論 文 の 内 容 の 要 旨

論文題目　Effects of the physical and perceptual representation of visual objects on visuomotor responses
（視覚運動反応における高次物体表象の影響）

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Visual events at the currently fixated location have a strong influence on the subsequent action taken. If a fixation stimulus disappears shortly (approximately 200 ms) before the presentation of a peripheral target, the reaction time of the subsequent saccade and manual movements is reduced as compared to if the fixation stimulus remained present. This response facilitation was first reported by Saslow (1967) and is termed the gap effect. The present study investigated the contributions of physical inputs and perceptual representation of a fixation stimulus on the saccadic and manual gap effects.

Chapter 1 (Introduction) described the general background of the research theme and addressed the objective and relevance of the present research. In short, according to the current understanding of the gap effect, mechanisms underlying response facilitation is divided into two major components. One is general motor preparation triggered by a temporal cue from events preceding the target onset (i.e., the general warning effect), and the other is the component(s) specific to the disappearance of the fixation stimulus. The current discussion on the gap effect is mostly about the latter component(s). Although various theories have been postulated regarding the fixation-offset-specific components of the gap effect, oculomotor release from active fixation processes (i.e., the fixation offset effect) and predisengagement of spatial attention from the attended fixation location (i.e., attentional predisengagement theory) are considered primary.

The fixation offset effect assumes that the maintenance of fixation interferes with the plan or execution of a subsequent saccadic movement at the oculomotor level, and the removal of the visual inputs of the fixation stimulus overcomes this interference and hence facilitates the subsequent saccade initiation; otherwise, the oculomotor release from active fixation processes takes place only after the target onset. Neural substrates of these processes have been found in the superior colliculus of non-human primates. In contrast, the attentional predisengagement theory assumes that the disappearance of the fixation stimulus prior to the target onset allows disengagement of attention from the fixation location because it assumes that (1) there is a strong coupling between attention and saccades, and (2) an attentional shift always precedes a saccade. This results in an immediate attentional and subsequent saccadic shift following the target onset; otherwise, the disengagement of attention takes place only after the target onset.

The objective of this study was to determine the contributions of the subjective and physical properties of the disappearance and maintenance of the fixation stimulus in the gap effect. The major advantage of the paradigm used in the preset studies is that separation of the contributions of the physical and the subjective disappearance of the fixation stimulus allows elucidating the roles of two competing hypotheses, the oculomotor-specific fixation offset and attentional disengagement in the gap effect. In general, the major difference between the fixation offset effect and the attentional predisengagement theory is that they attribute the origin of the gap effect to the different levels of neural mechanisms, namely subcortical and cortical processes, respectively. In other words, the fixation offset effect attributes the main cause of the gap effect to the physical disappearance of the fixation stimulus, whereas the attentional predisengagement theory assumes that the gap effect occurs as long as attentional disengagement from the fixation location successfully occurs. Hence, the physical disappearance of the fixation stimulus would be sufficient to cause the gap effect for the former hypothesis, whereas the subjective disappearance of the fixation stimulus would be sufficient for the latter hypothesis. Therefore, revealing the contributions of the physical and subjective disappearance of the fixation stimulus confirm/disconfirm these hypotheses.

Another interest of the present study was to investigate whether the saccadic and manual gap effects share underlying mechanisms, especially regarding cortical and subcortical processes. Unlike the saccadic gap effect, which is considered to be mediated by the subcortical oculomotor system (e.g., the fixation offset effect), the manual gap effect is more likely to depend on cortical mechanisms. Given these notions, it is expected that the physical and perceptual disappearance and maintenance of the fixation stimulus differentially affect saccadic and manual gap effects. More specifically, the saccadic gap effect should have a greater dependence on the physical inputs of a fixation stimulus, whereas the manual gap effect should have a greater dependence on the perceptual representation of a fixation stimulus. Toward these aims, a series of experiments was conducted by taking advantage of visual perceptual phenomena in which the physical inputs and perceptual representation of a fixation stimulus were separable. Each study is summarized below.

Chapter 2 (Study 1) investigated the effects of the physical disappearance and subjective maintenance of a fixation stimulus on the saccadic and manual gap effects. An occluded fixation point was created by covering the fixation stimulus with a moving mask 200 ms before the target onset in order to produce an anticipatory effect of the subjective maintenance and reappearance of the fixation point; i.e., phenomenal permanence and tunnel effect. The results showed that the occluded fixation stimulus partially reduced the saccadic gap effect and completely reduced the manual gap effect. This indicates that the subjective as well as physical disappearance of the fixation stimulus is necessary to induce the saccadic gap effect, whereas only the subjective disappearance of the fixation stimulus may be sufficient to induce the manual gap effect.

Chapter 3 (Study 2) tested the necessity of the physical disappearance of the fixation stimulus on the saccadic and manual gap effects while independently manipulating the subjective disappearance and maintenance of the fixation stimulus. For this purpose, the visibility of a fixation stimulus was manipulated by using binocular rivalry and the continuous flash suppression technique, in which a series of rapidly changing dynamic stimuli is presented to one eye such that the static stimuli on the other eye are rendered invisible. The results demonstrated that physical maintenance of an invisible fixation stimulus slightly but significantly reduced the saccadic gap effect but not the manual gap effect. Thus, combined with the results of Study 1, these results indicate that the saccadic gap effect occurs only when the fixation stimulus disappears both physically and subjectively, whereas the manual gap effect is strongly correlated with the subjective representation of a fixation stimulus. Furthermore, the results also indicate that the saccadic and manual gap effects arise from at least partially different mechanisms. In particular, unconscious processes seem to modulate an oculomotor-specific component of the saccadic gap effect, presumably via subcortical mechanisms.

Chapter 4 (Study 3) examined how a higher cognitive function, particularly social signals from a gaze-fixation stimulus, interacts with the saccadic and manual gap effects. To elucidate that, a facial fixation stimulus, which is often used in the areas of developmental, clinical, and experimental psychology, was tested. More specifically, the effects of a change in the state of eye contact (i.e., breaking vs. making eye contact) of a cartoon fixation stimulus influences the gap effect were examined. The results demonstrated that higher cognitive functions, particularly the perception of another person's gaze, differently modulate saccadic and manual facilitation in the gap paradigm. For saccadic responses, while the disappearance of eye contact between an observer and the facial fixation stimulus did not facilitate the saccade response more than the physical displacement of the fixation stimulus did, the appearance of eye contact caused strong response inhibition, resulting in the elimination of the general warning effect that was expected to occur as a result of the shift in the pupils dots. By contrast, for manual responses, there was no effect of the social signals from the eyes; both gaze shifts inhibited the subsequent manual reactions. This response inhibition could be attributable to the physical factors of the fixation stimulus (i.e., the shift of the pupil dots) rather than to social factors related to the gaze-fixation stimulus. The results demonstrated that even higher cognitive functions, particularly the perception of another person’s gaze, can modulate saccadic facilitation in the gap paradigm. Moreover, the effect of the geometric properties associated with the gaze shift, particularly the shift of the fixation stimulus, further highlights the difference between the saccadic and manual gap effects. That is, the shift of the fixation stimulus induces the saccadic gap effect but inhibits the manual gap effect.

Chapter 5 (Conclusion) summarized the findings of each study. In short, the results of the present series of studies demonstrate that the saccadic gap effect is primarily caused by the oculomotor-specific fixation offset effect, although its magnitude may be reduced by higher perceptual and cognitive functions, including attentional and social components. By contrast, the manual gap effect is presumably mediated by the different mechanisms. In particular, the manual gap effect largely depends on cortical mechanisms, rather than the subcortical mechanisms that underlie the saccadic gap effect. The results of the present experiments alone do not specify the exact components of the gap effects. However, these results do indicate that partially different processes mediate the saccadic and manual gap effects. Moreover, the dependence of unconscious information observed only in the saccadic gap effect can be considered evidence for the oculomotor-specific component in the gap effect. Further investigation on the neural substrates of the present paradigms should reveal how these mechanisms interact to achieve an efficient response when a fixated stimulus disappears.