別紙４－１（課程博士（英文））

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# Abstract（Doctor）

| Title of Thesis | Modulation of cognitive processing by semantic congruency: Evidence from the interaction between facial expression and color |
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Approx. 800 words


The face reflects emotional, physical, and other states. In particular, facial expressions and facial colors provide crucial cues for interpreting others' emotions. Facial expressions are observed as shape changes in facial components such as the mouth, eyes, and eyebrows. In contrast, facial color changes are caused by variations in blood flow beneath the skin, which also fluctuate with emotional arousal. For instance, when a person expresses anger, the eyebrows tend to lower, the lower eyelids become tense, and the lips are opened. Simultaneously, physiological arousal increases blood flow, resulting in a reddish facial appearance. Thus, although facial expression and facial color are independent phenomena, they are interrelated, and this relationship affects judgments and social evaluations. Previous studies have reported that reddish facial colors tend to appear angrier and more aggressive, even with the same facial shape. These modulations have often been discussed as arising from semantic congruency between facial expression and color, formed through physiological or associative knowledge. However, most previous studies relied solely on behavioral tasks (response with button judgment or rating), leaving it unclear whether the observed bias effect arises even under unintentional conditions or merely reflects a response bias at the time of judgmental decision. Therefore, this thesis aimed to elucidate whether cognitive modulation based on the semantic congruency between facial expression and color occurs even in the absence of deliberate (arbitrary) response bias, by employing psychophysical and electroencephalographic (EEG) approaches.

In the first study, I focused on memory color, which is formed from objects' color memory acquired through one's own experience, and examined how facial expression affects facial color memory. Two psychophysical tasks (color adjustment task and color selection task) were conducted to calculate and compare the subjective achromatic point for facial image stimuli with different facial expressions (anger, neutral, fear). The results showed that the subjective achromatic points for angry and fearful faces shifted in the opposite color direction compared to neutral faces. These findings suggested that facial color memories or memory colors depend on facial expressions and the facial colors of angry and fearful faces are memorized as higher saturated.

In the second study, to investigate top-down modulation of brain activity, I analyzed the event-related potential (ERP) P3, which reflects selective attention. An oddball task was conducted, wherein participants counted the occurrences of

infrequent target stimuli among facial image stimuli presented at two different frequencies. EEG was recorded throughout the task, and P3 amplitudes were calculated for each combination of facial expression (angry, neutral) and facial color (original, red, green). The results revealed a significant interaction between facial expression and facial color, showing that the P3 amplitudes for red angry faces were higher than those for red neutral faces. This finding suggested that brain activity reflecting selective attention is modulated by the semantic congruency between facial expression and color. In addition, since the interactions between facial expression and color were not observed at earlier ERP stages than the P3, it has been suggested that the semantic congruency between facial expression and color emerges at a later cognitive processing stage rather than at processing stages associated with either facial expression or facial color alone.

In the third study, I extended from static facial color conditions examined in previous research to dynamic conditions involving changes in facial color, and examined how semantic congruency, including contextual information, influences judgmental modulation. Facial expression judgment tasks were conducted using facial stimuli that differed in facial color state, including dynamic and static conditions. The results showed that, regardless of the total perceived amount of color or the presence of dynamic change, faces with a relatively redder final color were more likely to be judged as angry. These findings suggest that the terminal facial color plays a critical role in facial expression recognition.

The results of this study showed that cognitive modulation based on the semantic congruency between angry and red occurs even in the absence of intentional response bias. These findings suggest that knowledge of the semantic congruency between facial expressions and colors influences cognitive processing not as an explicit judgment strategy, but rather as a top-down process that modulates perception and evaluation. Based on these results, this study proposes a model in which knowledge derived from the semantic congruency between facial expressions and colors does not directly modulate responses. Rather, the congruency modulates cognitive processing, and this modulation subsequently manifests as changes in judgments and responses. This model is expected to extend beyond the relationship between facial expressions and colors, offering a broader framework for understanding how knowledge and memory influence human responses and judgments.