# Enhanced Experiments in the Liner Vection Phenomenon Using Peripheral Visual Field Stimulus in a Head-Mounted Display Environment

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Abstract: Liner vection (LV) is a visually induced, self-motion illusion caused by observing a pattern moving in a linear direction (hereafter, visual stimulus). It is known that LV is susceptible to the visual field, especially the peripheral visual field. Here, we ask what happens to LV if the visual stimulus is only displayed in the peripheral visual field. In a previous study, we masked the central region of the visual field, where the visual stimulus was not displayed, and then analyzed the strength of the LV. This experiment was conducted using a dome-type immersive display; the LV strength was found to be stronger with a visual stimulus applied to a 20° masked area than that it was without the mask. In the present study, we employ a head-mounted display (HMD) to confirm whether this phenomenon might also occur in a more common immersive display with a narrow visual field. Conducting a similar experiment to that of the previous study, a similar tendency is found, in spite of the narrowness of the visual field.

Keywords: Vection, self-motion, visual field, immersive display, HMD

## 1. Introduction

Recently, there has been a focus on the development of immersive displays, such as wide field-of-view (FoV) head-mounted displays (HMDs) or huge displays that can cover the human FoV, like CAVE or Oculus Rift. In order to estimate the immersion level of Virtual Reality (VR) space in these immersive displays, visually induced self-motion sensation is attractive. Visually induced self-motion sensation, generally called vection, is a self-motion illusion caused by observing patterns (hereafter, visual stimulus) moving in a certain direction. This sensation (i.e., vection), can be classified as of two types [1]—linear vection (LV) and circular vection (CV)—according to the direction of movement direction; LV is the sense of a rectilinear motion sense, and CV is the sense of a rotational motion. In this paper, we focus on LV.

There have been many studies investigating the relationship between the visual field and vection. It is known that LV is susceptible to the visual field, especially the peripheral visual field [2]. From these studies, we predicted that LV would be stronger if the peripheral visual field were emphasized by masking the central visual field. In order to confirm this, in our previous research [3], we masked an area in the central visual field, thus preventing the display of the visual stimuli, and analyzed the LV strength. The result of this experiment showed that LV strength was stronger for visual stimuli applied to a 20° masked area than without the mask.

In recent years, HMDs have become popular, and their performance has improved. Thus, it has become easier to provide an immersion experience similar to an immersive display, such as CAVE. However, there are certain differences between an HMD and immersive display, such as display size and aspect ratio, and these differences may affect the relationship between LV strength and visual field. In our previous research [3], we conducted the experiment using a dome-shaped immersive display. However, it is not necessarily the case that the same phenomenon (the LV strength becoming stronger by the masking of the central visual field of a visual stimulus) also occurs using HMD. Therefore, in this paper, we seek to confirm this, investigating whether the LV strength in an HMD environment becomes stronger by masking the central visual field, as in our previous study.

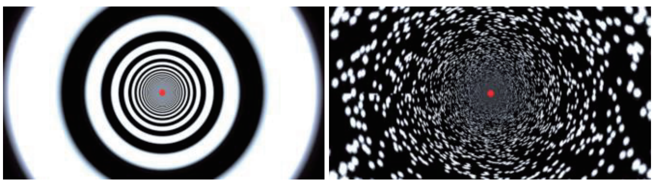
## 2. Experimental set-up

### 2.1 Head-mounted display

We used Oculus Rift CV1 as the HMD; this has a wide FoV, over 90° horizontally and over 82° vertically, including the floor-side view. Whereas the dome-shaped display we used in the previous study [3] could not present visual stimuli to the lower (floor-side) view, this HMD can do this. However, it should be noted that the horizontal FoV is narrower in the HMD than in the dome-shaped display.

### 2.2. Visual stimuli

Similar to previous studies, such as [4], we used virtual reality space to generate a seamless uniform visual stimulus. We prepared a virtual cylinder that was applied to a texture image and moved the cylinder in the parallel direction. In this step, we used two types of texture images: a black and white stripe and a random pattern of white dots on black (random dots), as shown in Figure 1 (a) and (b). Next, we created a visual stimulus so that the stripes or random dots moved from the front of the participant to the rear. The diameter of the virtual cylinder was 6.0 m and the moving speed was 4.0 m/s. The interval between the stripes was



(a) Stripe (b) Random dots

Figure 1: Visual stimulus we prepared

1.6 m, the size of the dots was 2° of the visual angle, and the density of the white dots (the black-to-white ratio) was approximately 4:1.

### 2.3. Masked area

To analyze the LV strength caused by stimulating the peripheral visual field, we applied the masked area to the central area of the FoV, similar to our previous study. The masked area was generated using a black, round, computer graphics object; the size of the masked area was 0° (without the mask), 20°, 40°, 60°, and 80° of the visual angle.

## 3. Experiment

### 3.1. Experimental condition

The participants, 10 adults, were presented with the visual stimulus in a standing state. We used two kinds of visual stimulus (random dots and stripes), as described in Section 2.2, and five masked area sizes (diameters), as described in Section 2.3, making 10 experimental patterns in total.

### 3.2. Experimental procedure

The experimental procedure was based on Thurstone's method, and selection was based the stimuli with which the participants felt a stronger vection. The number of attempts was ${}_{10}C_2 = 45$ times per participant.

The experimental procedure was as follows:

(1) Two patterns were randomly selected from the 10 patterns
(2) One of the two patterns was presented to the participant
(3) The second pattern was presented to the participant
(4) The participant was asked which pattern they felt had a stronger vection, after trying each twice
(5) To eliminate the effects of fatigue, participants were given time to rest
(6) Steps (1)–(5) were then repeated for the remaining combinations

Note that an additional break (approximately 1 min) was provided separately from step (5) once every nine trials.

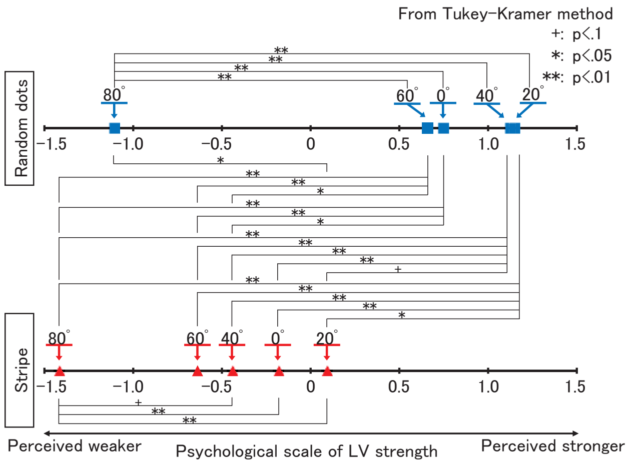



Figure 2: Relationship between LV and central masked area in HMD environment

### 3.3. Results and discussion

The experimental results are shown in Figure 2. The two numbered lines represent the psychological scale of the LV strength for each visual stimulus, with a stronger LV indicated by a larger numerical value.

As per Figure 2, the following was found:

(i) LV for the random dots was stronger than for the stripes, except for the 80° masked area
(ii) LV became weaker as the masked area became larger
(iii) LV was stronger when the visual stimulus was presented with a 20° masked area than without a masked area (i.e., the 0° condition)
(iv) LV was remarkably weak with the 80° masked area

Of the above results, (i), (ii), and (iii) were similar to our previous research, but (iv) was somewhat different. Specifically, the interval between 80° and the other conditions was wider than previously. Considering the reason for this difference, we identified find just one possible cause: the HMD's FoV was narrower than the dome-shaped display. This suggests that the 80° masked area might occupy almost all the HMD's FoV and that there are not enough cues to cause vection. However, as listed in (iii), LV was generally stronger when applied with small masked areas. This indicates that the HMD we used in the experiment was also able to stimulate the peripheral visual field sufficiently, indicating that the peripheral visual field was emphasized by masking the central visual field. Therefore, we can conclude that, under the HMD condition, LV strength is also increased by applying a central masked area, while it should be noted that too wide a masked area may weaken LV strength.

## 4. Conclusions and future work

In this study, we examined the relation between LV strength and the peripheral visual field using HMD as an immersive display. We demonstrated that LV strength is increased by stimulating peripheral visual field.

In the future, we will use HMD and focus on the role of the area of the peripheral visual field where a dome-shaped display cannot present visual stimuli (e.g. the floor-side view). We will also focus on functional differences between stereoscopic and monocular conditions.

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