R&D item

# 1. Data-driven modeling

## Progress until FY2023

### 1. Outline of the project

To construct a model for categorizing personality types driven by data, we began building the "High-Low Mixed Database" (Figure 1). Specifically, for the "low" part, we formulated survey items and daily behavior measurements using smartphones and conducted the first large-scale survey. For the "high" part, we conducted brain imaging data measurement experiments.

### 2. Outcome so far

**Item 1: Data-driven modeling**

(1) Formulation of the Basic Design of the "High-Low Mixed Database"

Based on the successful identification of subtypes of healthy individuals across various psychiatry symptom axes, we formulated nine types of clinical evaluation scales for large-scale surveys using the internet and smartphones. In collaboration with item 2 and the Social Implementation R&D item, we decided on questionnaires related to serenity and vitality. After a preliminary survey, we finalized the specifications and conducted the first large-scale survey and behavior measurement experiments following ethical approval.

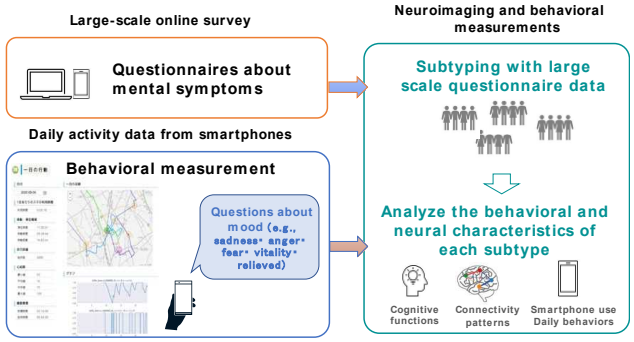


Figure 1: High-low mix database

(2) Construction of a Data-Driven Model for Categorizing Personality Types Related to Serenity and Vitality

For the "high" data, we formulated MRI imaging protocols in collaboration with item 3 and collected structural images (T1-weighted, T2-weighted, diffusion-weighted images), functional images (resting-state), and fieldmap images for correction from 26 individuals. Additionally, we conducted behavior tasks to measure cognitive function and individual traits in decision-making, which are considered intermediate data between "low" and "high" data. The acquired MRI data was stored in the constructed database system (XNAT).

**Item 2: Large-scale survey using the Internet and smartphones**

In collaboration with item 1 and 3 as well as Social Implementation R&D item, we formulated and conducted preliminary surveys of online questionnaires and behavior measurement experiments with 2,068 participants. From the questionnaire respondents, 130 individuals were selected for behavior measurement experiments. Following the preliminary survey, we finalized the specifications and conducted the first large-scale survey with 7,044 participants and behavior measurement and experience sampling experiments with 301 participants.

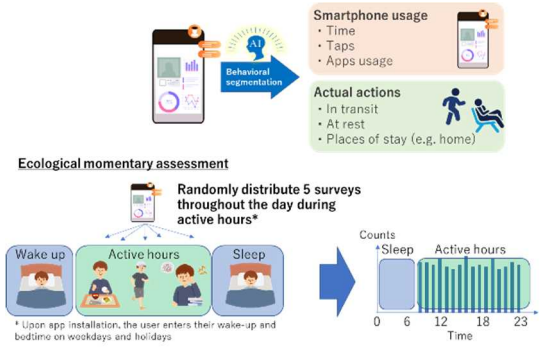


Figure 2: Behavior Measurement and Experience Sampling Using Smartphones

**Item 3: Optimization of data-driven analysis**

We built a docker pipeline for unified preprocessing of the data stored in the constructed database system. Using this analysis code, we analyzed both open and newly acquired data, confirming the removal of the influence of head motion artifacts. We used the hierarchical supervised/unsupervised learning developed as a candidate algorithm for subtype classification from brain images. The results of subtype classification using functional connectivity, which is helpful in distinguishing major depressive disorder, identified significant differences in individual characteristics (life satisfaction) and cognitive functions (attention) related to serenity and vitality between subtypes. These subtype differences were not due to head motion artifacts or the specific number of optimal functional connections.

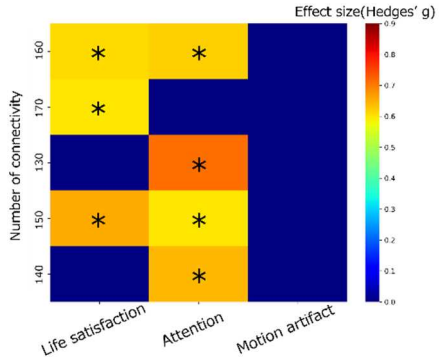


Figure 3: Relationship Between the Number of Functional Connections and Subtype Differences in Characteristics Related to Depression

### 3. Future plans

We will conduct the second large-scale survey to complete the "High-Low Mixed Database" by storing questionnaire, behavior measurement data, brain images, and cognitive tasks. We aim to find stable individual trait types within the constructed database.

R&D item

# 2. Neurofeedback

## Progress until FY2023

### 1. Outline of the project

In this project, we are developing technology aimed at creating a new society where machines coexist with humans. To achieve this goal, we have developed visualization devices capable of sufficiently capturing the transition of mental states. Furthermore, by utilizing this neurofeedback system, we aim participants to acquire a balance of dynamism and stability in brain networks, unaffected by external influences.

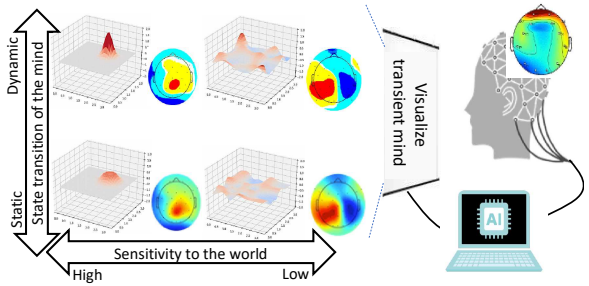


Figure 1: Schematic diagram of this R&D proposal

### 2. Outcome so far

**"Visualization of brain state transitions"**

By extracting common EEG states, referred to as templates, in advance, the transition of brain states is grossly visualized as transitions between these templates. We enhanced the spatiotemporal expression from conventional four templates (polarity-ignored ABCD) to ten polarized states (ABCDE±) reflecting transitions between topographical polarities (Figure 2, left). This model enabled the differentiation between young and elderly individuals (Figure 2, right, blue: young-dominant, red: elderly-dominant).

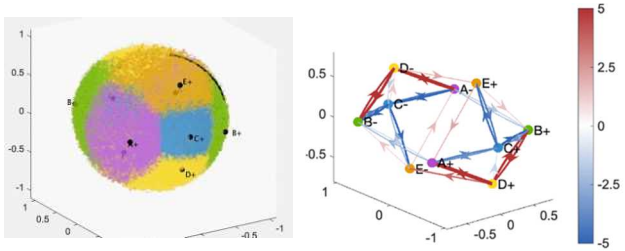

Figure 2: ten polarized states (ABCDE±) (left) and the difference between young and elderly (right)

**"Feedback Technology Development"**

By defining brain states in advance, such as EEG microstates, it becomes possible to pursue real-time feedback learning. To capture the instantaneous transitions between the ten polarized states, we achieved high temporal resolution in the neurofeedback system. Furthermore, participants have commenced training for the validation of the neurofeedback system's effectiveness.

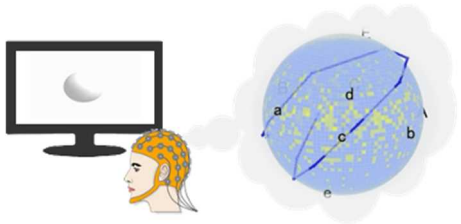


Figure 3: the system detects instantaneous transitions

**"Machine Learning of Brain State Transitions"**

We examined the performance of a Wilson-cowan-based generative model that simulates brain activities and of a data-driven model based on a pairwise-maximum-entropy model (pMEM). A source localization method was used for facilitating the communication between the models and also for extracting attractors that have neuroscientific relevance.

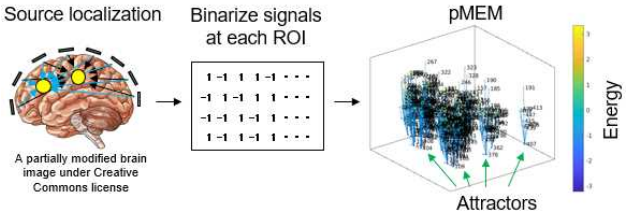


Figure 4: pMEM using source localization as its input

### 3. Future plans

We have implemented "detection of transitions between polarized 10 states" and defined specific transitions to be targeted for reinforcement in training. Consequently, there has been a significant improvement in the expression of dynamics compared to existing systems. Additionally, we are concurrently investigating the quantification of transitions between attractors using machine learning, with the intention of integrating this knowledge into future neurofeedback training. By combining these insights, we aim to implement neurofeedback that promotes peace of mind and ultimately strive for outcomes that can be beneficial to society as a whole.

R&D item

# 3. Social Implementation

## Progress until FY2023

### 1. Outline of the project

While advancing the study of Buddhist texts, we have developed a broad framework for meditation to be implemented via a smartphone app. We categorized human types based on afflictions mentioned in the scriptures and organized basic meditations for each type. This process helps tailor meditation selections to individual personalities. Concurrently, we progressed in developing the app, which must faithfully replicate the content from our research and withstand large-scale intervention experiments. We have initiated the creation of this app and completed the first of several meditation training programs, along with a preliminary experimental design.

### 2. Outcome so far

**R &D 1: Buddhist textual Survey and Meditation Design**

(1) Content creation for meditation app narration and more

In our meditation app, we aim to control automatic thinking by focusing on "awareness" and cultivating "compassion" through a 21-day course (See Fig. 1). We've developed four tailored meditation courses (addressing greed, anger, ignorance, and unbiased types) based on traditional practices. Additionally, the app includes meditations derived from Oriental perspectives to address issues like "loneliness/anxiety" and promote "positivity." We also integrated the app contents with the Oriental Meditation Archives. To validate the effectiveness and reliability of these meditations, we utilized biometric data and Digital Biomarkers (DBM), conducting preliminary experiments in collaboration with Professor Yoshiharu Yamamoto from the University of Tokyo. We are also exploring new analytical methods focusing on facial expressions, voice tone, and responses, in partnership with Professor Kalisch and Dr. Puhlmann from the Leibniz Resilience Research Institute in Germany.

Fig 1: Outline for meditation training

(2) Creation of an archive for meditation literacy required for content creation

To promote the sustained effects of practice through the mobile app by enhancing meditation and motivating practice, we have started preparing to provide organized information on traditional meditation practices and their explanations, as well as insights and considerations from modern scientific meditation research (see Figure 2).

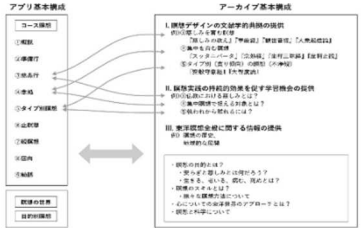


Figure 2: Correspondence between the Meditation App and the Oriental Meditation Archive

**R&D 2: Large-Scale Intervention Experiment**

(1) App Development

Specifications for an app to be used in a large-scale meditation intervention experiment have been compiled, and development has commenced. The app is required to handle experiments involving hundreds of participants. To meet this requirement, various features are planned to be incorporated into the app, such as a practice schedule function and a survey function.

(2) Creation of a prototype for meditation training content

Ultimately, the app will implement various meditation training programs. So far, one such program has been completed. This intervention program is based on the recent Mindfulness-based Intervention package. By creating this at an early stage as a prototype, we aim to optimize the development of app and future meditation training course. Moreover, it will allow for the comparison of newly developed meditation programs with this project in terms of effectiveness.

(3) Formulation of Experimental Design

An experimental design for conducting intervention research has been formulated, detailing the metrics to be used and the timing of measurements. Based on these decisions, the design underwent review by the University of Tokyo Ethics Committee, and approval was obtained for implementation.

(4) Conducting a Pilot Experiments

In collaboration with Yoshiharu Yamamoto, the PI, for different projects under Goal 9, a pilot experiments were conducted. These experiments were carried out over three days with participants in a meditation training program. Although it was a limited intervention, effects such as reduced anxiety were observed, exceeding expectations.

### 3. Future plans

To organize meditation systems, we will continue our textual study and work on creating meditation instructions based on Buddhist texts. Concurrently, we will advance the development of our app and begin large-scale intervention studies. Starting from the meditation retreat in Chiba this June, we will initiate a collaborative research project with the Leibniz Resilience Research Institute.