Title of Project : Science of personalized value development through adolescence: integration of brain, real-world, and life-course approaches

Kiyoto Kasai
(The University of Tokyo, Department of Neuropsychiatry, Professor)

Research Project Number : 16H06395 Researcher Number : 80322056

【Purpose of the Research Project】

Our project aims at establishing an interdisciplinary science which focuses on the development of "personalized value" through adolescence by integrating brain, real-world, and life-course approaches.

Human adolescence is far longer than those in non-human primates and is the life stage in which cerebral neocortex matures. While the childhood is associated with trans-generational incorporation of parent's value, the adolescence is characterized by social interactions with peers. Through such influences, a person's value is internalized and personalized to become "personalized value".

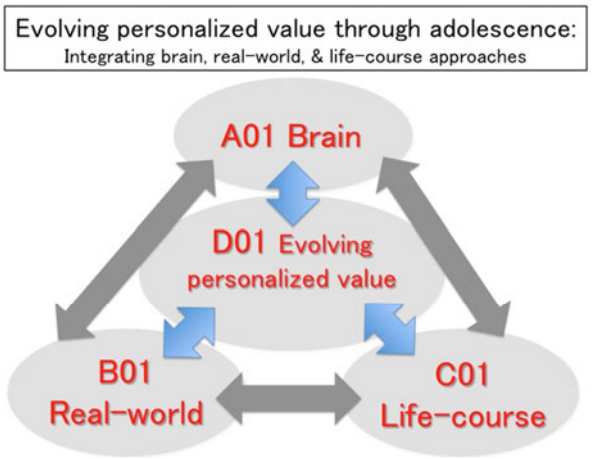
【Content of the Research Project】

A01 aims at uncovering the brain basis of the personalized value. Here, the value development can be modeled as the psychological process in which adolescents acquire the ability to control the conflict between value memory and actual behavior by using self-regulation including meta-cognition and language (inner-speech).

B01 considers "real-world" as a modulatory factor in the neural basis of value development. Here we propose a spiral model where active interaction with real-world influences the value development, which then shapes the action pattern in life, in turn inducing the plasticity in the brain circuit.

C01 will use life-course epidemiology to how the personalized value is developed in adolescence and how it influences later life. The Tokyo TEEN Cohort will be the main panel.

By integrating brain (A01), real-world (B01), and life-course (C01) approaches, D01 will deepen the conceptual framework of personalized value. Then, we will develop psychosocial intervention strategy to evolve the personalized value.



【Expected Research Achievements and Scientific Significance】

Our project will propose a new interdisciplinary science of "action brain", where we clarify how the brain evolves personalized value through adolescence to actively make influence upon the social environment and pursue subjective well-being. Our findings will ultimately contribute to policy making of education and health promotion in adolescence.

【Key Words】

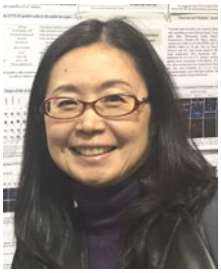
Adolescence: developmental stage from onset of puberty through maturation of neocortex.
Personalized value: a person's inner driver for long-term action, which will be internalized and personalized through adolescence.

【Term of Project】 FY2016-2020

【Budget Allocation】 1,112,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://value.umin.jp



Title of Project : Integrative Research toward Elucidation of Generative Brain Systems for Individuality

Noriko Osumi
(Tohoku University School of Medicine, Professor)

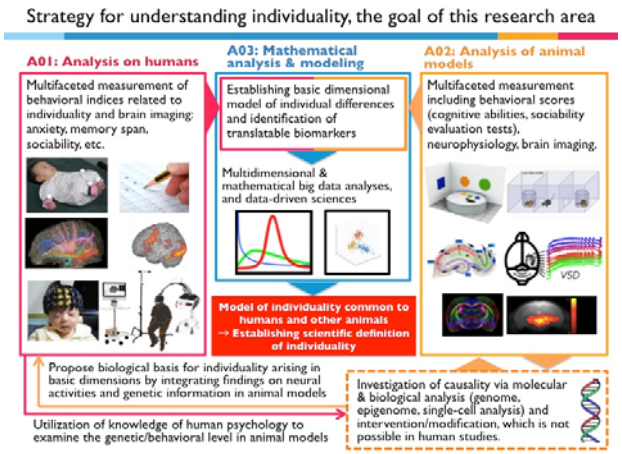
Research Project Number : 16H06524　Researcher Number : 00220343

【Purpose of the Research Project】

How does individuality emerge? Individual genomic differences (personal characteristics) form the basis, but the manifestation of individuality varies according to upbringing, lifestyle and other environmental factors. This is because of the epigenome, a mechanism that changes the way genes work in response to the environment. We see individuality in mental functions, such as cognitive faculties and personality, which depend on the function of the cerebral nervous system, but we lack a clear understanding of the neural basis or the genetic/environmental factors involved. In recent years, however, we have gained access to "big data," including human brain imaging data, data from observation of animal behavior, and neural activity data, facilitating various kinds of multivariate analyses. We now have an excellent opportunity to undertake research on individuality. In this innovative/interdisciplinary project, we aim to understand the emergence of individuality by elucidating diversity in brain development and evolution.

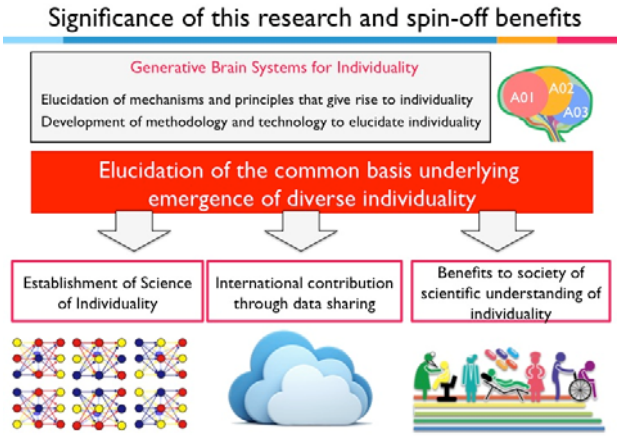
【Content of the Research Project】

Our innovative research will be undertaken through close collaboration among researchers in A01 humanities and social sciences, A02 biology, A03 mathematics and technology to understand emergence of individuality in humans and other animals based on diversity in cerebral nervous system growth and development and fluctuations due to intervention. By establishing models and frameworks common to humans and animals, it will be possible to do animal-based research on problems such as intrapopulation maladaptation and transmission to the next generation, which have hitherto been difficult to research using humans alone.



【Expected Research Achievements and Scientific Significance】

The creation of a new discipline that integrates research fields such as neural development, neurogenesis, developmental brain science, novel tools, big data, and mathematical models, has the potential to develop significantly in ways that could have a broad and powerful impact on related disciplines, such as medicine, informatics, pedagogics and humanities. We plan to promote this activity by establishing an international data-sharing platform. We believe the virtual "aggregation of knowledge" resulting from the creation of this new discipline has the potential to contribute significantly to international society. Moreover, by elucidating the neural basis and molecular mechanisms underlying the emergence of individuality, this research may facilitate effective utilization of our scientific understanding of diverse forms of individuality within society. Because it is important for our society to handle scientific knowledge relating to individuality with caution, we intend to examine the ethical, society, and legal issues associated with the dissemination and utilization of scientific information regarding individuality and to provide a basis for the formation of a social consensus.



【Key Words】

"Individuality": Here we refer to individual differences in traits and/or characteristics in organisms, ranging from animals to humans, as "individuality."

Basic dimension model: A model of a basic framework underlying personality structure

【Term of Project】　FY2016-2020

【Budget Allocation】 1,153,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://koseisouhatsu.jp
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Title of Project：Systems Science of Bio-Navigation

Koichi Hashimoto
(Tohoku University, Graduate School of Information Sciences, Professor)

Research Project Number：16H06535　Researcher Number：80228410

【Purpose of the Research Project】

Navigation is a fundamental behavior of animals including human. In navigation, the following three functions are required: the acquisition of dynamically-changing information from external and internal environment, the choice of route and destination based on the information, and the behavioral regulation to reach the destination. We aim for **systems science of bio-navigation** to understand the "algorithms" for the navigation of animals. To this end, we bring together experts from control engineering, data science, animal ecology, and neuroscience, and jointly work on how to measure, analyze, understand, and verify bio-navigation.

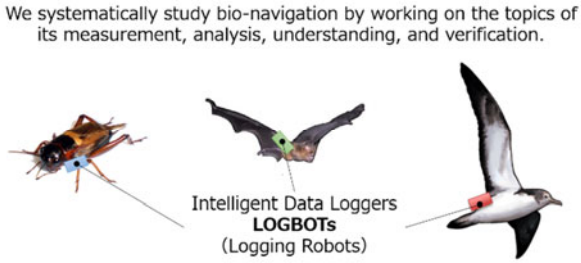


Figure 1: Systematic studies of bio-navigation.

【Content of the Research Project】

We work on the topics of measurement, analysis, understanding, and verification of bio-navigation. In *measurement*, we develop Logbots by making conventional data logging devices more autonomous for measuring high-dimensional signal in bio-navigation. In *analysis*, we provide generic data analysis toolbox for bio-navigation. In *understanding*, we build bio-navigation models to explore commonality and diversity across species. In *verification*, we verify the models by using tools developed in neuroscience, such as genetic engineering, neuronal activity monitoring, and optogenetic regulations.

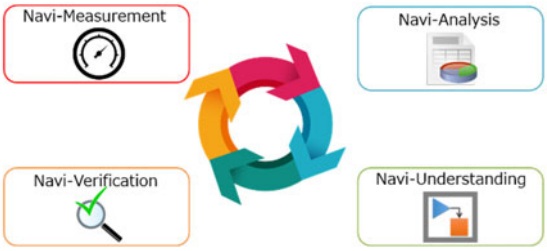


Figure 2: Four topics of bio-navigation studies.

【Expected Research Achievements and Scientific Significance】

The following three results are expected. (1) First, by developing Logbots, it would become possible to obtain novel and more accurate signals on bio-navigation over a long period of time. (2) Second, mathematical models of bio-navigation would be constructed, and they could be used for understanding the commonality and diversity across navigations of different species. At the same time, generic data analysis and modeling toolbox for bio-navigation studies would be developed. (3) Finally, by repeating the four processes in a synergistic way, each of control engineering, data science, animal ecology, and neuroscience fields could be largely progressed. In the future, the results obtained in this project will be extended for solving social and engineering challenges regarding navigations of humans and artificial things as well.

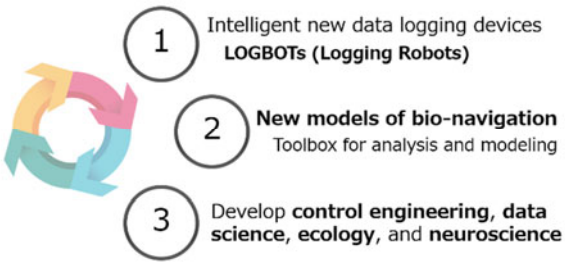


Figure 3: Expected results in this project.

【Key Words】

BIO-NAVIGATION: A general word representing a fundamental animal behavior to reach a destination in which animals acquire dynamically changing information from external and internal environment for the purpose of choosing a route to reach the destination.

LOGBOT: Logging device for measuring a variety of signals in bio-navigation over a long period of time by making existing data logging device far more intelligent and autonomous.

【Term of Project】 FY2016-2020

【Budget Allocation】 1,087,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://navi-science.org

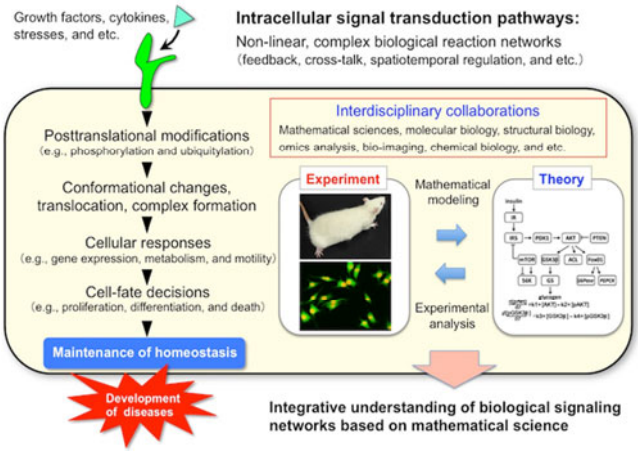
Title of Project : Integrative understanding of biological signaling networks based on mathematical science

Mutsuhiro Takekawa
(The University of Tokyo, The Institute of Medical Science, Professor)

Research Project Number : 16H06573 Researcher Number : 30322332

【Purpose of the Research Project】

Recent studies have revealed that the regulation of intracellular signaling, a fundamental biological process in living organisms, is not as simple as previously assumed, but is rather intricately modulated by various biological factors and mechanisms (e.g., feedback, cross-talk, and etc.). It is now widely appreciated that such complex and dynamic nature of intracellular signaling in itself serves as the driving force to generate the diversity of biological outcomes. In order to integrate numerous findings regarding signal transduction networks and to understand complex biological systems such as cells, tissues, or even the human body as a whole, introduction of cutting-edge technologies in the field of mathematical science into biomedical research is essential. In this project, we will elucidate the basic principles underlying the regulation of intracellular signaling and the resulting biological outcomes, and their failure in human diseases, through interdisciplinary collaborations between mathematical scientists and biomedical researchers. Our group also aims to develop novel mathematical theories to accurately predict biological responses, critical biomarkers, and therapeutic targets for human diseases.



【Content of the Research Project】

The main goal of this research project is to comprehensively understand the spatiotemporal regulation of signal transduction networks and its failure in human diseases at the molecular level by considering living organisms as dynamic systems composed of diverse biomolecules. To this end, researchers will promote this project by combining experimental approaches using molecular and "omics" techniques with theoretical approaches base on mathematical science. In particular, mathematical scientists will build mathematical models of signal transduction pathways from the actual measurement data obtained by molecular biologists, extract the principles of complex biological dynamics, and predict unexplored biological phenomena by means of computational simulation. Furthermore, the accuracy of the theoretical predictions will then be evaluated with wet-bench experiments. By repeating the cycle of such experimental and theoretical studies, we will elucidate the key principles of the regulation of signaling networks and biological functions, and eventually apply these basic findings to the development of novel therapeutic interventions for currently intractable diseases.

【Expected Research Achievements and Scientific Significance】

This interdisciplinary collaboration between mathematical scientists and biomedical researchers will gain a comprehensive understanding of the operating principles of complex biological signaling networks and phenomena, and provide useful findings for the development of diagnostic and therapeutic tools for human diseases such as cancer, diabetes, autoimmune, and neurodegenerative diseases. Furthermore, the integration of research outcomes and methodologies from various fields of science will create novel fundamental technologies and theories that can accurately predict biological responses and key therapeutic targets for human disorders, thereby leading to an innovation in the field of biomedical science.

【Key Words】

Omics: A field of research aiming at the characterization and quantification of the entire set of biological molecules (e.g., RNAs, proteins, or metabolites) in a cell, organ or organism.

【Term of Project】 FY2016-2020

【Budget Allocation】 1,022,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://math-signal.umin.jp/

Title of Project : Correspondence and Fusion of Artificial Intelligence and Brain Science

Kenji Doya
(Okinawa Institute of Science and Technology Graduate University, Neural Computation Unit, Professor)

Research Project Number : 16H06561 Researcher Number : 80188846

【Purpose of the Research Project】

The purpose of this research project is to bring together artificial intelligence research and brain science research, which separated apart while their own sophistication, and to promote developments of novel learning algorithms and deeper understanding of brain mechanisms. We aim to develop efficient algorithms and clarify brain's realization of **supervised learning of internal models, reinforcement learning by exploration and evaluation**, and representation learning to facilitate them. We further try to realize flexible artificial intelligent systems based on the understanding of the whole-brain architecture for flexibly linking those learning modules.

【Content of the Research Project】

Artificial intelligence and brain science have had a swinging relationship of convergence and divergence. In the early days of pattern recognition, multi-layer neural networks based on the anatomy and physiology of the visual cortex played a key role, but subsequent sophistication of machine learning promoted methods that are little related to the brain. Recently, however, the remarkable success of deep neural networks in learning from big data has re-evoked the interests in brain-like artificial intelligence.

Evidence suggests that the cerebellum, the basal ganglia, and the cerebral cortex are respectively specialized in supervised learning, reinforcement learning, and unsupervised representation learning, (Fig. 1). On the other hand, the recent success of artificial intelligence in beating a Go world champion has demonstrated that exquisite combination of supervised learning, reinforcement learning, and representation learning by deep neural networks can achieve human level or higher intelligence.

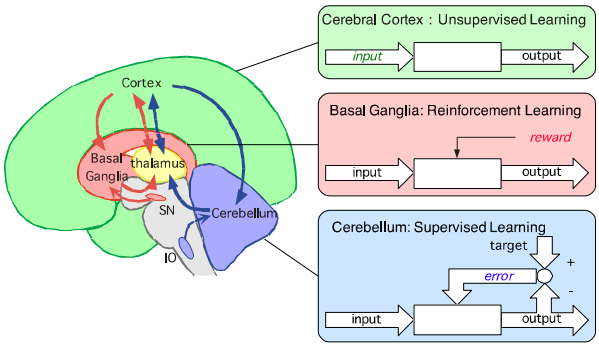


Fig. 1: Learning algorithms of cerebellum, basal ganglia, and cerebral cortex (Doya, 1999).

This project brings together leading researchers in artificial intelligence and brain science, let them learn the latest developments in each other's fields, and promote identifying the seeds of novel discovery and developments. In addition to developing novel algorithms for supervised learning, reinforcement learning, and deep representation learning and clarifying their implementation in the brain, we try to elucidate how those learning modules are flexibly integrated in the brain depending on the behavioral needs, and utilize the knowledge for developing artificial intelligence that allows human-like flexible actions and communication.

【Expected Research Achievements and Scientific Significance】

We expect to achieve better understanding of the mechanisms of deep neural network learning, data-efficient learning algorithms for humanoid robots, and hierarchical models to understand human intentions, for example. In a long run, we try to understand the self-organizing mechanism of learning modules in the brain and to derive the design principles for realizing artificial general intelligence.

The project will also aim to produce young scientists who can lead the crossing edges of artificial intelligence and brain science, through training programs such as summer schools, hackathons and international exchange programs.

【Key Words】

Deep neural network: a multi-layer network for discovering statistical features hidden in the data, from simple ones to gradually complex ones. It is widely used for image and speech recognition.

【Term of Project】 FY2016-2020

【Budget Allocation】 1,119,100 Thousand Yen

【Homepage Address and Other Contact Information】

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ncus@oist.jp

Title of Project : Creation and Promotion of the Will-Dynamics

Takeshi Sakurai
(University of Tsukuba, Faculty of Medicine, Professor)

Research Project Number : 16H06400　Researcher Number : 60251055

【Purpose of the Research Project】

To live a creative and active life, it is essential to have a high willpower: an ability to make an effort to overcome difficulties to achieve goals. The reward system, executive function controlled by the prefrontal cortex, etc. may be involved, but details of the neuroscientific mechanism of the willpower, a unique function of human, is unknown. This research area aims to reveal the mechanism of this mental function, and the impact of social/internal environment on willpower. Along with the research to identify the neural basis of willpower, interdisciplinary investigation will be performed by reserchers of neuroscience, psychiatry, internal medicine, educational psychology and sport science will closely cooperate each other to seek the methods to support the development of will-power through education and sport.

【Content of the Research Project】

This research area aims to perform multidimensional analyses of the molecular/neural basis of willpower and the condition caused by its impairment such as social withdrawal (hikikomori), apathy and modern depression, from the viewpoints of [1] neuroscientific understanding, [2]growth environment including education, society, exercise, diet and sleep, and [3]internal environment including endocrine system, metabolic abnormalities, intestinal bacterial flora, and presence of chronic inflammation. This research area also aims to help improving the people's willpower by feeding back the findings.

To scientifically understand the correlation between environment and willpower, specialists in educational psychology, psychosomatic medicine, etc. who can analyze the growth environment of young people including family, education and society in practice should perform multidimensional analyses in close cooperation with specialists in neuroscience, psychiatry, etc. who are familiar with the molecular/neural basis of mental growth and diseases caused by its impairment, and thereby characterize various aspects of the interface between human and environment.

It is likely that recent changes in growth environment in our society have had major impact on mental growth, no clear evidence has been available. In the field of neuroscience, investigations on reward system, a basis of willingness, have focused on the functions of dopamine neuron of the ventral tegmental area, ventral striatum, etc. However, sufficient feedback has not been provided to the actual human society. This area explores biological basis related with the development of willpower, paying attention to social environment and internal environment.

Figure.　Diagram of WILLDYNAMICS

【Expected Research Achievements and Scientific Significance】

[1] Neural basis of will-power be revealed, and brain-function imaging techniques, etc. which allow real-time analyses of its kinetics *in vivo* will be established.
[2] Molecular neuropathology will be explored, revealing how the maturation of mind-body correlation and willpower are affected by the changes in metabolic environment and internal environment including intestinal bacterial flora associated with modernization of our life.
[3] The principle of activation will be explored for the mechanism of correlation between growth environment, internal environment and development of mental functions, which will reveal the therapeutic target, resulting in the establishment of basic technologies for drug discovery/ diagnosis to restore volition.
[4] Scientific evidence will be obtained, demonstrating that impaired development of the mental functions related with willpower can be improved with optimized exercise, sleep, diet, etc.
[5] Longitudinal researches on social environment at schools will identify the environmental factors that may influence willpower. As a result, useful interventional supportive methods to reduce the environmental loads will be proposed.

【Key Words】

willpower, motivation, intestinal flora, social withdrawal, apathy, depression, internal environment, social environment, biological clock, volition, sleep, sport science, educational psychology, developmental disorder

【Term of Project】　FY2016-2020

【Budget Allocation】 1,153,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://willdynamics.com