Mind Articulation at JST

Yasushi Miyashita
Mind Articulation Project, ICORP, Japan Science and Technology Corporation
Email : yasushi@ma.jst.go.jp

The achievements of Mind Articulation at JST can be divided into three areas. First, the research focused on the brain mechanisms of cognition, particularly of visual imagery, has articulated a network of relevant brain areas and signal flows among them, using fMRI and electrophysiology as major tools for measurements (Miyashita & Hayashi, 2000; see also ***References***). The inferior temporal cortex and the prefrontal cortex were found to be the major components of the system. The analysis of the system was further extended into the cellular/molecular level (see below). Second, the works pushed by Kensuke Sekihara and his collaborators have created new computational methods for analyzing MEG data in a situation where various kinds of noises make conventional dipole-estimation methods impossible. Among the newly developed methods, 'MEG-MUSIC algorithm' and 'MEG covariance difference analysis' have been successfully applied to the analyses of linguistic tasks. Third, the collaborative research has been developed toward unification of the brain science and linguistics, particularly using fMRI as a tool for measurements. Kuniyoshi Sakai and David Embick have made a great contribution in this work, which clarified a new feature of syntactic specializations of Broca's area.

Some of the researches in areas two and three of Mind Articulation at JST will be detailed in other presentations at this conference by the leaders of each research. In this presentation, I will discuss the general impact of Mind Articulation in the development of collaboration and also present some of the major findings from the first area of the achievements.

I. Toward unification of multiple approaches in the brain science

The understanding of cognition requires an integrative approach in brain science and cognitive science; it should presumably include functional neuroimaging analysis of global brain activities, behavioral/psychological analysis that identifies various 'agent' processes (or functional subprocesses) for the cognition, electrophysiological analyses of single cell activities and of neuronal networks that implement each 'agent' process, and analyses of molecular/cellular mechanisms underlying these networks. However, these integrative analyses have been possible only in a few domains of cognition. Visual imagery is an outstanding example of such domains. Mind Articulation at JST took advantage of wide collaboration that was enabled by the project. Some of the collaborative network can be seen from the speakers' list at the first international symposium of the project (also see the MIT Press book "Image, Language, Brain").

II. Visual imagery

Our ability to "*see with the mind's eye*" has been of interest to philosophers and scientists for a long time. A philosopher once wrote, "Create an image of the Pantheon in your mind. Can you count the columns that support its pediment ?" (Alain, 1926), asking whether "(strong) image" and "(weak) perception" are distinguishable in both psychological and epistemological dimensions (Sartre, 1938). The Pantheon's column example is among the best known tests of such a distinction. We now have a variety of approaches (including neuroimaging, electrophysiological, psychophysical and neuropsychological methods) to investigate where and how the images of objects, scenes and living beings are generated, stored and maintained in the brain. Even the question of to what degree the processes involved in visual perception and imagery share a common neural substrate has partially been answered by the project (Miyashita & Hayashi, 2000).

In particular, the project aimed to provide a solid neurobiological basis by using an animal model, since the nature of the internal representation that lies in the deepest structure for visual imagery has been long debated (Pylyshyn, 1981; Kosslyn, 1994). The investigations conducted by the project strongly suggest contributions of depictive representation in both humans and monkeys, although propositional representation may also contribute to imagery generation when verbal instruction triggers the imagery generation in humans.

III. Neural basis of image manipulation

In the course of studies, we first devised an animal model of imagery task: Macaque monkeys were trained to memorize visual objects in associative memory and to retrieve the image of an object from long-term storage according to an associative cue. The necessity for image generation and its initiation time were controlled by a color switch, independently of the cue itself. In the inferotemporal cortex, we found a group of neurons, whose activity represented the active image of a specific object in mind and could be recalled or suppressed according to the necessity of image generation. Then we asked from where does such a prospective activation of an object's image originate. We devised a novel monkey preparation, "a partial split-brain preparation", to behaviorally and electrophysiologically investigate this question. We found that, although visual long-term memory is stored in the inferotemporal cortex, memory retrieval and image manipulation are under the executive control of the prefrontal cortex (Hasegawa et al, 1998; Tomita et al, 1999). It was also asked how the images of objects are encoded in long-term storage. We found that inferotemporal neurons can encode associative relations between objects and that the interaction between the medial temporal lobe and inferotemporal cortex plays an essential role in reorganization of neural circuits for the encoding process. We further asked molecular basis of the neural circuit reorganization. Since brain-derived neurotrophic factor (BDNF) is implicated in activity-dependent neural reorganization, we tested the hypothesis that BDNF would be upregulated in the inferotemporal cortex during formation of visual pair-association memory, and recently obtained positive evidence (Tokuyama et al, 2000).

These studies demonstrate functional roles of the neural interactions among the inferotemporal cortex, prefrontal cortex and medial temporal lobe in encoding, retrieval and manipulation of visual memory and imagery.

References

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