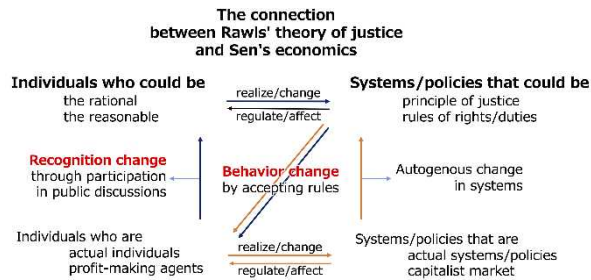


# Specifying and updating of well-being and agency in society

## Progress until FY2022

### 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" (Assignment 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).

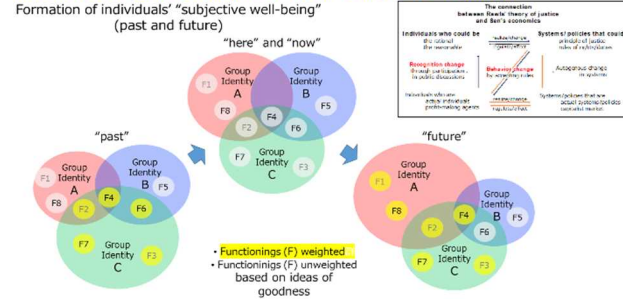


This year, (1) based on the deciphering of key literature, we envisioned a methodological framework for extracting the "capability for well-being" of individuals. (2) In parallel with the work of collecting and organizing large-scale textual data, we conducted a preliminary analysis to identify the main axes of welfare and subjectivity using the geometry of culture approach and the word embedding model.

### 2. Outcome so far

(1) Capturing welfare rooted in inter-personal

### Reconstructing the concepts of "Well-being" and "Agency"

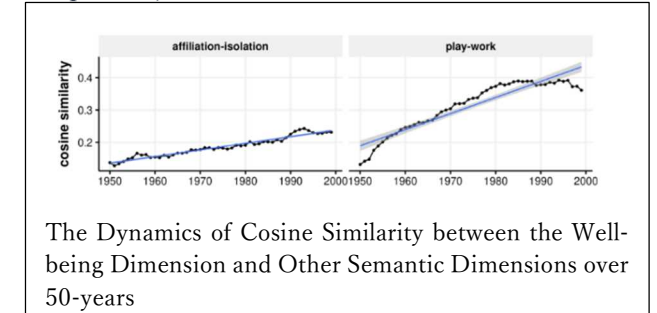


relationships: Although welfare is often rooted in inter-personal relationships and cannot necessarily be broken down by individual, the lists presented by most happiness research to date do not adequately capture cases that manifest in relationships with others.

(2) Capturing public judgment or civic opinion among individuals: We have conceived of a "capability universe" that can capture the multidimensional and multilevel structure of individual evaluation, paying close attention to the informational basis of individual preferences, evaluations, judgments, and opinions, as well as the differences in their destinations, purposes, and contexts.

(3) 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).



The Dynamics of Cosine Similarity between the Well-being Dimension and Other Semantic Dimensions over 50-years

### 3. Future plans

(1) Clarify the concept of "city capability," which is composed of multidimensional groups. (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: University of Tokyo)

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

### Progress until FY2022

#### 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 aspirations from the perspectives of welfare and agency. We conduct work in modeling the interrelationship of aspirations and joy in mobility experiences, establishing mathematical methodologies for discovering joys and aspirations 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 (aspirations 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 aspirations and joy 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 (Figure 2). 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.

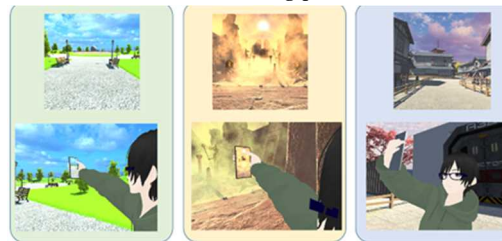


Figure 2. VR travel application

#### 3. Future plans

We conduct experiments with VR travel content, recording conditions where visual imagery in VR space, walking behaviors, dialogue, and proactive actions appear. We also collect biometric data and brain activity data. We analyze these data to separate trends common to all users and trends corresponding to the mindsets of individual users and model the relationships between presented data and behavioral data in each mindset. This allows us to mathematically express the joy and aspirations that each user subjectively feels, and we aim to build a system that can dynamically customize VR content.

Research on behavior change technology through VR is expanding globally; however, many aspects of its impact on the heart remain unclear, leaving us without a comprehensive theoretical framework. In the future, using the dataset collected with the platform we've built and applying the Free Energy Principle(\*), we aim to build a framework for mathematically discussing what kind of VR experiences should be presented to make appropriate experiences for individual users by modeling the interrelationship between aspirations and joy at an individual level.

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

(\* An information-processing model of the brain proposed by Karl Friston, which hypothesizes that the brain performs to minimize the free energy, and it is expected to be able to explain well-being mathematically.)

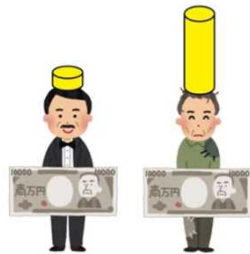
(INAMURA Tetsunari: Tamagawa University)

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

## Progress until FY2022

### 1. Outline of the project

We need to measure the "goodness" of each policy at the group and societal level to make our society free and fair. However, it is known that such an index cannot be successfully created without methods for comparing the well-being (or utility) of different people (Arrow's impossibility theorem; Arrow, 1963). It is also known that it is impossible to compare utility across individuals using classical methods based solely on behavioral data. In our project, we propose methods to measure well-being in an interpersonally comparable manner by combining various physiological indices (Plan 3-1).



Interpersonal comparison of utility

In addition, we are strengthening our MEG research system to clarify the neural circuit dynamics of human pleasure and aspiration, and have human MEG and marmoset ECoG experiments on "sense of self of agency" and MEG experiments on "narrative self" underway (Issue 3-2).

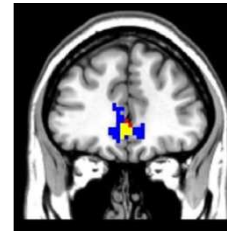
It is thought that the poorer a person is, the more pleased they will be when they receive 10,000 yen. However, there is no scientific method to compare the pleasure across individuals.

### 2. Outcome so far

(1) Quantification of the intensity of pleasure using brain indices

- We determined the direction for the development of a technique for reading utility with high accuracy (multi-echo fMRI imaging, analysis using generative models).

- We are using an independent database (ABCD study) to analyze the activity of brain regions that we have identified as correlated with utility prediction error (Matsumori et al., 2021).



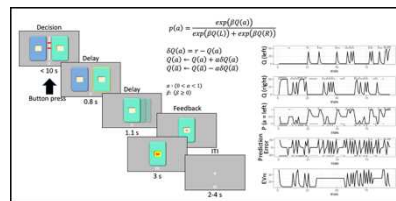
Neural representation of utility

- In order to reveal the dynamic process by which utility is computed in the brain at high temporal resolution, we determined the design of the utility task for the MEG experiment.

(2) Quantification of the aspiration using brain indices

- We determined the direction for the experimental task by focusing on "second-order desire (having the desire to have a certain desire)" (Frankfurt, 1971), which has been discussed in relation to free will.

- In order to clarify the neural dynamics of the process of constructing a model of the external world through



interaction with the environment and the process of

acquiring a "sense of agency," MEG measurements using an exploratory task were conducted on healthy subjects.

- To elucidate in detail the neural circuit dynamics of the "sense of agency" in vocalization, we analyzed cortical electroencephalography (ECoG) data acquired from electrodes (96 channels) covering the frontal and temporal lobes of a marmoset while the marmoset was required to vocalize with the voice of another individual. We observed suppression of activity in the auditory cortex and temporal changes in activity in the hemisphere during vocalization. The functional connectivity between the frontal and temporal lobes was investigated (presented at Japan Neuroscience Society and the Society for Neuroscience).

- In order to determine the neural circuit dynamics of autobiographical memory and its evaluation, which is at the core of the "narrative self," we determined the details of the autobiographical memory task for the MEG experiment in conjunction with R&D 2-1.

### 3. Future plans

We will try to develop utility estimation techniques using data that can be easily obtained from cameras. This will lead to applications in the evaluation of mobility policies in smart cities.

Using MEG with optically pumped atomic magnetometer (OPM), we will investigate brain activity during free and exploratory actions in a Virtual Reality (VR) space city (smart city, urban, rural, etc.), and reveal the neural circuit dynamics involved in the discovery of "pleasure" and "aspiration" associated with mobility.

(MATSUMORI Kaosu: Tamagawa University

MATSUMOTO Madoka: NCNP, Ralph Adolphs: Caltech)

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

## Progress until FY2022

### 1. Outline of the project

We found that subjective value is distributed and encoded by neurons in various areas of the reward system and published this finding in a leading international journal, providing an important scientific basis for this project. In addition, we examined information representation of the intensity of desire in neuronal activity and confirmed a significant increase in osmotic pressure after feeding (Project 4-1). In addition, we constructed experimental setups to examine the neural representations of subjective reward value and hierarchical cognition and began training monkeys in each behavioral task. We also conducted human behavioral and fMRI experiments to examine the relationship between hierarchical cognition and prosociality and published an international paper. (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 (medial and central orbitofrontal areas, ventral striatum, dorsal striatum) 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) (Project 4-1).

(2) Research and development aimed at establishing an

objective evaluation method for thirst

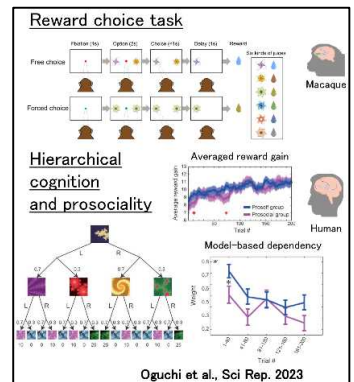
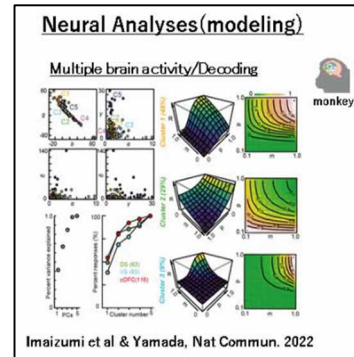
We collected blood samples from four water-restricted monkeys before and after feeding, with no water absorption during feeding, and measured osmolality and

observed a significant increase in it. (Project 4-1).

(1) Development and training of behavioral tasks to elucidate the neural basis of the subjective value of reward

New experimental setups were constructed for simultaneous recording from multiple cortical and subcortical regions using multi-contact electrodes. We developed a procedure to approach the hippocampus and recorded neural activity there. We next constructed a reward choice task and a category inference task to investigate the neural basis of the subjective value of rewards and hierarchical cognition, respectively, and began training three monkeys in total.

In addition, we conducted human behavioral and fMRI experiments on the relationship between hierarchical cognition and social decision-making and published a part of



the results (Proselfs depend more on model-based than model-free learning in a non-social probabilistic state-transition task. Oguchi M, et al. Sci Rep. 2023, 13(1), 1419). In the fMRI experiment, we constructed a new donation task and took fMRI data from undergraduate students. (Project 4-2)

### 3. Future plans

We aim to establish the biological plausibility of the inter-individual comparisons by establishing an identification technology for collective activity analysis of multiple brain regions involved in the neural representation of utility, and to establish a behavioral data analysis that enables subjective comparison between humans and monkeys. In addition, we aim to measure blood ghrelin concentration, which is an indicator of hunger, in order to establish an objective evaluation method for craving. After these, we will identify the biological principles that create human joy and aspirations (project 4-1).

To reveal the brain mechanisms that represent the subjective value of rewards using macaque monkeys, we will conduct multi-cellular recordings simultaneously from multiple cortical and subcortical areas while the monkeys performing a reward task that mixes free and forced choices. We will further explore the hierarchical dynamics in the brain that represent subjective values 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)

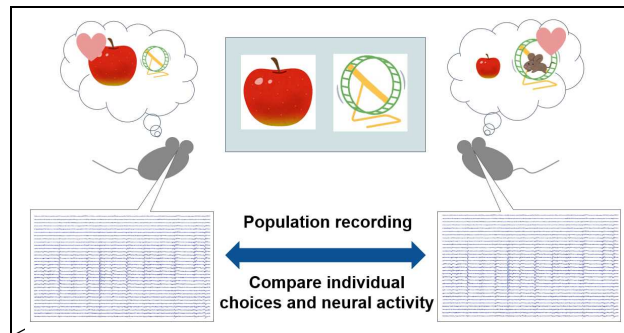
(YAMADA Hiroshi: Tsukuba University  
OGUCHI Mineki, Tamagawa University)

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

## Progress until FY2022

### 1. Outline of the project

We record and analyze multi-cellular neural activity from the prefrontal cortex of rats (10 rats) during task execution using high-density integrated electrodes (Neuropixels).

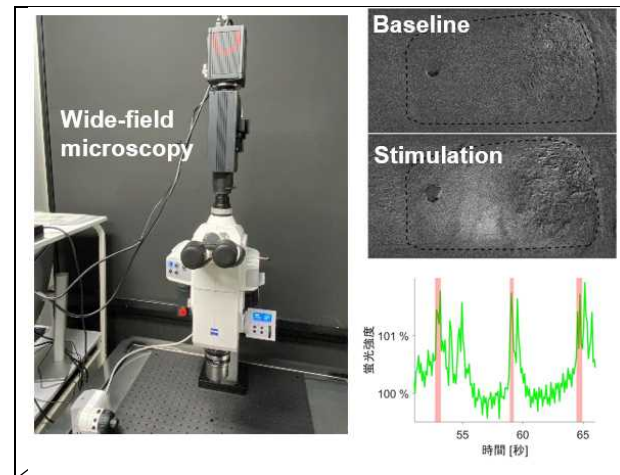


### 2. Outcome so far

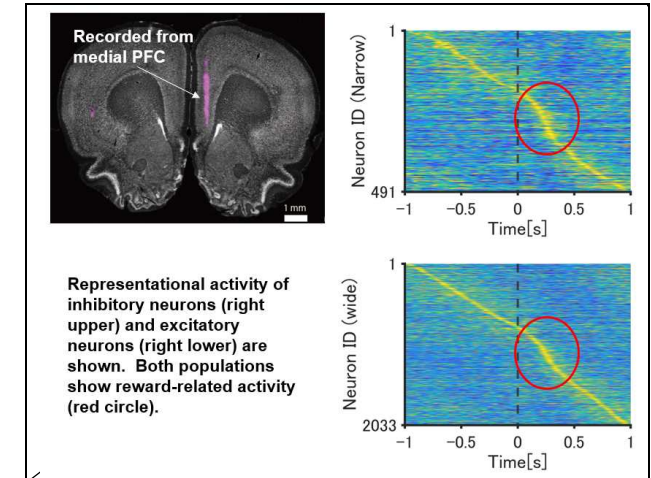
- (1) Implementation of microscopy and start of staffing and optimization of measurement
  - (a) In addition to Neuropixels for deep brain regions, we installed a wide-field microscope for measuring signals from the cerebral cortex.
  - (b) An adeno-associated virus vector expressing GCaMP6, a fluorescent protein for measuring neural activity, was injected into the cerebral cortex, and changes in the brightness of GCaMP6 were successfully measured through

an open window.

(c) A postdoctoral researcher with extensive experience in visual psychological experiments using mice, measurement experiments using optical devices, and task design for animal behavior was hired as of March 1, 2023.



- (2) Physiological data measurement on behavior and desire for reward during operant conditioning  
Neural activity from the medial prefrontal cortex was recorded during performance of the FR1 task, which is immediately rewarded by a button press. Recording was performed across periods in which the subjective value of the reward changed throughout the session. Experiments were conducted on 10 rats, and the analysis is ongoing.



### 3. Future plans

We will investigate how the subjective value of reward is expressed in the rat brain, using tasks that can be easily performed by rats, such as classical conditioning. For this purpose, we will establish methods for transducing genetically encoded fluorescent probes to the whole cortical surface of the rat. We will also continue to analyze data obtained from operant conditioning experiments. Furthermore, we will develop probability search tasks that can be compared to human studies using a virtual reality system.

(TANAKA Yasuhiro: Tamagawa University)