Some Considerations on Visual Stimulus Enhancing Linear Vection Phenomenon in Immersive Space

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Abstract: Vection is a visually induced illusion of self-motion caused by observing a visual stimulus. To analyze vection caused by peripheral visual field, we need to present a visual stimulus over the entire peripheral visual field. Because the displays in previous studies were too narrow to analyze vection caused by the peripheral visual field, we used an immersive display in this study. We prepared 10 patterns (two visual stimuli in five masked areas) as experimental conditions and conducted an experiment based on Thurstone's method. Our results indicated that random dots provide stronger linear vection (LV) than stripes and suggested that the LV strength would become stronger if the masked area was smaller; however, visual stimulus applied to the 0° masked area (without a mask) was weaker than that applied to the 20° masked area.

Keywords: vection, self-motion, visual field, field-of-view, immersive display, masked area

1. Introduction

Vection is a visually induced illusion of self-motion that is caused by observing patterns (visual stimulus) moving in a certain direction. Vection can be divided into rectilinear motion sense (linear vection; LV) and rotational motion sense (circular vection; CV) [1].

While many studies have investigated the relationship between the visual field and vection, most of them focus on CV, e.g. [2][3]. To address this gap, we discuss the relationship between LV and the visual field in this study.

One study concerning the relationship between LV and the visual field suggests the importance of the peripheral visual field on LV strength [4]. In addition, there are studies that analyze LV caused by stimulating the peripheral visual field by applying visual stimuli to masked areas in the central visual field [5]. The viewing angle of a human is approximately 200° in the horizontal direction; hence, we can discuss the interaction between the peripheral visual field and vection strength in more detail by stimulating the entire visual field. Furthermore, the roles of the visual field differ between the central and peripheral visual fields as the peripheral visual field is more sensitive to moving sense.

However, the displays used in previous studies did not have a large enough field-of-view. That is, they were too narrow to accurately discuss the peripheral visual field.

To provide a sufficiently wide field-of-view display, we used an immersive X-Media Galaxy/Dome Type display.

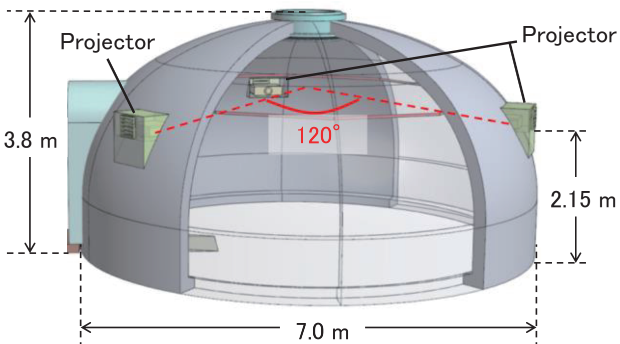


Figure 1: X-Dome and the position of each projector.

2. Experimental setup

2.1. X-Media Galaxy/Dome Type display

X-Media Galaxy/Dome Type (or X-Dome) display is a dome-shaped immersive display with a diameter of 7.0 m and a height of 3.8 m. It can display a full 360° scene using three projectors equipped on the X-Dome wall (Figure 1).

2.2. Vection visual stimuli

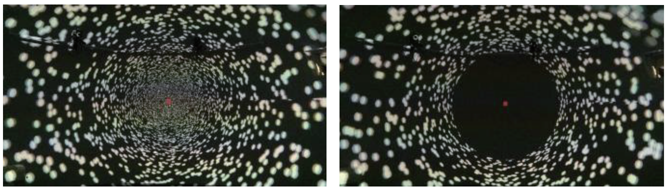
Similar to previous studies e.g. [5], we used virtual reality space to generate a seamless uniform visual stimulus. We prepared a virtual cylinder that was applied to a texture image and moved the cylinder in the parallel direction. In this step, we used two types of texture images: a black and white stripe and a random pattern of white dots on black (random dots). Then, we created a visual stimulus by projecting this cylinder on the inside wall of the X-Dome so that the stripes or random dots moved from the front of the subject to the rear.

The diameter of the virtual cylinder was 6.0 m and moving speed was 4.0 m/s. In addition, the interval between the stripes was 1.6 m, the size of the dots was 2° of the visual angle, and the density of the white dots, i.e., 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 need to introduce visual stimuli to the peripheral visual field. Therefore, we applied the masked area to the central area of the display similar to previous studies. The masked area was generated using a black round computer graphics object; the size of the masked area was 0° (without a masked area), 20°, 40°, 60°, and 80° of the visual angle.

The random dot visual stimulus without a masked area and with a 20° masked area is shown in Figures 2 (a) and (b).



(a) Without masked area (b) With 20° masked area

Figure 2: Random dot visual stimulus projected onto X-Dome wall.

3. Experiment

3.1. Experimental condition

Participants were 10 adults (eight males and two females). The subject stood 0.55 m from the X-Dome wall and was presented with the visual stimulus (Figure 2). We used random dots and stripes (two patterns) as the visual stimulus, as discussed in Section 2.2. The size (i.e., diameter) of the masked area was 0° (without a masked area), 20°, 40°, 60° and 80° of the visual angle (five patterns). Therefore, there were 10 experimental patterns.

3.2. Experimental procedure

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

The experimental procedure is listed below:

(1) Two patterns were randomly selected from the 10 patterns

(2) One of the two patterns was presented to the subject

(3) The second pattern was presented to the subject

(4) The subject was asked which pattern felt stronger vection after trying both a first and a second time

(5) To eliminate the effects of fatigue, enough time was given for the subjects 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.

3.3. Results and discussion

The experimental results are shown in Figure 3. The two number lines in the diagram represent the psychological scale of the strength for each visual stimulus. The subject feels a stronger LV when the numerical value is smaller. Using a sign test, we confirmed that these results were significant. Therefore, the following can be concluded:

(A) There were significant differences between the responses to random dots and stripes.

(B) There were significant differences between 20° vs 40°, 20° vs 60°, and 20° vs 60° in the random dots case, whereas there were no significant differences in the stripes case.

(C) LV strength was the strongest/weakest when the size of the masked area was 20°/80° of the visual angle.

As mentioned in point (A), random dots provided a stronger LV than the stripes, meaning that differences in the visual stimulus may influence the LV strength. This might be caused by perceived depth of the textures because it is known that LV strength is affected by the depth cue of visual stimuli [6]. Point (B) indicates that subjects cannot feel the difference clearly with the stripe pattern; therefore, it may be too weak to compare the LV strength. This, in conjunction with point (C), suggests that the effects and tendencies of the masked area do not depend on the type of visual stimulus (i.e., stripes or random dots) but rather on the degree of differences depending on its type.

4. Conclusions and future work

In this study, we examined visual stimuli and the peripheral visual field using an immersive display. We experimentally demonstrated that the masked area in the central visual field affects the LV strength and suggested that the LV strength depends on the type of visual stimulus.

In future, we will explore LV in other directions, e.g., the backward, rising, and/or falling moving senses. We can apply the present findings to any virtual reality content.

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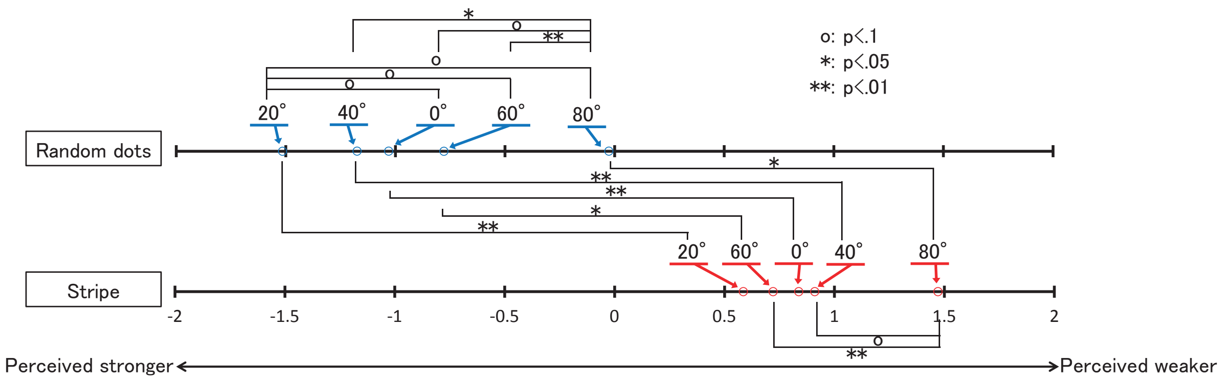

Figure 3: Experimental results number line (psychological measure of vection strength); smaller numbers indicate larger responses.