論 文 の 内 容 の 要 旨

論文題目　Effects of spatial background contexts on visual object representation
（空間的背景情報が物体認知に及ぼす影響）

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The visual system processes information received from visible light to create visual perception of the surrounding environment. Vision is essential for survival on a daily basis because it facilitates awareness and interpretation of the surrounding environment, enabling interaction with this environment by guiding goal-oriented actions, such as grasping and reaching, which are reliant on vision to localize objects in visual space. For example, launching an application on one's mobile device requires (1) finding the icon's location on the display, and (2) moving the hand to touch it. The first step relies on localizing the icon on the display and the second step relies on estimating the distance between the icon and the hand. However, the perceived location of a visual object might be displaced from its physical location, which results from the brain's ability to process information from the surrounding environment, and the brain cannot process all sensory information equally; therefore, object localization is impaired.

Visual attention is crucial for the precise localization of visual objects because attention is focused on selected stimuli, and attended stimuli are processed using more cognitive resources than are non-attended stimuli. Therefore, spatial perception at attended locations and performance of goal-oriented action would be enhanced. However, sensory transients presented briefly outside of current attentional focus induce involuntary attentional shift because stimuli appearing suddenly are potentially threating (i.e., invasion by predators); this involuntary attention shift would cause systematic errors in object localization. Many studies have shown that sensory transients presented before or after a visual target can induce mislocalization of visual targets in different directions. However, it is currently unclear whether a single mechanism underlies mislocalization induced by dynamic attentional shift in the visual space. Furthermore, the perceptual system integrates information from different modalities to construct the world; therefore, it may be that peripheral transients in modalities other than vision would also induce a spatial distortion in visual space.

The present thesis aims to explore how dynamic attentional shift distorts visual space, and to propose an integrated account of the effects of peripheral transients on visual localization. Sensory transients that capture attention prompt mislocalization in two respects. First, they draw attention away from the visual target, reducing the distribution of attentional resources towards the target, thereby impairing performance at the information processing stage and shifting the perceived location of the visual target away from the peripheral transient (repulsion effect). Second, spatial information relating to a peripheral stimulus is also processed when attention is attracted toward that stimulus, which leads to the erroneous integration of relevant spatial information. This biases the perceived location of the visual target toward the peripheral transient (attraction effect). Therefore, peripheral stimuli induce spatial distortion. Furthermore, the visual system would combine multisensory information around the location representation of a visual target. The perceived location of the visual target would be biased toward peripheral transients from modalities other than vision.

In chapter 2, the experimental paradigm of attentional repulsion and attraction (Suzuki & Cavanagh, 1997; Ono & Watanabe, 2010) was applied to explore whether a single mechanism underlies mislocalization induced by dynamic attentional shift. In this experiment, two vertical lines appeared above and below the center fixation as visual targets and visual transients were presented before or after the target as attentional cues. Participants undertook a forced-choice task in which they were asked to judge horizontal misalignment of two vertical lines and were required to choose a misalignment direction, even if there was no apparent misalignment. When cue presentation preceded the target, the perceived location of the visual target was shifted away from the cues (attentional repulsion) and when cue presentation succeeded the target, the perceived location of the targets was shifted closer to the cues (attentional attraction). Experiments were conducted to examine (1) whether effect sizes of the repulsion effect and the attraction effect would differ with the same experimental parameters, (2) whether the two effects would interact, and (3) whether the locus of attentional focus or the direction of dynamic attentional shift would determine mislocalization effects. The results showed that (1) the effect size of spatial distortion was smaller with the presentation of preceding cues than with that of succeeding cues with same experimental parameters, (2) the two effects did not interact with each other, (3) static attentional focus at cues induced the repulsion effect and dynamic attentional shift induced the attraction effect. It suggests that the repulsion and attraction effects are independent. The repulsion effect occurs due to the cost of processing preceding sensory transients, whereas the attraction effect occurs because of attentional shift induced by subsequent sensory transients.

In chapter 3, we explore whether depth information relating to peripheral transients has additional influence on spatial distortion. Visual cues were presented before or after the targets in different depth planes relative to the target, under both binocular and monocular stereopsis viewing. The results showed that spatial distortion was stronger when both preceding and succeeding cues were presented in the depth plane further away from the target. However, depth modulation of preceding cues was only observed under binocular stereopsis viewing. In contrast, depth modulation of succeeding cues was observed under both binocular and monocular stereopsis viewing. Further experiments indicated that depth modulation of preceding cues was observed when observers shifted attention from the fixation point to the depth plane further away from the fixation point. This implies that because attention resources are higher in near space, the additional costs of shifting attention along depths could be compensated for by the apparently enhanced state of visual attention in near space. Therefore, larger displacement is only observed when shifting attention to far space. Conversely, a larger attraction effect was observed with closer target-cue distance, even if no depth information was provided and the physical size of the cue was the same. This implies that the attraction effect was mainly modulated by retinal coordination. The results of chapter 3 also suggest that the underlying mechanisms of the repulsion and attraction effects are different.

In chapter 4, we explore how the perceptual system integrates information relating to sensory transients from modalities other than vision to determine the perceived location of a visual target. In this chapter, a visual object moved toward the center of the computer screen and then disappeared abruptly, a brief sound was presented to observers around the moment of visual motion offset. Observers were asked to report the perceived vanishing location of the visual target. Results showed that when the sound was presented before the visual motion cessation, the perceived visual offset location was shifted backward. This indicated that mislocalization resulting from the timing of visual motion offset was attracted to the timing of the brief sound. In addition, when the sound was lateralized, the sound’s spatial information influenced the perceived location of the visual motion offset. Larger spatial attraction was observed when the brief sound was presented at the same side as the starting position of the target. Enhanced displacement of perceived visual motion offset occurs because the audiovisual dynamic capture is larger when the auditory and visual stimuli are presented in the same hemifield. Further experiments indicated that the spatial information of the lateralized sound did not influence the judgment of the timing of visual motion offset, implying that the effect of the lateralized sound was mainly in the spatial domain. Therefore, both temporal and spatial information relating to the brief sound can induce a mislocalization effect on the perceived location of visual motion offset.

In chapter 5, the findings of experiments from chapter 2 to 4 are summarized, potential applications for daily life are discussed, and possible directions for future research are suggested.

In summary, results of these experiments suggest that the perceptual system integrates information from different modalities to determine the perceived location of visual targets. Sensory transients presented at peripheral regions induced mislocalization in two different respects. First, sensory transients attract attention to process spatial information and the following visual target is processed with fewer attentional resources, which leads to a systemic error whereby the perceived location of the target is shifted away from the sensory transient. Second, the visual system integrates multisensory information from both the visual target and the contextual background to form location representations of the visual target. Therefore, information relating to peripheral transients may also be integrated, which biases the target's perceived location towards the peripheral transient in the short-term memory trace.

The results of the present research suggests that there is asymmetry in the allocation of spatial attention in 3D space and implies that observers are biased towards processing details in near space in a 3D environment. When making a virtual 3D environment, developers should focus on providing and updating detailed information in near space. By doing so, vivid 3D perception could be archived effectively. In addition, it is not necessary to update every detail at every moment in far space. Details of the contents of far space could be presented and updated when observers need to shift their attention towards them. This could be useful for conserving system resources in presenting a virtual 3D environment or reducing the cost of making a virtual 3D environment on a larger scale.

Finally, we discuss possible future research in academic fields. The results of the present thesis could prompt further research not only in psychophysics, but also in other fields such as studies in developmental disorders and brain imaging.