Title of Project : Developmental Dynamics of Human Brain from Pattern Formation to Generation of Behaviors

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Research Project Number : 26220004　Researcher Number : 00272477
Research Area :　Informatics
Keyword :　Biological information, complex systems

【Purpose and Background of the Research】

Human brain imaging studies have shown the properties of the structural and functional network of the brain. However, limited information is available as to the ontogenetic mechanisms how the complex network of the human brain is constructed. The present study covers issues from the pattern formation in fetus to emergence of behavior in young infants. In particular, we focus on the interplay between spontaneous activity of the brain and the changes in structural network, and sleep state dependent mechanisms for processing external stimuli and learning. The purpose of the study is to empirically and theoretically elucidate the pattern formation of the brain in embryo, the generation of white matter tract and gyrus in fetus, the functional development of the brain in preterm-born infants, and learning-dependent changes in the functional network of the brain in young infants by means of neuroimaging techniques, behavioral measurement, and computer simulation.

【Research Methods】

(1) To reveal the mechanisms for genesis of white matter tract and folding of the cortex in embryo and fetus, magnetic resonance (MR) microscope imaging and diffusion tensor imaging (DTI) of specimens of embryos and fetuses are performed.
(2) To clarify the typical and atypical development of the functional network of the brain, near infrared spectroscopy (NIRS) is used for detecting the cerebral blood oxygenation of preterm-born infants in a neonatal intensive care unit.

(3) To understand the mechanisms underlying differentiation of sleep and awake states and functional roles of sleep for learning, spontaneous and stimulus-induced activity and learning-related changes in activity of the cortex in young infants are measured by using NIRS and EEG.
(4) Developmental processes of the brain from embryo to infant are modeled as dynamical systems and computer simulations are performed. We link the theory of pattern formation with information theory with neural networks.

【Expected Research Achievements and Scientific Significance】

The present study will provide profound insight into understanding dynamic principles for each of three different developmental processes regarding pattern formation of the brain, generation of functional networks, and transition of sleep states in relation to learning and how these processes over different time scales interact with each other. The present study will also establish a new framework for understanding pattern formation and information creation in the brain as complex systems.

【Publications Relevant to the Project】

・Taga G et al.: Phil. Trans. R. Soc. A. 369, 4495-4511, 2011
・Imai M et al.: Neuroimage 85, 272-278, 2014
・Watanabe H et al.: Human Brain Mapping 34, 543-565, 2013
・Yamada S & Takakuwa T eds.: The human embryo. InTech publisher, 2012
・Fujimoto K et al.: PLoS ONE, e2772, 2008

【Term of Project】 FY2014-2018

【Budget Allocation】 150,100 Thousand Yen
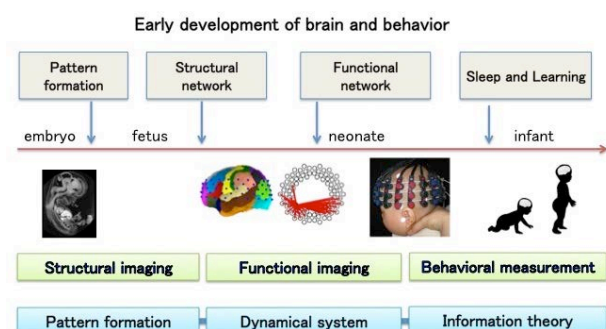
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Fig1. Research strategy