R&D item

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

Progress until FY2023

1. Outline of the project

The task of this assignment is to conceptualize a pretheory 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) 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) Extending Sen's original formulation, and using the two concepts of "group" (a group of individuals with similar resources and capacities to use them) and "type" (differences in combinations of independent and exclusionary behaviors; behavioral characteristics), we propose a method to approximate individual capability

by aggregating the achieved functionings of individuals different of types in а given group.



(2) Comparative scrutiny of previous studies suggested that highly abstract lists with weak correspondence to actions or situations have a prescriptive character and that implicit assumptions about goodness may influence responses.

This study proposes a model that links the experience of going out/home activities with the difficulties encountered and the functionings realized.



4 categories & 10 functionings 3 categories & 12 utilization abilities

(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).

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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)





R&D item

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

Progress until FY2023

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 fullbody 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.

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3. Future plans

In the future, to further elucidate the impact of social behaviors in VR environments on brain activity, we are considering expanding our experimental systems to not only humans but also animals such as monkeys and rats. As an inter-project collaboration, we plan to proceed with experiments on social behavior in rats and monkeys under the cooperation of Matsumoto PJ(project), Takumi PJ, and Tsutsui PJ. By setting situations in the VR environment where the other's behavior and appearance differ from usual, and measuring brain activity in these instances, we will clarify the brain activities and establish indicators for evaluating pleasure and aspiration. Finally, we aim to develop a methodology to discover pleasure and aspiration in humans using these results.

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)



R&D irtem

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

Progress until FY2023

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 "happiness" (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 "happiness" in an interpersonally comparable manner by combining various physiological indices. Rich happiness (such as "pleasure" and "aspiration") arises from being guaranteed the freedom to move (mobility) and the freedom to choose. In such an environment, people feel a sense of "belonging" and achieve a good state of mental and social well-being. Therefore, in normative economics, the goal of society is to ensure that individuals can lead lives they have reason to value, that is, to guarantee substantial freedoms for each person (Sen, 1999).

We aim not only to improve "happiness" at the individual level but also to aggregate it at the societal level and achieve equality. We are developing innovative technology to measure indicators of "happiness" from brain activity, making it possible to compare happiness across individuals. By achieving the projects, we will bridge detailed neuroscientific findings on brain indicators of "pleasure" and "aspiration" as felt by individuals to real-world activities, such as evaluating mobility policies in smart cities. This will contribute to the creation of societal technologies that enhance "well-being" through brain indicators.

2. Outcome so far

(1) Quantification of "pleasure" using brain indices

• We conducted experiments to investigate how to reduce fMRI noise, which is essential for interpersonal comparisons, and found that our method reduces noise better than existing ones.

• The analysis of the neural representation of utility was conducted using a large scale fMRI database (ABCD study), and we

obtained quantitative data showing that the "marginal utility of money" diminishes with income level across individuals.

• We investigated the dynamic process by which utility is computed in the human brain using MEG (magnetoencephalography) with high temporal resolution. We examined the decoding of reward prediction errors and their relationship to socio-economic status, exploring whether it is possible to compare individuals based on brain indicators of "pleasure" derived from MEG signals.

(2) Quantification of the "aspiration" using brain indices

• The relationship between the two concepts of utility (experiential utility and decision utility), which are considered to be the basis of "pleasure" and "aspiration", was investigated, and we found decision utility is constructed by integrating the "pleasure" provided by rewards.

• We investigated the dynamic process underlying the sense of controlling one's actions and their outcomes ("sense of agency") using MEG (magnetoencephalography) with high temporal resolution. By employing Q-learning, a type of reinforcement learning, we calculated the prediction errors and the transitions of expectations for action outcomes, decoding these from brain activity data.

•To elucidate the neural circuitry underlying the "sense of agency," we conducted electrocorticogram (ECoG) in marmosets during self-initiated vocalization. We observed the functional connectivity between the frontal and temporal lobes, focusing on the causality in the top-down direction (from the frontal lobe to the temporal lobe) within specific frequency bands during vocalization.

• To study the dynamic process of "autobiographical memory" which drives "aspiration," we developed an experimental system using virtual reality (VR) for mobility virtual experiences and measured the brain activity through MEG.

• By recording single neurons from epileptic patients, we have found that abstract context information is represented by human hippocampus.

3. Future plans

If we succeed in quantifying and socially aggregating the diverse "pleasure" and "aspiration" of people, it could become a significant well-being indicator that complements GDP, as envisioned by the OECD and the United Nations ("Beyond GDP"). Moving forward, we will scientifically identify what constitutes a "rich environment" and "freedom of action" crucial to "happiness" in modern society. Using VR technology and other methods to create controlled rich experimental environments, we will measure brain activity and validate our findings through various approaches to ensure the legitimacy of our developments. (MATSUMORI Kaosu: Tamagawa University, MATSUMOTO Madoka: Kyoto University, Ralph Adolphs: Caltech)







R&D item

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

Progress until FY2023

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 developed behavioral tasks to examine the subjective value of reward and desire, as well as the neural representation of hierarchical cognition in monkeys, and began recording neural activity. We also conducted fMRI experiments in humans to examine interactions between hierarchical cognition and social preferences and found that prosocials and proselfs 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 monkeyhuman interspecies comparison of utility estimated from behavior

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

compared the gambling behavior of them and showed that their value judgments very similar. are (Dvnamic 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) Research and development to elucidate neural indices of subjective value of reward

To investigate the neural basis of the subjective value of reward, we developed and improved a free and forced choice task of multiple types of juices, trained two monkeys, and started recording neural activity.

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

We have also developed and improved a category inference task to investigate the neural basis of hierarchical

Free & forced reward choice task and neural recording cognition and are now Fixation Condition 1st rew training two monkeys. In addition. to examine the interaction between



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hierarchical cognition and social preferences, we

developed a donation task and conducted fMRI experiments. We found that the prosocials and proselfs 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)

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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 multicellular recordings simultaneously from multiple cortical and subcortical areas while the monkeys perform 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 interindividual comparisons of neural representations of reward value in rodents to human understanding. (Project 4-2)

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





R&D item

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

Progress until FY2023

1. Outline of the project

We are measuring brain activity using widefield microscopes and high-density electrodes. This helps us understand what rewards and desires the animals are experiencing. Additionally, we are developing behavioral tasks that may contribute to understanding decision-making.



2. Outcome so far

(1) We conducted a study on reward value using classical conditioning. Rats were trained to associate a sound cue with the availability of water, leading to anticipatory licking behavior. Next, we introduced fluorescent protein sensitive to specific substances using viral vectors. Some brain regions showed responses to rewards under a wide-field microscope. Neurons in these regions showed similar responses when their activity was examined using highdensity electrodes. Through combined analysis on the same animals, we gained deeper insights into how the brain responds to rewards. Further detailed analysis of these findings is planned.



(2) To understand desire mechanisms akin to human research, we established behavioral tasks in animal models. Last year, we initiated a simple task where animals received a reward upon pressing a button, concurrently analyzing neural activity in the medial prefrontal cortex. In 2023, we integrated with video-based behavioral analysis. As a multiple choices task, we refined our training methods for quicker learning. These advancements enable us to develop more intricate tasks resembling human studies. Through these tasks, we explore neural activity changes during relearning and its association with rewards and desires.



3. Future plans

We aim to measure and investigate the neural representation of subjective value of rewards in the rat brain at high density and resolution. We will administer manipulations to alter the value of rewards across individuals and observe differences in brain activity in response to these alterations. Additionally, we will develop tasks that aid in furthering our understanding of desire. Furthermore, we will engage in theoretical investigations to compare neural representations of value across individuals. (TANAKA Yasuhiro: Tamagawa University)

