R&D Item

1. Interpreting mental states through brain and autonomic nerves

Progress until FY2025

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.

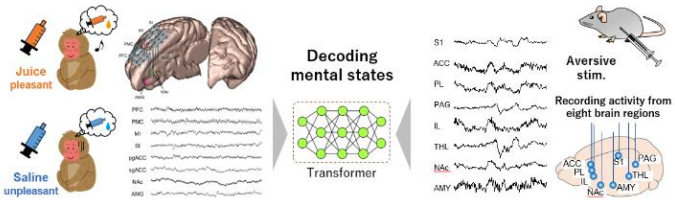
Here, our R&D Item 1 aims to develop **precise and multi-dimensional mind sensing based on brain and autonomic nervous activities** combined with behavioral data. Our goal is to offer a reliable mind-interpretation method suitable for everyday use.

Rich, but expensive

Handy, but inaccurate

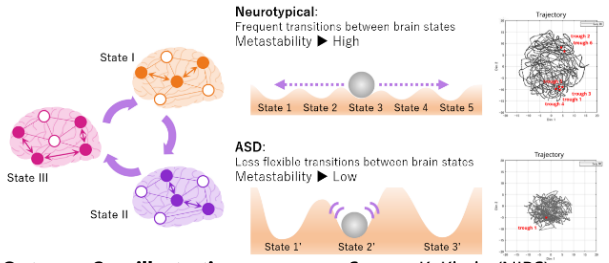
2. Outcome so far

1. *Successfully decoded animals' mental states with high accuracy from brain activity of deep and surface areas using a Transformer model*
2. *Successfully visualized individual traits by focusing on fluctuations in EEG phase-synchronization networks*
3. *Successfully formulated a mathematical index of shared emotional resonance based on empathic EEG activity recorded from multiple individuals*



Outcome 1 — illustrative summary
Source: K.I. Tsutsui & T. Sasaki (Tohoku U)

Outcome 1: Using a Transformer model, a machine-learning approach originally developed for natural language processing, we successfully decoded mental states from brain activity. In a study using monkeys, we analyzed neural activity simultaneously recorded from deep and surface brain areas, identified the brain regions in which the animals' mental states were reflected, and successfully decoded positive and negative emotional states. In experiments using mice, we showed that EEG activity recorded from multiple brain regions enabled more accurate discrimination of aversive visceral pain states than conventional methods.



Outcome 2 — illustrative summary Source: K. Kitajo (NIPS)

Outcome 2: We developed an index that accurately quantifies fluctuations, or metastability, in EEG phase-synchronization networks. Using this index, we identified differences in EEG metastability between typically developing individuals and individuals with ASD, and successfully visualized individual traits.

Outcome 3 — illustrative summary Source: K.I. Tsutsui (Tohoku U)

Outcome 3: We quantified changes in EEG activity that occur when empathy arises among multiple individuals and developed an algorithm for detecting "shared emotional resonance." We also presented an exhibit related to this achievement at Moonshot Park during Expo 2025 Osaka, Kansai, Japan.

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)

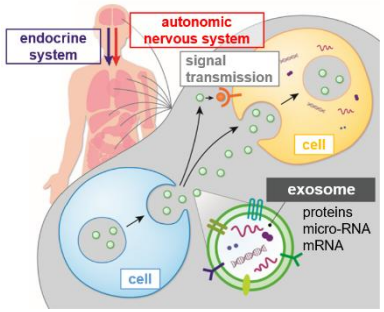
R&D Item

2. Interpreting mental states through exosomes

Progress until FY2025

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 Translator* 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**.

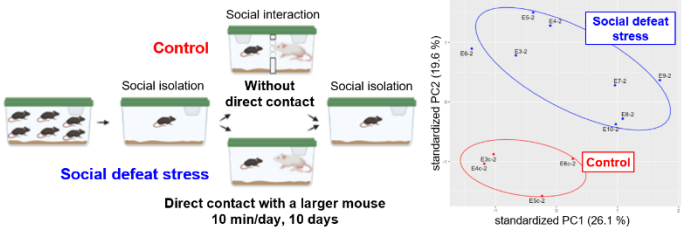
Our R&D Item 2 aims to unravel the interactions of the brain and other organs mediated by exosomes through biochemical examinations and AI-based data analysis.

2. Outcome so far

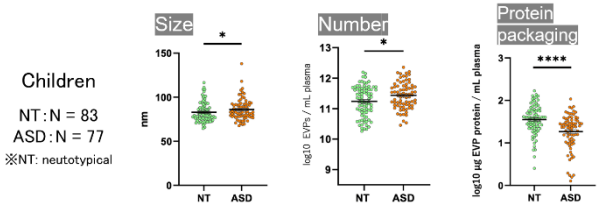
1. *Social stress alters the amount and composition of proteins in exosomes*
2. *Discovered differences in exosome composition between children with ASD and typically developing children*
3. *Established a new measurement and analysis system for assessing behavioral traits in mice and discovered sex differences in the pathology of a neurodevelopmental disorder model*

Outcome 1: We examined exosomes from mice that had developed depressive-like states following social stress and found that both the levels and composition of their protein contents were markedly altered.

Outcome 2: We analyzed the protein composition of exosomes from children with autism spectrum disorder (ASD) and typically developing children, and identified differences between the two groups. We further found that AI-based analysis enables highly accurate classification of ASD.

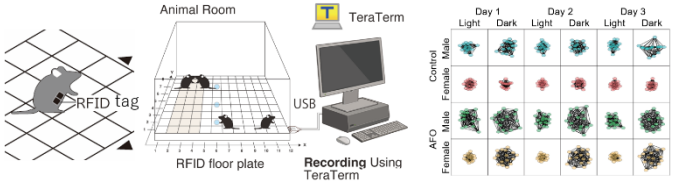


Outcome 1 — illustrative summary
Source: A. Hoshino & A. Nasiri Kenari (U Tokyo)



Outcome 2 — illustrative summary Source: A. Hoshino (U Tokyo)

Outcome 3: We established a system for recording the positions of group-housed mice while individually identifying them, and for analyzing their behavioral traits. Using this system, we demonstrated reduced sociality and sex differences in pathological phenotypes in a neurodevelopmental disorder model.



Outcome 3 — illustrative summary Source: N. Osumi (Tohoku U)

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

3. Future plans

We 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,
Tohoku U: N. Osumi)

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

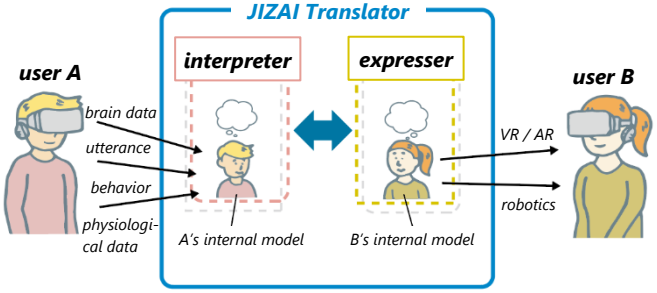
R&D Item

3. Functions of *JIZAI Translator*

Progress until FY2025

1. Outline of the project

In R&D Item 3, we aim to develop *JIZAI Translator* itself and, specifically, its **key functions necessary to support our everyday interactions**.



Illustation of *JIZAI Translator* (when A speaks to B)

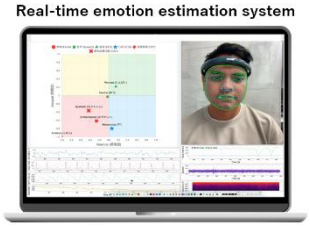
JIZAI Translator consists of two components: an **interpreter** "reads" the user's mental state and an **expresser** "conveys" it to another user.

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 Translator* can assist our mundane communication.

2. Outcome so far

1. *Developed a framework for visualizing users' mental states by integrating various biosignals*
2. *Developed an XR conversation system that enables comfortable communication with others*
3. *Developed an AI-agent-based support system that helps users naturally become aware of their own emotions*
4. *Successfully estimated speakers' emotions from speech features*
5. *Automatic extraction of nonverbal features and classification of individuals with ASD and TD individuals based on extracted features*

Outcome 1: We developed a system that visualizes users' mental states in real time based on biosignals, including facial expressions, speech, heart rate, and EEG activity.

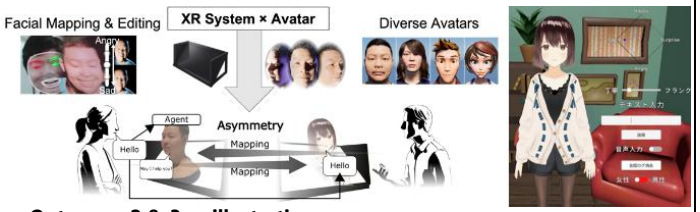


Outcome 1 — illustrative summary
Source: Y. Nagai (U Tokyo)

Outcome 2: We developed an XR conversation system that provides a comfortable communication environment by allowing the appearance and richness of facial expressions to be flexibly adjusted according to each user's characteristics.

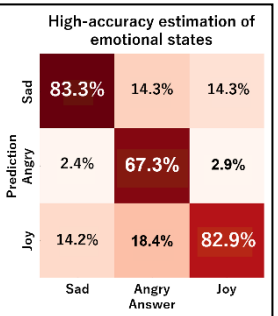
Outcome 3: We developed a support system, called the Mirroring Agent, that estimates users' emotions from their facial expressions and reflects them in an AI agent. This system enables users to naturally become aware of their own emotions, even when they have difficulty recognizing them.

Outcome 4: We developed a model that estimates gender and emotions from various speech features, achieving high classification accuracies of 98.4% for gender and 77.0% for emotions.

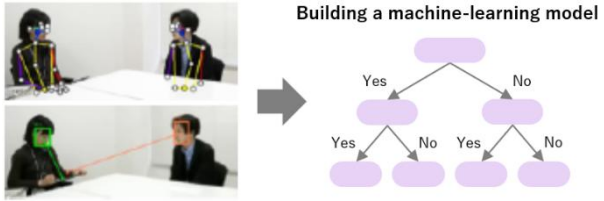


Outcomes 2 & 3 — illustrative summary
Source: M. Inami & H. Saito (U Tokyo)

Outcome 5: We automatically extracted nonverbal behavioral features, including posture and gaze (396 and 117 features, respectively), and successfully classified individuals with ASD and typically developing individuals with high accuracy. We also identified ASD-characteristic behavioral indices, such as face-looking ratio and gaze-transition patterns.



Outcome 4 — illustrative summary
Source: F. Homae (Tokyo Metropolitan U)



Outcome 5 — illustrative summary Source: M. Hariyama (Tohoku U)

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 Translator* 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)

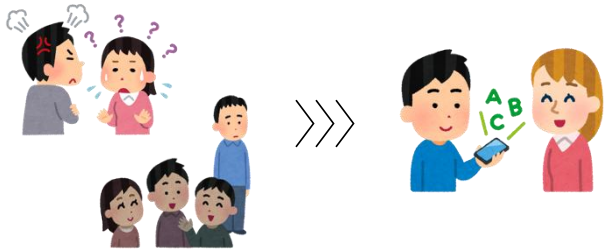
R&D Item

4／5. Social implementation of *JIZAI Translator* (neurodiversity / education)

Progress until FY2025

1. Outline of the project

In R&D Items 4 and 5, we analyze and solve problems in *JIZAI Translator* implemented in the following two contexts. R&D item 4 focuses on using *JIZAI Translator* 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 Translator.

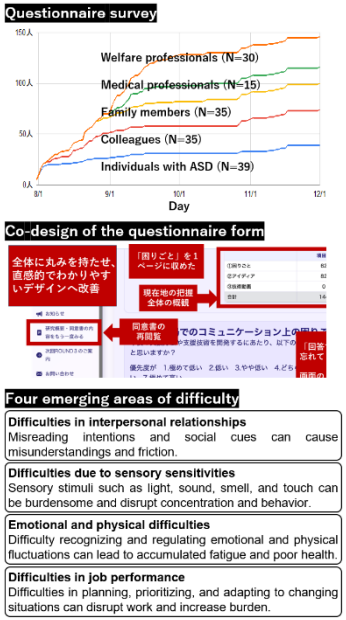
R&D item 5 addresses **classroom use of *JIZAI Translator* for education**. Along with the MEXT initiative to install up-to-date devices for students to utilize in their study, our R&D Item 5 aims at providing proof-of-concept cases of educational application.

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 Translator* useful to them.

2. Outcome so far

1. *Identifying the features that should be implemented as a priority in "JIZAI Translator"*
2. *Acquisition of physiological and behavioral data using EEG and behavioral measurement systems, and establishment of a database and social implementation hub*
3. *Started research into the social implementation of "JIZAI Translator"*

Outcome 1: Through a Delphi survey co-designed with autistic individuals, we identified priority elements and functions for *JIZAI Translator*. Repeated surveys clarified four key difficulties: interpersonal relationships, sensory hypersensitivity, emotional/physical difficulties, and task performance. These findings have been shared with the R&D teams to guide core function development for social implementation.



Outcome 1 — illustrative summary
Source: S. Kumagaya (U Tokyo)

Outcome 2: Using the previously developed system for simultaneous, low-burden recording of EEG and behavioral data, we are collecting physiological and behavioral data from individuals with developmental conditions. We are also establishing a framework that serves as a hub for collaboration among PIs, enabling them to use these data and test prototypes of *JIZAI Translator* in real-world settings.

Outcome 2 — illustrative summary
Source: M. Nakamura (Showa Medical U)

Outcome 3: In addition to promoting the development of a wide range of environments with a view to implementing the prototype of *JIZAI Translator* in society, we have begun demonstrations at specialized day care centers for autistic people and to individuals with autism in collaboration with R&D Item 3. Based on feedback from participants, we will continue to select and implement useful elemental functions.

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 Translator* for educational use.

(Tokyo U: S. Kumagaya, Showa Medical U: M. Nakamura, Tohoku U: K.I. Tsutsui)

R&D Item

6. Ethical, legal, and social issues (ELSI) involved in *JIZAI Translator*

Progress until FY2025

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 Translator* socially acceptable.

Privacy issues may be salient in JIZAI Translator.

Protecting participants is our utmost priority.

Since *JIZAI Translator* 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 Translator* 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

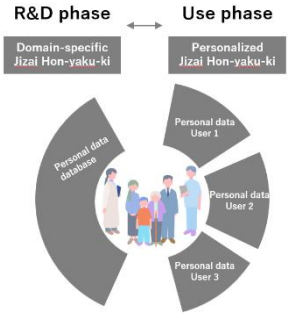
1. *ELSI Review Meeting with External Experts*
2. *Exchanged opinions and conducted interviews with scholars to analyze ELSI-related concerns*
3. *Clarifying ELSI issues to develop guidelines for Moonshot Goal 9 and "JIZAI-Translator"*

Outcome 1: We held the 3rd ELSI Workshop, "Toward AI Research and Development with ELSI Considerations," at the Graduate School of Medicine, the University of Tokyo Hongo Campus, in a hybrid format. Dr. Yuri Nakao from Fujitsu's Data & Security Research Laboratory was invited as a speaker, and participants discussed AI R&D that reflects ethical values in society. The R&D teams also provided comments related to *JIZAI Translator*, followed by a general discussion. This workshop advanced discussions on ELSI issues in AI for implementing *JIZAI Translator*.

Outcome 2: Continuing from the previous year, we exchanged views with R&D members at project-wide meetings held in October and November 2025. Based on the research presentations, we identified ELSI concerns and issues related to data management and public/patient involvement (PPI), particularly by distinguishing between the development and use phases of the devices. We then considered possible directions for addressing these issues and shared them with the R&D members.

Outcome 3: As part of the Moonshot Goal 9 ELSI Working Group, we contributed to the development of ELSI guidelines for Moonshot Goal 9 as a whole. In developing guidelines for *JIZAI Translator*, we also clarified ELSI issues from four perspectives: use and acceptance, handling of personal information, legal risk assessment, and bioethics.

Outcome 1 — The 3rd ELSI review meeting
Source: https://jizai2050.org/inside-story/1312



Outcome 2 — illustrative summary

In this way, by taking an agile approach of collaborating with scientists and engineers to consider ELSI from the early stages of research and development, we are promoting the creation of an environment in which *JIZAI Translator* is socially accepted.

3. Future plans

We will continue the ongoing collaboration between scholars from various academic disciplines to achieve consensus on important ELSI issues in 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 Translator* and communication aids in general.

(Tohoku U: N. Osumi, S. Hara,
U Tokyo: S. Aketani, E. Nakazawa)

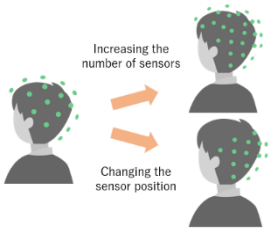
R&D Item

7. Advancement of mental-state decoding technologies through next-generation magnetic sensing

Progress until FY2025

1. Outline of the project

R&D Item 7 aims to **advance technologies for decoding mental states** by introducing **optically pumped magnetometer magnetoencephalography (OPM-MEG)**, a next-generation magnetic sensing technology. This is expected to accelerate R&D toward the social implementation of *JIZAI Translator*.



Optimizing OPM sensors

Brain activity measurement in naturalistic environments with wearable devices

As a next-generation brain activity measurement technology, OPM-MEG enables more accurate and flexible measurement of brain activity than conventional methods. By attaching lightweight sensors to the head, **it allows brain activity to be measured in naturalistic situations with free movement**, such as while drinking coffee.

In R&D Item 7, we will install this system at the National Institute for Physiological Sciences, optimize the OPM sensors, refine the data analysis pipeline, and validate methods for decoding mental states to advance the development of *JIZAI Translator*.

2. Outcome so far

1. *Installation of a high-performance magnetically shielded room for OPM-MEG measurements*
2. *Selection of an OPM-MEG system compatible with hyperscanning*
3. *Optimization and development of sensors for stable measurement of brain activity from deep brain regions*
4. *Establishment of an operational framework and research community for OPM-MEG*

Outcome 1: Before introducing OPM-MEG, we installed a high-performance magnetically shielded room required for measurement at the National Institute for Physiological Sciences. OPM-MEG measures the tiny magnetic field changes generated in the brain. By using a shielded room that blocks the Earth's magnetic field and environmental noise, it becomes possible to accurately detect magnetic field changes derived from brain activity.

Outcome 1 — magnetically shielded room Source: K. Kitajo (NIPS)

Outcome 2: We selected and are introducing Japan's first OPM-MEG system compatible with hyperscanning, which enables simultaneous measurement of brain activity from multiple individuals. Installation work is progressing smoothly, and the system is scheduled to become operational during FY2026.

Outcome 3: We designed and fabricated a dedicated 3D-printed OPM sensor array that can place OPM sensors over the entire head and neck. This enables sensor layouts to be optimized for target brain regions, including deep brain areas.

Outcome 4: We established a management framework and operation guidelines for OPM-MEG. We also set up a user meeting within Moonshot Goal 9 to collect user needs and feedback. To build an OPM-MEG research community, we established collaborations with University College London and the University of Nottingham, and organized international symposia and domestic research meetings.

Outcome 4 — international symposium held at NIPS
Source: K. Kitajo (NIPS)

3. Future plans

Going forward, we will use OPM-MEG to estimate mental states during communication from brain activity. We will also strengthen the operational framework centered on the National Institute for Physiological Sciences and the JIZAI2050 Project to support efficient use within Moonshot Goal 9.

(NIPS: K. Kitajo, UCL: S. Bestmann)

R&D Item

A1. Development of long-term neural indicators linked to mental well-being

Progress until FY2025

1. Outline of the project

In our R&D Item A1, we aim to **develop technology to identify components of brain activity that serve as long-term neural indicators of mental "well-going" and read them in real time**.

In addition to joy, anger, sadness, and happiness, human emotions include higher-level emotions that are complex mixtures of these emotions. To precisely read the state of the human mind using *JIZAI Translator*, it is essential to be able to read these higher-level emotions.

In this research project, we are working on developing technology to identify components related to **"relieving fear and anxiety (sense of safety)"** and **"a mind that remains unaffected by emotional disturbances (resilience)"** from EEG, fMRI, and MEG signals, and to **read these in real time**.

2. Outcome so far

1. *Establishment of novel concurrent EEG-fMRI setup with peripheral physiological measures*
2. *Identification of candidate markers related to fear extinction*
3. *Identification of brain activity markers that show how humans stay mentally stable during emotional stress*
4. *Translational finding: lower excitability in visual areas is linked to resilience in mice and humans*

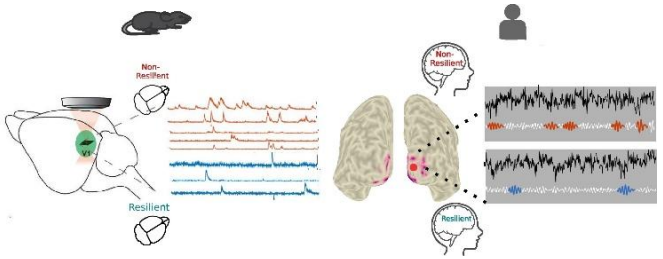
Outcome 1: We established a technically advanced concurrent EEG-fMRI setup with carbon-wire-loop technology during a 3-day fear extinction protocol, also including the application of light footshocks and the measurement of skin conductance responses. This setup allows us to record human brain activity simultaneously with EEG and fMRI. We can now investigate the neural signatures reflecting the transition from negative to positive mental/emotional states, such as the transition from fear to safety.

Outcomes 1 (left & middle) & 2 (right) — illustrative summary
Source: T. O. Bergmann（LIR）

Outcome 2: We found that, during the process of fear extinction, "relief" is represented as a prediction-error signal in the ventral striatum.

Outcome 3: Our research shows that a key brain region called the right Inferior Frontal Gyrus (IFG) helps keep us focused during emotional situations by regulating activity in the visual cortex and reducing the impact of emotional distractions.

Outcome 3 — illustrative summary Source: E. Pinzuti & O. Tüscher (LIR)



Outcome 4 — illustrative summary
Source: E. Pinzuti & O. Tüscher (LIR)

Outcome 4: We found in both humans and mice, that lower excitability (lower bursts) in visual areas is linked to better visual performance and protection from stimuli interference, highlighting a shared brain mechanism for resilience across species. We have developed new analysis tools to gain a better understanding of the role of these transient (bursts) activations.

3. Future plans

Going forward, we will use our newly developed measurement systems and analytical tools to identify brain-state transitions between stable and stressed states, and between fear and safety, in humans, monkeys, and mice. By comparing brain activity patterns across species and models such as ADHD and ASD, we aim to establish cross-species neural markers of safety and resilience.

(LIR: T. O. Bergman, O. Tüscher)