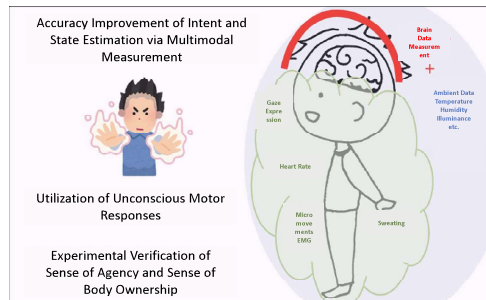# Human-Centered BMI
—Harnessing Users' Conscious and Unconscious Processes—

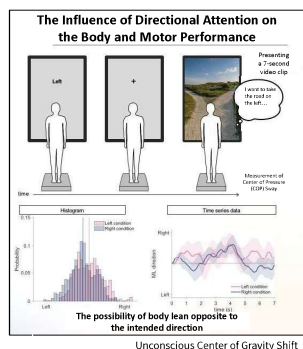Katsumi Watanabe, Professor, Faculty of Science and Engineering, Waseda University

Overview

This research aims to accumulate scientific knowledge regarding the estimation of psycho-physical states applicable to BMI (Brain-Machine Interface) and Cybernetic Avatar (CA) related technologies, and to conduct R&D on utilizing latent information appearing on the body surface. Specifically, we will clarify the limits and scope of intentions and mental states decodable from non-contact surface information, and seek to improve performance and expand applicability in daily life by combining this information complementarily with brain information. Furthermore, anticipating a future with multiple operators and multiple CAs, we will conduct research to elucidate the relationships between sense of body ownership, sense of agency, and performance. This will establish a scientific foundation for measuring and improving the user experience of BMI technology and CAs for both individuals and groups.

Accuracy Improvement of Intent and State Estimation via Multimodal Measurement

Utilization of Unconscious Motor Responses

Experimental Verification of Sense of Agency and Sense of Body Ownership

R&D Approach: Utilizing Involuntary Responses and Their Underlying Processes

Harnessing Unconscious Body and Behavioral Reactions

The Influence of Directional Attention on the Body and Motor Performance

The possibility of body lean opposite to the intended direction

Unconscious Center of Gravity Shift

PNS Activity: Up
Heart Rate: Down

PNS Activity: No Change
Heart Rate: Down

Estimation of Intimacy Level via Physiological Responses

Even when people believe they are doing nothing (or actively trying to be still), their intentions, emotions, and other internal states manifest in their face, body, and behavior. In this research theme, we do not treat such unconscious reactions as mere noise. Instead, we regard them as crucial information that complements BMI technology designed to liberate humans, and we are accumulating scientific knowledge that will lead to technologies realizing a state of greater control and freedom.

For example, findings such as "unconscious shifts of body weight to the right when intending to move left," "changes in body weight distribution when a face of someone who committed a moral wrong is presented," and "changes in heart rate and parasympathetic nerve activity depending on whether a close friend is directly in front or to the right" are all pieces of information unknowingly broadcast by humans. By combining these with BMI data, we expect to improve the accuracy of intention and state estimation.

BMI in Daily Life

For new technologies, including BMI, to permeate society, not only technological advances but also how they are used in daily life and how they are accepted by society are crucial. Based on the perspective that "there are things we only discover through actual use," this project aims to continuously measure data over a long period. Rather than giving up on the challenge of measurement in daily life as too difficult, we are proceeding to discover, in a bottom-up manner, "when measurement is truly possible" and "what usage patterns lead to greater utility".

Continuous use of BMI in day-to-day life
お茶の間で気軽に脳波計測
ベストプラクティスの収集と計測の限界の確認

E-sports Player
EEG Spectral Display during Resting (Sitting), Desk Work, and Esports Gameplay: Characterized by greater alpha power during resting and greater gamma power during Esports gameplay.

PLUG measurement

Esports Play

EEG While Playing Online Games in the Living Room

Building the Research Foundation for Agency Engineering

One of the key concepts of Goal 1 is the Cybernetic Avatar (CA). CAs are entities that operate as extensions of oneself, whether in the physical or virtual world. The future we envision includes scenarios where "multiple operators control a single CA," "one operator controls multiple CAs," and even "multiple operators control multiple CAs." While goals include enhancing productivity and creativity, for these technologies to truly lead to human joy and value, maintaining and improving the user's sense of "being the agent" (sense of agency) and sense of "being a participant" (sense of contribution) are essential.

In cognitive science and neuroscience, a significant body of research has been accumulated on individual sense of agency, but very little research has explored multiple operators or multiple CAs. Therefore, we are conducting cross-team R&D to investigate the relationships among sense of body ownership, sense of agency, and performance, assuming a future where multiple operators and multiple CAs exist.

For instance, consider a task where a large group of people tries to draw a circle as smoothly as possible using a single cursor. Individual participants can only see the average position of the cursor from all inputs. By meticulously analyzing aspects such as "how task performance changes," "whether the team succeeded," "how much one contributed," and "whether one can respond cooperatively to others' inputs" in such a situation, we aim to clarify the characteristics, limitations, and expandability of multi-CA operation and multi-subject participation. Specifically, we are exploring methods to optimize the actual contribution of each individual while maintaining the multiple operators' sense of agency and subjective contribution. Furthermore, this knowledge may provide guidelines on when and to what extent AI support should be introduced into CA operation and BMI technology.

Participants cannot see their actual cursor position.

Cursor Position of Participant 2 (x_2, y_2)

Cursor Position of Participant 1 (x_1, y_1)

Averaged Cursor Position $(x_{c,N}) = \frac{(x_1 + x_2)}{2}, \frac{(y_1 + y_2)}{2}$

$$x_{c,N} = \frac{1}{K}\sum_{i=1}^{K} x_{i,N}$$
$$y_{c,N} = \frac{1}{K}\sum_{i=1}^{K} y_{i,N}$$

$$c_N = \frac{1}{K}\sum_{i=1}^{K} p_{i,N}$$

c_N: Cursor (Averaged) Position at Frame N
$p_{i,N}$: Position of Participant i at Frame N
K: Number of Participants

Online Platform for Cooperative Motor Experiments

Sending the cursor position of each participant

Participant 1 Participant 2 Participant N

Participant's Task Display

Collaborative Motor Task by Two Participants

Collaborative Motor Task by Five Participants

Collaborative Motor Task by Eight Participants

Developing an Experimental Platform for Group Collaboration

Future Prospects

When aiming to enhance productivity and creativity while simultaneously maintaining (or improving) individual well-being, we believe that understanding the "conscious and unconscious processes of the user (human)" is crucial. This is just as important as technological progress in clarifying how to measure the "subjective experience" of users employing CA and BMI technologies, and how that information should be fed back to society and individuals. Moving forward, we will continue to conduct research that prioritizes the "feelings" (mental states) of both individuals and groups, anticipating the future to be achieved through the Moonshot program.

Katsumi Watanabe

Professor, Faculty of Science and Engineering, Waseda University

Completed the Computational and Neural Systems program at California Institute of Technology (Caltech) in 2001 (PhD). At the current position after serving as Associate Professor at the Research Center for Advanced Science and Technology, The University of Tokyo, and other roles. Has participated in the Moonshot program since 2020. Specializes in Cognitive Science, Psychology (Cognitive Psychology), and Neuroscience. Conducts research aimed at the scientific elucidation of the conscious and unconscious processes that create the subjective phenomenon of the human mind, using cutting-edge methods from cognitive science, psychology, and neuroscience; the expansion of cognitive science to other research fields; and the societal implementation of these findings through industry-academia collaboration.

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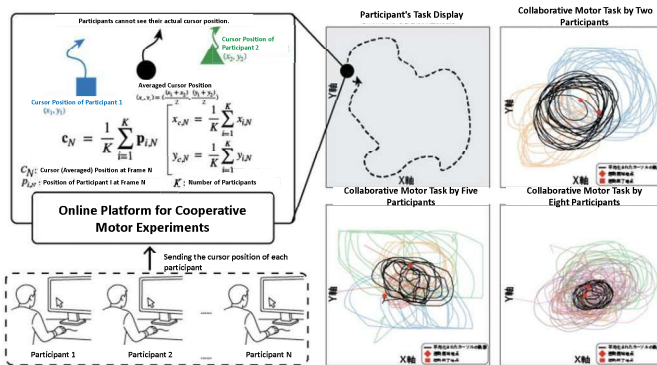Researcher, Sony Computer Science Laboratories, Inc.

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Internet of Brains