論 文 内 容 の 要 旨

The decision-making of human life are exits on hundred to thousands times in all the day. It involves decisions for both a simple thing and a serious problem such as 'What I want to eat', 'Which clothes I want' and 'How to solve a problem'. Among these decision-making problems, purchase decision-making is a familiar decision to come across many times. When buying a product, especially the more expensive the product, people compare various information for good decision-making. All people have acquired the opportunity to purchase products easily and more variety by online shopping of the Internet, which is popular in recent years. However, it is difficult by the self-choose that satisfied consumer requirements, because of the many product lineups. Furthermore, the consumer cannot check the real products, they are possible only viewing the product images and the commentary letter of the product information displayed on the screen. Therefore, consumers are required to support the decision-making regarding the purchase of products. As one way to understand human decision-making, it is important to elucidate the brain representation. In the field of neuro-marketing, which explores human decision-making process, is attracting attention by measuring the reaction of the brain in an objective way and taking advantage of brain science and psychophysics knowledge. The methods such as the functional magnetic resonance imaging (fMRI), the functional near infra-red spectroscopy, the positron emission tomography and the electroencephalography are used in the field of neuroscience in order to explore the human decision-making process. Several studies by the traditional univariate analysis aimed to elucidate the neural mechanisms associated with the decision-making based on abstract rewards. One area that has been shown repeatedly to be activated by diverse rewarding stimuli is the ventromedial prefrontal cortex (vmPFC). This brain region has been shown in several neuroimaging studies to be active for a variety of primary and abstract rewards. Mounting evidence in these studies and others supports the idea that this region is involved in converting the value of these diverse stimuli to a common scale for action selection. This dissertation focuses on two things related to decision-making. One is a transition of Brain Activation in decision-making at problem-solving by long-term learning. We focuse the executive functions, which include decision-making, cognitive processing and planning. The target task is the Tower of Hanoi (ToH) puzzle task which is used to confirm execution function and activated brain regions. Brain activity is recorded during task performance using fMRI. The other thing is brain representation by human's choice in the purchase decision-making. We focuse on evaluation criteria, which is the motivation for choosing decision-making. In this dissertation, I describe the three investigated results that brain representations involved with decision-making. Firstly, we examined a transition of Brain Activation in decision-making at problem-solving by long-term learning. We focused on brain activity before and after learning and conducted a long-term learning experiment to investigate the difference in cerebral activity. As a task for confirming the brain region to be activated by the executive function, we chose the task to solve the Tower of Hanoi and conducted individual learning experiment. From the results of individual learning and fMRI analysis, it can be considered that the brain activity changes in the anterior cingulate cortex depending on the progress of learning. Also, we have considered that the place of brain activation changed due to the difference in learning time. Next, we focused on brain activation during the decision-making process, which was selected based on a single evaluation criterion. We experimented to investigate the common and specific brain activity by type of the evaluation criteria. From the scanned fMRI data of the choice tasks in each evaluation criterion, common brain activation and specific brain activation were performed by whole-brain analysis. This study investigated brain

activation during the decision-making process of preference while using different evaluation criteria, and identified common and specific activation regions related to each evaluation criterion. As for common activation regions, the bilateral occipital gyri had significant activation during price choice, color choice and year choice. The occipital gyrus is thought to be the brain region related to visual processing, and it was reported that this region is related to preference rated tasks. Conversely, as for specific activation regions, the left fusiform gyrus was activated significantly during color choice. The fusiform gyrus is thought to be the brain region related to color processing, and it was reported that this region is related to preference rated tasks. These reported studies investigated relationship between difference in preference rate and the brain activity different, there was a correlation between these. However, this study investigated common brain activity by type of the evaluation criteria. There is no report that occipital gyrus and fusiform gyrus are involved in the influence on the brain activity due to the difference in evaluation criteria, this result seems to be a new finding. During color choice, the left insula was also activated. The insula is known for its involvement in value-based decision-making. It integrates the internal state, sensory signals and information about the salience and relative value of stimuli during response selection. Furthermore, the right precuneus was found to be more active during color choice compared with price and year choice. The precuneus is especially documented for its involvement in attention. This suggests that the increased activation in the precuneus reflects an increased attention to the color pairs compared with the price or year pairs. Therefore, it is possible that the participants made a simple numerical value comparison between the left information and the right information. In the case of color choice, it is thought that the two color names displayed on the screen were processed based on the preference of the subjects. Therefore, it is considered that attention to color choice was higher than price and year choice, and the precuneus was activated. The vmPFC has been shown in several neuroimaging studies to be active for a variety of primary and abstract rewards. These findings suggest that the vmPFC in the representation of complex appetitive states has several roles. However, all decision-making studies did not report that vmPFC is involved in decision-making. It suggests that the activated region differs depending on the evaluation criteria in the case of evaluating based on a value of alternative or preference by the individual. In this study, the analysis was performed based on our hypothesis that brain activity difference by evaluation criteria appears in vmPFC. Our results show that vmPFC was activated in all of the tasks by different evaluation criteria during the decision-making process. From the investigation of different activations on vmPFC for each evaluation criterion of alternatives, there were no differences in activation levels in the choice of each category. However, the activated detail regions on the vmPFC varied by each criterion. Some investigators have suggested that subjects' preference judgments stem result from ``a competition between hedonic and utilitarian aspects of each choice alternative", ``competition between subjective emotional states such as desire and willpower", ``the selection of a specific dimension that enhances the contrast between the alternatives", or ``habit-based processing". Therefore, the brain performed different processes with price, color and year choice. As a result, it is believed that choices by each alternative category represented brain activation on specific coordinates. The experiment measured brain activity during a paired comparison based on the price, color or product year as a single evaluation criterion by fMRI, in order to elucidate the brain regions comprehensively involved in decision-making and to identify the specific brain regions involved in each evaluation criterion. From the scanned fMRI data of the choice tasks in each evaluation criterion, common brain activation and specific brain activation were performed by whole-brain analysis. As a common activation region in choice tasks by each evaluation criterion, the bilateral occipital gyri had significant activation. Related work reported that the occipital gyrus is thought to be the brain region related to a visual processing and preference rated tasks. This result had shown that the difference in preference rate is reflected the brain activity difference in occipital gyrus. This study investigated the common brain activity by type of the evaluation criteria, occipital gyrus was significantly activated at decision making by all evaluation

criteria. Therefore, this result suggests that occipital gyrus is a region comprehensively related to decision-making. As for specific activation regions in choice tasks by each evaluation criterion, the left fusiform gyrus, left insula and right precuneus were activated significantly during color choice. During price and year choice, specific activation was not observed. The results suggests that attention to color choice becomes greater compared to price or year choice. With the vmPFC, which has been reported to be involved in decision-making, significant activation was not observed from the results of the whole-brain analysis. The tasks of related work are decision-making for alternatives with different attractiveness or values based on a single evaluation criterion. This study analysed the brain activation differences among each evaluation criterion on decision-making, so these results did not focus on the differences in attractiveness or values. A ROI analysis for vmPFC was performed in order to confirm the differences of the brain activation in the vmPFC by evaluation criteria. In the ROI analysis result, significant activations on the vmPFC were observed with all tasks by each evaluation criterion, and these detailed coordinates were located in different coordinates. This result suggests a possibility that detailed activity regions in vmPFC differs by the types of evaluation criteria. In future work, in order to understand the relationship between the brain activated regions and the types of evaluation criteria on decision-making, we will continue to experiment with other types of evaluation criteria, and also verify the relevance of brain regions other than the vmPFC. Finally, we investigated the representation of evaluation criterion categories in a decision-making using MVPA method. We focused on vmPFC, NAcc, and insula as regions of interest. Each combination of the four evaluation criteria was analyzed into a binary classification by MVPA. From the results of the binary classification by MVPA, vmPFC and NAcc showed that these regions have a possibility capable of expressing the influence of evaluation criteria at decision-making.