The Effects of Three Dimensional Stimulus Configuration on Self-Motion Perception Induced by Large Visual Display

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Abstract

The interactions between two-dimensional and three-dimensional stimulus configurations on visually induced self-motion perception (vection) were examined. The experiment revealed that there is no 2D-3D interaction, and vection strength is determined solely by the size of the moving background stimulus, which should be a primary factor in inducing vection.

1. Introduction

Visual stimulus which occupies large part of observer's visual field and moves uniformly can induce illusory self-motion perception to the opposite direction. This perceptual phenomenon is called vection, and widely accepted as an evidence of strong effects of visual information on self-motion perception. When an observer moves within the natural visual circumstances, retinal images of the external scene move in a direction that is opposite to the self-motion. These retinal motions are consistent with the visual stimulation that can induce vection. Thus, vection reflects the natural relationship between self-motion and retinal image motion of the external scene.

In a history of vection studies, it has been repeatedly indicated that there were two major factors which can affect occurrence and strength of vection, namely stimulus depth structure and stimulus eccentricity. A series of investigations has shown that most distant visual stimulus in the observer's visual field, i.e., background stimulus, determines observer's self-motion perception. In the natural visual circumstances, a distant object hardly moves independently of the observer, and retinal image motion of such a background is most likely reflects observer's self-motion. Thus, the background stimulus can create a reliable frame of reference for observer's self-orientation. It might be why the vection is dominated by the background stimulus, not by the foreground stimulus.

As to the other major factor, i.e., stimulus eccentricity, early vection studies indicated that visual stimulus which was presented onto the observer's peripheral visual field can induce stronger vection as compared to the one induced by the centrally presented visual stimulus. In some recent studies, however, it has been shown that the central stimulus can affect self-motion perception as well as the peripheral stimulus. Thus, there is no consistent conclusion on the effects of stimulus eccentricity on self-motion perception at this time.

Concerning to the above mentioned discrepancies on the effects of stimulus eccentricities, Howard & Heckman suggested possible artifacts of perceived depth of the visual stimulus [1]. They insisted that centrally placed stimulus appeared as figure on ground, and thus, nearer to the observer, even if there was no actual stimulus depth. On the other hand, when the moving stimulus was presented on peripheral visual field, observers would more likely to perceive moving stimulus was presented entire visual field behind the central mask. As described earlier, perceived depth of the visual stimulus has very strong effect on vection. The contradictions about stimulus eccentricities would be due to the uncontrolled perceptual changes of stimulus depth structure.

In this investigation, the effects of stimulus eccentricity on vection were reconsidered under the stimulus situation where perceived stimulus depth structure was determined explicitly by a binocular disparity, and a stimulus combination of a static foreground and a moving background was employed.

With using these stimulus settings, the moving stimulus was always perceived as a background behind the static stimulus, and the observer could not perceive any further depth extent behind the moving stimulus. Thus, the effects of stimulus eccentricity can be isolated from the artifact of perceived depth. These attempts would contribute our better knowledge about interaction between two major factors concerning self-motion perception, namely stimulus depth, i.e., three-dimensional configuration, and stimulus eccentricity, i.e., two-dimensional stimulus configuration.

2. Method

Stimulus

Visual stimulus was composed of three components, namely the static and the moving patterns, and a fixation cross. Both the static and the moving patterns were random-dot patterns overlapped with each other with different binocular disparities. The static pattern had a binocularly crossed disparity of 36 arc min, which corresponds to the situation wherein the pattern was perceived 15 cm closer than the screen. On the other hand, the moving pattern was given a zero-disparity relative to the screen, and perceived coplanar with it. The moving pattern moved from left to right at a constant speed of 50 deg/sec, while the static pattern remained still. The static pattern was presented onto an entire area of the screen, whereas the moving pattern was presented on a restricted area determined by a stimulus condition.

Condition

The screen area on which the moving pattern was presented was varied and there were two types of stimulus presentation, namely central and peripheral conditions. In the central condition, the moving pattern was presented on a central circular area. On the other hand, in the peripheral condition, the moving pattern was presented on a peripheral annular area, and the central region of the screen was left blank. The size of the stimulus was also manipulated. The radius of the central stimulus and the inner radius of the peripheral stimulus was varied for four different levels—10, 20, 30 and 40 deg. The outer edges of the peripheral stimulus were set to a 60 vertical deg and 90 horizontal deg. Thus, the sizes of the moving pattern were 314, 1260, 2830 and 4300 deg^2 in the case of the central stimulus and 5090, 4140, 2570 and 1100 deg^2 in the case of the peripheral stimulus, for each stimulus-size condition.

In addition, there was a control condition in which the standard stimulus was used. The standard stimulus was composed of a moving pattern which was presented entire area of the screen without the static pattern (stimulus size: 5400 deg^2). Stimulus attributes of the standard stimulus, including the motion speed, were set identical to the one of the moving pattern in the experimental stimulus.

Procedure

The subjects were five adult volunteers (four men and one woman, whose ages ranged from 24 to 32 years) with corrected-to-normal vision. All the subjects had previous experiences of vection observations but were naïve for the purpose of the experiment. In a darkened room, the subjects sat in an upright position in front of the screen, without a chin rest or any other head constraints, and observed the stimulus with fixating their eyes on the fixation cross at a viewing distance of 100 cm. They wore goggles with orthogonally-polarised filters for stereoscopic observations. The edges of the goggles limited the subjects' visual fields to 60 vertical degree and 90 horizontal degree. They could not observe anything other than the stimulus, such as edges of the screen or the wall and the floor of the room. Stimulus presentation lasted for was 120 s.

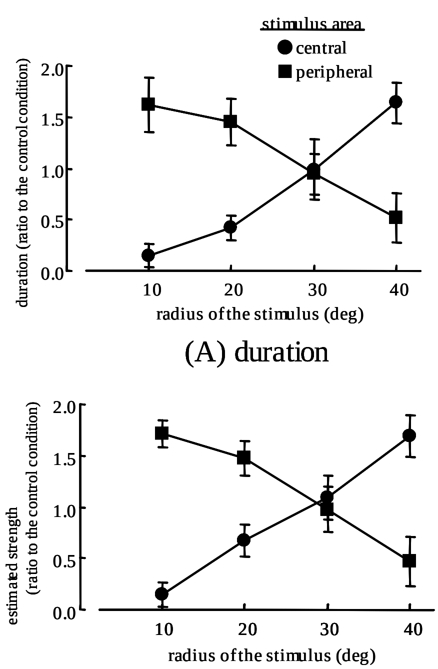
As indices of perceived strength of self-motion, duration and estimated magnitude of vection were measured in each experimental trial. Observers held a button in their hand, and pressed it continuously whenever they perceived self-motion during a trial. Accumulated duration was calculated in accordance with the button press under each trial. At the end of each trial, subjects were required to estimate the perceived strength of the self-motion during the trial, with a scale ranging from 0 (no vection was perceived) to 100 (vection of the same strength as that with standard stimulus was perceived) or beyond. Each stimulus condition was repeated six times in random order. In order to establish the standard for strength estimation, subjects experienced six training trials with the standard stimulus before experimental trials. The standard stimulus was the visual stimulus which was identical to the one used in the control condition.

3. Results and Discussion

All subjects reported that the moving stimulus was always perceived as background behind the static pattern, and there was no further depth extent beyond it, regardless to the stimulus eccentricity and its size. This result proofed the hypothesis assuming that manipulation of the stimulus eccentricity cannot affect observer's perception of stimulus depth under the stimulus situation used in the experiment.

Duration and estimated strength of vection obtained in each experimental trial were converted into a ratio to those obtained under the control condition. Both indices of vection strength were averaged across the subjects because similar tendencies were obtained from each subject. Figure 1 indicates averaged duration (a) and estimated strength (b) as a function of the radius of the central stimulus or the inner radius of the peripheral stimulus. Vection strength was increased with increasing the radius of the central circular stimulus as indicated by longer duration and higher estimation. On the other hand, vection strength was decreased with increasing the inner radius of the peripheral annular stimulus as indicated by shorter duration and lower estimation. These results showed that perceived strength of self-motion depends on the size of the moving pattern, regardless to the type of stimulus presentation (central or peripheral). Analyses of variance indicate that there were significant main effects of stimulus size both in the central stimulus condition (Duration: $F(3,16)=40.39$, $p<.01$; Estimation: $F(3,16)=26.89$, $p<.01$), and in the peripheral stimulus condition (Duration: $F(3,16)=107.20$, $p<.01$; Estimation: $F(3, 16)=28.45$, $p<.01$).

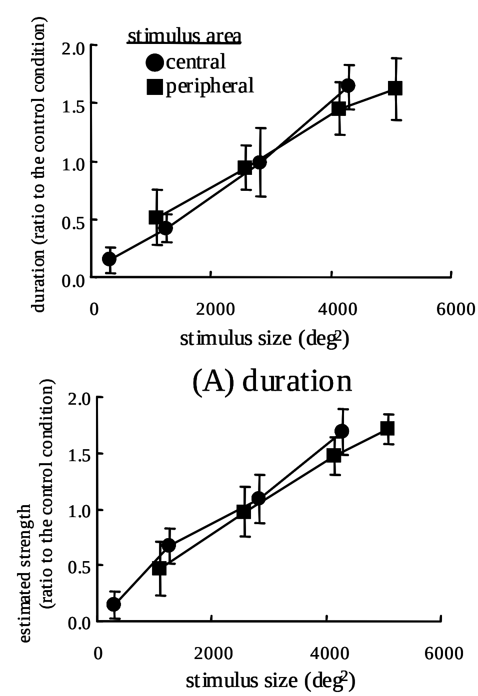
The result of this experiment indicated that the larger the moving pattern grew, the stronger the self-motion perception became. This was consistent with the previous studies [2][3]. In order to represent the relationship between the stimulus size and the strength of vection, each index of vection strength was replotted against the area of the moving pattern calculated on the basis of the actual stimulus shape (figure 2). Both duration and estimation increase linearly as a function of the size of the moving pattern. Furthermore, it should be noted that there was no difference of vection strength between the central and the peripheral stimulus per unit stimulus size.



(A) duration

(B) estimated strength

Figure 1 Strength of vection as a function of stimulus radius



(A) duration

(B) estimated strength

Figure 2 Vection strength replotted as a function of stimulus size

The results of this experiment indicated that vection strength linearly increases as a function of the stimulus size independently of the stimulus eccentricities, and the central and peripheral stimulus can induce self-motion perception with same strength if the stimulus sizes were equalized. These results clearly replicated the previous studies which showed that vection inducing potentials were homogeneous across the eccentricities [2][4]. The experiment reported in this article employed stimulus situation where the moving pattern was presented behind the static pattern, and the depth structure of the visual stimulus was explicitly defined by the binocular disparity. In such a situation, manipulation of the stimulus area cannot affect observer's perception of stimulus depth. Thus, it can be concluded that stimulus eccentricity has no effect on self-motion perception, if there is no perceived stimulus-depth artifacts. Traditional proposition that the peripheral visual stimulus can induce stronger vection as compared with the one induced by the central stimulus would be a consequence of perceive depth of the visual stimulus covaried with manipulation of the stimulus eccentricity [1].

The present study investigated that the effects of the stimulus eccentricity and the stimulus size on self-motion perception in the situation where the stimulus depth was defined explicitly by the binocular disparity, and revealed that the stimulus eccentricity cannot affect the strength of vection, in a situation where the moving background was presented behind the static foreground. As mentioned earlier, the stimulus eccentricity and the stimulus depth are two major factors in vection. These two factors have been investigated separately, and an interaction between them has been not considered for long years, although there are a few exceptions [1][5]. The present study can be assessed as a one of possible approaches to examine the interactions between important visual factors concerning self-motion perception.

4. References

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