【Grant-in-Aid for Scientific Research (S)】

Evolutionary foundations of communicative behavior: imitation, empathy, and reward.

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Purpose and Background of the Research

●Outline of the Research

Communicative behavior has been studied across various disciplines, but a divergence between human and animal studies has hindered evolutionary understanding. This study aims to provide a comprehensive view of communicative behavior by examining the interaction of imitation, empathy, and reward. Signals are exchanged through imitation based on empathy, resulting in internal and external rewards. Understanding communicative behavior as an interaction between these cognitive systems enhances our understanding of its nature.

The study focuses on neural circuits and behaviors in diverse animal species, including birds, rodents, primates, and humans. We investigate vocal learning in birds, emotional contagion in rodents, and turn-taking and social interactions. Our hypotheses propose that imitation and empathy form the basis of communicative behavior, controlled by the reward system. These systems are essential for predicting others' behavior. Various methods, such as observation, cognitive experiments, function brain measurements, and neural activity recordings, are employed to explore the mechanisms and evolution of communicative behavior. Additionally, we consider design guidelines and adaptation strategies for diverse communication styles among humans, animals, and artifacts.

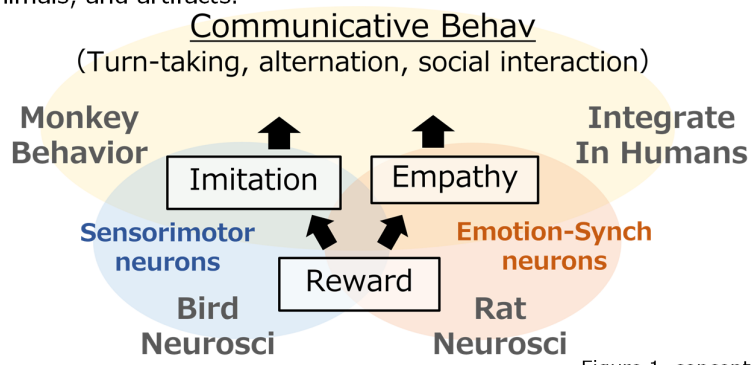

Figure 1. concept of the study

● Uniqueness and creativity

This program integrates communication research, which has traditionally focused on functional descriptions, by dividing the domains into three separate cognitive systems: imitation, emphthy, and reward. We explore their mechanisms, and the interactions between the systems in parallel. The creative aspects of this research is to show that the interaction between cognitive systems enables prediction of others' behavior. Specifically, we will analyze the following diverse behaviors: vocal learning in birds, emotional contagion in rodents, and alternation and social behavior in birds, rodents, and primates. The uniqueness of this study is that it explores the universality of communicative behaviors.

● Positioning

Early on, it was noted that imitation and empathy share a common foundation. Recently, it has been suggested that these are multilayered, with an innate sensorimotor mechanism at their core, which has been called as mirror systems. This study aims to understand communicative behavior by redefining mirror systems as sensorimotor neurons and emotion-synchronization neurons. It redefines communicative behavior based on shared cognitive systems between humans and animals, allowing mapping between conceptual levels and brain functions. This perspective enables comprehensive research on communication modes between humans, animals, and artifacts (Fig 2). Additionally, studying the three systems is essential to analyze new remote and surrogate communication styles facilitated by various devices. Understanding these systems and their interactions is also valuable in designing artifacts for natural human communication.

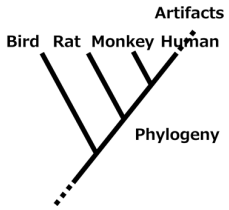

Figure 2: Phylogenetic Relationships of Research Subjects

Expected Research Achievements

● Research Methods

In this study, we will test hypotheses on vocal learning, emotional contagion, and social behavior in birds, rodents, and primates. By examining these hypotheses in various species and behavioral models, we aim to understand universal communication mechanisms. We hypothesize correspondences between cognitive systems and the brain, with imitation involving the premotor cortex and basal ganglia, empathy involving the amygdala, insula, and anterior cingulate gyrus, and reward involving the ventral tegmental area and substantia nigra. We will record brain activity using various techniques and analyze gene expressions (Fig 3). Additionally, we will discuss communication style design guidelines and conduct model building and simulation studies based on experimental results.

● Vocal learning

Male songbirds memorize songs from their fathers as auditory stimuli and learn them through vocal-motor feedback during adolescence. Our research aims to understand how the three systems contribute to vocal learning in birds. We will record the learning process in young birds to examine the correspondence between neural system activities involved.

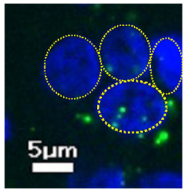

Figure 3. Auditory-vocal neurons

● Emotional contagion

Rats emit 50 kHz sounds for social, sexual, or physiological pleasure and 22 kHz sounds for discomfort. Our research aims to understand how the three systems contribute to emotional contagion in rats and their interactions. We will conduct experiments to measure neural activity during situations where rats emit emotional sounds and during approach-avoidance behavior induced by playing back emotional sounds to rats.

● Turn-taking and social behavior

We will measure how the three systems are involved in turn-taking, a primitive communicative behavior. In addition to studying vocal turn-taking, we will use lever or button pressing as models to investigate alternation behavior. We will also explore the function of the three systems in the interaction of social groups in a semi-natural environment. These studies aim to comprehensively understand communicative behavior and offer potential solutions to current issues in human society.

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