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Topic-Setting Program to Advance Cutting-Edge

Humanities and Social Sciences Research

（Area Cultivation Program）

Progress Report

（Summary of Final Report）

[Understanding of individual mental identity using the multidimensional and multidisciplinary cognitive behavior analysis]

Core-Researcher: Makoto Ichikawa

Institution: Chiba University

Academic Unit: Graduate School of Humanities

Position: Professor

Research Period: 2017 - 2020

1. Basic information of research project

Research Area	"Cognitive turn" and the transformation of identities
Project Title	Understanding of individual mental identity using the multidimensional and multidisciplinary cognitive behavior analysis
Institution	Chiba University
Core-Researcher (Name, Academic Unit & Position)	Makoto Ichikawa (Grad School of Humanities, Professor)
Project Period	2017 - 2020
Appropriations Plan (¥)	2017 2,925,000 JPY
	2018 4,928,300 JPY
	2019 4,022,200 JPY
	2020 1,287,000 JPY

2. Purpose of research

This research project aims to establish a multidimensional cognitive-behavioral analysis approach based on not only subjective indicators of the individual's state, but also subjective indicators of the individual's behavior and measurements of the individual's surrounding environmental factors, in order to explore and clarify the private inner life that forms the basis of the individual's mental identity. Project members have tried to establish a multidimensional cognitive-behavioral analysis approach. In particular, we analyzed the relationship between physiological and behavioral indices, environmental characteristics, and cognitive task performance in a real-time, multidimensional manner, and realized cognitive and sensory environment settings, communication aids, and behavior prediction that take into account the diversity of individuals.

3. Outline of research (Including study member)

The private inner life of an individual is considered to be the basis of that individual's mental identity. The core of the paradigm shift by the behavioral sciences, including cognitive science, is the paradoxical perspective that behavior, which is externally visible and objectively observable, is the key to understanding the private interior. Based on this perspective, cognitive science has inferred the private interior by examining human behavior under controlled experimental conditions and checking it against models. Psychology, baptized by cognitive science, has achieved substantial results in elucidating the internal processes underlying identity (phenomenal characteristics of perception, sensitivity, decision-making, personality, etc.) based on experiments and questionnaires.

However, there have been two problems with conventional cognitive science research

methods. First, although conventional methods are effective in elucidating the "subjective" aspects of mental characteristics, they have various limitations in understanding the "objective" aspects. For example, the answers given in the questionnaires were only the subjective judgments of the participants. Second, in the laboratory experiments, multiple parameters had to be manipulated individually for a systematic understanding of psychological characteristics, and the experimental environment deviated from the daily scene. In addition, because individual experiments were the mainstream, it became difficult to elucidate the mental characteristics that support dynamic identities that change in relation to others.

In order to solve these problems and objectively elucidate the internal processes underlying the mental identity of each individual, this study has aimed to establish a new approach called “Multidimensional Cognitive Behavioral Analysis (MCBA)”. Multidimensional cognitive-behavioral analysis is an approach to psychological experiments in which not only "subjective" data from questionnaires, but also (a) physiological data (eye movements, blinks, heartbeat, body temperature, sweating, respiration, EEG, etc.), (b) behavioral observation data (video images during the execution of cognitive tasks, location information from GPS, etc.), (c) environmental data (temperature, humidity, power consumption, etc.), and (d) data from the experiment are collected. This is an approach to collect "objective" data such as (a) temperature, humidity, electricity consumption, lighting intensity, etc., in a multidimensional and comprehensive manner, and to examine the relationship between environment and psychology through data mining. By making full use of the cross-disciplinary collaboration system that has been established at Chiba University, we have organized three research groups, the "*Internal Observation Group*", "*Behavioral Observation Group*", and "*Environmental Observation Group*", by integrating knowledge and methodologies from different fields such as image processing, physiological measurement, machine learning, artificial intelligence, and information communication, with a focus on psychology. We have developed research that organically integrates these studies. Through multidimensional analysis, including real-time calculation of correlations among various indices, we have aimed to establish indices with high validity, robustness against noise, and high predictive power for the internal states of individuals. Based on this multidimensional analysis of the relationships among various indicators, we have attempted to construct a system for setting up a cognitive and emotional environment, assisting communication, and predicting behavior that takes into account the diversity of individuals.

Project members

Researchers	Name	Academic Unit, Position	Roles in project
Core-Researcher	Makoto Ichikawa	Chiba Univ., Grad School of Humanities, Prof.	Supervision, Psychological experiment
Internal observation			
Group Leader	Tomokazu Ushitani	Chiba Univ. Grad School of Humanities, Associate Prof.	Psychological experiment, Physiological data collection
Member	Eiji Kimura	Chiba Univ., Grad School of Humanities, Prof.	Psychological experiment, Behavioral data collection
Member	Rumi Tokunaga	Chiba Univ., College of Liberal Arts and Sciences, Assistant Prof.	Behavior analysis, Deep learning
Member	Midori Tanaka	Chiba Univ., College of Liberal Arts and Sciences, Assistant Prof.	Behavioral data collection and analysis
Behavioral observation			
Group Leader	Toshihiko Matsuka	Chiba Univ., Grad School of Humanities, Prof.	Behavioral data collection and analysis
Member	Yasuharu Den	Chiba Univ., Grad School of Humanities, Prof.	Behavioral data collection and analysis
Member	Akihiro Abe	Chiba Univ., Grad School of Humanities, Prof.	Real time data collection and analysis
Member	Sachiyo Arai	Chiba Univ., Grad School of Engineering, Prof.	Environmental information analysis
Member	Kazuhiko Kawamoto	Chiba Univ., Grad School of Engineering, Prof.	Behavior data collection and analysis, Deep learning

Member	Yoko Mizokami	Chiba Univ., Grad School of Engineering, Prof.	Behavior data collection and analysis, Deep learning
Member	Noriko Yata	Chiba Univ., Grad School of Engineering, Assistant Prof.	Behavior data collection and analysis, Deep learning
Environmental observation			
Group Leader	Hiroo Sekiya	Chiba Univ., Grad School of Engineering, Prof.	Environmental information analysis
Member	Yoshitsugu Manabe	Chiba Univ., Grad School of Engineering, Prof.	Environmental information analysis
Member	Takahiko Horiuchi	Chiba Univ., Grad School of Engineering, Prof.	Real time data collection and analysis
Member	Nobuyoshi Komuro	Chiba Univ., Grad School of Engineering, Associate Prof.	Real time data collection and analysis
Member	Shoko Imaizumi	Chiba Univ., Grad School of Engineering, Associate Prof.	Environmental information analysis
Member	Keita Hirai	Chiba Univ., Grad School of Engineering, Associate Prof.	Real time data collection and analysis
Member	Kien Nguyen	Chiba Univ., Grad School of Engineering, Assistant Prof.	Environmental information analysis

4. Research results and outcomes produced

In this study, we have been trying to understand the influence of various internal and external factors and the interaction of multiple factors on human psychological characteristics in detail, and to establish a method to identify the psychological characteristics of each individual more efficiently and simply than before.

Internal Observation Group

The "*Internal Observation Group*" has clarified psychological characteristics based on

behavioral indices such as reaction time and correct response rate, which were examined using cognitive science methodologies. Members of this group also collected data on physiological indices such as heartbeat, respiration, body temperature, blink of eyes, and perspiration, and examined their relationships with psychological characteristics such as perception, cognition, sensitivity judgment, and decision making. As a result, they found that, in human observers, arousal emotional responses evoked by image observation improved the temporal accuracy of visual information processing, while it rather decreased the temporal accuracy for the visual stimuli presented after emotional images. Also, they found that endogenous attention increased the temporal accuracy of both lower-order and higher-order visual information processing. These results indicate that mental time, which would be a core of individual's mental identity, is not determined by external stimuli, but by the internal characteristics of the individual, such as the emotions and endogenous attention. Moreover, they found that the respiratory phase, a biological cycle that can be consciously manipulated by observer, can alter the degree to which endogenous and exogenous attention facilitate visual information processing. However, they found that the temporal relationship between two sounds perceived simultaneously varied depending on the external stimulus characteristics, such as the frequency difference between the stimuli.

They also investigate how the visual processing extracties the outline of the various color distributions in the external environment. They found that the average perceived color shifted from the physical average to the most vivid color element according to the physical characteristics of the stimuli, such as the dispersion of the presented colors.

In collaboration with the *Behavioral Observation Group*, they examined the processing characteristics in categorization tasks for humans, other species (such as birds), and machines. For human observers, they found a tendency not to recognize the structural properties of the stimuli themselves and a tendency to conserve cognitive resources for recognizing the target structure. It is interesting to note that this processing strategy is different from that of machine learning, which makes full use of memory, and is rather similar to that of pigeons, and that similarities were found among species with very different phylogenetic characteristics.

Furthermore, we analyzed the relationship between the sensibility of perceiving the content of the lecture as "interesting" and physiological indices. In addition, through collaboration with the *Environmental Observation Group*, they succeeded in estimating the internal state of an individual from environmental data with high accuracy (see details in the *Environmental Observation Group* section).

Behavioral Observation Group

The "*Behavioral Observation Group*" have attempted to clarify the intentions and purposes of human behavior, as well as the knowledge and thoughts used in that behavior, based on not only

behavioral science experiments but also data analysis using computer models with deep learning techniques. For the analysis of human behavior, members of this group developed a deep learning model that automatically labels the user's behavioral history from first-person video, and experimentally demonstrated its effectiveness. They also introduced multi-task learning, which has a pseudo effect of data expansion, and showed that it improves recognition accuracy compared to conventional methods. Using machine learning, they proposed a method for automatically constructing connected actions of two motion data using convolutional networks (CNNs).

In order to measure the behavior of many participants simultaneously in real time, they developed and verified a method for collecting human flow data using ultra-wide band (UWB). A behavioral model of evacuees with different objectives and personality traits was developed, taking into account the intrinsic characteristics of individuals.

They conducted experiments by the use of gaze measurement, and confirmed that the observer's personality traits affect observation behavior, and that those affected observation would cause different impressions for the same face. They also found that although the impression of another person's face fluctuates with gaze guidance, the way in which it fluctuates depends on the observer's personality traits.

They examined what kind of linguistic behaviors are used to construct shared beliefs when collaborating with others, and found that only a small number of dialogues followed external structures, which were previously thought to be common, but rather dialogues contained inaccurate information, and that participants self-corrected inaccurate information. These results imply that the construction of shared beliefs among individuals is not only forward, but also retrospectively revised, constructed, and reconstructed. On the other hand, conversational analysis of utterance framing choice revealed that non-explicit reference points are influential. This result indicates that external information has an unconscious influence on the choice of utterances among individuals.

They conducted an interview analysis of people with dementia and their families, as well as a multi-person conversation analysis of the elderly. In both cases, they found that family members were more likely to notice minor behavioral changes in the early stages of dementia if speech was exchanged with less cognitive bias. These results imply that the internal property of cognitive bias influences the awareness of other-cognitive behavioral changes.

Color-optical experiments demonstrated that, by the use of luminance histogram statistics and photometric parameters of experimental stimuli in response to illumination diffusivity changes, we can predict the perception of illumination diffusivity and texture. They clarified the effect of naturalness in the color and brightness contrast of images on the correction of visual vividness to changes in visual field saturation, and identified the brain sites associated with this correction. Also, they found that the prominence of pigmented spots in face images varied depending on image characteristics, such as their size and density, as well as their location and distribution. On the other

hand, with regard to the perception of multiple racial complexions, they found that reddish faces appeared brighter than yellowish faces in the case of Japanese subjects, regardless of the racial complexion.

Environmental Observation Group

The goal of the "*Environmental Observation Group*" was to collect real-time data on the physical environment and to examine the relationship between this data and performance on cognitive tasks. Members of this group constructed a sensor network to measure environmental data related to human perception and behavior, and analyzed the data using machine learning. They also attempted to construct a network system that can efficiently process data acquired at various locations in a space where many individuals are active. By adding the function of spiking neurons to the sensor nodes of the sensor network, the entire sensor network can process information in a distributed manner like a brain. By placing sensors for temperature, humidity, illumination, human presence, and carbon dioxide on the ceiling of the laboratory, and sensors for power consumption on the switchboard, they constructed a system that can automatically collect this environmental information on the server.

In the joint research with the "*Internal Observation Group*", they succeeded in estimating the mental state (stress state, etc.) estimated from biological data with an accuracy of about 80% from non-contact real-time indoor environmental data. In particular, the carbon dioxide concentration in the environment, the surface temperature of the face, and the distance between individuals were shown to be of high importance.

In order to represent the actual space in VR, they developed a method to model the space in three dimensions and applied it to experiments such as behavior analysis. They proposed a method of dividing three-dimensional data into small regions and integrating the data by finding correspondences based on the features of the regions. With this method, they were able to integrate data with less overlap than the conventional method, and the processing speed was also faster than the conventional method. In addition, they proposed a method for estimating the three-dimensional shapes and arrangements of objects and rooms in a scene from a single indoor image using deep neural networks.

In order to conduct efficient cognitive experiments in a situation close to the real environment, they have developed VR and AR technologies and conducted experiments to investigate spatial cognitive abilities in other collaboration with the "*Internal Observation Group*". They conducted a visual search experiment to find a specific object among other objects, and obtained results showing a linear relationship between the number of objects and the search time, as in previous studies in two dimensions. They measured stereoscopic sensitivity based on binocular disparity using an HMD and developed a method to identify the extent to which the participants

obtained depth information from binocular disparity. Furthermore, they measured the flash-lag effect for stimuli synchronized with hand movements in 3D space and found that the flash-lag effect was more likely to occur for back-and-forth movements than for left-right movements of the hand, indicating anisotropy in visual space.

In this research project based on three groups (Internal Observation, Behavioral Observation, and Environmental Observation), we confirmed that there are two types of internal states related to the identity of each individual: one is the characteristics that vary in response to external factors such as physical stimuli and environmental characteristics, and the other is the characteristics that vary in response to internal factors related to the processing of such external stimuli. In addition, we have succeeded in constructing a highly accurate prediction method using objective factors such as environmental, physiological, and behavioral factors. These research results not only make it possible to construct a technology to infer an individual's internal state from objective environmental factors, but also suggest that an individual's subjective state and identity are determined by objective factors in the environment and provide a new perspective on an individual's mental identity. This provides a new perspective on individual mental identity.

Future development

In this research project, we confirmed that there are two types of characteristics of an individual's mental identity: characteristics that vary in response to external factors such as stimuli and environmental characteristics, and characteristics that vary in response to internal factors related to the processing of such external factors. For each of these factors, we were able to construct a method to predict them based on objective factors such as environmental, physiological, and behavioral factors. It was also shown that the subjective state and mental identity of an individual are not only based on internal factors but are also determined by external factors that can be measured in terms of environment and behavior, and that the contents of these factors can be estimated with high accuracy from behavioral and environmental indicators that can be measured objectively by the use of various sensors. In the future, we will use machine learning and data mining methods to clarify the relationship between behavioral, physiological, and environmental indices and psychological characteristics related to various domains, such as higher-order processing in perceptual cognition, sensitivity judgment, and decision making. In addition to the subjective and subjective understanding of psychological characteristics underlying psychological identity, it is expected that the understanding based on objective factors will be greatly advanced.

In addition to the subjective understanding of psychological characteristics, objective understanding can be greatly advanced by elucidating the relationship between psychological characteristics such as perceptual cognition and sensitivity judgment and behavioral and

physiological indicators using data mining methods. In particular, the present study revealed that pupil diameter and heart rate are indicators of higher-order subjective changes that fluctuate more rapidly, such as changes in consciousness. Furthermore, we found that conscious phase manipulation of respiration, which is inextricably linked to physiological states such as heart rate, affects attentional tasks. Based on these results, we believe that we will be able to open the door to the elucidation of the whole picture of human cognition, including the interrelationship between psychological characteristics and physiological indicators, through the understanding of the elucidation of the pathways of respiration (behavior), autonomic nervous system (physiology), and attentional tasks (behavior and psychology) in the field of cognitive science.

In this study, we believe that we have achieved an attempt to expand the elucidation of psychological and behavioral characteristics, which have been limited to humans in the laboratory, to real-life situations such as actual communication scenes and group movement scenes. As a ripple effect of this study, it has been difficult to elucidate the psychological and behavioral characteristics in real-life situations using conventional methods such as factorial programming, but we hope to overcome this difficulty by incorporating information science methods such as deep learning.

In conventional environmental measurement using sensor networks, only sparse data can be obtained both spatially and temporally due to the placement and performance of the sensors. However, in this study, we have shown that it is possible to achieve dense and highly accurate estimation of environmental information in space by applying machine learning to sparse data. We hope to develop more accurate and efficient estimation techniques based on the use of multidimensional sensor information.

The methodology developed in this study, “Multidimensional Cognitive Behavioral Analysis (MCBA)”, which allows us to infer the mental content of multiple individuals from the measurement of multidimensional factors related to the environment and behavior using non-contact sensors, is also suitable for dealing with new coronavirus infections by avoiding people densification. The methodology developed in this study, which allows us to infer the mental contents of multiple individuals from various measurements in real time, is expected to be useful in controlling the environmental characteristics of public spaces used by large numbers of people in the future.