別紙４－１（課程博士（英文））

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Abstract (Doctor)

Title of Thesis	Contribution of facial color on expression recognition, and emotional response to visual and auditory stimuli: evidence from pupillometry

Approx. 800 words

Human emotion is a mechanism for survival strategies, such as behavioral motivation and the signal of crisis avoidance. The study about human emotions began in philosophy and has conducted in various fields such as psychology, physiology, and engineering. Many studies on the relationship between emotions and physiological responses have focused on the pupillary response in recent years. The pupillary response has been attracting attention as a new physiological indicator that can indirectly extract human emotional responses because it reflects the activity of the locus coeruleus (LC). In this thesis, we investigated the mechanisms of emotion and facial expression recognition, which have not yet been elucidated, using pupillary responses (Chapter 2 and 3). In addition, we attempted to estimate emotional states using the pupillary responses based on these findings (Chapter 4).

In the Chapter 2, we investigated the contribution of facial color to expression recognition in blur images with the measurement of behavior and pupillary change. In the experiment, the face stimuli of facial colors (natural color, reddish) with different expressions (neutral and anger) in 3 blur levels were presented. Participants performed a task of expression identification to the stimulus. Behavioral results indicated that the facial color has a significant contribution to expression recognition as blur level increases. Then, the results of pupillometry showed that the reddish-color provided the information necessary to identify anger. These results showed the contribution of facial color increases in both psychophysics and pupillary experiment as blur level increases, which suggested that facial color emphasizes the characteristics of specific facial expressions.

In the Chapter 3, we aimed to elucidate the relationship of attentional states to emotional unimodal stimuli (pictures or sounds) and emotional responses by measuring the pupil diameter. In experiment 1, we investigated the relationship of the attentional state with emotional visual stimuli and emotional responses by using pupillometry. We observed that the velocity of pupillary dilation was faster during the presentation of emotionally arousing pictures compared to that of neutral ones, regardless of the valence of the pictures. Importantly, this effect was not dependent on the task condition. In experiment 2, we investigated the relationship of the attentional state with emotional auditory sounds and emotional responses. We observed a trend towards a significant interaction between the stimulus and the task conditions with regard to the velocity of pupillary dilation. In the emotional and auditory detection tasks, the velocity of pupillary dilation was faster with positive and neutral sounds than negative sounds. However, there were no significant differences between the no task and visual detection task conditions. Taken together, the current data reveal that different pupillary responses were elicited to emotional visual and auditory stimuli, at least in the point that there is no attentional effect to emotional responses to visual stimuli, despite both experiments being sufficiently controlled to be of symmetrical experimental design.

In the Chapter 4, we investigated pupillary responses to an auditory stimulus after a positive, negative, or neutral emotional state was elicited by an emotional image. An emotional image was followed by a beep sound that was either repetitive or unexpected, and the pupillary dilation was measured. Our results showed that the early component of the pupillary response to the beep sound was larger for negative and positive emotional states than neutral, whereas the

late component was larger for positive emotional states. The pupil response's peak latency was earlier for negative images than neutral or positive. Finally, SVM classified the emotional state based on the pupillary response with 80¥% accuracy. Our study suggests that emotional states can be estimated from the amplitude and the latency of pupil activity in response to an auditory probe.

Through these experiments, this study elucidated the unresolved cognitive mechanisms of emotion recognition and facial expression recognition using pupillary responses and proposed a new emotion estimation method. These findings provide important evidence to support the usefulness of pupillary response as a new physiological indicator in emotion research. These findings also support the effectiveness of pupillary response as an objective emotion estimation method that does not rely on subjective responses, and further research is recommended.