEG/behavior recording system.*

Outcome 1: We applied the Delphi method, a structured forecasting approach of discussion relying on experts' input. In addition to the usual experts in science and engineering, we had those with developmental conditions as "experts" on their experiences.

This kind of collaboration lays the ground for our user-led research in this R&D project. It will further provide prototype practices incorporating the viewpoints of users with disabilities.



Outcome 1 — illustrative summary of the Delphi method

Outcome 2: We established a system to record electroencephalography (EEG) simultaneously with active behavior.

One key in this R&D is to collect brain data from users, including people with developmental conditions. Existing EEG recorders took much time to put electrodes on the surface of their head, casting them a heavy burden to participate in our research.

Outcome 2 — a user-friendly EEG-recorder

We introduced a wearable, head-mounted EEG recorder to make the recording process less burdensome to participants. We also developed a system that enables real-time EEG/behavior recording and simultaneous EEG/behavior recording from multiple participants. This is a step to analyze users' brain activities during real-life communication.

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

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. Tsutsui)

国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency

R&D Theme

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

Progress until FY2022

1. Outline of the project

In R&D Theme 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.

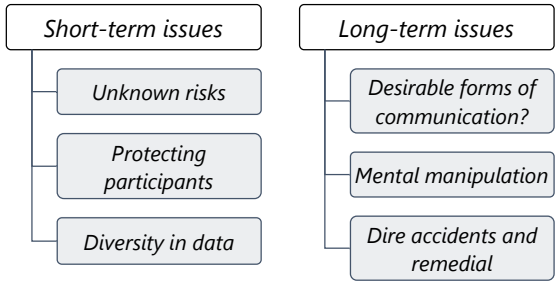
Since *Jizai Hon-yaku-ki* builds on emerging biology and neuroscience, it may cause various ethical concerns regarding **privacy** and **unfamiliar forms of communication**. Also, our highest priority is to protect the rights of participants in our R&D. *Jizai Hon-yaku-ki* should reduce — rather than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

The primary task of our R&D Theme 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. *Compiled a list of potential issues relevant to our R&D of Jizai Hon-yaku-ki;*
2. *Started the data management working-group in our R&D project;*
3. *Analyzed ethical issues concerning mental manipulation.*

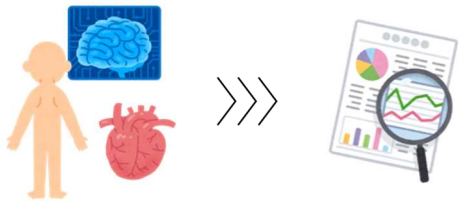
Outcome 1: We compiled a list of ethical, legal, and social issues relevant to this R&D project. The list is twofold to reflect the distinction between (1) issues that can be salient shortly and (2) issues of longer-term relevance.



Two lists of ELSI relevant to Jizai R&D project (abr.)

Outcome 2: We established a working group to address data-related issues in every phase of this R&D project — from data generation to data collection, storage, analysis, archiving, and destruction.

We are trying in this project to "integrate" ethical perspectives into the R&D project at its earliest stage through the active collaboration between scientists, engineers, and ethicists.



Data-related issues are worth serious attention, because our R&D deals with sensitive neurological and physiological data.

Outcome 3: We analyzed the ethical issues concerning "mental manipulation" — one of the prominent issues in our R&D project. Mental manipulation as such is everywhere, but it has been unclear what makes manipulation ethically problematic. The insight from this ethical inquiry will tell us what kind of supportive intervention is (im)permissible in *Jizai Hon-yaku-ki*.

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 Theme 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)