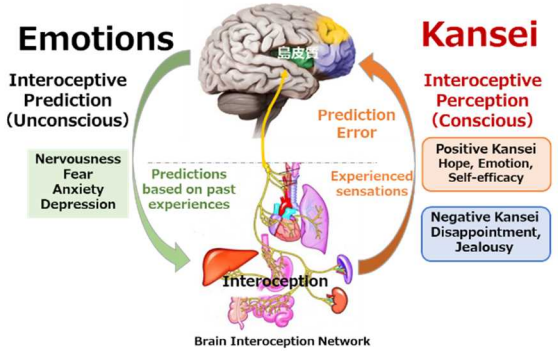
R&D Theme

Promotion of research innovation by fusion of music and brain

Research Progress in Year 2022

1. Summary

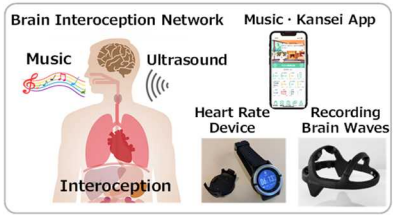
In this project, we will investigate the relationship between interoception (visceral sensations) and the brain, clarify and visualize the brain mechanisms of KANSEI, and use music as a tool that affects KANSEI beyond the oral language barrier. We aim to realize a society in which the next generation can play an active role in a rich and fulfilling way by making people aware of their unconscious positive sensibilities and increasing their "psychological capital" such as hope, efficacy, resilience, and optimism.



Our aim is to create innovation through the fusion of different fields, music and KANSEI neuroscience, and reduce their gap. In this R&D project, we will translate the artistic KANSEI (non-verbal experience) of musicians into the language of scientists, demonstrate the effects of music on KANSEI through neuroscience, and finding solutions to possible challenges in this project will help to foster innovation and technologies.

2. Expected Results for Year2022

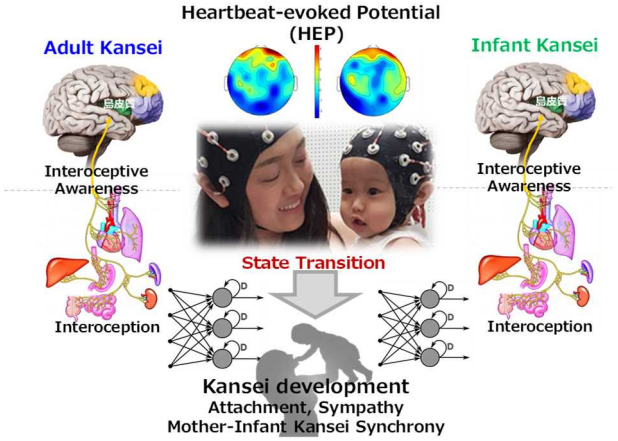
Humans live by anticipating future events. The brain forms memories of interoceptive changes from past episodes. Seth & Friston (2016) suggest that emotions arise when the brain infers the meaning of interoceptive changes based on past experiences. In 2022, we published a paper on interoceptive control by the insular cortex, which is the basis for elucidating the brain mechanisms of KANSEI (Fermin, Friston & Yamawaki; 2022).



In order to investigate how the brain processes interoceptive sensations when listening to music, we developed a music/KANSEI app that incorporates questionnaires such as awareness of interoceptive sensations related to KANSEI, stress, and resilience, and measures of heart rate and brain waves with wearable devices. We built a simultaneous measurement system as follows.

Researchers participate in music workshops to experience emotions elicited by music, perform psychological surveys using emotional apps such as interoceptive awareness of performers and conductors, and use objective emotional evaluation methods. We performed preliminary studies on the responses of heartbeat changes and brain activity during music performances and stimulation to ultrahigh-frequency sounds that cannot be consciously perceived by the human ear. Musicians and neuroscientists discussed the usefulness of KANSEI apps and the issues of biometric measurement.

In addition, for the next Japanese generation (infants) who should play an active role in 2050, we will examine how interoceptive sensations and heartbeat changes modulate the brain heartbeat-evoked potential (HEP) by simultaneous measurement of brain waves and heartbeats, and investigate the roles of music in KANSEI development. Thus, music experiments with adults, infants and technological development to understand KANSEI and mental health underlie the foundation of this project.



3. Future Plans

By cooperating with the general public and having infants as participants, we will build a research environment to validate our research results on the neuroscience of KANSEI and its relationship with music.

We will discuss the development of a Music Edutainment program that allows participants to understand the neural and psychological mechanisms of KANSEI while enjoying music, discuss issues for social implementation of KANSEI visualization technology, and examine research strategies that will lead to innovation creation.

We will collaborate with schools and local governments to develop childcare and education systems that use music to nurture children's sensibilities.

Informed consent for KANSEI research targeting children and ELSI for social implementation through industry-academia collaboration will also be extensively examined, and research that will lead to innovation will be promoted.

(YAMAWAKI Shigeto, Hiroshima University)

ここから、新・未来へ
MOONSHOT RESEARCH & DEVELOPMENT PROGRAM

R&D Theme

Construction and social implementation of a research platform for Music and KANSEI Brain Science Research for all citizens

Progress through FY2022

1. Overview

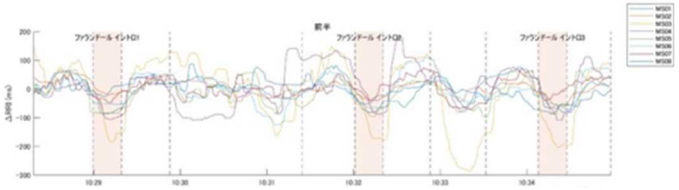
In this study, our objective is to establish a Music and KANSEI Brain Science Research Platform (MKOS) that engages citizens of all age groups, ranging from children to adults. Our aim is to develop a foundation for Music Edutainment, allowing individuals to actively participate in KANSEI Brain Science research while enjoying the process. We also conduct active open discussions with the participants. The feasibility study investigates the impact of music on the brain's interoceptive sensory network (BIN) and aspires to create a Music Edutainment research program that facilitates everyone's appreciation of the effect on sensitivity and BIN.

2. Achievements as of FY2022

【MKOS construction and bio instrumentation feasibility study】

In July 2022, with the cooperation of public facilities, we organized a music workshop (WS) that involved approximately 100 local junior high school students, high school students, university students, working adults, and professional and amateur musicians. About 200 spectators also participated. Biometric measurements on conductors and musicians during concerts showed an elevation in heart rate and synchronization of heartbeats among musicians during performances.

Heat rate of 8 professional musicians（R-R interval）



In addition, a survey of the inner receptive sense subjective questionnaire was conducted through the application. Before and after the performance, we obtained answers from the performers and audience members. The performers provided feedback on operability, question content, and when to use it.

Simultaneous EEG and physiological measurements during an orchestral performance

▼Simultaneous measurement of 8 professional musicians

inner receptive sense subjective questionnaire ▸

▲Heat rate measure and watch type (spectator)

▼Brain wave measure (12ch dry electrodes) (spectator)

【Music Edutainment foundation model construction】

In October 2022, teachers, performers, and dancers underwent joint experiences involving ultra-high frequencies alongside principal investigators (PI) Honda, Sasaoka, and Machizawa. Biometric measurements were performed during these sessions. Furthermore, to address environmental noise when measuring electroencephalogram (EEG) outside the laboratory, we utilized an electromagnetic noise measuring device to perform measurements at the venue, confirming that there are no major issues with brain wave measurements. Additionally, to create teaching materials for future Music Edutainment, we measured the ultra-high frequencies produced by each musical instrument during play.

【Co-creation research with other PMs and PIs】

In December 2022, in collaboration with Yamaha Corporation, we conducted a survey on differences in reverberation effects during performances and listening, involving 10 performers and 6 audience members (performers after the performance and music educators). We collected data to create a new subjective psychology questionnaire. Biometric measurements revealed changes in heart rate during performances due to reverberation, while the employment of the BPQ very short form enabled the observation of emotional variations in the audience. Furthermore, the subjective psychology questionnaire disclosed emotional changes, both positive and negative, following the musical experience.

3. Future Developments

To expand the scope of WSs, we are fostering collaboration with the board of education, schools, and local communities. Furthermore, by broadly disseminating information about MS9 activities and increasing participants with various backgrounds, we endeavor to promote the realization of more diverse and large-scale projects. We also aspire to link the research findings to music therapy, enabling the inclusion of music therapy as a preventive measure for mental and physical health within compulsory education music classes. By incorporating scientific elements into the traditional knowledge of music therapy and accommodating it to diverse sensibilities, we aim to realize a mentally healthy and dynamic society for everyone.

(NISHIMOTO Tomomi, Hiroshima University).

国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency

R&D Theme

Dynamics of integrating interoception and exteroception in parent–infant musical engagement

Progress until FY2022

1. Outline of the project

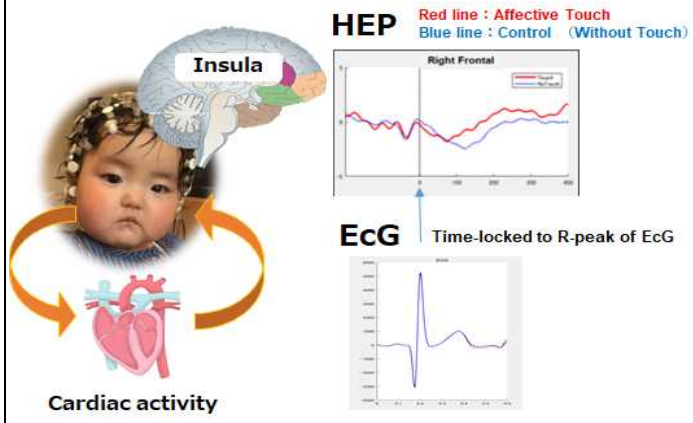
In today's society, where the nuclear family is increasingly the norm, a rising number of parents (mothers) suffer from isolation and excessive stress. In addition, the number of children who are forced to grow up in abusive or otherwise inappropriate environments, as well as the number of children who are addicted to the Internet, bullied, truant from school, or committing suicide, is increasing markedly. Changes associated with the Covid-19 pandemic have accelerated these problems.

To address the pressing issues surrounding parenting, we aim to understand the physiological and psychological dynamics that occur during parent–infant interactions in natural settings. Using a visualization process, we develop **"*personalized*" methods for parenting support by promoting parent–infant musical engagement**. Our ultimate aim is to create an **Awareness Music Sound (AMS)** approach for *KANSEI* development, which effectively reduces physiological and psychological stress while elevating joy and self-efficacy within each parent–infant pair.

2. Outcome so far

Development of a Hyperscanning Electroencephalogram (EEG) and electrocardiogram (ECG) Measurement System for Studying Infant–Caregiver Interactions

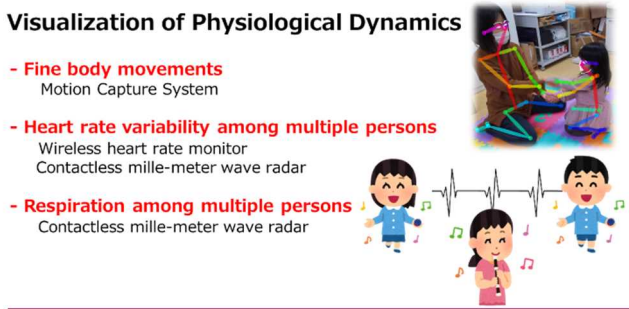
Heartbeat-evoked potentials (HEP), which are considered one of the biomarkers of *KANSEI* have been validated in human infants. Measurements revealed HEP responses (positive peaks) from frontal to central regions during a resting state. In addition, the experience of receiving affective touch (touch that affects interoception) increased the activity of HEPs in infants.



To measure HEP during infant–caregiver interactions, we constructed an evaluation system that can stably measure the EEG and ECG of the two parties. We introduced a hyperscanning EEG + ECG simultaneous measurement system and an EEG cap with active electrodes. In addition, a sensorlesss motion capture system was used as an indicator of the motor system.

Field experiment on parent–infant musical engagement

We implemented a field experiment to collect biometric data without (as much as possible) constraining the bodies of the infants and their parents as they listened to awareness music together. To this end, in addition to a wireless heart rate monitor and a markerless motion capture camera, we introduced a sensor system (in collaboration with Prof. Takuya Sakamoto, Graduate School of Engineering, Kyoto University) that measures respiration, and heart rate without contact.



3. Future plans

1. Visualize the dynamic transition of neurophysiological synchronization between parents and infants using multimodal biometric measurements.
2. Investigate the relationship between the results of the experiments and the positive/negative *KANSEI* (subjective feeling) exhibited by each parent and infant.
3. Conduct field experiments to evaluate the physiological, psychological, and behavioral characteristics of several parent–infant pairs during the awareness music experience at Kyoto University

(MYOWA Masako, Kyoto University).

R&D Theme

Elucidation of mechanisms to promote awareness of internal receptive sensation of inaudible high-frequency sounds and its social implementation.

Progress until FY2022

1. Outline of the project

Music contains not only musical scales, melodies, rhythms, harmonies, and other elements that can be described in musical notation, but also timbres, fluctuations, spatial expansiveness, and many other non-verbal elements that are difficult to express in musical notation. Such elements play an indispensable role in music's ability to resonate with the human mind. We revealed that the music of various cultures on earth contains an abundance of inaudible high-frequency sounds above 20 kHz. In addition, it has been shown that such inaudible high-frequency sounds are abundant in the natural environmental sounds of tropical rainforests, where human genes are evolutionarily created, but are almost completely absent in the environmental sounds of modern cities. Furthermore, we have shown using advanced integrated imaging techniques that sounds rich in ultra-high frequency sounds activate the nervous system that generates mental and physical health and richness, such as the midbrain and the interbrain, making people feel comfortable with sounds, and may have effects that lead to mental and physical health, such as improving immunity and decreasing stress hormones.

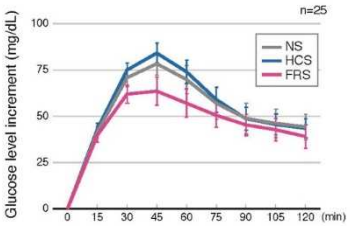
This project aims to elucidate the mechanism by which Awareness Music Sound, including inaudible high-frequency sound, can lead to mental and physical well-being through the autonomic nervous system, and to implement this mechanism in society.

2. Outcome so far

It is widely known that stress management is important to prevent not only mental illnesses such as depression and anxiety, but also lifestyle-related diseases such as diabetes and hypertension, and to maintain a healthy mind and body. Music is expected to be one effective approach. However, conventional music therapy is largely dependent on subjective factors such as individual preferences and psychological state, making it difficult to achieve stable therapeutic effects due to the large variation among individuals. On the other hand, the effects of inaudible high-frequency sound are less susceptible to psychological influences, and thus are expected to be an effective approach for developing mental enrichment using music.

Therefore, in this project, targeting the prevention of diabetes, the effects of inaudible high frequency sounds on blood glucose levels were investigated using the oral glucose tolerance test used for the diagnosis of diabetes. As a result, we found that natural environmental sounds including inaudible high-frequency sounds (FRS: redline) statistically significantly suppressed the rise in blood glucose levels ($P < 0.0001$) when compared to listening to natural environmental sounds without inaudible high-frequency sounds (HCS: blue line) or no environmental sounds (NS: gray line).

Furthermore, the blood glucose suppression effect of inaudible high-frequency sound was more pronounced in older people and people with routinely high blood glucose levels (high HbA1C group), suggesting the possibility of a preventive effect on people at high risk of developing diabetes.



The results of this study were published in Scientific Reports, a sister journal of Nature, and were covered by many media reports.

3. Future plans

Modern medicine, as typified by drug therapy, surgical treatment, and regenerative medicine, is dominated by "material medicine," which approaches diseases from a material aspect. The results of this research are expected to pave the way for "information medicine," in which sensory information contained in music is used via the cranial nervous system to treat and prevent diseases that are difficult to approach with material medicine, and to bring about a healthy and prosperous body and mind.

(HONDA Manabu, National Center of Neurology and Psychiatry)

R&D Theme

Identification of Awareness Music/Sound and the AMS Effects of Sensitive Period

Progress until FY2022

1. Outline of the project

Music has strong appealing power to the auditory, motor, emotional, and proprioceptive systems. We investigate how music appeals to the brain to create the Awareness Music Sound (AMS). We specifically focus on how the interaction between interoceptive and exteroceptive perception has developed in the evolutionary process, and experimentally verify the homology between humans and animals. In addition, we examine how the auditory environment during infancy (i.e., the sensitive period) affects the development of the interoceptive perception and its neural basis.

In this project, we would like to (i) identify the acoustic information structures of AMS (i.e., rhythms, chords, ultra-high frequency tones, etc.) that may promote the awareness of the interoceptive perception, (ii) investigate how manipulation of autonomic nervous systems (e.g., vagus nerve system) affects the interoceptive and exteroceptive perception, (iii) investigate how a nurturing environment such as mother-child separation and/or an early exposure to music during the sensitive period influences the neural development of exteroceptive and interoceptive sensory systems, (iv) elucidate how music promotes interaction and sense of unity among individuals in terms of inter-individual synchronization of motor and interoceptive systems, and (v) implement AMS in the society across species between humans and animals (e.g., pets).

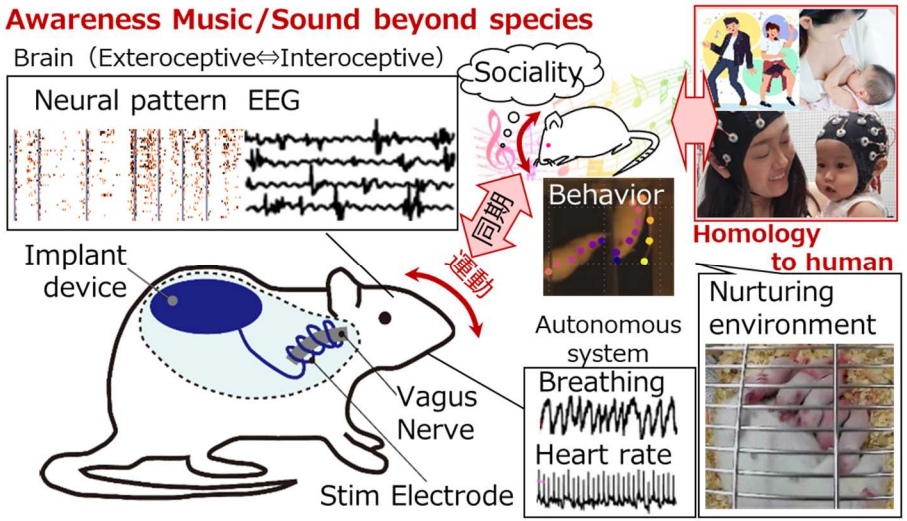
2. Outcome so far

We have physiologically and behaviorally verified the effects of AMS in animal experiments. We specifically elucidated how the rhythm in music gained appeal to the brain. A wireless accelerometer attached to the head of a rat precisely revealed that rats show beat synchronization most disinctly in the original music and that the beat synchronization pattern during music was similar between rats and humans. We then demonstrated that the neural dynamics in the auditory cortex matched the dynamics of music, suggesting that music has developed in human society over a long period of time because of a strong appeal power to the brain across species. Thus, our study demonstrated that rats can serve as a groundbreaking experimental model to verify the effects of AMS.

3. Future plans

We will (i) investigate how the interaction between interoceptive and exteroceptive awareness evolves, (ii) verify the homology of AMS effects between humans and animals, (iii) establish physiological setups to monitor and regulate the autonomic and emotional states in rodents, (iv) translationally investigate autonomous system, e.g., heartbeat evoked potential and vagus nerve stimulation, (v) investigate how AMS can appeal to the autonomic and emotional systems and promote interoceptive awareness, and (vi) translationally clarify the long-term exposure effect of AMS in behavior and physiological experiments.

(TAKAHASHI Hirokazu, University of Tokyo)



国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency

R&D Theme

Investigation to elucidate the KANSEI mechanism and to develop its brain scientific model based on the analyses of simultaneous fMRI-EEG-BIN measurement data

Progress until FY2022

1. Outline of the project

In this theme, we hypothesize that the brain-interoception network (BIN) is involved in interoceptive awareness that triggers KANSEI evaluation. We aim to verify the hypothesis and elucidate the mechanism by analyzing brain and physiological data from fMRI-EEG and multimodal physiological measurements (Fig. 1).

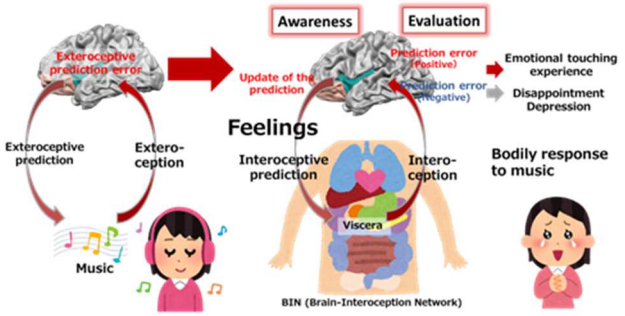


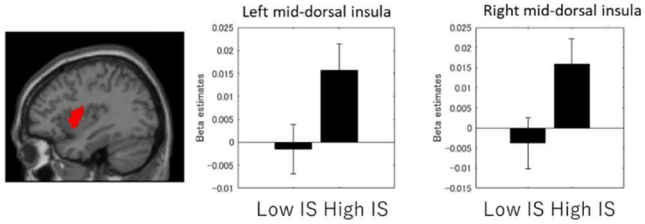
Figure 1. The hypothesis in this theme

2. Outcome so far

We published a paper on the insula-centered interoceptive information processing hypothesis, which is the theoretical basis of this theme (Fermin, Friston, & Yamawaki, 2022).

Participants' heart rate and brain activity were measured during an emotional rating task to musical stimuli. Dividing participants into high and low interoceptive sensitivity (IS) groups based on their performance in a heartbeat discrimination task, we found an increase in heart rate in the high IS group when valence level was high and the mid insula activity correlated with valence level (Fig. 2; Maekawa et al., submitted). The mid insula is known to receive afferent signals from visceral organs and transmit to the anterior insula, suggesting that interoceptive information is used more in the high IS group for valence rating.

Figure 2. The mid insula activity modulated by the interoceptive sensitivity



The effect of uncertainty in predicting musical chords on interoception was examined using heartbeat evoked potential (HEP). The results showed that the HEPs observed in the frontal EEG channels while predicting the next chord were larger for chord sequences with high uncertainty than for chord sequences with low uncertainty (Fig. 3; Ono et al., submitted), suggesting that uncertainty in prediction influences interoceptive processing.

To demonstrate the basic findings in the field, we are measuring the heart rate of music performers using a wearable device and acquired data on subjective KANSEI evaluation using an application running on a smartphone at a workshop and extracted issues in field measurement (Fig. 4).

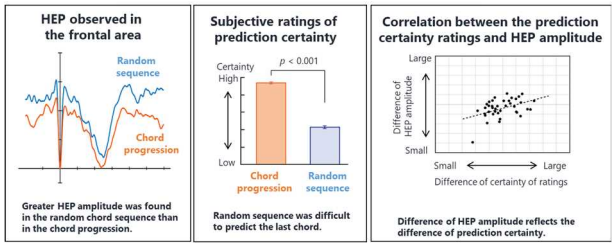


Figure 3. HEP modulated by the musical predictability

Figure 4. Measurement at the music workshop

3. Future plans

We will continue to elucidate BIN and identify indices to visualize interoceptive awareness. In addition, we will verify whether the obtained indices are related to the emotions related to music, and conduct field experiments to establish a theoretical and technological foundation for Awareness Music/Sound.

(SASAOKA Takafumi, Hiroshima University)

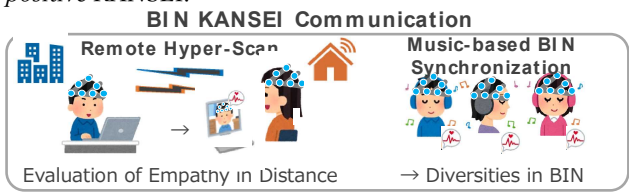
R&D Theme

Remote KANSEI Quantification with Wearable BIN system & Music-based Neuro-Bio-Feedback

Progress until FY2022

1. Outline of the project

With the development of wearable EEG technologies in daily life, technologies to quantify KANSEI, which has been difficult to date, are readily available. However, it is pivotal to establish convenient yet reliable neurophysiological assessment technology for sound and music in daily life supported by brain-interoception network (BIN) monitoring. In this theme, we will advance the basic research to the fundamental technologies to achieve social implementation. First, we will develop a multimodal neuro-physiological KANSEI interface with wearable EEGs and physiological monitoring devices and identify indices to measure and visualize the BIN in real-time. With advancing informatics, concurrent and remote data collection from the citizens is expected to foster the quantitative evaluation of *positive* KANSEI.

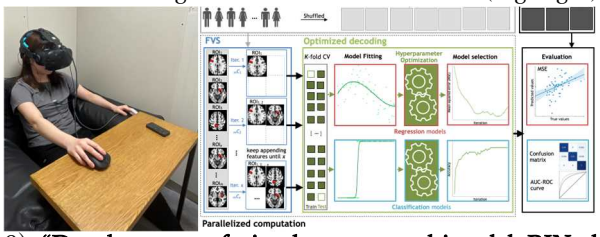


Together with these neuroscientific basis, we will foster to minimize *negative* KANSEI. The development of Neuro-Bio Feedback technology would lead to the creation of the Awareness Music/Sound that optimizes the BIN of individuals in real-time with sounds and music.

2. Outcome so far

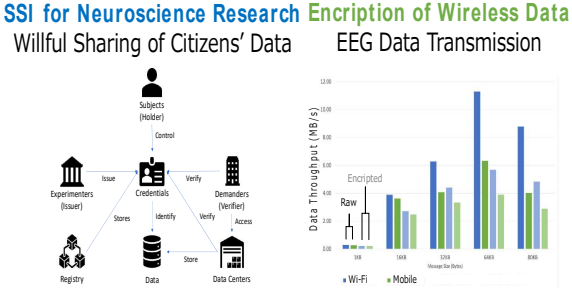
1) **"Development of Sensory Visualization Technology Using Wearable BIN Measurement"**

We have established a BIN monitoring setting that simultaneously monitors multimodal physiological indices together with EEGs (Fig. left). We have also released a new methodology to improve the decoding accuracy of existing machine learning on multivariate neural data (Fig. right).



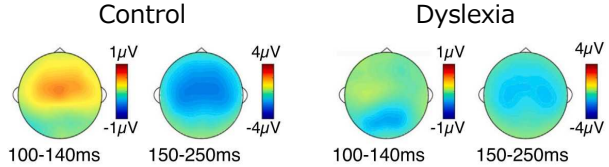
2) **"Development of simultaneous multimodal BIN data collection and remote visualization of sensitivity"**

As a trustable platform for curating personal, multimodal neurophysiological information obtained from citizens in the near future, we developed a self-sovereign authentication (SSI) system that securely establishes authentication between data providers and their users (Ding, Sato & Machizawa, 2022), it was awarded the Best Paper Award at the IEEE Software Defined Systems.



3) **"Statistical Learning and neural underpinnings on Musical perception, recognition and appreciation"**

We covertly learn acoustic notes and our brain implicitly acquire statistical rules behind the musical notes. Our research on statistical learning revealed the neural underpinnings of developmental dyslexia associated with both perception and attentional processes.



4) **"BIN assessments across generations and species"**

We are bridging the gap from basic research to real-world applications and promoting the technical commonality of BIN measurement methods between generations (adults to children) and between species (humans to rodents).

3. Future plans

The decoding method is expected to be applied to practical use in the real-world with guaranteed fidelity, serving a foundation for reliable application of neural functions obtained in basic research in the general public. With interindividual differences on BIN in mind, we will identify indices that can be utilized in the real world with neuroscientific model of KANSEI and decoding of multimodal neurophysiological information. It is expected to enhance "mental capital" and feedback in the real world based on reliable markers found in basic brain science research through BIN measurements

(MACHIZAWA Maro, Hiroshima University).

.