

# 1. Specifying and updating of well-being and agency in society

## Progress until FY2024

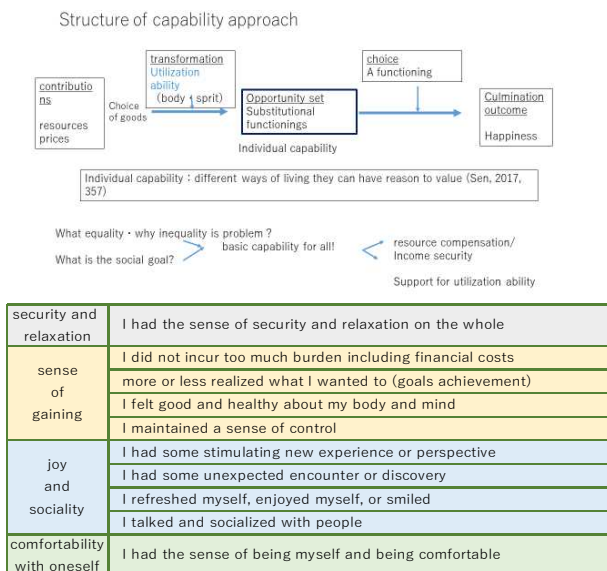
### 1. Outline of the project

The task of this assignment is to conceptualize a pre-theory to guide the fact-finding study (survey and experiment). Specifically, we will construct a list and hypothesis concerning welfare and subjectivity, and define the concept of "city capability" (Task 1-1). In addition, we will utilize full-text digital data from the National Diet Library to analyze data related to the concept of welfare and subjectivity (Task 1-2). This year, (1) we programmed procedures for estimating individual capability (normative axioms and statistical criteria) and applied them to consensus building on welfare and transportation policies and to surveys of visually impaired people in Japan and Bangladesh, and (2) In parallel with the work of collecting and organizing large-scale textual data, we conducted a preliminary analysis to identify the main axes of welfare and subjectivity using the geometry of culture approach and the word embedding model.

### 2. Outcome so far

(1) The following is an overview of the capability estimation procedure.

The observed values (achievement function points) of individuals belonging to a group  $j$  over  $T$  periods are aggregated under rules that satisfy certain evaluation criteria (inter-individual comparability and freedom/equality norms) to identify the capability of group  $j$  = the capability of an individual in a given identity.



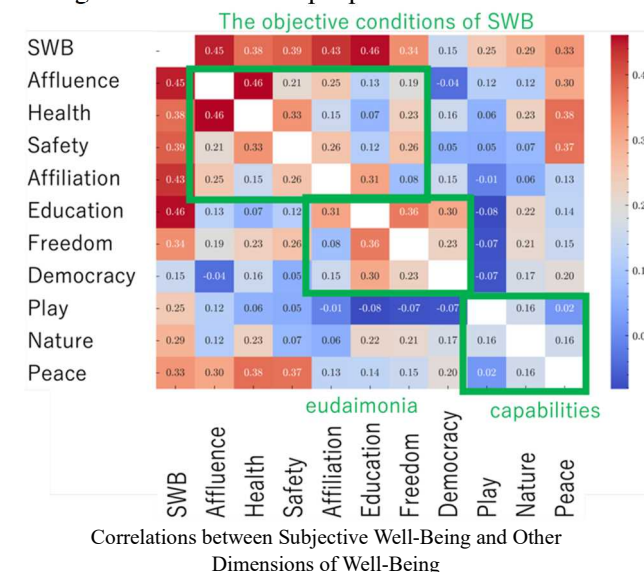
#### 4 categories & 10 functionings

(2) Implementation of Data Collection and Organization Regarding Concepts of Well-being and Agency: During the fiscal year, we collected and organized large-scale text data for analysis in and after the fiscal year of 2023. For the large-scale text data, we considered the availability and the relevance to our goal of identifying the key axes of well-being and agency. As a result, we decided to use the full-text data of the National Diet Library (which includes all books published from the Meiji era to 1968, and all magazines published up to 1989 that are in the library's collection). In this fiscal year, we organized the data by the year of publication and constructed metadata (including publication year, author, genre, etc.), as well as conducted cleaning of the main text data (conversion from old Japanese character forms to modern forms, removal of English numerals,

morphological analysis using MeCab, conversion to text files segmented by morphemes).

### 3. Future plans

(1) we continue the capability survey to understand the hidden needs of respondents who show no intention of using the public system. (2) In collaboration with neuroscience and animal psychology, we will elucidate the logic linking medical intervention and social support to enhance "capability for well-being." (3) Conduct an analysis of the National Diet Library's full-text data based on the geometric approach to culture, and examine the philosophically and normatively proposed concepts of well-being and agency in line with the actual thoughts and attitudes of people.



(GOTOH Reiko: Teikyo University

TAKIKAWA Hiroki: The University of Tokyo)

## 2. Development and updating the system to discover pleasure and aspiration in society

### Progress until FY2024

#### 1. Outline of the project

We aim to develop a system that utilizes Virtual Reality (VR) technology to create virtual experiences to maximize personal subjective pleasure and aspiration from the perspectives of welfare and agency. We conduct work in modeling the interrelationship of aspiration and pleasure in mobility experiences, establishing mathematical methodologies for discovering pleasures and aspiration that connect to individual welfare and agency, and building a framework for discussing the optimization of experiences from an individual to a group level. By integrating these, we aim to realize a support system that allows users not to overly depend on services provided by AI systems but actively engage in social activities of their own volition.

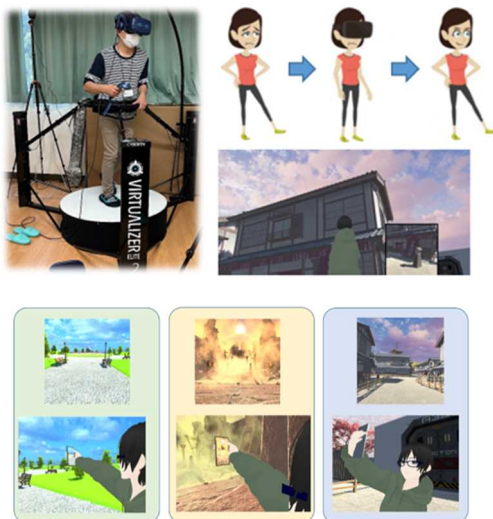


Figure 1. Developed VR experience provider and recorder

#### 2. Outcome so far

When designing virtual experiences in a VR space, it's necessary to mathematically grasp the user's psychological state (aspiration and pleasure) to determine what kind of content (visual and audio signals) the system should provide - a system design theory is needed. As a foundation for establishing this design theory, we built a system capable of uniformly recording VR content visuals, audio, user biometric data (gaze, pupil diameter, skin potential, heart rate, electrocardiogram, brain measurement data), and full-body movement data (Figure 1).

Furthermore, in collaboration with the members of Research and Development Project 3-2 using the above platform, we built an experimental system to analyze mobility experiences related to aspiration and pleasure through travel in VR space. Specifically, we used a VR walking device that allowed actual movement in VR and created a VR application to tour six tourist spots. To investigate the impact of mobility experiences on memory, we built a feature that allows for photo taking on a smartphone during VR travel. This provides for retrospectively looking back on memories and establishing a system foundation for evaluating proactive actions.



Figure 2. a VR environment for social experiment

Left: Condition of being ignored by others

Right: Condition of engaging in prosocial behavior

Creation of VR Content in Collaboration with Sociology

In sociology, the research method known as the capability approach aims to clarify the factors that influence pleasure and aspiration by identifying the typical "can do or cannot do" elements in everyday life. In collaboration with the Research and Development Project 1 member, we have established a foundation to quantitatively analyze the impact on users' pleasure and aspiration by realistically experiencing these "can do or cannot do" scenarios in a VR environment. Specifically, as shown in Figure 2, by comparing experiences under conditions such as "engaging in prosocial behavior with others vs. being ignored by others," it becomes possible to investigate the factors that delight in pleasure and aspiration unique to each user.

#### 3. Future plans

In the future, to gain deeper insights into how social behaviors and agency in virtual reality (VR) environments influence brain activity, we will collaborate with the team from Project 3-2. Specifically, we will measure brain activity changes following virtual experiences using magnetoencephalography (MEG), analyzing how pleasure and aspiration are reflected in neural activities. Additionally, we will investigate how active behavior in virtual spaces influences neural activities involved in encoding spatial location and orientation, and examine differences between experiences in real and virtual environments. Ultimately, we aim to utilize these findings to establish methodologies for discovering and supporting human pleasure and aspiration.

Through such efforts, we aim to realize an assistive system that can provide VR experiences that support the discovery of appropriate pleasure and aspiration for individual users to support a well-being society in 2050.

(INAMURA Tetsunari: Tamagawa University)

### 3. Developing technology for inter-personal comparison of pleasure and aspiration by human brain indicators

#### Progress until FY2024

##### 1. Outline of the project

In order to create a society that is both free and just, it is essential to evaluate the collective and societal "good" of various public policies. However, it is well known that such indicators cannot be effectively constructed without a way to compare individuals' "happiness" across different people (Arrow's Impossibility Theorem; Arrow, 1963). In recent years, there has been a growing emphasis on life-satisfaction, beyond material wealth as represented by Gross Domestic Product (GDP). In 2022, the United Nations High-Level Advisory Board produced a report on the "Beyond GDP" initiative, in which well-being and agency, as framed in Amartya Sen's Capability Approach (Sen 1999 Development as Freedom), were identified as key outcome elements.

Our research aims to create innovative technology capable of measuring individuals' subjective well-being—which has traditionally been difficult to assess objectively—through brain indicators (brain activity), making it possible to compare happiness across individuals. In addition to developing brain indicators related to hedonic happiness, which arises from rewards such as food or money, we will also focus on indicators associated with eudaimonic happiness—derived from the agency (freedom of choice). By aggregating these interpersonally comparable brain indicators of happiness at the societal level, we aim to contribute to the realization of equity based on social choice theory. Through the successful achievement of this project's goals, brain indicators (brain activity) reflecting individuals' subjective experiences of happiness can be applied to real-world contexts—such as evaluating mobility policies in smart cities—thereby contributing to the development of social technologies that enhance well-being at the collective and societal levels.

##### 2. Outcome so far

(1) Development of technology to make "happiness"

interpersonally comparable through brain indicators (brain activity)

● Using functional magnetic resonance imaging (fMRI) data from a large and diverse sample of several thousand individuals, we demonstrated that subjective "happiness" derived from rewards such as money can be made interpersonally comparable through brain indicators (brain activity). When comparing brain activity related to the desire for money and the pleasure of receiving it across individuals with different socioeconomic statuses (SES), we found that economically disadvantaged individuals exhibited greater brain responses to monetary rewards—indicating higher pleasure—while simultaneously showing lower desire for money. Moreover, we found that brain indicators of subjective "happiness" derived from monetary rewards can be represented as the inner product of a weight vector and a brain activity vector across widespread brain regions, including the prefrontal cortex and basal ganglia. Furthermore, using a behavioral economics model (prospect theory), we confirmed through fMRI that the utility (i.e., subjective value) of monetary rewards can be compared across individuals using brain activity. In addition, magnetoencephalography (MEG) revealed that brain activity patterns—particularly in the frontal lobe and across extensive brain regions—vary depending on utility, with millisecond-scale temporal resolution. These findings suggest the possibility of aggregating individuals' subjective "happiness" in real time at the societal level using neural indicators. They also challenge a foundational assumption in traditional cost-benefit analysis used in public policy evaluation—namely, that "the value of one yen is equal for everyone." This research paves the way for the societal implementation of policy evaluation systems grounded in brain-based indicators.

(2) Development of technology to measure brain activity related to rich happiness

● Using MEG (magnetoencephalography), we identified the neural dynamics underlying the sense of "choosing and

controlling one's own life"—a factor widely recognized as essential to happiness and life satisfaction—through comparative analysis between reinforcement learning models and brain activity. Employing a free-choice task, which represents one of the simplest forms of agency emphasized in the Capability Approach, we found that brain activity was significantly greater during free-choice conditions compared to forced-choice conditions—a phenomenon known as the "free-choice premium." These findings suggest that it is possible to measure the happiness derived from having opportunities for free choice through brain activity.

● Using single-neuron recordings in humans, we revealed that the ability to form high-level, abstract representations—which enables generalization by leveraging regularities in the world—relies on the abstract and orthogonal encoding by populations of hippocampal neurons (Courellis et al., 2024, Nature). These findings offer important insights into how rich happiness, as experienced in the real world, is represented in the brain.

##### 3. Future plans

If we succeed in quantifying the "happiness" of diverse individuals through brain indicators and aggregating it at the societal level, it is expected to become a powerful well-being metric that could complement GDP, as envisioned by the OECD and the United Nations. Going forward, we will conduct neuroscience research under more naturalistic conditions to scientifically identify what constitutes a "rich environment" and "freedom of action"—key elements of happiness in contemporary society. By recreating these enriched environments using technologies such as virtual reality and precisely controlling them, we aim to enhance brain-measurement accuracy through the use of various brain imaging techniques, thereby ensuring scientific validity and rigor in our development efforts. (MATSUMORI Kaosu: Hitotsubashi University, MATSUMOTO Madoka: Kyoto University, Ralph Adolphs: Caltech)



## 4. Comprehensive understanding of utility representation in primate brain for interindividual comparison

### Progress until FY2024

#### 1. Outline of the project

We have obtained evidence to understand how pleasure and aspiration evolved and drove us to achieve goals in the brain. Particularly, both monkeys and humans feel similarly during the gamble; after lucky win they feel more likely to win. Our findings were reported at the high-ranked scientific journal (Project 4-1). We have developed behavioral tasks to examine the subjective value of reward and hierarchical cognition in macaque monkeys, and obtained preliminary results suggesting functional differences in the prefrontal cortex, amygdala, and hippocampus. We also conducted fMRI experiments in humans to examine interactions between hierarchical cognition and social preferences and found that prosocials and proselves use their brains differently (Project 4-2).

#### 2. Outcome so far

(1) Research and development in identifying neural representations of utility

We estimated the parameters that individual neurons in brain regions involved in reward processing have when representing expected subjective value and selected the best model. The results were published in an international journal (Imaizumi Y, et al. and Yamada H. *Nat Commun.* 2022, 13(1): 5855).

(2) Research and development aimed for monkey-human interspecies comparison of utility estimated from behavior

By conducting similar behavior measurement experiments in monkeys and humans, we directly

compared their gambling behavior and showed that their value judgments are very similar. (**Dynamic prospect theory: Two core decision theories coexist in the gambling behavior of monkeys and humans.** Tymula A et al, and Yamada H. *Sci Adv.* 2023, 9(20): eade7972.) (Project 4-1).

(3) Hunger and thirst are evaluated by blood contents (Suwa et al & Yamada, 2024). A new analytic tool for brain activity was developed and applied to brain-wide activity (Chen et al & Yamada, 2024, 2025)

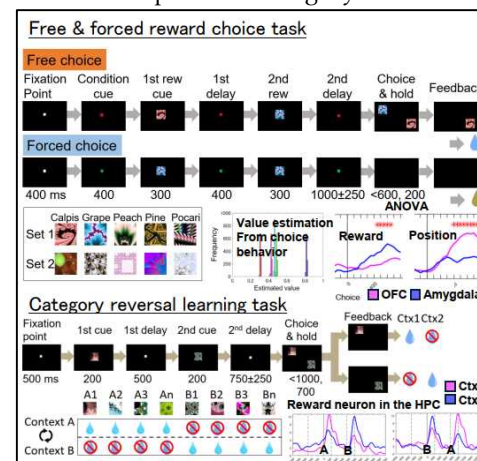
(4) Research and development to elucidate neural indices of subjective value of reward

We trained monkeys on a newly-developed free and forced reward choice task, recorded neural activity in multiple brain regions, and obtained results suggesting functional differences between the OFC and amygdala.

(5) Research and development to elucidate neural indices of hierarchical representation of aspiration

We have also developed a category reversal inference task

requiring hierarchical processing and identified reward predictive and category-en coding neurons in the



macaque LPFC and hippocampus. In addition, to examine the interaction between hierarchical cognition and social preferences, we developed a donation task and conducted fMRI experiments. We found that the prosocials and proselves showed contrasting behavioral tendencies and neural representations. This study received an excellent poster award (23rd Winter Workshop of "Brain and Mind Mechanisms"). (Project 4-2)

#### 3. Future plans

We established the biologically plausible model for the inter-individual comparisons by developing an identification technic for collective activity analysis of multiple brain regions involved in the neural representation of utility. Now, we aim to measure blood ghrelin concentration, which is an indicator of hunger, in order to establish an objective evaluation method for craving. Then, we will identify the biological principles that yield human pleasure and aspiration (project 4-1).

To reveal the brain mechanisms that represent the subjective value of rewards, we will conduct functional network analysis of multiple cortical and subcortical areas to the data obtained from free and forced reward choice tasks. We will further explore the hierarchical dynamics in the brain using the devaluation method and pathway-selective chemogenetic manipulation. This study intended to mediate the translation of findings from inter-individual comparisons of neural representations of reward value in rodents to human understanding. (Project 4-2)

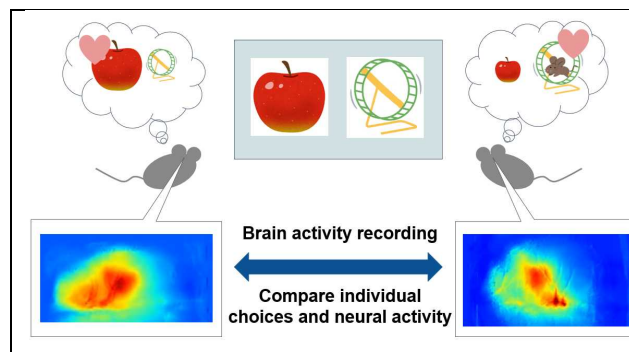
(YAMADA Hiroshi: Tsukuba University,  
 OGUCHI Mineki, Tamagawa University)

## 5. Comprehensive understanding of subjective reward value representation in rodent brain for interindividual comparison

### Progress until FY2024

#### 1. Outline of the project

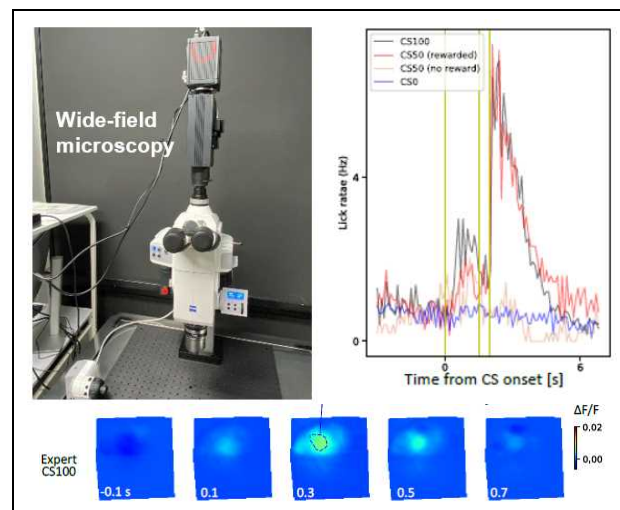
We record brain activity using wide-field imaging and dense electrode arrays in behaving animals. This approach reveals the rewards and motivational states that the animals currently experience. We also design behavioral tasks that clarify the neural basis of learning and decision making.



#### 2. Outcome so far

(1) Using a classical-conditioning paradigm, we quantified neural representations of the subjective value of water in rodents. A brief auditory cue consistently preceded the delivery of a water droplet, and animals rapidly acquired anticipatory licking. Viral delivery of a genetically engineered calcium indicator enabled cortex-wide fluorescence imaging, which we combined with ultra-dense

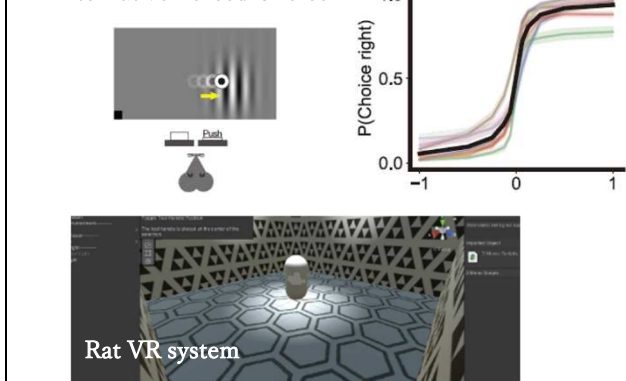
silicon probe recordings to sample hundreds of neurons concurrently. Population analyses revealed neural coding of the reward and its predictive cue; moreover, activity patterns were reorganized as animals progressed from thirst to satiety, indicating that cortical and subcortical circuits dynamically update internal value estimates in accordance with motivational state.



(2) We study how reward pursuit drives action in rats. Because the animals cannot verbalize their state, we train them to “report” motivation by learning a two-choice task and selecting the option they value more. During performance we capture large-scale neural activity with cortex-wide imaging and ultra-dense electrodes, revealing

how context and experience sculpt reward coding. To extend the approach, we are building a head-fixed virtual-reality arena that runs the same experiments in richer, controllable environments.

#### 2-Alternative Forced Choice



#### 3. Future plans

We will record the neural representation of subjective reward value at high density and resolution, transiently shifting that value to track how brain activity changes. We will design new tasks that probe motivational drive, and develop theory for comparing value-related neural codes across individual animals.

(TANAKA Yasuhiro: Tamagawa University)